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Surgeon-Performed Ultrasound for Detection of Silicone Breast Implant Rupture: A narrative Review

Ahmed AlSultan[1], Danny Aughsteen[1], David Kadrian[1]

[1] Australasian College of Cosmetic Surgery and Medicine, Australia.

Abstract

Rupture is a common long-term complication of silicone breast implants and is frequently silent, requiring imaging for detection. Since 2020, US Food and Drug Administration guidance has recommended ultrasound or MRI for rupture surveillance, but the reported accuracy of ultrasound is operator-dependent. This review appraises the evidence for high-resolution ultrasound performed by the treating surgeon (surgeon-performed ultrasound, SPUS) for the detection of silicone implant rupture. A review of PubMed/MEDLINE, Embase, and Scopus was conducted from inception to April 2025. Studies reporting SPUS diagnostic accuracy against surgical or histopathological reference standards, surgeon training or learning-curve outcomes, or the influence of SPUS findings on management were included. The methodological quality of diagnostic accuracy studies was assessed using QUADAS-2. Findings were synthesised narratively. Across the included studies, SPUS achieved high diagnostic accuracy for Silicone implant rupture, with reported sensitivity of 85-100% and specificity of 96-100% against surgical confirmation – figures broadly in line with radiologist-performed ultrasound, though no study directly compared the two operator groups in the same patients. Accuracy depended on the interpretive criteria applied: the stepladder sign, a traditional marker of intracapsular rupture, was unreliable in highly cohesive, form-stable gel implants, and diagnosis instead relied on the broken-shell and snowstorm signs. Diagnostic performance improved with operator experience, with proficiency reported after approximately 60 examinations following short formal training, a finding not yet externally validated. SPUS can achieve diagnostic accuracy for silicone implant rupture broadly in line with figures reported for radiologist-performed ultrasound when criteria specific to highly cohesive, form-stable implants are used, and may offer a means of delivering rupture surveillance within the surgical follow-up pathway, though this has not been directly tested and practical barriers-including self-referral bias, equipment cost, and the absence of accredited training-remain unresolved. The evidence derives largely from single-centre studies; prospective multicentre comparison with MRI is needed before SPUS can be considered a standard of care.

Keyword: Surgeon-performed ultrasound; Silicone breast implants; Implant rupture; High-resolution ultrasound; Diagnostic accuracy; Breast implant surveillance.

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Introduction

Breast augmentation with silicone gel implants is among the most frequently performed aesthetic surgical procedures worldwide.[1] Implant shell failure is a recognised long-term complication of these devices, and its detection presents a particular clinical problem.[2] Unlike saline implant deflation, which produces an obvious loss of volume and is usually apparent on examination, rupture of a silicone gel implant is frequently silent and cannot be reliably identified clinically.[3] Rupture is conventionally classified by the relationship of extravasated gel to the periprosthetic

Address or corresponding
Dr. Ahmed AlSultan, Cosmetic Surgeon,
MBChB, PGDipSurgAnat, MS Plastic & Recon Surg, FACCS
Australasian College of Cosmetic Surgery and Medicine,
Australia.
Email: dr_aalsultan@hotmail.com

fibrous capsule. In intracapsular rupture, the more common form, silicone remains confined within the capsule and the breast may appear entirely normal. In extracapsular rupture, silicone extends beyond the capsule and may produce contour change, a palpable mass, or regional lymphadenopathy.[4]

Because rupture is often asymptomatic, its detection depends on imaging rather than examination. Regulatory guidance on which modality to use has changed materially. Until 2020, the United States Food and Drug Administration recommended magnetic resonance imaging (MRI) beginning three years after implantation and biennially thereafter. In 2020 this recommendation was revised: asymptomatic patients are now advised to undergo ultrasound or MRI at five to six years post-implantation and every two to three years subsequently, with MRI reserved for symptomatic patients or where ultrasound findings are equivocal.[5] The American College of Radiology has aligned its Appropriateness Criteria with this position.[6]

Ultrasound is becoming an acceptable imaging modality as an alternative to MRI for routine rupture surveillance in asymptomatic patients, offering advantages over MRI in accessibility and cost.[7] The sensitivity and specificity of USS in detecting intracapsular and extracapsular rupture are approaching that of MRI.[8]

This shift does not, however, resolve the question of who should perform the examination. Ultrasound is operator-dependent, and its reported diagnostic performance in breast implant assessment varies considerably between studies, with specificity ranging from 55% to 100%.[9,10] Several factors plausibly contribute to this variation, including operator training and case volume, and the interpretive criteria applied - several sonographic signs established for earlier implant generations perform poorly in highly cohesive, form-stable implants, and the stepladder sign in particular has been shown to occur in intact highly cohesive, form-stable implants.[11] Diagnostic accuracy in this setting is thus influenced by operator skill and the validity of the criteria used, though not fully explained by either. Whether trained surgeons applying structured protocols can match radiologist-level accuracy is therefore the question this review assesses.

Against this background, there is growing interest in high-resolution ultrasound performed by the treating surgeon at the point of care, rather than by a radiologist in a separate imaging department. Surgeon-performed ultrasound (SPUS) offers a route to surveillance within the existing surgical follow-up pathway, but its adoption raises further questions that are not addressed by the radiology literature: what training is required to reach radiologist-level accuracy, and how SPUS findings affect subsequent clinical management. Existing reviews of breast implant imaging have been written primarily from a radiological perspective[3,4] and do not evaluate the surgeon as operator. To our knowledge, the evidence relating specifically to SPUS has not previously been synthesised.

