Beyond Diagnosis: Transvaginal Ultrasound Phenotypes of Adenomyosis and Their Relationship to Clinical Symptoms

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Abstract

Adenomyosis is increasingly recognized by noninvasive imaging in women with pelvic pain, heavy menstrual bleeding, and reproductive difficulties. Yet the relationship between ultrasound-detected disease and symptoms remains inconsistent, and diagnostic criteria are often confused with severity classification. This narrative review critically examines the anatomical and pathological basis of adenomyosis, the revised Morphological Uterus Sonographic Assessment (MUSA) terminology, the respective diagnostic roles of transvaginal ultrasound and magnetic resonance imaging, and the potential value of ultrasound phenotyping for clinical assessment. Direct signs—including myometrial cysts, hyperechogenic islands, and subendometrial echogenic lines or buds—are distinguished from indirect markers of myometrial remodeling. Evidence from comparative studies supports transvaginal ultrasound as a first-line investigation, with MRI reserved for selected equivocal or anatomically complex presentations. Lesion distribution, junctional-zone changes, and degree of myometrial involvement may relate to clinical manifestations, but findings across observational studies are not uniform. Coexisting endometriosis, leiomyomas, hormonal exposure, and differences in symptom measurement complicate interpretation. Elastography, advanced Doppler techniques, and artificial intelligence offer opportunities for improved characterization but currently lack the external validation required for routine severity prediction. We propose separating diagnostic confidence, anatomical imaging burden, and patient-reported symptom burden in reporting and research. Prospective, multicenter studies with standardized acquisition, independent validation, and clinically meaningful outcomes are needed before sonographic scores can reliably guide prognosis or treatment selection.

Keywords: Adenomyosis, Transvaginal ultrasonography, MUSA, Junctional zone

Introduction

Adenomyosis is a heterogeneous uterine disorder characterized by endometrial-type glands and stroma within the myometrium, accompanied by variable smooth-muscle hypertrophy, fibrosis, and inflammatory change. The condition may present with heavy menstrual bleeding, dysmenorrhea, chronic pelvic pain, infertility, or no symptoms. Its clinical significance is not captured adequately by the simple distinction between presence and absence of disease. Women with similar ultrasound appearances can report markedly different symptoms, while extensive pain may coexist with relatively subtle imaging signs. This discordance is central to contemporary discussions about how adenomyosis should be identified, classified, and communicated in clinical practice. [1]

Historically, diagnosis depended on hysterectomy specimens, producing estimates biased toward older, symptomatic women who underwent surgery. Transvaginal ultrasound (TVUS) and magnetic resonance imaging (MRI) now identify disease in women of reproductive age, including those seeking fertility treatment and those who wish to avoid hysterectomy. The resulting diagnostic expansion has also exposed inconsistencies in terminology, the threshold for assigning a diagnosis, and the significance of isolated sonographic features. Consensus reporting represents an important advance, but a standard descriptive vocabulary is not the same as a validated severity system or prognostic model. [2]

This narrative review examines the anatomical and biological foundations of adenomyosis, the revised Morphological Uterus Sonographic Assessment (MUSA) features, the performance and limitations of imaging techniques, and the relationship between sonographic phenotype and clinical symptoms. Particular attention is given to the distinction between imaging evidence of disease and clinically meaningful disease burden, the interpretation of proposed scoring approaches, and the methodological requirements for future validation. The goal is to provide a practical, evidence-based framework for radiologists and gynecologists assessing adenomyosis across different clinical settings. [3]

Anatomical and pathological basis of imaging findings

The endometrium and inner myometrium form a closely integrated functional unit. The junctional zone (JZ), visible as a relatively low-signal subendometrial band on T2-weighted MRI and variably appreciable on high-quality ultrasonography, differs in cellular density, vascular arrangement, and contractile behavior from the outer myometrium. Menstrual-cycle variation in uterine peristalsis and steroid responsiveness affects the appearance of this compartment. Interpretation therefore requires awareness that normal physiology, age, hormonal therapy, pregnancy-related change, and image acquisition can influence apparent JZ thickness or continuity. [4]

Histopathological and imaging boundaries do not coincide perfectly. The JZ is a functional and imaging concept rather than a sharply delineated histological structure; consequently, measurement-based classifications assume an anatomical precision that cannot always be reproduced. Studies comparing ultrasound and tissue findings show that JZ disruption can be informative but should not be treated as a standalone histological proof of ectopic glands. This distinction becomes particularly relevant when uterine contraction, scars, or technical artifacts mimic focal interruption. [5]

