Noninvasive Imaging Techniques for Quantification of Fibrosis in Benign Gynecologic Disease

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Background & Objective

Fibrosis — excess extracellular matrix and collagen — underlies symptom burden in leiomyomas, adenomyosis, and intrauterine adhesions, yet the diagnostic reference standard remains **invasive histopathology**. Quantitative imaging that reports tissue *stiffness* or *water diffusion* could measure fibrosis noninvasively.

Objective. **Systematically evaluate quantitative imaging modalities for non-invasive assessment of fibrosis in benign uterine pathology.**

Methods

PRISMA-guided search of **PubMed/MEDLINE, Embase, Scopus, Web of Science, and Cochrane Library**, extended with supplementary gray-literature and conference-proceedings searches, for original human studies of quantitative imaging against fibrosis, intrauterine adhesions, hysteroscopy, or treatment response. Risk of bias and applicability were appraised with a **QUADAS-2**–style framework.

Modalities reviewed.

Ultrasound — shear-wave (SWE), strain elastography, ARFI/VTQ.

MRI — elastography (MRE), diffusion-weighted (DWI/ADC), IVIM, kurtosis (DKI), T2-weighted.

Microscopy — atomic force (AFM).

Study selection

Records identified	442
Screened (title / abstract)	442
Eligible	42
Included in synthesis after citation deduplication	20

Study Landscape

20 studies | **1,400** patients

Condition mix (categories overlap)

Leiomyoma	n = 13
Adenomyosis	n = 7
Endometrial fibrosis / IUA	n = 4
Histologic correlation	**12**/ 20 studies

Figure 1. Leiomyoma stiffness on MRE (kPa)

Mean / median values and reported ranges per study; tick marks the central value.

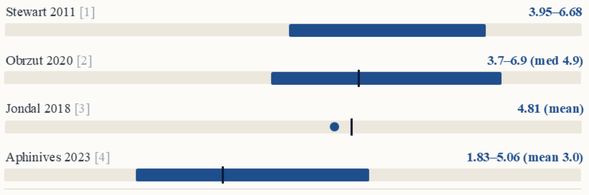
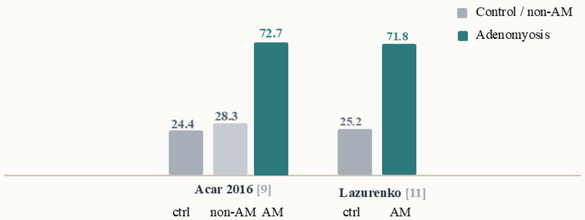


Figure 2. Adenomyosis vs. control stiffness

SWE Young's modulus E_{mean} (kPa) — two independent cohorts; both show ~3× stiffening.



Diagnostic Accuracy

Figure 3. Area under the ROC curve (AUC) by modality & condition

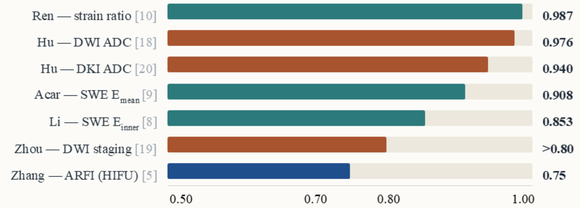
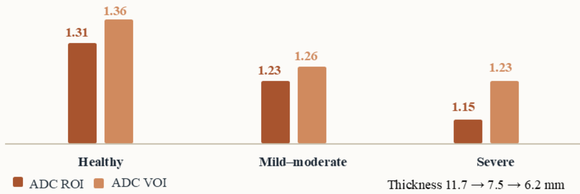


Figure 4. Endometrial ADC falls with fibrosis severity

Zhou 2024 [19] — ADC (×10⁻³ mm²/s)



Sensitivity / specificity highlights

SWE — normal vs adenomyosis [7]	93.1% / 82.1%
SWE E_{mean} — adenomyosis [9]	89.7% / 92.9%
Strain ratio — AM vs fibroid [12]	100% / 96.2%
US + elastography — accuracy [15]	91.95%

Imaging & Histology

Why the signal means fibrosis — imaging metrics map onto tissue composition (histologic correlation in 12 / 20 studies):

- **Leiomyoma stiffness rises with connective-tissue %** across <15 / 15–30 / >30% strata [2].
- **TGF-β and α-SMA correlate with stiffness & fibrosis degree**; PGP9.5 tracks stiffness & dysmenorrhea [10].
- **AFM Young's modulus tracks collagen area fraction &** expression at the microscale. **α-SMA**
- **Restricted diffusion (lower ADC, higher kurtosis)** mirrors dense endometrial scar [18–20].

Conclusions

Elastography and diffusion-based MRI enable **reproducible, non-invasive quantification of fibrosis** in benign uterine disease, with imaging metrics correlating with histologic markers. Stiffness predicted response to **focused ultrasound and uterine artery embolization** , supporting potential for treatment planning.

Prospective validation against standardized histologic reference standards is needed before clinical implementation.

Limitations & evidence quality

Overall quality (QUADAS-2–style, n=20)

- No study rated High; predominantly small pilot / feasibility cohorts with heterogeneous protocols and devices.
- Most common flag is the **reference-standard** domain — many used clinical, US, or MRI diagnosis rather than blinded histopathology.
- Non-uniform metrics (kPa, m/s, strain ratio) limit cross-study pooling.

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