The aim of this narrative review is therefore to appraise and synthesise the published evidence on surgeon-performed ultrasound for the detection of silicone breast implant rupture. Three questions are addressed: the reported diagnostic accuracy of SPUS against surgical or histopathological reference standards; the training required to attain diagnostic competence; and the influence of SPUS findings on clinical and operative decision-making.

Methods

A review was conducted to identify studies evaluating surgeon-performed ultrasound (SPUS) for the detection of silicone breast implant rupture. PubMed/ MEDLINE, Embase, and Scopus were searched from database inception to April 2025. Search strategies combined keywords and Medical Subject Headings across three concept areas: silicone breast implants; implant rupture or device failure; and ultrasound imaging, including point-of-care ultrasound and ultrasound performed by surgeons. Queries were adapted to the syntax and indexing of each database.

The reference lists of all included studies and of relevant review articles were screened manually to identify eligible studies not retrieved electronically.

Eligibility criteria The population of interest was women ≥18 years with silicone breast implants, of any generation, placed for cosmetic augmentation or breast reconstruction. The index test was high-resolution ultrasound performed by a plastic or breast surgeon, including office-based and point-of-care examination. Reference standards were intraoperative findings, histopathological examination, radiologist-performed ultrasound, or magnetic resonance imaging. Studies were eligible if they reported at least one of the following: measures of SPUS diagnostic accuracy (sensitivity, specificity, or predictive values); surgeon training or learning-curve outcomes; or the effect of SPUS findings on clinical or operative decision-making.

Eligible designs were diagnostic accuracy studies, prospective or retrospective cohort studies, case series of ten or more patients, cross-sectional surveys, and educational or methodological studies describing SPUS training. Publications without original data (editorials, opinion pieces, and narrative reviews) were excluded from the synthesis but retained for background. Only English-language publications were considered.

Study selection and quality assessment Selection proceeded in two phases: titles and abstracts of all retrieved records were screened against the eligibility criteria, and the full texts of potentially eligible studies were then assessed for inclusion. Screening was performed by a single reviewer and verified by a senior reviewer, with a third author consulted to resolve disagreements and confirm final inclusion decisions, disagreements were resolved by discussion among the three authors. Data were extracted onto a standardised form recording study design, setting, sample size, implant characteristics, ultrasound equipment and technique, operator background and training, reference standard, and key outcomes. The methodological quality of diagnostic accuracy studies was assessed with the QUADAS-2 tool across its four domains: patient selection, index test, reference standard, and flow and timing. The case series and cross-sectional survey were assess narratively for methodological limitations given the absence of a validated risk-of-bias tool suited to those designs.

Data synthesis Heterogeneity in study design, population, and outcome reporting precluded formal meta-analysis. A narrative synthesis was therefore undertaken, structured around the three review questions: diagnostic accuracy, training and learning curve, and the influence of SPUS findings on clinical and operative management. Where appropriate, ranges of reported diagnostic accuracy measures were summarised descriptively.

Results

The search identified twenty-eight studies but only ten studies met the eligibility criteria. Of these, seven reported diagnostic accuracy data, two were descriptive case series without formal accuracy metrics, and one was a cross-sectional survey of practice; studies were published between 2014 and 2025. Study size varied widely, from a 16-patient pilot study to a screening cohort of 2,790 patients. Surgical confirmation cohorts, against which diagnostic accuracy was calculated, were smaller, ranging from 28 to 480 implants. The diagnostic accuracy studies used intraoperative findings, histopathological examination, or both as the primary reference standard. Study characteristics are summarised in **Table 1**.

Reported diagnostic performance of SPUS against surgical or histopathological reference standards was high but not uniform. In an operative cohort of 104 explored implants, Glener *et al.*[10] reported a sensitivity of 90.9%, specificity of 100%, positive predictive value of 100%, and negative predictive value of 97.6%. Bang *et al*;[12] in a surgical cohort of 136 patients, found complete concordance between preoperative ultrasound and intraoperative findings for both ruptured (55/55) and intact (217/217) breasts.

Kim *et al*.[13] similarly reported full agreement between preoperative sonographic and intraoperative findings. Ferenz *et al*.[14] reported a sensitivity of 85.2% and specificity of 96.1% across 480 implants examined by two surgeons. In contrast, Salzman *et al*;[15] in which scans were performed by operators of varying backgrounds after one day of training, yielded a positive predictive value of 75% in the surgically confirmed subgroup.

Accuracy depended on the interpretive criteria applied. In a six-year prospective cohort of 303 implants, Rochira *et al*.[11] observed the stepladder sign - traditionally regarded as indicating intracapsular rupture- in 56% of implants at six years; none of the 24 implants removed on the basis of this sign alone was ruptured, giving the sign a positive predictive value of 0% in highly cohesive, form-stable gel implants. Rupture in this cohort was instead indicated by a discontinuous echogenic shell line. Kim *et al*.[13] reported complete agreement between the snowstorm sign and histopathological evidence of silicone migration into the periprosthetic capsule (80/80 capsules), and on this basis proposed a three-tier, pathology-correlated classification of rupture (subcapsular, intracapsular, extracapsular). In a pilot study of 28 implants, Stachs *et al*.[16] reported that adding real-time sonoelastography to B-mode ultrasound distinguished intact implants, which produced a blue-green-red pattern whereas ruptured implants produced a mixed, non-layered pattern with yellow-green figures; agreement with surgical findings was complete in the five ruptured implants.