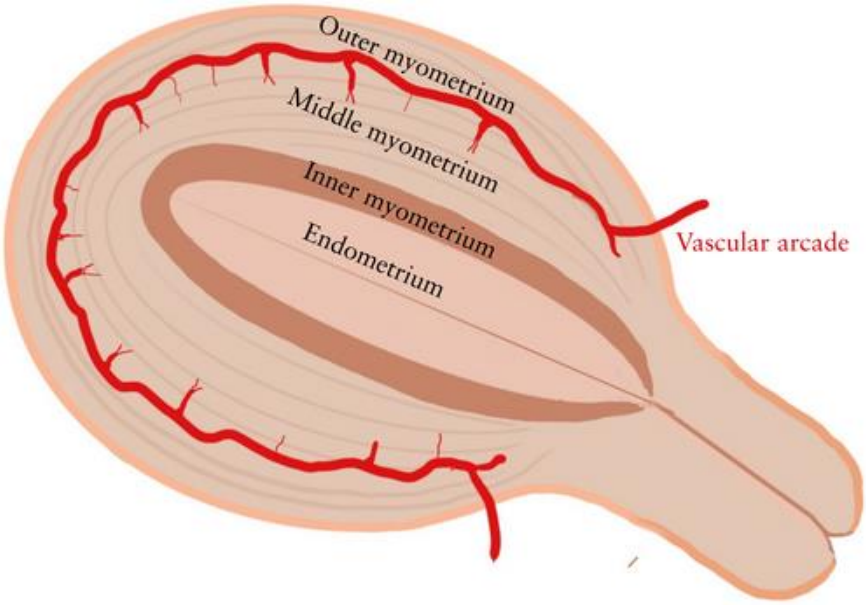


Figure 1. Junctional-zone anatomy and the endometrial–myometrial interface. Schematic sagittal representation of the endometrium, inner and outer myometrium and vascular arcade. Harmsen et al. (2023) [4].

Adenomyosis can involve the inner myometrium, outer myometrium, or both, and may be diffuse, focal, or mixed. Focal adenomyosis is not synonymous with leiomyoma: the former frequently has indistinct margins and associated architectural distortion, while a leiomyoma more often forms a circumscribed mass with a pseudocapsule and peripheral vessels. However, both entities frequently coexist. Detailed topographic description is consequently more useful than forcing all lesions into a single category without accounting for overlapping disease. [3]

Three-dimensional ultrasonography can reconstruct the coronal plane of the uterine cavity and endometrial–myometrial interface. Histology-correlated work provides a biological rationale for evaluating JZ asymmetry, interruptions, and subendometrial extensions, but the relationship is not one-to-one. Differences in tissue orientation and sectioning can alter correlation with sonographic planes. Moreover, diagnostic sensitivity varies according to lesion depth and the reference standard used, making a negative histological section an imperfect comparator for an entire uterus with patchy disease. [6]

The earliest phase of adenomyosis may include abnormalities in the endometrial–myometrial interface before the uterus becomes enlarged. In younger women, these changes may be detected during evaluation for severe menstrual pain or infertility. It remains difficult to distinguish early disease from nonspecific JZ variation without longitudinal evidence. Radiology reports should therefore describe the confidence attached to findings and avoid suggesting progression or extensive invasion from a single equivocal sign. [7]

Pathogenesis: connecting tissue remodeling with sonographic phenotype

The pathogenesis of adenomyosis is not explained by one mechanism. Proposed models include invagination of the basal endometrium following repeated tissue injury and repair, metaplastic development from Müllerian remnants or progenitor cells, and myometrial invasion facilitated by abnormal tissue remodeling. These mechanisms may coexist and may differ across adenomyosis phenotypes. A model centered on repetitive injury is attractive because it links uterine contractile stress, local estrogen production, inflammation, and subsequent fibrosis, yet its applicability to every case is not established. [8]

Molecular studies describe altered estrogen and progesterone signaling, inflammatory mediators, angiogenesis, neurogenesis, and extracellular-matrix deposition. These processes offer plausible explanations for heterogeneous echotexture, myometrial stiffening, altered vascular distribution, and progressive uterine remodeling. They also suggest why the number of visible foci cannot reliably summarize pain: sensory nerve changes, inflammatory activity, and local tissue pressure may vary independently of structural lesion extent. Imaging detects the macroscopic consequences of these processes but does not directly measure their biological activity. [9, 10]

Hormonal resistance and abnormal wound repair may contribute to the persistence of ectopic endometrial tissue and the formation of surrounding smooth-muscle hyperplasia. Epithelial–mesenchymal transitions and fibroblast activation are among the pathways investigated in experimental and human studies. From an imaging perspective, this combination produces a lesion that can be both infiltrative and fibrotic, rather than a simple cystic focus. A radiologist therefore should expect mixed direct and secondary signs, with differing prominence according to disease stage, tissue composition, and local distribution. [11]

The relationship with endometriosis deserves specific attention. Coexisting pelvic endometriosis can increase pain and infertility independently of adenomyosis and may influence referral patterns to specialized imaging services. The two disorders share inflammatory and hormonal pathways but should not be treated as anatomically identical. When severe dysmenorrhea is disproportionate to uterine imaging findings, evaluation for deep endometriosis, adhesions, and other pelvic abnormalities is important before attributing all symptoms to adenomyosis. [12]

Clinical epidemiology also complicates causal interpretation. Age, parity, prior uterine intervention, hormonal exposure, and associated fibroids affect both the likelihood of detecting adenomyosis and the symptoms that trigger investigation. Imaging-based prevalence is not directly comparable to hysterectomy-based prevalence, and hospital cohorts may contain an excess of severe disease. Future phenotype studies should consider these variables prospectively rather than presenting unadjusted symptom associations as specific effects of uterine adenomyosis. [13]

Standardizing the examination: the revised MUSA framework

The revised MUSA consensus separates direct signs, which more closely represent ectopic endometrial tissue within the myometrium, from indirect signs, which reflect associated remodeling. The three direct signs are myometrial cysts, hyperechogenic islands, and echogenic subendometrial lines or buds. Indirect signs are a globular uterus, asymmetrical myometrial thickening, fan-shaped shadowing, translesional vascularity, and an irregular or interrupted JZ. This classification is particularly useful because it prevents an isolated nonspecific shape change from being interpreted as equivalent to a direct tissue-related observation. [2]

