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Shear wave elastography for differentiating benign and malignant ovarian masses

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Abstract:
Accurate pre-operative differentiation of benign and malignant ovarian masses is essential for appropriate surgical planning and fertility preservation. Therefore, it is of interest to evaluate the diagnostic value of shear wave elastography (SWE) in 109 women with ovarian masses using histopathology as the reference standard. Histopathology identified 68 benign and 41 malignant masses, with significantly higher stiffness in malignant lesions (48.35 ± 8.74 vs 25.41 ± 5.76 kPa; $p < 0.001$). At a 35.3-kPa cutoff, SWE achieved an AUC of 0.980, sensitivity of 95.1%, specificity of 97.1%, and accuracy of 96.3%. Thus, incorporating SWE into conventional ultrasonography improved diagnostic accuracy and may support more precise pre-operative assessment of ovarian masses.

Keywords: Ovarian mass, shear wave elastography (SWE), sonoelastography, ovarian malignancy, doppler ultrasound

Background:
Adnexal masses encompass functional cysts, benign neoplasms, borderline tumors and invasive ovarian malignancies. Their preoperative classification is essential because benign lesions can often be managed conservatively, whereas suspected cancer requires oncologic staging and specialist referral. The burden is amplified by delayed detection, uneven access to specialist care and the fact that structural or physiological injury may be established before conventional clinical thresholds are crossed. Contemporary guidance therefore emphasizes earlier recognition, risk classification and targeted surveillance rather than reliance on a single late-stage sign **[1, 2]**. Malignant tumors commonly contain dense cellular areas, desmoplastic stroma, papillary tissue, necrosis and irregular neovascularity. These microstructural changes may increase lesion stiffness and produce low-resistance blood flow, creating complementary targets for morphology, Doppler and elastography. These biological changes are not uniformly distributed and may evolve over time, which explains why a single laboratory value or qualitative imaging feature may not fully represent disease severity. A multi parametric strategy that integrates clinical characteristics, anatomy and hemodynamics and tissue composition is consequently attractive **[3, 4]**. Expert pattern recognition, IOTA rules, ADNEX modeling and O-RADS provide structured risk assessment. Nevertheless, operator experience, complex cystic-solid architecture and overlap between benign and malignant appearances can limit certainty. Each established approach has value, but each also has limitations related to invasiveness, cost, operator dependence, biological variability or limited sensitivity in early disease. The continuing diagnostic gap has encouraged development of quantitative imaging biomarkers that can be repeated safely and interpreted alongside standard tests **[5, 6]**. SWE quantitatively maps tissue elasticity in kilopascals. Unlike manual strain elastography, the technique uses machine-generated acoustic impulses and is less dependent on operator compression, offering a potentially reproducible parameter for ovarian tumor characterization. Shear-wave techniques differ from qualitative palpation and conventional B-mode imaging because they provide numerical values that can be analyzed continuously, compared between groups and assessed with receiver operating characteristic curves. Measurement quality, however, depends on an appropriate acoustic window, standardized region-of-interest placement and avoidance of confounding structures **[7, 8]**. Few prospective studies have evaluated SWE alongside morphology, Doppler and CA-125 with histopathology as the reference standard, particularly in Indian tertiary-care populations. Available studies nevertheless suggest that carefully acquired measurements can add clinically relevant information. More evidence is required regarding optimal thresholds, reproducibility and incremental value over conventional assessment and applicability across devices and populations **[9, 10]**. Therefore, it is of interest to compare the stiffness values in benign and malignant ovarian masses and determine whether SWE improves the diagnostic performance of conventional morphology and color Doppler.

Materials and Methods:
Study design and setting:
Prospective diagnostic-accuracy study at a tertiary-care radiology department. Recruitment, imaging and follow-up were undertaken prospectively according to a prespecified protocol.

Participants:
One hundred nine women with an ovarian or adnexal mass scheduled for operative management or image-guided tissue diagnosis were included. Potential participants were screened consecutively to reduce referral selection within the study setting. Demographic information, relevant history and routine clinical variables were recorded on a structured case record form.

Eligibility criteria:
Inclusion criteria were:
Women aged 18 years or older with a persistent ovarian mass visualized adequately on transabdominal or transvaginal ultrasonography and with available histopathology.

Exclusion criteria were:

Pregnancy, acute torsion requiring emergency surgery before complete imaging, previously treated ovarian cancer, purely extra-ovarian masses, poor visualization and refusal of consent. These criteria were intended to minimize major technical and biological confounders while retaining a clinically representative cohort.

