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Uterine Evaluation Using Morphological Uterus Sonographic Assessment Diagnostic Protocol: A Literature Review

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Abstract

BACKGROUND: Myometrial lesion is one of the major causes of the need for gynecologic surgeries. Ultrasonography (USG) is the primary modality in myometrial radiological examination. Thus, a consistent procedure for reporting evaluation findings is needed.

METHODS: We reviewed literature from textbooks and journals from 2000 to 2019 containing information about myometrial sonographic evaluation.

RESULTS: Morphological Uterus Sonographic Assessment is a consensus statement on terms, definitions, and measurements that may be used to describe findings and report the sonographic features of the myometrium using gray-scale sonography, color/power Doppler, and three-dimensional (3D) ultrasound imaging. The procedure consists of reports on the sonographic features of the uterine corpus, myometrium, and myometrial lesion.

CONCLUSION: The need for a standardized terminology to describe sonographic findings of the myometrium, both normal and pathological, has given this protocol an advantage to show its benefit, that is, not only just for a clinical background but also research purposes. We suggest researchers and clinicians continue to develop further and study the relevance and use of the consensus, especially the correlation of sonographic findings with clinical and histological features.

Introduction

The myometrial lesion is one of the major causes for the need for gynecologic surgeries worldwide, with most lesions, happen to be benign. Uterine fibroids and adenomyosis are the most frequent findings, while malignant neoplasms such as sarcoma occur more rarely [1], [2].

Since ultrasonography (USG) has been the primary modality in a myometrial radiological examination, there is a need for a standardized procedure for reporting myometrial lesions. This has been done for endometrial lesions with the International Endometrial Tumor Analysis (IETA) consensus [3], [4].

Morphological Uterus Sonographic Assessment (MUSA), published in 2015, is a consensus statement on terms, definitions, and measurements that may be used to describe findings and report the sonographic features of the myometrium using gray-scale sonography, color/power Doppler, and 3D ultrasound imaging. The consensus was made based on opinions and findings by various experts in the fields of gynecologic sonography, fertility, hysteroscopy, general gynecology, and clinical research, who were also members of International Ovarian Tumor Analysis, IETA, and European Society of Gynaelogical Endoscopy [2], [3].

The need for a standardized procedure has brought MUSA an advantage to reduce intra- and inter-observer variability in pathologic evaluation, to evaluate medical and surgical treatment, to compare USG to other imaging techniques, and also for research purposes, especially in collecting data for meta-analysis [3].

Anatomy

The uterus is a hollow, thick-walled, and contractile organ to receive the product of fertilization along with its nesting, growth, and subsequent birth. Three overlapping tunics form its anatomical constitution from outside to inside: A serosatunic, a muscular tunic, and a tunica mucosa. The muscular tunic is mainly composed of smooth muscle fibers, which together constitute the so-called myometrium [5].

Myometrium consists of smooth muscles and loose connective tissue, blood vessels, lymphatic vessels, and nerves. It is dense and thick in fundus

and the middle part of uterus but thin in fallopian tubes. Uterine corpus has four layers of muscles: Submucosal, vascular, supravascular, and subserousal. The submucosal layer is composed of longitudinal and some oblique smooth muscle fibers. The lumen of the uterine tube passes through the uterine wall, and this layer forms a circular muscle coat. The vascular layer is external to the submucosal layer and is rich in blood vessels and longitudinal muscle; it is succeeded by a layer of predominantly circular muscle, the supravascular layer. The outer, thin, longitudinal muscle layer, the subserousal layer, lies adjacent to the serosa [6].

Transabdominal versus Transvaginal Sonography (TVS)

The image of the pelvic organs through the anterior abdominal wall in the suprapubic region can be looked at by transabdominal sonography (TAS). There are two significant limitations of TAS. The first is to use lower frequencies for imaging due to the long distance between the transducer and the pelvic organs. Another limitation is the beam degrading effect of the anterior abdominal wall, especially in a patient with an obesity problem. Both of these limitations lead to degradation in image quality. TVS produces greatly improved resolution compared to TAS, primarily due to the higher frequencies employed and the absence of beam deformation by the anterior abdominal wall. Significant advantages of TVS over TAS are better image quality and avoidance of patient discomfort due to full urinary bladder. Some differences of both techniques are shown in Table 1 [7].

Table 1: Comparison between TVS and TAS [7]

	TVS	TAS
Full bladder	Not essential	Essential
Probe frequency	5–5.7 MHz	3–5 MHz
Resolution	High	Moderate
Field of view	Small	Large
Contraindication	Virgin, vaginal obstruction, PROM	None
Interventional uses	More	Limited

TVS: Transvaginal sonography, TAS: Transabdominal sonography.