An optimized TVUS examination should acquire sagittal and transverse uterine views, scan the entire myometrium systematically, and document both anterior and posterior wall involvement. An appropriate transducer frequency balances penetration and spatial resolution; gain, focal zone, depth, and harmonic settings should be adjusted to the uterine size. The examiner should record focal or diffuse distribution, involved walls, lesion extent, and concurrent masses. Short cine clips and stored orthogonal images can improve review and interobserver discussion. Reporting a structured set of findings is more reproducible than relying on an impression of a heterogeneous uterus alone. [14]

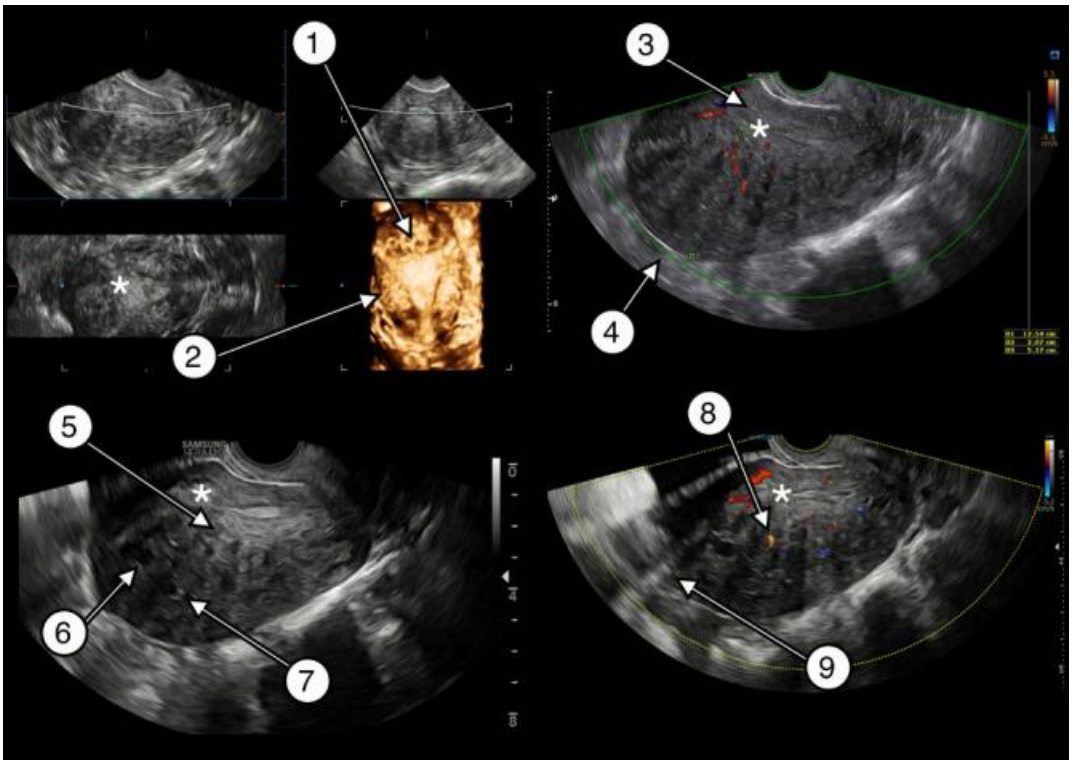


Figure 2. Standardized MUSA ultrasound features of adenomyosis. Composite 2D/3D transvaginal ultrasound illustrating (1) interrupted junctional zone, (2) irregular junctional zone, (3) asymmetrical myometrial thickening, (4) globular uterus, (5) echogenic subendometrial lines and buds, (6) myometrial cysts, (7) hyperechogenic islands, (8) translesional vascularity and (9) fan-shaped shadowing. Harmsen et al. (2022) [2].

Myometrial cysts may appear anechoic or contain low-level echoes, with or without a hyperechoic rim. Small cysts can be missed when gain is too low or when they lie deep in a bulky myometrium. Conversely, prominent vascular spaces and artifactual clefts may be mistaken for cysts. Color or power Doppler can distinguish vascular structures from nonvascular cystic spaces. Identification of a convincing cyst is useful, but a normal scan without cysts does not exclude disease, particularly when the lesions are predominantly solid or fibrotic. [2]

Hyperechogenic islands describe echogenic myometrial areas without the organization of a well-demarcated fibroid. Echogenic subendometrial lines and buds are extensions emerging from the endometrial border into the myometrium; their orientation and anatomical relation to the endometrium matter more than an arbitrary count. Both findings can support direct involvement, especially when seen with other concordant abnormalities. They require careful differentiation from scar tissue, normal interface irregularities, intracavitary lesions, and technical artifacts. [14]

Indirect signs need contextual interpretation. A globular uterus reflects overall shape, not simply enlargement. Asymmetrical wall thickening can arise from adenomyosis, but it may also be produced by a poorly recognized fibroid or transient contraction. Fan-shaped shadowing suggests altered myometrial architecture when not explained by a discrete mass. Translesional vessels coursing through a poorly defined abnormal region differ from the peripheral vascular pattern often observed around leiomyomas, although Doppler patterns are not independently definitive. [2]