Imaging protocol:
Each lesion underwent standardized gray-scale assessment for size, locularity, wall irregularity, septa, solid tissue, papillary projections, ascites and bilaterality. Color Doppler was used to record vascular distribution, resistive index and pulsatility index. SWE was performed over the most representative solid component while avoiding calcification, necrosis and large vessels; repeated measurements were averaged. The transducer was held with minimal additional pressure. Measurements affected by motion, poor propagation maps or obvious artifacts were repeated. The final value represented the average or median of technically acceptable acquisitions, consistent with the source protocol.

Outcome assessment:
Histopathology served as the reference standard. The primary outcome was diagnostic performance of mean SWE for malignancy. Secondary outcomes included correlations with Doppler, CA-125 and IOTA features and the incremental accuracy of combining modalities. Outcome adjudication used the clinical records, laboratory results, operative or histopathologic findings, endoscopy or follow-up information relevant to each study. Imaging results were recorded before final outcome classification whenever feasible.

Quality control:
All examinations were performed by radiologists or trained operators familiar with the equipment. A consistent machine preset, patient position and region-of-interest strategy were used. Images and numerical values were stored at the time of examination. Periodic review of acquisitions was undertaken to identify artifacts, extreme values and protocol deviations.

Ethical considerations:
The study protocol had institutional ethics approval as documented in the source thesis. Written informed consent was obtained before enrolment. Participant confidentiality was maintained through coded data and investigations were performed without altering indicated clinical care.

Statistical analysis:
Group means were compared by t test or Mann–Whitney U-test. Categorical imaging features were compared by chi-square test. ROC curves generated optimal cut-offs. Logistic regression evaluated independent predictors. Correlations used Pearson or Spearman coefficients. $P < 0.05$ was significant. Diagnostic indices were reported with clinically interpretable thresholds. Missing observations were handled by complete-case analysis for the affected comparison; no imputation was applied to primary outcome data.

Results:
Table 1 presents the clinical and ultrasonographic characteristics of 109 women, including 68 (62.4%) benign and 41 (37.6%) malignant ovarian masses. The mean age was significantly higher in the malignant group (51.1 ± 11.2 years) than in the benign group (34.9 ± 8.4 years; $p < 0.001$). Solid components were observed in 82.9% of malignant lesions compared with 17.6% of benign lesions ($p < 0.001$). Similarly, papillary projections were more frequent in malignant masses (70.7% vs 10.3%; $p < 0.001$). Ascites was identified in 63.4% of malignant cases compared with 4.4% of benign cases ($p < 0.001$), while bilateral involvement occurred in 39.0% and 11.8%, respectively ($p = 0.001$). These findings demonstrated that increasing age, solid components, papillary projections, ascites, and bilateral involvement were significantly associated with malignant ovarian masses. **Table 2** demonstrates significant differences in Doppler indices and shear wave elastography measurements between benign and malignant ovarian masses. The mean resistive index was significantly lower in malignant lesions (0.41 ± 0.06) than in benign lesions (0.62 ± 0.08; $p < 0.001$). Similarly, the pulsatility index was lower in malignant masses (0.69 ± 0.11 vs 1.34 ± 0.18; $p < 0.001$). Mean SWE values were significantly higher in malignant lesions (48.35 ± 8.74 kPa) compared with benign lesions (25.41 ± 5.76 kPa; $p < 0.001$), representing approximately a 1.9-fold increase in stiffness. Maximum SWE values also demonstrated significantly greater stiffness in malignant masses (66.40 ± 11.60 vs 34.10 ± 7.90 kPa; $p < 0.001$). These findings indicated that malignant ovarian masses exhibited lower vascular resistance and substantially greater tissue stiffness, supporting the diagnostic value of SWE alongside Doppler assessment. **Table 3** compares the diagnostic performance of conventional morphology, morphology combined with Doppler, and the addition of SWE. Morphology alone demonstrated 85% sensitivity, 70% specificity, 75% accuracy, and an AUC of 0.81. Adding Doppler improved sensitivity to 88%, specificity to 78%, accuracy to 82%, and AUC to 0.88. The incorporation of SWE produced the highest diagnostic performance, achieving 95.1% sensitivity, 97.1% specificity, 96.3% accuracy, and an AUC of 0.98 at a stiffness threshold of 35.3 kPa. Compared with morphology alone, the combined approach improved diagnostic accuracy by 21.3 percentage points and specificity by 27.1 percentage points. These findings demonstrated that incorporating SWE substantially enhanced discrimination between benign and malignant ovarian masses, potentially improving preoperative risk assessment and surgical planning.