Reported training interventions were short. Oni *et al*.[7] found that a one-day structured orientation enabled plastic surgeons to begin point-of-care ultrasound examination. Ferenz *et al*;[14] following 1.5 days of formal training, quantified the subsequent learning curve: regression analysis showed a statistically significant linear improvement in sensitivity with cumulative case volume ($p=0.0003$), with sensitivity exceeding published benchmarks after approximately 60 examinations. Salzman[15] reported that one day of training sufficed for operators of varying backgrounds to perform the examination, but that inexperienced interpreters tended to over-read, producing false-positive diagnoses; review of scans by an experienced surgeon improved the positive predictive value.

Influence on clinical and operative management Three studies reported effects of SPUS findings on management. Kim *et al*.[13] linked the snowstorm sign to histologically confirmed silicone migration, informing the decision for, and extent of, capsulectomy at revision surgery. Glener *et al*.[10] reported that in-office surveillance data supported a selective approach to capsule management in confirmed rupture without other pathology. Salzman[15] surveyed 584 women undergoing screening: 99.5% wished to know their implant status, and a positive diagnosis permitted planned elective revision rather than unplanned surgery.

Limitations of the evidence The principal limitation across studies was operator dependence. Radiologist-performed ultrasound itself shows variability, with specificity as low as 55% reported by Satti *et al*;[9] a plausible contributor is reliance on the stepladder sign which showed 100% false-positive rate in highly cohesive, form-stable implants.[11] Inexperience was associated with over-reading and unnecessary referral,[15] and one study reported sensitivity improving with cumulative case volume up to approximately 60 examinations;[14] this single learning-curve estimate has not been externally validated and the period of elevated diagnostic risk during early adoption-with its attendant risk of missed or misclassified rupture-should be regarded as clinically meaningful rather than a brief or incidental phase. Equipment, scanning protocols, and training content varied across studies, and no study directly compared SPUS with MRI in the same patients. This mirrors the variability seen in radiologist-performed series, underscoring that the case for SPUS rests not on the surgeon's professional background but on structured training, adequate case volume, and the use of valid interpretive criteria, without which, SPUS would be expected to show comparable variability.