MUSA Protocol

As an outline, the MUSA protocol of reporting procedure consists of reports on the sonographic features of uterine corpus, myometrium, and myometrial lesion. More details on this are shown in Table 2.

Uterine corpus

The uterine corpus is measured as shown in Figure 1. When we want to evaluate the myometrium (e.g., in the diagnosis of adenomyosis) with the USG scan, we should exclude the cervix to measure the uterine volume. If we want to evaluate the length of the entire uterus (including the cervix), we should sum the total length of the uterine corpus (d1) and the cervical length. The total length of the uterine corpus is calculated from a summary of the length of fundus (from the fundal serosal surface of the uterus to the fundal tip of the endometrial cavity) to the endometrial cavity length (from the fundal tip of the endometrial cavity to the internal os of the cervix). In turn, each should be measured separately in the longitudinal plane of the uterus. The longest anteroposterior diameter (d2) of the uterus is measured in the sagittal plane and the longest transverse diameter is measured in the transverse plane. The formula for uterine volume calculation based on these measurements is displayed in Table 1 and Figure 1. The serosal contour of the uterus is reported as either regular or lobulated (Figure 2) [2], [3].

Myometrium

The anterior and posterior myometrial walls are calculated from the external uterine serosa to the external endometrial contour. It should include the junctional zone (JZ) but not the endometrium. The myometrial walls are calculated in the sagittal plane, perpendicular to the endometrium. Both measurements are listed from the same image, and the measurements should be captured from the thickest point of the myometrial wall. Myometrial walls are reported as symmetrical or asymmetrical. The overall echogenicity of the myometrium is recorded as homogeneous or heterogeneous [2], [3].

JZ

The endometrial-myometrial junction or inner myometrium, known as the junctional zone (JZ), is the transitional zone between the endometrium and the outer myometrium. In the non-pregnant uterus, it has been observed that highly specific contraction waves begin exclusively from the JZ and partake in the regulation of diverse reproductive events, such as sperm transport, embryo implantation, and hemostasis during menstruation. Conversely, growing evidence indicated that disruption of the normal JZ architecture is associated with hyperplasia (that seems to precede adenomyosis) and adenomyosis inevitably alters the coordinated peristaltic activity of the inner myometrium [8]. The Junctional zone (JZ) on ultrasound examination was reported in Table 3.

Myometrial lesion

Myometrial lesions may be *well-defined* or *ill-defined*. A fibroid is typically a well-defined lesion, while adenomyosis is often ill-defined. The definition of ill-defined lesions is difficult to define and measurements

Table 2: Reporting the myometrium on ultrasound examination

Feature	Description/term	Quantification/measurement
Uterine corpus*t (Figure 1)	Length, anteroposterior diameter, transverse diameter, volume*	Length (dl) [fundus] + [cavity]; anteroposterior diameter (d2); transverse diameter (d3); volume (cm^3) =dl (cm) x d2 (cm) x d3 (cm) x 0.5231
Uterine corpus and cervixt (Figure 1)	Regular Robulatedt	Total length = [fundus] + [cavity] + [cervix] = dl+ct
Serosal contourt (Figure 2) Myometrium	Symmetrical/asymmetrical*	Ratio or subjective impression of asymmetry*
Myometrial walls* (Figure 3)	Homogeneous/heterogeneous * Well-defined/ill-defined*	–
Overall echogenicity* Myometrial lesions* Number* Location*t Site [Figure 3][1,4] Size*tt	Location: Anterior, posterior, fundal, right lateral or left lateral, global* Site (for well-defined lesions): FIGO-classification 1-7"	Exact number (n)*
Outer lesion-free margin (OFM) t t [Figure 5]	–	Three perpendicular diameters (al, a2, a3) and/or volume (cm^3) = al (cm) x a2 (cm) x a3 (cm) x 0.5231
Inner lesion-free margin (IFM) f t [Figure 5]		Minimum distance between serosal surface and outermost border of lesiontt
Penetration of ill-defined lesionst (Figure 6)	Ratio between thickness of lesion and the total uterine wall thickness, measured on the same imaget	Minimum distance between endometrium and inner border of lesiontt Penetration=maximum diameter of lesion perpendicular to endometrium/maximum wall thickness perpendicular to endometriumf
Extent of ill-defined lesionsf	Localized (< 50% of total uterine volume involved) or diffuse (> 50% of total uterine volume involved) t	Proportion (%) of myometrium volume involvedt
Echogenicityt (Figures 4 and 7)	Uniform: Hypo-, iso-, hyper-echogenic; non-uniform: Mixed echogenicity, cystic areas (regular/irregular); anechogenic, low level, ground glass, mixed echogenicity of cyst fluidt	Very hypoechogenic (— —), hypoechogenic (—), isoechogenic, hyperechogenic (+), very hyperechogenic (++) f
Rimt (Figure 8)	Hypo- or hyperechogenic, or ill-definedf	–
Shapef (Figure 8)	Round/not-round: oval, lobulated, irregularf	–
Shadowing (Figure 5a) Edge*t	Present/absent*	Degree of shadowing: slight, moderate, strongf
Internal*t	Present/absent*	Degree of shadowing: slight, moderate, strong
Fan-shaped*f (Figure 5c)	Present/absent*	Degree of shadowing: slight, moderate, strongf
Cysts* (Figure 6a) Sizet	Present/absent*	Maximum diameter of largest cystt Exact number (or single, 1-5, > 5) t
Number of cystst Echogenicityt	Cyst fluid: anechogenic, low level, ground glass, mixed echogenicity; hyperechogenic rim: present/absent	
Hyperechogenic islands* (Figure 6b)	Present/absent*	
Outlinet Sizet Number!.	Regular, irregular or ill-definedt	Maximum diameter Exact number (or single, 1–5, >5) t
Subendometrial echogenic lines and buds* [Figure 7] Number!.	Present/absent*	Exact number (or single, 1–5, >5) Locationf

