

Resolution versus Reliability: Interpreting Ultra-High-Frequency Ultrasound in Melanoma Recurrence Detection [Letter]

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Dear editor

We read with great interest the study by Russo et al¹. The authors are to be commended for addressing a clinically relevant and technically challenging problem, namely the detection of clinically occult local recurrence in melanoma excision scars using ultra-high-frequency ultrasound (UHFUS). By systematically evaluating micrometric-resolution morphological features and Doppler vascular signals, the study provides valuable insight into the potential of advanced ultrasound techniques to detect subclinical disease within postoperative tissue. A key strength of the work lies in its pragmatic and technically structured design, incorporating high-frequency transducers, standardized acquisition protocols, and a clearly defined semeiotic classification framework; however, future studies would benefit from larger, multicenter cohorts and comparative evaluation with conventional imaging modalities to strengthen the generalizability of these findings.

From a technical imaging perspective, the study effectively exploits the resolution–penetration trade-off inherent to ultrasound physics. Transducers operating at 48–70 MHz provide axial resolutions approaching 30–60 µm, enabling visualization of fine dermal architecture and small hypoechoic nodules that are not resolvable with conventional 10–18 MHz probes.² However, this increased resolution is accompanied by limited penetration depth and increased susceptibility to attenuation and acoustic shadowing, particularly in fibrotic or collagen-dense scar tissue. In such environments, acoustic impedance mismatches and anisotropic collagen alignment may produce signal heterogeneity and speckle variation, potentially mimicking or obscuring true pathological findings. Furthermore, the shallow penetration restricts assessment of deeper subcutaneous planes, which may harbor early recurrence beyond the effective imaging window. Optimization strategies such as compound imaging, dynamic range adjustment, and probe angulation may partially mitigate these limitations, although they introduce additional operator dependency.

The integration of Doppler imaging adds a functional dimension by detecting low-flow vascular signals associated with tumor neoangiogenesis. Nevertheless, Doppler sensitivity at these frequencies introduces important interpretative challenges. Low pulse repetition frequency (PRF) and high gain settings—required to detect slow microvascular flow—are inherently prone to motion artifacts, blooming artifacts, and noise amplification.³ At ultra-high frequencies, even minimal transducer motion may generate spurious signals due to increased system sensitivity. In postoperative scars, vascular signals may also arise from benign processes such as inflammation, granulation tissue, or fibroblast-driven remodeling rather than true tumor recurrence. These overlapping hemodynamic signatures reduce specificity and may account for false-positive findings. Emerging approaches such as contrast-enhanced ultrasound (CEUS) and advanced microvascular imaging techniques may improve specificity by enabling better characterization of vascular architecture and perfusion patterns.^{4,5}

Another important technical consideration relates to image interpretation. The semeiotic classification proposed by the authors, while structured, relies on qualitative assessment of morphology and vascularity without clearly defined quantitative thresholds. In high-resolution ultrasound, subtle variations in echogenicity, lesion margins, and vascular patterns are highly sensitive to acquisition parameters, including gain, focus, and probe pressure. This raises the possibility that minor technical

variations could significantly influence classification outcomes. Incorporating quantitative approaches—such as lesion thickness measurements, vascular density indices, or texture-based analysis—may improve reproducibility. In this context, radiomics offers a promising framework, as it enables extraction of high-dimensional quantitative features from imaging data to support objective differentiation between benign and malignant tissue.^{6,7}

This limitation is further underscored by the study design, in which all examinations were performed by a single expert operator. While this ensures internal consistency, it creates a “high-signal, low-noise” evaluation environment that may overestimate real-world performance. In clinical practice, variability in probe handling, pressure, and parameter selection can significantly influence both grayscale and Doppler findings. The absence of interobserver agreement metrics therefore represents a critical limitation, as reproducibility is essential for broader clinical adoption. Standardized acquisition protocols, including predefined Doppler settings and scanning techniques, should be established and validated across operators.

Several additional methodological considerations merit attention. The lack of a comparator arm using conventional high-frequency ultrasound limits assessment of the incremental diagnostic value attributable specifically to UHFUS. Moreover, reliance on follow-up rather than systematic histopathologic confirmation for benign cases introduces verification bias, a recognized limitation in diagnostic accuracy studies. The relatively short follow-up period for ultrasound-negative scars may also lead to underestimation of delayed recurrences, thereby inflating the reported negative predictive value.

In conclusion, the authors present a technically sophisticated and clinically relevant application of UHFUS in melanoma follow-up. However, factors such as Doppler sensitivity limitations, tissue heterogeneity, operator dependency, and methodological constraints must be addressed before widespread clinical adoption. Future work should prioritize multicenter validation, standardized acquisition protocols, and incorporation of quantitative imaging approaches to ensure reproducibility and clinical robustness.

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