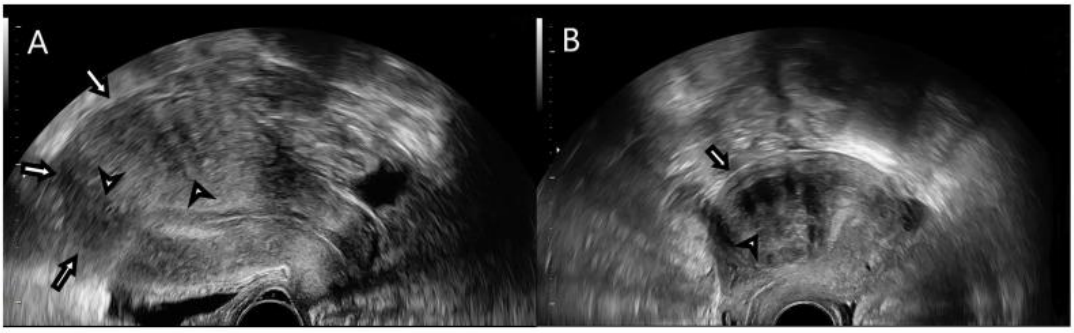


Figure 3. Grayscale ultrasound: adenomyosis compared with a uterine fibroid. Panel A demonstrates features of adenomyosis, including globular enlargement, fan-shaped shadowing and myometrial cysts; panel B shows a more circumscribed leiomyoma. Săsăran et al. (2021) [32].

JZ irregularity and interruption may be better assessed with a three-dimensional coronal reconstruction when the two-dimensional interface is unclear. Acquisition of a diagnostically useful volume requires the entire cavity and relevant walls to be included, adequate image quality, and avoidance of motion artifacts. Interpretation becomes more difficult with substantial uterine distortion or multiple leiomyomas. A statement that the JZ could not be reliably assessed is preferable to classifying unvisualized segments as abnormal. The updated definitions are intended to improve shared recognition, not to imply that each sign has a fixed, validated diagnostic weight. [5]

Diagnostic performance and the role of MRI

Transvaginal ultrasound is typically the initial imaging examination because it is accessible, dynamic, relatively inexpensive, and able to identify associated uterine and adnexal pathology. The evidence base nevertheless includes heterogeneous studies that use different definitions, examiner expertise, and histological standards. A structured review and meta-analysis established that both ultrasound and MRI can support noninvasive diagnosis, while also highlighting uncertainty caused by selection and verification bias. Reported sensitivity and specificity should not be transposed uncritically to asymptomatic screening populations or to adolescents with small-volume disease. [15]

In a head-to-head meta-analysis of six studies involving 595 women with hysterectomy pathology as reference, pooled TVUS sensitivity and specificity were 75% and 81%, compared with 69% and 80% for MRI; the difference was not statistically significant. The analysis showed substantial heterogeneity, and some cohorts had a high risk of selection bias. These results favor TVUS as a practical first-line modality without showing that MRI is inferior in every clinical subgroup. MRI may be particularly useful when ultrasound is inconclusive, when extensive coexisting leiomyomas obscure uterine architecture, or when surgical mapping requires a broader field of view. [16]

On MRI, the most familiar feature is JZ thickening on T2-weighted imaging, but thickness thresholds alone have limitations. Focal or diffuse low-signal thickening, small high-signal myometrial foci, and ill-defined areas of altered myometrial signal must be considered together. Physiological contractions, hormonal treatment, menopause, and menstrual-cycle timing affect the JZ. Technical quality and multiplanar review can prevent false-positive interpretations caused by oblique imaging or transient contraction. [17, 18]

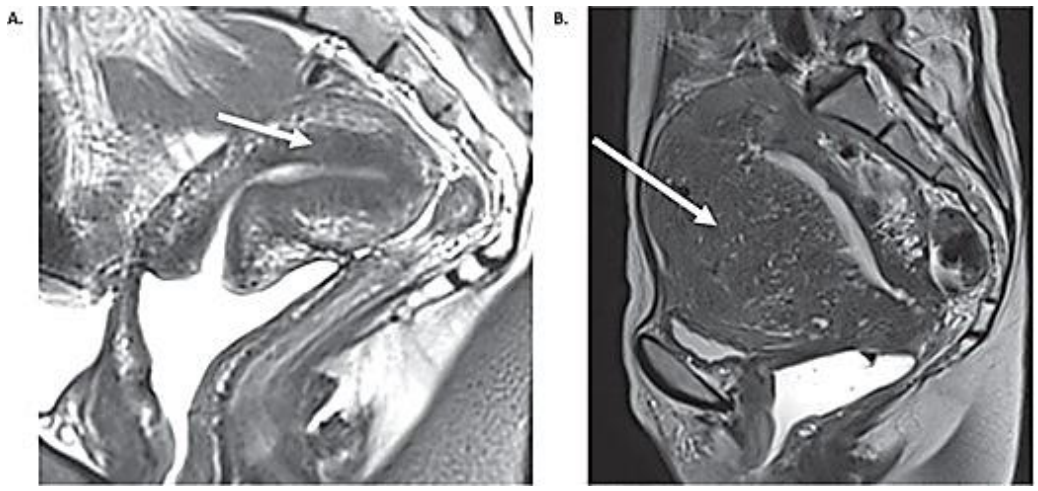


Figure 4. MRI appearances of uterine adenomyosis. Sagittal T2-weighted images illustrate junctional-zone thickening (A) and extensive adenomyosis with intramyometrial cystic foci (B). Chapron et al. (2020) [1].