Definitions of terms and their quantifications are described in text and illustrated by ultrasound images and schematic diagrams. Measurements are reported in mm or cm (to tenths of a cm). *Items of importance in daily clinical practice. fItems of interest for research purposes. tIf clinically relevant (e.g., pre-operative work-up before myomectomy).

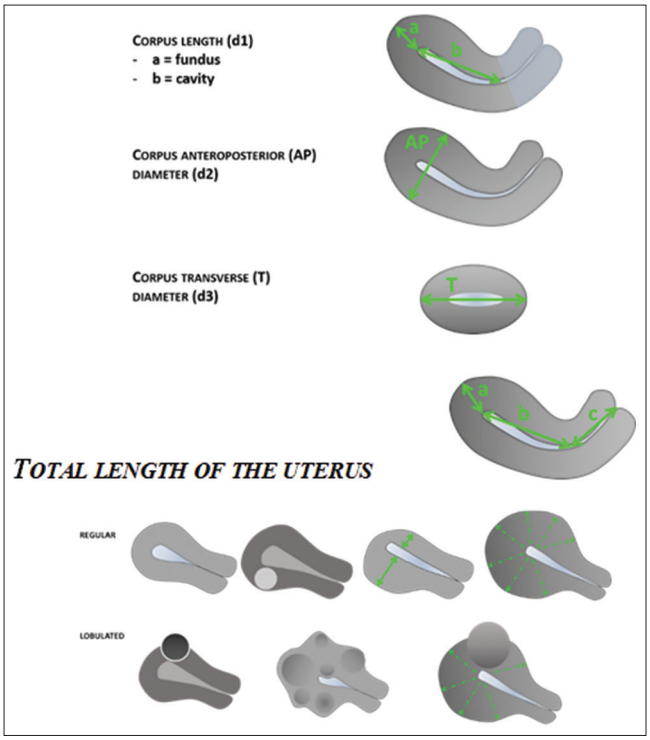

Figure 1: Uterine Measurement and Serosal Contour [3]

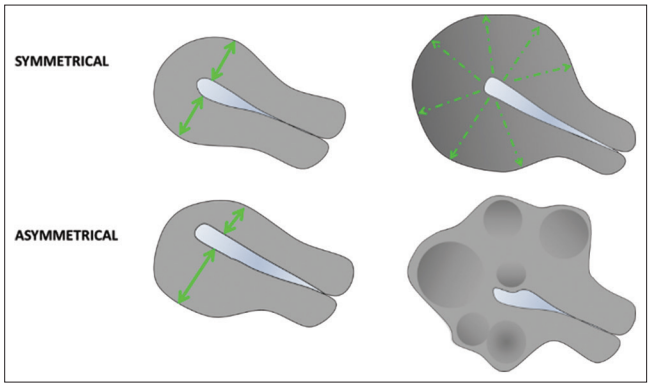

Figure 2: Symmetrical and Asymmetrical Myometrial Wall [3]

may be incorrect. The boundary of an ill-defined lesion can be appraised subjectively as the percentage of the whole myometrial volume which involved [9]. If it's lower than 50% of the total myometrium is involved, the lesion is proclaimed as localized, if it's greater than or equal to 50% of the myometrium is involved, it is reported as diffuse. If the lesion is localized (usually in well-defined lesion), the lesion *location* is reported as anterior, posterior, fundal, right lateral, left lateral, or global [2], [3], [10]