Table 1: Clinical and gray-scale characteristics

Variable	Benign (n=68)	Malignant (n=41)	p-value
Age (years)	34.9 ± 8.4	51.1 ± 11.2	<0.001
Solid component, n (%)	12 (17.6)	34 (82.9)	<0.001
Papillary projections, n (%)	7 (10.3)	29 (70.7)	<0.001
Ascites, n (%)	3 (4.4)	26 (63.4)	<0.001
Bilateral masses, n (%)	8 (11.8)	16 (39.0)	0.001

Values are presented as mean ± standard deviation or n (%) unless otherwise specified.

Table 2: Doppler and elastography measurements

Parameter	Benign	Malignant	p-value
Resistive index	0.62 ± 0.08	0.41 ± 0.06	<0.001
Pulsatility index	1.34 ± 0.18	0.69 ± 0.11	<0.001
Mean SWE (kPa)	25.41 ± 5.76	48.35 ± 8.74	<0.001
Maximum SWE (kPa)	34.10 ± 7.90	66.40 ± 11.60	<0.001

Values are presented as mean ± standard deviation or n (%) unless otherwise specified.

Table 3: Diagnostic performance of imaging strategies

Strategy	Sensitivity (%)	Specificity (%)	Accuracy (%)	AUC
Morphology alone	85	70	75	0.81
Morphology + Doppler	88	78	82	0.88
Morphology + Doppler + SWE	95.1	97.1	96.3	0.98

Values are presented as mean ± standard deviation or n (%) unless otherwise specified.

Discussion:

The magnitude of separation between groups is clinically important because overlap is the principal barrier to translation of any new imaging biomarker. In the present dataset, the selected threshold balanced sensitivity and specificity rather than maximizing one at the expense of the other. This pattern is broadly consistent with recent prospective work in the same field **[11, 12].** Comparison with prior research should account for differences in equipment, acquisition mode, region of interest, disease spectrum and reference standard. Studies using different vendors or shear-wave implementations often report numerically different cut-offs even when their overall diagnostic conclusions agree **[13].** The observed associations also fit current pathophysiological understanding. Structural remodeling, fibrosis, cellularity, congestion, inflammation or altered vascular resistance can change wave propagation or Doppler indices. The measured parameter should therefore be interpreted as an integrated biomechanical signal rather than a direct histological measurement **[14].** SWE should be interpreted as part of a multi parametric examination rather than in isolation. A low-stiffness lesion with benign morphology and high-resistance flow may support conservative management, whereas a stiff lesion with papillary tissue, ascites and low resistance should prompt gynecologic-oncology referral. Such use respects the probabilistic nature of diagnostic testing: a value below a validated lower threshold can reduce concern, an intermediate value can trigger repeat or complementary testing and a high value can support specialist assessment or definitive investigation **[15].** An important strength was the use of a defined acquisition protocol with clinically meaningful reference outcomes. Prospective or serial data collection reduced recall error and analysis of both continuous values and diagnostic thresholds made the findings relevant to researchers and clinicians. The inclusion of conventional clinical or laboratory variables allowed the new parameter to be considered in context rather than as an isolated technology **[16].** Selection was enriched for surgically managed lesions, which can inflate malignancy prevalence. Measurements were device- and operator-dependent, cystic lesions had limited measurable solid tissue and histologic subtype-specific thresholds could not be estimated reliably. Additional sources of variability include operator experience, patient preparation, body habitus, measurement depth and biological fluctuation. These limitations caution against direct transfer of the reported threshold to another machine without local validation **[17].** Future research should use multicenter prospective designs, vendor-neutral quality criteria and blinded outcome adjudication. Reproducibility studies, longitudinal response assessment and decision-curve analysis would clarify whether the technique improves patient outcomes or reduces invasive testing. Where appropriate, integration with machine-learning or validated clinical scores may provide better calibration than any single variable **[18].** The present findings are supported by Rajbongshi *et al*., who demonstrated the diagnostic utility of SWE in differentiating benign and malignant breast lesions using histopathological correlation **[19].** Goswami et al. similarly reported improved lesion characterization using ultrasound elastography, supporting its complementary role in conventional imaging **[20].** Abdelhady et al. highlighted the clinical applications of SWE in gynecological disorders, including ovarian lesions **[21].** Safdar *et al*. also demonstrated significantly greater stiffness in malignant breast lesions, reinforcing the diagnostic potential of quantitative elastography, although organ-specific thresholds require validation **[22].**

Conclusion:

Quantitative ovarian SWE significantly differentiated malignant from benign masses and improved the diagnostic performance of morphology and Doppler. A threshold near 35 kPa showed high sensitivity and specificity in this cohort. External validation and standardized acquisition are needed before universal adoption.

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