Adenomyosis and leiomyomas can coexist in the same uterus and complicate interpretation of each other. MRI offers excellent soft-tissue contrast for distinguishing a circumscribed smooth-muscle mass from diffuse or focal infiltrative myometrial disease. However, histological correlation is also imperfect when surgical specimens are fragmented or when diagnostic thresholds vary. The correct imaging goal is to establish a probable diagnosis and meaningful disease mapping, not to claim that MRI or TVUS routinely provides microscopic certainty. [19]

Comparative accuracy should be interpreted in terms of the clinical question. For a symptomatic woman with multiple clear direct MUSA signs, ultrasound may provide sufficient information for initial management. For an infertile patient with uncertain JZ changes or a uterus distorted by several masses, MRI may answer questions left unresolved by ultrasound. An imaging report should disclose uncertainty rather than giving a binary negative result when technical limitations are substantial. Sequential imaging can be valuable if it resolves ambiguity, but indiscriminate duplicate imaging increases cost without necessarily improving decisions. [20]

Phenotype, topography and symptom severity

Pain and bleeding have related but distinct biological and anatomical determinants. Dysmenorrhea may reflect inflammation, uterine hypercontractility, neural sensitization, and coexisting endometriosis, whereas heavy menstrual bleeding may involve altered uterine contractility, vascular changes, increased endometrial surface area, and associated cavity pathology. Symptom severity therefore should not be expected to rise uniformly with sonographic lesion count. Different symptom instruments measure different constructs: visual analogue pain scores, bleeding pictograms, and quality-of-life questionnaires cannot be substituted for one another. [1, 21]

Exacoustos and colleagues investigated whether sonographic type and degree of myometrial involvement relate to symptoms, illustrating the potential importance of topography rather than a positive-versus-negative scan. Their proposed classification is clinically interesting because it describes disease extent and localization. It does not mean that a particular numerical adaptation of the scheme, or a locally defined 0–20 score, has been universally validated. Any newly assembled score must have an explicit item definition, measurement protocol, derivation cohort, reproducibility analysis, and validation before diagnostic or prognostic thresholds can be advocated. [22]

The reproducibility of classification is itself a major issue. Lazzeri and colleagues examined interobserver agreement in assessing adenomyosis type and degree. Agreement in an expert environment may not generalize to routine services where probe quality, operator training, and uterine complexity vary. A clinically useful classification must allow different readers to assign comparable phenotype labels. Beyond overall agreement, feature-level reliability and consistency of the anatomical distribution are important because a total burden score may conceal disagreement about the underlying lesion map. [23]

Ultrasound findings among younger women may have a different clinical interpretation from those in peri-menopausal hysterectomy cohorts. Studies of nulligravid younger women and studies stratified by reproductive age support examining symptom patterns within age-defined populations. In younger patients, severe dysmenorrhea and infertility may prompt scanning before prominent uterine enlargement occurs. In older patients, fibroids, age-related bleeding disorders, and treatment exposure may dominate the clinical picture. These factors should be specified when comparing phenotype–symptom relationships between studies. [24]

Investigations of ultrasound characteristics and clinical outcomes have not established a single sign or scoring formula that reliably predicts every symptom dimension. Selection of patients from fertility clinics, symptomatic gynecology services, or hysterectomy cohorts changes the distribution of disease. Pain analyses are vulnerable to confounding by endometriosis, whereas bleeding analyses need information on fibroids and endometrial pathology. Therefore, any observed association between diffuse disease, JZ abnormalities, and symptom severity should be viewed as a population-dependent relationship rather than an independent causal effect. [25, 26]

A lesion's spatial relationship with the uterine cavity may be relevant to abnormal bleeding, while outer myometrial involvement may coexist with endometriosis-related pain. Yet simple inner-versus-outer distinctions understate anatomical complexity and are not sufficiently validated to determine treatment. Reports should preserve clinically useful descriptors—location, depth, diffuse or focal distribution, and cavity distortion—without assigning a deterministic symptom pattern from imaging alone. [3]

A pragmatic reporting framework can distinguish three separate outputs: confidence in the imaging diagnosis, anatomical burden of visible disease, and patient-reported clinical burden. These domains should be documented alongside one another rather than collapsed into one severity label. A uterus with subtle direct findings but disabling pain warrants appropriate evaluation, and a globular uterus with multiple abnormalities in an asymptomatic woman does not automatically require intervention. This framework reflects the clinical reality that diagnosis and treatment selection are linked but are not identical decisions. [22]

Junctional-zone dysfunction, fertility and reproductive outcomes

The JZ participates in uterine peristalsis, sperm transport, implantation, and the structural support of early pregnancy. Adenomyosis-associated changes in JZ architecture and contractility provide plausible mechanisms for subfertility, though imaging abnormalities do not prove that an individual woman's infertility is caused by adenomyosis. Fertility investigations must also address ovarian reserve, tubal and male factors, endometriosis, age, and prior treatment. A radiological phenotype is most useful when interpreted as one component of a comprehensive reproductive assessment. [27, 28]

Disordered uterine contractions and changes in endometrial receptivity have both been proposed to affect implantation. Imaging studies sometimes identify thicker or less regular JZ structures among women with infertility, but physiological variability and inconsistent imaging thresholds limit definitive conclusions. There is no evidence that a single thickness threshold reliably predicts spontaneous conception across all patient

groups. For assisted reproduction, the possible relationship between JZ function, embryo transfer, and implantation calls for careful prospective designs and consistent cycle-related imaging conditions. [29]