Number, location, site, and size

Lesion number is reported accurately. The lesion *location* is reported as anterior, posterior, fundal, right lateral, left lateral, or global. Although lesion location can be defined during 2D scanning, the use of 3D USG may help illustrating the findings for the surgeon. Tomographic ultrasound imaging is especially suited in the reporting to the surgeons who are confident with the interpretation of similar tomographic images from CT scan or MRI. Uterine *fibroids* are further recorded according to the *FIGO classification* [2], [3], [11].

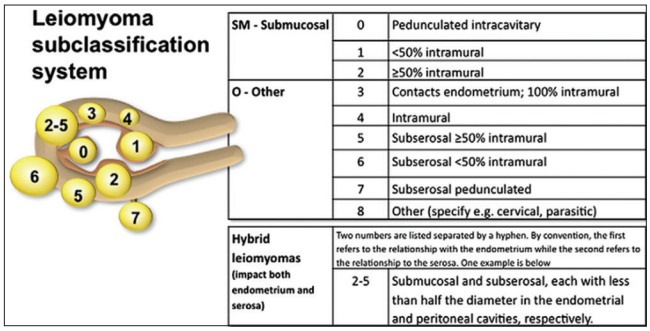

Figure 3: FIGO leiomyoma sub-classification system [11]

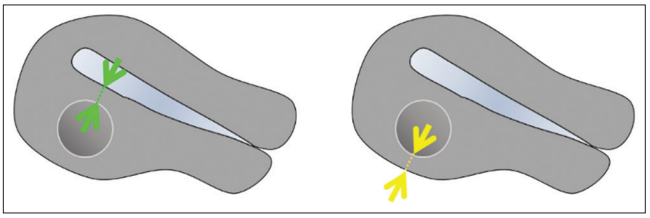

Figure 4: Inner lesion-free margin and OFM [3]

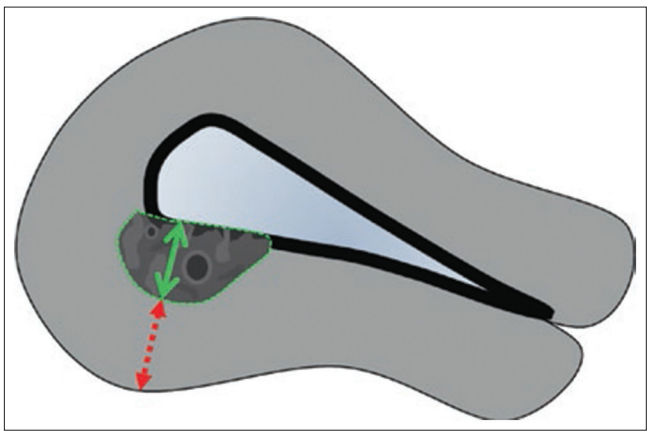

Figure 5: Penetration in ill-defined lesion [2]

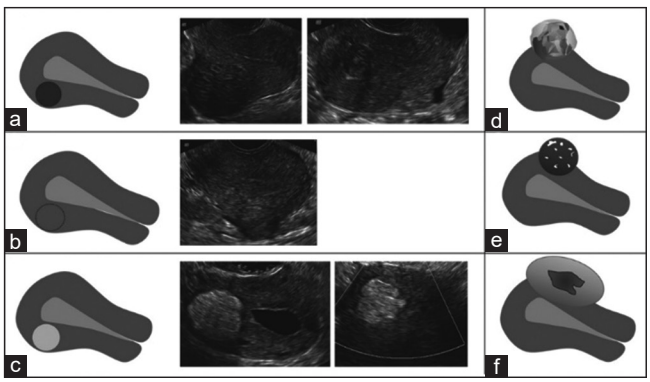

Figure 6: Echogenicity of myometrial lesion[2] Uniform (hypoechogenic (a), isoechogenic (b), or hyperechogenic (c)) or non–uniform (with mixed echogenicity (d), echogenic areas (e), or cystic areas (f)

Inner and outer lesion free margin

Inner lesion-free margin is the minimum distance from lesion to the endometrium, while outer lesion-free margin (OFM) is the minimum distance from lesion to uterine serosal surface [3], [12]. The vascularization finding was reported in Table 4.