Table 1

Rochira et al. (2016)	*Kim et al. (2024)*	*Oni et al. (2018)*	*Glener et al. (2025)*	*Ferenz et al. (2023)*	*Salzman (2022)*	*Benito-Ruiz and de Cabo (2014)*	*Carr et al. (2020)*	*Stachs et al. (2015)*	*Bang et al. (2022)*
Citation: Rochira D, Cavalcanti P, Ottaviani A, Tambasco D. Longitudinal Ultrasound Study of Breast Implant Rupture Over a Six-Year Interval. Ann Plast Surg. 2016;76(2):150-154. Design: Prospective longitudinal cohort; diagnostic accuracy study.	Citation: Kim J-H, Kim Y-G, Song K-Y, et al. Exploration of Point-of-Care Ultrasonography for Silicone Breast Implant Rupture Detection and Classification. Medicina. 2024;60(2):306. Design: Retrospective diagnostic accuracy study / large surgical case series.	Citation: Oni G, Chow W, Ramakrishnan V, Griffiths M. Plastic Surgeon–Led Ultrasound. Plast Reconstr Surg. 2018;141(2):300e-309e. Design: Retrospective case series / narrative review of clinical applications (thematic).	Citation: Glener AD, Sergesketter AR, Adams WP Jr. Outcomes of In-Office, High Resolution Ultrasound Silicone Breast Implant Surveillance by Plastic Surgeons. Aesthet Surg J. 2025;45(1):48–55. Design: Retrospective diagnostic accuracy and cohort study (single-surgeon).	Citation: Ferenz S, McGuire P, Glicksman C. The Efficacy and Associated Learning Curve of Office-Based High-Resolution Ultrasound to Detect Shell Failure in Breast Implants. Aesthet Surg J. 2023;43(6):657-661. Design: Retrospective diagnostic accuracy study with explicit learning curve analysis.	Citation: Salzman MJ. Silent Rupture of Silicone Gel Breast Implants: High-Resolution Ultrasound Scans and Surveys of 584 Women. Plast Reconstr Surg. 2022;149(1):7-14. Design: Prospective, multicenter diagnostic study with integrated patient survey.	Retrospective case series / technical report.	Carr LW, Roberts J, Meridi AF, et al. Breast implant imaging surveillance among U.S. Plastic Surgeons: U.S. Food and Drug Administration Recommendations versus Clinical Reality. Plast Reconstr Surg. 2020. Design: Cross-sectional survey.	Stachs A, Dieterich M, Hartmann S, et al. Diagnosis of Ruptured Breast Implants Through High-Resolution Ultrasound Combined With Real-Time Elastography. Aesthet Surg J. 2015. Design: Prospective diagnostic pilot study.	Bang BS, Jung SH, Lee EK, et al. A Surgeon's Empirical Perspectives on Use of High-resolution Ultrasound in Preoperatively Detecting a Rupture in the Context of Breast Implant Crisis in Korea. Aesth Plast Surg. 2022. Design: Retrospective diagnostic accuracy study.
N: 156 patients, 303 implants. Indication: Mixed - Augmentation (119), Mastopexy with implants (28), Reconstruction (9). Implant Gen: Last generation (Allergan/McGhan, implanted 2004-2008).	N: 2790 patients (5557 implants) screened; 89 surgical patients (111 ruptured implants). Indication: Exclusively aesthetic augmentation. Implant Gen: Not specified, but presumed modern.	N: Illustrative cases from a general plastic surgery practice (not a focused diagnostic cohort). Indication: Broad – includes breast, hand, lymphedema, trauma. Implant Gen: Not applicable.	N: 254 patients, 508 implants. Indication: Aesthetic (implants placed by senior author). Implant Gen: Generations 4, 5, 6 (post-1993). Median age at US: 119 months (~10 yrs).	N: 480 implants examined across two practices. Indication: Patients presenting for US screening/surgery. Implant Gen: 6% Gen 3, 47% Gen 4, 47% Gen 5.	N: 584 women, 1153 implants. Indication: Mixed - Cosmetic (72.2%), Reconstructive (11.3%). Implant Gen: Allergan, Mentor, Sientra implants placed between 2000-2015.	Case series from a single practice (breast implants main focus).	N: 662 responding ASPS surgeons. Indication: Not specified (presumably mixed). Implant Gen: Not applicable.	N: 16 patients, 28 implants. Indication: Mixed (cosmetic & recon). Implant Gen: Mixed (cohesive and non-cohesive).	N: 136 patients (surgical cohort). Indication: Aesthetic and reconstructive. Implant Gen: Various.
Device: ESAOTE MYLAB40. Probe: 10 MHz & 15 MHz linear. Protocol: Pre-op scan, then q6mo for 24mo, final scan at 6 years. Systematic examination.	Device: Aplio i600 (Canon). Probe: 7–18 MHz linear transducer. Protocol: Standardized scan using the Korean Society of Breast Implant Research (KoSBIR) checklist. Minimum 6 images/videos per breast.	Device: Sonosite S-Nerve. Probe: L25X transducer (high-frequency). Protocol: Point-of-care applications. For breast: used for rupture, contracture, guiding fat grafting, seroma drainage.	Device: Terason uSmart 3200T. Protocol: Systematic, templated in-office technique. Video and still documentation. Standardized sweeps (inferior midline, medial/lateral).	Device: PS Imaging HRUS & Butterfly system. Probe: Frequency 1-10 MHz. Protocol: Systematic examination of anterior/lateral aspects. Pressure applied to flatten folds.	Device: Clarius handheld scanner. Probe: 7-13 MHz linear. Protocol: Standardized across sites. Still and video images captured and stored electronically.	*Aloka/Mindray systems, 7.5-12 MHz linear probes. Routine follow-up.*	Survey of imaging practice patterns. Key Finding: Only 37.7% of surgeons recommend MRI at FDA intervals.	Device: Philips iU22. Probe: 12 MHz linear. Protocol: HRUS + Real-time elastography (strain imaging).	Device: Canon Aplio i600. Probe: 7–18 MHz linear. Protocol: Structured HRUS examination.
Described as the same operator, plastic surgeon, and expert in breast sonography.	A seasoned breast surgeon specializing in breast implant ultrasonography with 12 years of experience.	Plastic surgeons (senior author and trainees). Training: 1-day orientation with ultrasonographer/radiologist.	Plastic surgeon (senior author, W.P.A.).	Two plastic surgeons. Training: 1 full day in-person + 0.5 day in-office hands-on training.	Multiple: Plastic surgeons, nurses, medical assistants at 9 sites. Training: 1-day office training session. Final scan review by an HRUS-experienced plastic surgeon (M.J.S.).	Plastic surgeon (first author) performing scans.	Survey respondents (practicing US plastic surgeons).	An experienced breast surgeon (AS).	Surgeons (implied to be the authors).
1. Surgical findings (for definitive rupture diagnosis). 2. MRI (used for further evaluation of select cases). 3. Clinical follow-up (for majority).	1. Surgical pathology of the periprosthetic capsule (111 capsules analyzed). 2. Intraoperative gross findings.	Surgical exploration / clinical course (for illustrative cases). No formal diagnostic comparator.	Surgical findings in the operative cohort (104 explored implants).	Surgical findings for all 480 implants (all patients underwent surgery).	Surgical findings in the subset who underwent operation (40 out of 82 women with US-diagnosed rupture).	Surgical findings for ruptures; clinical follow-up.	Self-reported practice patterns.	Surgical findings for ruptured implants (n=5). Clinical/MRI follow-up for others.	Surgical findings at reoperation (gold standard).