Reports among women undergoing assisted reproduction have explored ultrasound-defined adenomyosis in relation to reproductive outcomes, including donor-oocyte cycles. Such designs reduce some sources of embryo-related confounding but cannot remove all differences in uterine disease, prior treatment, or coexisting pathology. Imaging may support counseling and planning, but associations with pregnancy outcomes should not be transformed into promises of benefit from specific pretreatment strategies without randomized evidence. [30]

Fertility-preserving management frequently requires balancing symptom control against the reproductive implications of therapy. Reviews of treatment and reproductive outcomes identify considerable methodological variation in surgical interventions, hormonal suppression, and assisted reproduction protocols. Radiologists contribute by identifying the distribution of disease, associated leiomyomas or endometriosis, and features relevant to uterine-sparing procedures. The imaging report should explain the anatomy without presuming that lesion excision or prolonged hormonal therapy improves pregnancy outcomes in every patient. [31]

A standardized fertility-oriented report might include uterine size, cavity relationship, direct and indirect MUSA features, focality, predominant wall, JZ visibility, associated fibroids, and signs of endometriosis where the examination permits. This approach provides more actionable information than a single unspecified grade. In longitudinal fertility care, comparison should account for different machines, operators, menstrual-cycle phases, and use of hormonal medication. Changes in imaging may reflect treatment effects or physiological variation rather than true alteration in adenomyosis extent. [4]

Adjunct techniques: elastography, Doppler and artificial intelligence

Elastography aims to measure tissue mechanical properties that conventional gray-scale imaging can only infer indirectly. Adenomyosis-associated fibrosis and smooth-muscle remodeling may produce stiffness patterns distinct from fibroids or normal myometrium. Small studies have examined strain-ratio elastography as an additional diagnostic discriminator, but the technique is sensitive to probe compression, region-of-interest selection, lesion depth, and adjacent tissue characteristics. The available findings are promising for research and problem-solving, not sufficient to replace morphological ultrasound assessment. [32, 33]

Combined TVUS and strain-ratio elastography has been explored for patients with coexisting uterine fibroids and adenomyosis. This is a clinically relevant test case because mixed pathology commonly generates uncertainty about symptoms and lesion boundaries. However, small pilot samples do not establish generalizable thresholds, and diagnostic performance can be inflated when obvious lesions or highly selected controls are used. Wider clinical use requires multicenter testing, harmonized acquisition, and external validation against appropriate reference standards. [34]

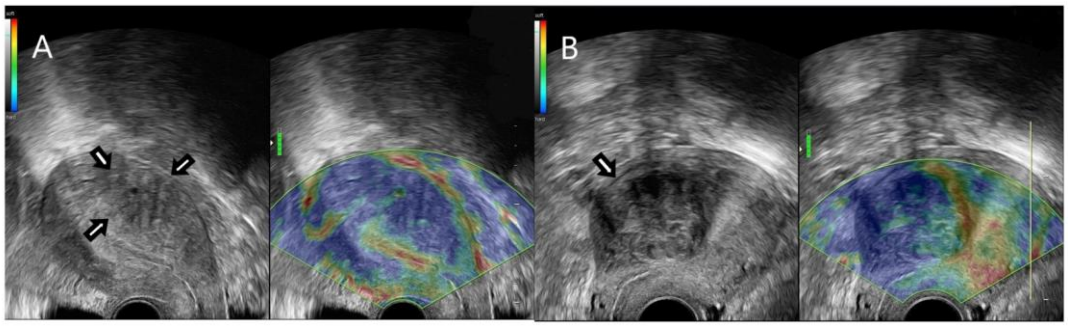


Figure 5. Strain-ratio elastography of adenomyosis and leiomyoma. Paired grayscale and elastographic views demonstrate the appearance of an adenomyotic lesion (A) and uterine fibroid (B). Elastographic measurements should be interpreted as adjunctive rather than diagnostic in isolation. Săsăran et al. (2021) [32].

Reproducibility is an essential condition for elastography adoption. Studies comparing imaging techniques and MRI reference assessments have illustrated that technique-dependent variation can limit interpretation. A stiffness value measured on one system should not automatically be compared with a different manufacturer's device or software version. The appropriate endpoint for future work is not merely a statistically different mean strain ratio; it is an independently validated improvement in clinical decisions over a high-quality MUSA examination. [35]

Color Doppler supports morphological diagnosis by demonstrating vascular paths through an abnormal myometrium and by helping distinguish cysts from vessels. Newer microvascular flow techniques may improve display of small vessels, but vascular changes are not unique to adenomyosis. Perfusion also depends on menstrual phase and equipment settings. Vascularity metrics should therefore be viewed as complementary descriptors rather than absolute proof of disease or independent severity indicators. [14]

Artificial intelligence methods can assist with feature recognition, segmentation, and standardization of image interpretation. Early deep-learning reports in adenomyosis suggest technical feasibility, but clinical claims depend on patient-level separation of training and testing data, representative external datasets, and transparent assessment against experienced readers. Algorithms trained on images selected because disease was already obvious may fail in equivocal cases and in routine populations. Radiomics and AI-based scores should be evaluated for calibration, discrimination, repeatability, transportability, and patient-relevant outcomes before being incorporated into treatment algorithms. [36]