Rochira et al. (2016)	*Kim et al. (2024)*	*Oni et al. (2018)*	*Glener et al. (2025)*	*Ferenz et al. (2023)*	*Salzman (2022)*	*Benito-Ruiz and de Cabo (2014)*	*Carr et al. (2020)*	*Stachs et al. (2015)*	*Bang et al. (2022)*
• Overall Rupture Rate: 1% (3/303). • Stepladder Sign Prevalence: 56% (170/303) at 6 yrs. • False-Positive Rate of Stepladder Sign: 100% (0/24 implants removed based on this sign were ruptured). • True Rupture Sign: Discontinuous echogenic line (broken shell sign). • Metrics: PPV of stepladder sign = 0%.	• Diagnostic Agreement: 100% between preoperative US and surgical findings for rupture. • Snowstorm Sign Correlation: 100% (80/80 capsules with snowstorm sign on US had silicone migration on pathology). • Proposed Classification: Pathologic 3-type: Subcapsular (US: snowstorm -), Intracapsular (US: snowstorm +, tissue invasion -), Extracapsular (US: snowstorm +, tissue invasion +).	• Feasibility: Demonstrates broad utility of POCUS across plastic surgery. • Breast Applications: Rupture detection, capsular assessment, ultrasound-guided fat grafting over implants, scar release, seroma drainage. • No formal accuracy metrics provided for rupture detection.	• Diagnostic Accuracy (Operative Cohort, n=104): Sensitivity: 90.9% (95% CI 70.8-98.9), Specificity: 100% (95% CI 95.6-100), PPV: 100% (95% CI 83.2-100), NPV: 97.6% (95% CI 91.6-99.4), Accuracy: 98.1%. • Implant Survival: 10-yr: 98%; 15-yr: 80% (99.4%/91.8% for surveillance-only subgroup).	• Overall Diagnostic Accuracy (n=480): Accuracy: 93.3%, Sensitivity: 85.2%, Specificity: 96.1%, PPV: 88.1%, NPV: 95.0%. • Learning Curve: Linear regression showed significant improvement in sensitivity over time (p=0.0003). Surgeons exceeded literature sensitivity standard after ~60 scans.	• Rupture Prevalence: 14% of women (82/584); 8% of implants (92/1153) on US. • Positive Predictive Value (PPV): 75% (30/40 US-diagnosed ruptures were surgically confirmed). • Negative Predictive Value (Estimate): 98.1% (993/1012 non-suspect scans were true negatives). • Survey Findings: 99.5% of women want to know about rupture; 95.2% want it removed; 95.5% would get future US screening if scan was negative.	Case-based illustration of rupture signs (stepladder, snowstorm), rotation assessment via marker identification.	Primary Outcome: MRI recommendation rate. Key Stats: 37.7% recommend MRI per FDA. 55% image "only if a problem." Academic, early-career, low-volume surgeons more likely to recommend MRI.	Rupture Rate: 17.9% (5/28). Elastography Findings: Intact implants showed a "bull's-eye" artifact (blue-green-red pattern). Ruptured implants showed a mixed, non-layered pattern. Perfect agreement (5/5) between US+elasto and surgery for rupture.	Diagnostic Accuracy: 100% agreement between preoperative HRUS and surgical findings for rupture (55/55 ruptured breasts) and non-rupture (217/217 non-ruptured breasts).
Operator described as an expert. No specific training protocol detailed.	Operator has 12 years of specialized experience. Emphasizes the critical role of a standardized checklist (KoSBIR) for consistent imaging.	Explicitly addresses training. A short, formal 1-day orientation was sufficient for surgeons to begin using POCUS effectively. Describes a short learning curve.	Training not explicitly detailed; technique described as simple and reproducible. Implies surgeon expertise is key.	Primary focus of the study. 1.5 days of formal training. First study to quantify the learning curve: Shows linear improvement, with proficiency (exceeding literature sensitivity) reached after approximately 60 scans.	1-day training for multiple operator types (surgeons, nurses, MAs). Notes that inexperience leads to over-reading (high false-positives). Accuracy improves with experience; final review by an expert surgeon improved PPV.	Advocates for surgeons to attend courses, work with specialists, and gain experience.	Not addressed.	Feasibility demonstrated; elastography deemed "straightforward" without a long learning curve.	Not formally analyzed, but authors note HRUS is operator-dependent and requires "in-depth understanding."
Critical Warning: Reliance on the outdated stepladder sign leads to unnecessary surgical explanations, patient distress, and increased costs. Highlights the imperative to update diagnostic criteria for modern implants.	Direct Surgical Guidance: US reliability allows for same-day diagnosis and surgical planning. The proposed classification directly informs the decision for and extent of capsulectomy during revisional surgery.	Practice Transformation: Advocates for POCUS to streamline care, avoid delays for radiology referrals, and enable immediate bedside interventions (drainage, guided injections). Enhances surgical precision and patient satisfaction.	Validates an In-Office Model: Demonstrates that plastic surgeon-delivered, office-based HRUS is a highly accurate, convenient, and patient-accepted surveillance model that can improve compliance and provides excellent long-term implant survival data.	Supports Implementation: Provides empirical evidence for the expected learning curve, reassuring surgeons that accuracy improves predictably with volume. Data supports the argument for integrating HRUS into training and practice.	Addresses Patient Needs & System Failure: Highlights overwhelming patient anxiety about silent rupture and very low MRI compliance. Positions HRUS as a convenient, patient-demanded solution that addresses the surveillance gap.	Positions US as an extension of physical exam, allowing in-office diagnosis/treatment (e.g., seroma drainage), avoiding unnecessary referrals.	Documents the MRI adherence gap. Highlights system failure of MRI-based surveillance due to cost, time, access. Provides rationale for seeking alternatives like in-office US.	Introduces elastography as a potential adjunct. May help differentiate intact from ruptured implants, especially in equivocal B-mode US cases. Could reduce need for confirmatory MRI.	Validates HRUS as a highly accurate preoperative tool. Demonstrates utility in a "crisis" context (high patient anxiety, device fraud). Emphasizes role in surgical planning (extent of capsulectomy, incision choice).
Theme 1 (Diagnostic Accuracy): Critical paper. Demonstrates that diagnostic criteria are generation-specific. Traditional stepladder sign is invalid for modern cohesive gels, defining what not to use. Theme 3 (Clinical Impact): Highlights a major potential negative impact (unnecessary surgery) of misinterpretation.	Theme 1 (Diagnostic Accuracy): Strong supportive evidence. Provides data for high accuracy and refines the rupture classification system based on pathology. Theme 3 (Clinical Impact): Directly links specific US findings (snowstorm sign) to surgical decision-making (capsulectomy).	Theme 2 (Training): Key feasibility model. Demonstrates that short, formal training is a viable entry point. Theme 4 (Implementation): Philosophical foundation. Articulates the point-of-care philosophy for plastic surgery, outlining broad benefits beyond rupture detection.	Theme 1 (Diagnostic Accuracy): Key contemporary evidence. Provides robust, calculated metrics (high Sens, Spec, PPV, NPV) from a large, single-surgeon cohort, strongly supporting diagnostic validity. Theme 4 (Implementation): Exemplar of a successful clinical practice model for in-office surveillance.	Theme 2 (Training): Most important paper for this theme. First to quantify the learning curve, providing a concrete benchmark (~60 scans) for achieving proficiency. Essential for curriculum design. Theme 4 (Implementation): Provides data to mitigate concerns about the initial learning phase.	Theme 3 (Clinical Impact): Unique and crucial contribution. Provides patient-reported outcome data revealing high anxiety and strong preferences, justifying the shift to accessible screening. Theme 4 (Implementation): Strongly supports HRUS as a practical and patient-preferred alternative to MRI, solving the compliance problem.	Theme 2 (Training): Early advocate for surgeon training. Theme 4 (Implementation): Classic paper outlining the why and how of SPUS integration into a surgical practice.	Theme 3 (Clinical Impact): Foundational paper. Quantifies the clinical reality that MRI surveillance is failing, creating a powerful rationale for the adoption of surgeon-performed US as a practical solution.	Theme 1 (Diagnostic Accuracy) & Theme 4 (Implementation): Explores an advanced, adjunctive imaging technology (elastography) that could future-proof surgeon-performed US, enhancing its diagnostic confidence.	Theme 1 (Diagnostic Accuracy): Provides strong, large-scale supportive data for HRUS accuracy from an Asian context. Theme 3 (Clinical Impact): Links HRUS directly to crisis management (BIA-ALCL, device fraud) and detailed surgical planning.