The greatest opportunity for emerging technologies may be reducing subjectivity rather than discovering an entirely new diagnostic sign. Automated mapping of the JZ, consistent estimation of involved myometrial volume, and structured integration of direct features could create reproducible phenotype descriptors. These measures need to demonstrate incremental value beyond existing expert imaging reports. A system that accurately predicts a radiologist's label but fails to improve symptom stratification, fertility counseling, or management decisions would have limited clinical usefulness. [37]

Clinical integration and longitudinal assessment

A clinically useful report starts with the referral question. For evaluation of bleeding, the examination should assess the endometrium, cavity abnormalities, and fibroids alongside adenomyosis. For dysmenorrhea or chronic pelvic pain, the examiner should consider endometriosis and alternative pelvic causes. For infertility, uterine architecture and cavity relationships deserve more detailed mapping. An identical set of images may therefore need different emphases in the final interpretation, while the underlying descriptive criteria remain consistent. [1]

Ultrasound can also contribute to longitudinal treatment assessment, although imaging change and symptom change should be documented separately. A smaller uterus or altered echotexture after hormonal therapy does not necessarily demonstrate proportional pain relief, and symptomatic improvement may occur without disappearance of direct MUSA features. Reports should use baseline and follow-up measurements acquired under comparable conditions and should identify the intervention and elapsed time. Claims of treatment response require predefined clinical and imaging endpoints. [38]

Medical treatment literature includes hormonal methods and symptom-targeted therapies that influence bleeding and pain through mechanisms not confined to sonographically visible tissue regression. Thus, the decision to treat should be based on symptoms, reproductive goals, patient preferences, contraindications, and coexisting conditions, rather than ultrasound burden alone. In situations where imaging detects mild disease without symptoms, observation may be appropriate. Where symptoms are severe but imaging is equivocal, escalation of clinical evaluation is more appropriate than falsely reassuring the patient because no dramatic lesion is visible. [39]

One approach to structured reporting is to record: the confidence level of diagnosis; the number and type of direct signs; relevant indirect signs; topographical description; JZ assessability; other uterine and pelvic pathology; and a concise statement about uncertainty. These fields avoid falsely presenting the unvalidated sum of signs as a universally accepted severity measure. If a research score is used, the report should name the exact instrument and explain whether its thresholds are validated, exploratory, or locally predefined. [3]

Patients value the ability to connect imaging with possible causes of symptoms, but radiology should not overstate causation. The appropriate wording is that findings are compatible with adenomyosis and may contribute to symptoms, rather than asserting that the observed lesion explains all bleeding, pain, or infertility. This calibrated language helps clinicians maintain a broader differential diagnosis and encourages joint decisions based on clinical context. [40]

Methodological gaps and priorities for future research

The chief limitation of the existing literature is not lack of proposed imaging features but lack of consistent linkage between standardized morphology and validated patient-centered outcomes. Studies vary in definitions, scoring approaches, reference standards, the population recruited, and the reporting of confounders. A rigorous prospective study should preregister diagnostic criteria, perform blinded imaging assessment, and collect menstrual bleeding, dysmenorrhea, noncyclic pain, dyspareunia, and quality-of-life data with instruments appropriate to each outcome. Coexisting endometriosis, fibroids, and hormonal therapy must be recorded explicitly. [41]

A multicenter study should first test whether feature recognition is reliable across operators and machines. It should then establish whether direct features add information beyond indirect remodeling signs and whether topographical mapping improves prediction over a simple count. Models must avoid combining correlated inputs without examining redundancy, and they should be validated at the patient level in separate centers. Calibration, clinically meaningful decision thresholds, and net benefit are as important as an impressive area under the receiver operating characteristic curve. [23]

Histopathology remains important for biological understanding but is an imperfect universal reference standard for fertility-preserving women, who are unlikely to undergo hysterectomy. Studies limited to surgical specimens risk spectrum bias. Researchers should consider carefully defined composite clinical–imaging assessment, longitudinal follow-up, or appropriate operative tissue reference when available, while acknowledging potential incorporation bias. When the index test contributes to the final diagnostic definition, independent accuracy cannot be inferred from simple agreement between them. [15]

An additional priority is establishing whether standardized phenotype describes future symptom course or response to therapy rather than only cross-sectional association. Prognostic models need temporal ordering: imaging features must be recorded before the outcome they are claimed to predict. Treatment changes, medication adherence, menopause transition, and pregnancy plans can alter outcomes over time. Repeated symptom and imaging measurements may clarify whether a particular phenotype has a distinct trajectory, but correlation at one visit does not establish a prediction rule. [38]

Mechanistic research could clarify why some small lesions produce severe pain while extensive diffuse disease remains asymptomatic. The relationships among nerve density, inflammation, fibrosis, contractility, and observed ultrasound patterns are promising targets. Linking imaging to tissue biomarkers where ethically available may reveal phenotype-specific mechanisms, but biomarker associations should be replicated independently. Such work may ultimately support genuinely personalized classification rather than relying on total lesion burden as a surrogate for biological activity. [42]

Research on the JZ offers an opportunity to integrate functional imaging and morphology. Dynamic uterine contractility measurements, high-resolution three-dimensional mapping, and reproducible MRI descriptors may provide complementary information. Nevertheless, additional measurements are only useful if they change prognostic estimates or management after accounting for established clinical factors. Standardized acquisition and reporting are prerequisites for comparing modalities or combining data in multicenter machine-learning datasets. [43, 44]