Discussion

This narrative review indicates that surgeon-performed high-resolution ultrasound (SPUS) can achieve high diagnostic accuracy for silicone implant rupture and is practical to integrate into surgical follow-up, though the evidence derives largely from single-centre studies. In the included studies, SPUS performed with contemporary interpretive criteria achieved accuracy for rupture detection comparable to that reported for radiologist-performed ultrasound. SPUS also informed surgical planning and offers a means of addressing the documented shortcomings of MRI-based monitoring. This discussion places these findings in the context of the wider breast implant imaging literature and outlines implications for practice and research. The diagnostic accuracy of SPUS reported in this review falls within a range broadly comparable to figures reported for radiologist-performed USS. For example, an accuracy of 96% was reported by Spit *et al*;[17] though no included study directly compared surgeon and radiologist operators scanning the same patients. This remains an indirect comparison across different study populations rather than evidence of equivalence. Radiologist-performed USS itself shows considerable variability, with specificity as low as 55% reported by Satti *et al*.[9] demonstrating that diagnostic performance is not necessarily intrinsic to the modality but depends on operator skill and the interpretive criteria applied - a dependency that applies as much to the SPUS comparison being drawn here as to the radiologist studies themselves.

A central finding concerns the reinterpretation of classic sonographic signs for highly cohesive, form-stable gel implants. Traditional teaching, as illustrated by Lake *et al*.[3] and Oliver and Stormo;[18] presents the stepladder sign as an indicator of intracapsular rupture. The longitudinal study by Rochira *et al*.[11] provides the counterpoint: in their surgical cohort, the stepladder sign was observed in a high proportion of intact contemporary implants, reflecting benign age-related gel fracture, and carried a 100% false-positive rate for rupture. Surgeons adopting SPUS should therefore not rely on this sign, as doing so risks unnecessary surgical intervention. Accurate diagnosis in highly cohesive, form-stable implants rests instead on the discontinuous shell (broken shell) sign and the snowstorm sign of extravasated silicone. Kim *et al.*[13] reported complete agreement between the snowstorm sign and histopathological evidence of silicone migration, and proposed a pathology-correlated classification that directly informs preoperative decision-making. Operator-dependence is the persistent critique of ultrasound in this setting, noted in the radiology literature by Spit *et al.*[17] and Satti *et al*.[9] This dependence is not solely attributable to outdated interpretive criteria or insufficient training; ultrasound is inherently operator-subjective in real time, and factors such as acoustic shadowing, implant positioning, and patient body habitus can limit image quality regardless of operator experience. Updated criteria and structured training may narrow, but are unlikely to eliminate, this variability. The evidence synthesised here suggests the problem is at least partially tractable with training, though not fully resolved by it. Ferenz *et al.*[14] demonstrated a linear improvement in sensitivity with cumulative case volume, with sensitivity exceeding published benchmarks after approximately 60 examinations, in that single-centre cohort. This finding indicates that a measurable learning curve exists, but it derives from one study and one training pathway; it should not be read as a fixed competency threshold generalisable across operators, equipment, or implant types, and the risk of misdiagnosis during the early part of that curve- as also noted by Salzman- remains clinically significant.[15] The training models described by Salzman[15] and by Oni *et al*.[7] further suggest that short formal training followed by supervised early practice enables plastic surgeons to attain and maintain diagnostic competence. This is a distinguishing feature of the surgeon-performed model: the operator masters a focused skill set applied to a defined patient population. The clinical relevance of SPUS is best understood against the documented poor real-world adherence to MRI-based surveillance. Under the pre-2020 FDA recommendation of MRI screening from

three years post-implantation, Carr *et al.*[19] found that only 37.7% of responding US plastic surgeons recommended MRI at the advised intervals, and 55% imaged implants only when a problem was suspected; the authors attributed poor adherence to the cost, time commitments, and equipment constraints of MRI. The 2020 revision of FDA guidance, permitting ultrasound as an alternative screening modality, acknowledged these barriers. The guidance specifies the imaging modality but does not address who should perform it; SPUS is one possible route to delivering ultrasound-based surveillance within this framework, not a model the FDA has specifically considered or endorsed. Whether SPUS specifically can improve on this adherence problem has not been tested-no included study compared SPUS uptake or adherence against MRI-based pathways-but its integration into the existing surgical follow-up visit, rather than requiring a separate imaging appointment, is a plausible mechanism worth prospective evaluation. This direction is consistent with the radiology literature: Spit *et al.*[17] conclude in favour of ultrasound as the initial examination, with MRI reserved for problem-solving. The radiology review by Seiler *et al.*[4] describes the conventional signs of rupture (keyhole, stepladder, linguine, snowstorm) but cautions that cohesive implants may fracture rather than collapse, obscuring these classic appearances. This accords with the findings of Rochira *et al.*[11] and Kim *et al.*[13] that the stepladder sign is unreliable in highly cohesive, form-stable implants, and reinforces the need for generation-specific interpretive criteria in SPUS training. Several limitations must be acknowledged. At review level, screening and selection were performed by a single reviewer with senior verification rather than by two independent reviewers, and only English-language publications were included, both of which introduce potential selection bias. At evidence level, most included studies were single-centre, retrospective, or conducted by early adopters of the in-office model, several of whom are developers or advocates of the techniques they evaluate; selection and performance bias cannot be excluded. Diagnostic accuracy, though generally high, was not uniform, and the low specificity reported by Satti *et al.*[9] illustrates the dependence of results on training and on the application of modern interpretive criteria. Training protocols and equipment varied across studies, limiting comparability. No included study compared SPUS directly with MRI in the same patients. Beyond the methodological limitation of the review itself, the wider adoption of SPUS raises practical challenges not addressed by diagnostic accuracy alone. The scanning surgeon is also the clinician who stands to perform any subsequent surgery. Self-referral bias is a structural risk distinct from the study-level performance bias noted above. USS equipment represents a further cost to the practice, and the medicolegal implications of a missed or misclassified rupture identified by a surgeon rather than an accredited sonographer or radiologist have not been established. To our knowledge, there is currently no accredited SPUS training pathway or competency certification, and the training described across included studies was informal and non-standardised. Spit *et al.*[17] is the only same-patient comparison of ultrasound and MRI in this literature, and it used radiologist operators. Finally, whether the reassurance provided by SPUS surveillance translates into long-term outcomes, such as implant longevity or sustained patient satisfaction, remains unknown. For clinical practice, these findings support the formal integration of SPUS training into plastic surgery curricula and continuing education, with emphasis on generation-specific rupture signs and explicit movement away from the stepladder sign. Clinics adopting SPUS should use standardised scanning protocols covering the implant shell, periprosthetic space, and axillary regions, with expert review of scans during the early learning period, as described by Salzman.[15] Dedicated implant surveillance clinics, as modelled by Glener *et al.*[10] and Jaeger *et al*;[8] offer a structure for delivering this care. Three research priorities follow. First, prospective multicentre diagnostic accuracy studies comparing SPUS directly with MRI, using surgical confirmation as the reference standard, are needed. Second, formal cost-effectiveness analyses of SPUS-based surveillance against MRI-based pathways would inform adoption decisions.

Third, training modules and competency benchmarks should be standardised, building on the learning-curve data of Ferenz *et al*.[14] Beyond rupture detection, the extension of high-resolution ultrasound to earlier capsular pathology has been proposed but remains unvalidated and was outside the scope of this review.

Conclusion

This narrative review indicates that surgeon-performed high-resolution ultrasound can achieve diagnostic accuracy for silicon breast implant rupture broadly in line with that reported for radiologist-performed ultrasound, provided that criteria specific to highly cohesive, form-stable implant are applied; no included study, however, directly compared surgeon and radiologist operators in the same patients. The learning curve was identifiable in the available evidence, with one study reporting sensitivity improving after approximately 60 examinations following short formal training. This single estimate requires replication before it can be treated as generalisable competency benchmark, and the diagnostic risk during the early learning period should not be understated. By brining rupture surveillance into the surgical follow-up pathway, SPUS may offer a practical means of improving adherence to the screening envisaged by current FDA guidance-an adherence gap well documented for MRI-based protocols. This guidance is silent on operator, however, and its application to the surgical setting reflect the authors' interpretation rather than and FDA position; the potential adherence benefit has not been directly tested. Practical barriers-including self-referral bias, equipment cost, and the absence of accredited SPUS training-remain unresolved. The evidence remains limited to predominantly single-centre studies, and prospective multicentre comparison of SPUS with MRI against surgical confirmation is needed before SPUS can be recommended as a standard care. In the interim, adaptation should be accompanied by structured training, standardised scanning protocols, and expert review during early practice.