Interpretive pitfalls and a practical reporting standard

Several diagnostic pitfalls arise from assigning undue significance to a solitary indirect feature. A bulky or globular uterus can accompany leiomyomas, parity-related remodeling, and physiological variation. Transient myometrial contraction may create focal thickness differences that disappear on repeat scanning. A technically compromised image may suggest JZ interruption simply because the endometrial border is partly obscured. These situations should be documented as uncertain rather than retrospectively counted as positive signs. A short interval of dynamic scanning, selective use of Doppler, or targeted MRI can clarify whether an apparent lesion represents persistent structural abnormality. This improves the specificity of communication without creating an unsupported numerical threshold. [45]

An additional pitfall is assuming that MRI is a perfect reference test against which ultrasound findings can be judged. Objective MRI measures vary in their operational definitions, cycle sensitivity, and reproducibility. Clinical MRI reports also depend on reader expertise and the chosen threshold for abnormality. Surgical pathology, meanwhile, usually samples a selected population and cannot resolve the true disease status of women who retain their uterus. Diagnostic research should present the uncertainty around every comparator, report uninterpretable examinations, and make the mechanism of adjudication transparent. Without these safeguards, impressive discrimination estimates may reflect study design rather than real-world diagnostic performance. [46]

Concordance between clinical imaging and histology requires particular caution when only one part of a heterogeneous uterus is sampled. A focal region of adenomyosis may be missed by routine sections, and imaging can reveal changes not encompassed by a limited pathologic report. Conversely, the detection of scattered glands on histology does not establish that symptoms were caused by those glands. Research linking histology, sonographic burden, and symptom measures should explicitly distinguish lesion presence, anatomical distribution, and disease activity. These are related constructs, but they do not share one definitive measurement scale. [47]

Studies of infertility further illustrate the limits of attribution. Endometriosis, ovulatory factors, uterine fibroids, age, and previous assisted reproduction all influence reproductive outcomes and may correlate with the probability of detecting adenomyosis. Prospective studies should examine these factors jointly and separate spontaneous conception, implantation after embryo transfer, pregnancy loss, and live birth. A significant association with one outcome does not imply similar effects on the others. This approach would also avoid turning imaging-defined uterine abnormalities into rigid treatment indications when the evidence remains observational and population dependent. [48]

For routine reports, anatomical mapping should be understandable to the referring clinician without relying on a local scoring convention. Describing whether disease is focal, diffuse, anterior, posterior, or circumferential can guide the clinical discussion. The number of convincing direct signs and the quality of JZ visualization should accompany this description. An uncertainty statement is especially important when a distorted uterine cavity prevents a full examination. Where a research protocol demands a total score, item definitions, derivation source, clinical purpose, and threshold validation should be supplied. An unexplained aggregate number should not be labeled a universally recognized MUSA or Morosetti severity classification. [49]

A long-term goal is to combine standardized ultrasound with biological and functional outcomes, without making the report too complex for clinical use. In particular, it would be valuable to understand whether mechanical stiffness, neural remodeling, and abnormal peristalsis correspond to distinct sonographic phenotypes. These hypotheses should be investigated with longitudinal cohorts, tissue studies where appropriate, and independent external replication. Clinical decisions will remain centered on symptoms and reproductive aims until such markers show a demonstrable improvement in prognosis, treatment response prediction, or shared decision-making beyond conventional imaging. [50]

Implications for multidisciplinary care

The most effective use of a structured adenomyosis report is in multidisciplinary interpretation. Imaging can establish a credible anatomical substrate, document associated pathology, and identify limitations of the examination, but symptom burden and fertility priorities must be obtained directly from the patient. A shared summary of these components can support counseling about monitoring, medical treatment, fertility-directed care, or procedural options. This model may also improve research by defining the exact clinical decision that a proposed imaging marker is intended to inform, rather than evaluating a score solely because it correlates with an existing imaging label. Clear separation of anatomical observations from clinical interpretation is particularly important when ovarian and extrauterine disorders coexist. [1]

In practical terms, the future of adenomyosis imaging is likely to depend less on continually multiplying individual signs than on improving their definition, reproducibility, and clinical interpretation. Direct signs, careful mapping, and standardized JZ assessment provide a foundation. Their value will increase when outcome studies identify which combinations carry information about pain, bleeding, fertility, or response to intervention. Until then, a precise description with appropriately calibrated uncertainty remains more useful than declaring severity from an inadequately validated composite number. [2]

Conclusion

Transvaginal ultrasound is the appropriate first-line imaging method for suspected adenomyosis, and the revised MUSA definitions provide a reproducible vocabulary for distinguishing direct evidence of ectopic myometrial tissue from secondary uterine remodeling. The clinical impact of adenomyosis, however, cannot be reduced to the number of sonographic signs or a single unvalidated severity score. A meaningful radiological assessment should integrate diagnostic confidence, anatomical phenotype, JZ evaluation,

coexisting pelvic pathology, and separately measured symptoms. MRI and emerging adjunct techniques can resolve selected diagnostic questions, but their use should be guided by incremental clinical value. Prospective multicenter validation linking standardized imaging to pain, bleeding, fertility, and treatment outcomes is necessary before imaging-based burden scores can be relied upon for prognosis or treatment selection.

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