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References

1. International Society of Aesthetic Plastic Surgery. ISAPS International Survey on Aesthetic/Cosmetic Procedures Performed in 2024. Mount Royal (NJ): ISAPS; 2025. Available from: https://www.isaps.org/discover/about-isaps/global-statistics/global-survey-2024-full-report-and-press-releases/.
2. Noreña-Rengifo BD, Sanín-Ramírez MP, Adrada BE, Luengas AB, Martínez de Vega V, Guirguis MS, *et al*. MRI for Evaluation of Complications of Breast Augmentation. *Radiographics*. 2022;**42(4)**:929–46.
3. Lake E, Ahmad S, Dobrashian R. The sonographic appearances of breast implant rupture. *Clin Radiol*. 2013;**68(8)**:851–8.
4. Seiler SJ, Sharma PB, Hayes JC, Ganti R, Mootz AR, Eads ED, *et al*. Multimodality Imaging-based Evaluation of Single-Lumen Silicone Breast Implants for Rupture. *Radiographics*. 2017;**37(2)**:366–82.
5. United States Food and Drug Administration. Breast implants - certain labeling recommendations to improve patient communication: guidance for industry and Food and Drug Administration staff. Silver Spring (MD): US Department of Health and Human Services, Food and Drug Administration, Center for Devices and Radiological Health; 2020. Available from: https://www.fda.gov/regulatory-information/search-fda-guidance-documents/breast-implants-certain-labeling-recommendations-improve-patient-communication.
6. Bennett DL, Brown A, Freer PE, Bahl M, Dibble EH, Greenwood HI, *et al*. ACR Appropriateness Criteria® Breast Implant Evaluation: Update 2025. *J Am Coll Radiol*. 2026;**23(4)**:658–80.
7. Oni G, Chow W, Ramakrishnan V, Griffiths M. Plastic Surgeon-Led Ultrasound. *Plast Reconstr Surg*. 2018;**141(2)**:300e–9e.
8. Jaeger M, Randquist C, Gahm J. Anatomical Breast Implant Assessment Using Ultrasound: A Case Series from the International Breast Implant Check Clinic. *Plast Reconstr Surg Glob Open*. 2023;**11(12)**:e5469.
9. Satti SK, Mohyuddin A, Bin Khalid QS. Diagnostic efficacy of high-resolution ultrasound in the assessment of breast implants. *Pak J Radiol*. 2020;30(1).

10. Glener AD, Sergesketter AR, Adams WP, Jr. Outcomes of In-Office, High Resolution Ultrasound Silicone Breast Implant Surveillance by Plastic Surgeons. *Aesthet Surg J*. 2024;**45(1)**:48–55.
11. Rochira D, Cavalcanti P, Ottaviani A, Tambasco D. Longitudinal Ultrasound Study of Breast Implant Rupture Over a Six-Year Interval. *Ann Plast Surg*. 2016;**76(2)**:150–4.
12. Bang BS, Jung SH, Lee EK, Sung JY, Song KY, Yoo YB, *et al*. A Surgeon's Empirical Perspectives on Use of High-resolution Ultrasound in Preoperatively Detecting a Rupture in the Context of Breast Implant Crisis in Korea. *Aesthetic Plast Surg*. 2022;**46(4)**:1668–78.
13. Kim JH, Kim YG, Song KY, Lim HG, Jeong JP, Sung JY, *et al*. Exploration of Point-of-Care Ultrasonography for Silicone Breast Implant Rupture Detection and Classification. *Medicina (Kaunas)*. 2024;60(2).
14. Ferenz S, McGuire P, Glicksman C. The Efficacy and Associated Learning Curve of Office-Based High-Resolution Ultrasound to Detect Shell Failure in Breast Implants. *Aesthet Surg J*. 2023;**43(6)**:657–61.
15. Salzman MJ. Silent Rupture of Silicone Gel Breast Implants: High-Resolution Ultrasound Scans and Surveys of 584 Women. *Plast Reconstr Surg*. 2022;**149(1)**:7–14.
16. Stachs A, Dieterich M, Hartmann S, Stubert J, Reimer T, Gerber B. Diagnosis of ruptured breast implants through high-resolution ultrasound combined with real-time elastography. *Aesthet Surg J*. 2015;35(4):410–8.
17. Spit KA, Azahaf S, de Blok CJM, Duvivier KM, Wiebenga OT, Nanayakkara PWB. Ultrasound versus MRI for evaluation of silicone leakage from silicone breast implants. *Heliyon*. 2024;10(12):e33325.
18. Oliver HL, Stormo J. Sonographic Confirmation of Intracapsular and Extracapsular Breast Implant Rupture. J Diagnost Med Sonography. 2019;**35(2)**:152–6.
19. Carr LW, Roberts J, Mericli AF, Liu J, Arribas EM, Clemens MW. Breast Implant Imaging Surveillance among U.S. Plastic Surgeons: U.S. Food and Drug Administration Recommendations versus Clinical Reality. *Plast Reconstr Surg*. 2020;**145(6)**:1381–7.