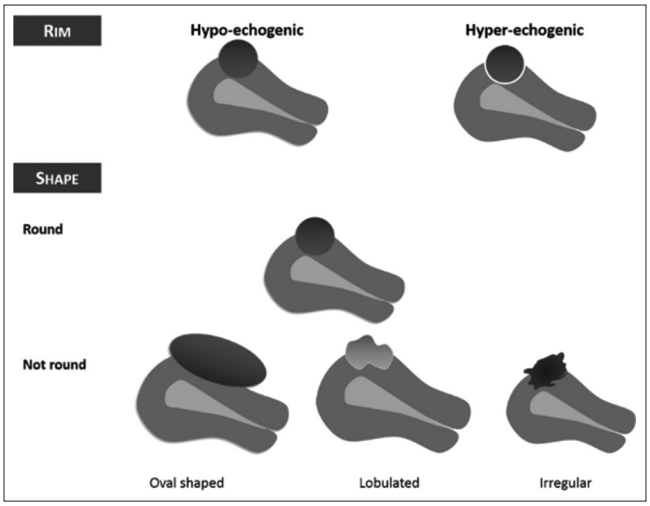

Figure 7: Myometrial lesion rim [3]

Table 3: Reporting the junctional zone (JZ) on ultrasound examination

Structure	Description	Measurement
JZ4f	Regular, irregular, interrupted, not visible, not assessable*	*Maximum* $_{(JZmax)}$ and minimum $_{(JZmin)}$ JZ thickness in mm or ratio JZ/total myometrial wall thicknesst
Irregular or interrupted JZt	Location: Anterior, posterior, fundus, lateral right, lateral left, or globalt	Magnitude of irregularity: (JZ_{max}) - (JZ_{min}) = $JZd_{i}f$; extent of irregularity: proportion (%) of JZ that is irregular (<50% or>50%) t
Interrupted JZt	Location: Anterior, posterior, fundus, lateral right, lateral left, or globalt	Interruption of JZ: proportion (%) of JZ not visualized (< 50% or>50%) t
Irregularity in JZt	Cystic areas, hyperechogenic dots, hyperechogenic buds and lines (in each location) t	

Definitions of terms and their quantifications are described in text and illustrated by ultrasound images and schematic diagrams (Figures 2 and 4). *Items of importance in daily clinical practice. fItems of interest for research purposes.

Table 4: Vascularization finding report [3]

Vascularization to be assessed	Description	Measurement
Whole uterus		
Overall vessel pattern* [Figure 8]	Uniform, non-uniforms	No color (1); minimal color (2); moderate color (3); abundant color (4)*
Lesions		
Amount of color (in a lesion)* (Figure S10)	Color score (both percentage of lesion being vascularized and color hue are taken into account)*	No color (1); minimal color (2); moderate color (3); abundant color (4) t
In case of uneven spread of vascularizationt	Color score in most vascularized pant	0–100%t Iso-, hypo-, hypervascularityt
	Percent of solid tissue with color signal Compared to adjacent myometriumt	
Location of vesselst (Figures 8 and 9)	Circumferential, intralesional; uniform, non-uniform (areas with increased/decreased vascularity) t	
Vessel morphologyt (Figures 8 and 11)	Number: single, multiple; size: large and equal, small and equal, unequal; branching: Regular, irregular, no branching; direction: perpendicular, not perpendicularl	

*Items of importance in daily clinical practice. TItems of interest for research purposes.

Penetration and extent (ill-defined lesion)

The penetration is defined as the ratio between the thickness of the lesion (measured as the maximal lesion diameter perpendicular to the endometrium) and

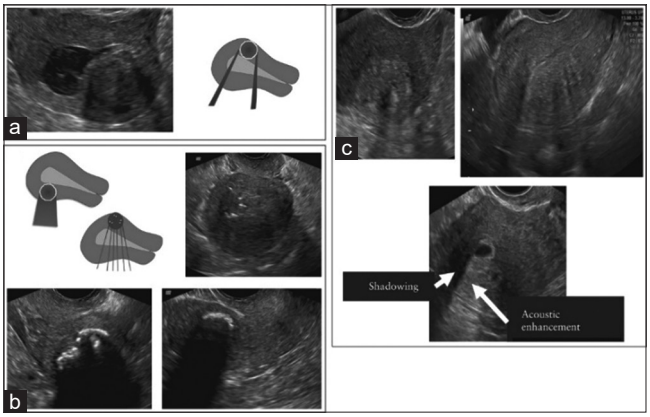

Figure 8: Shadowing [3] Edge shadowing (a), internal shadowing (b), and fan-shaped shadowing (c)

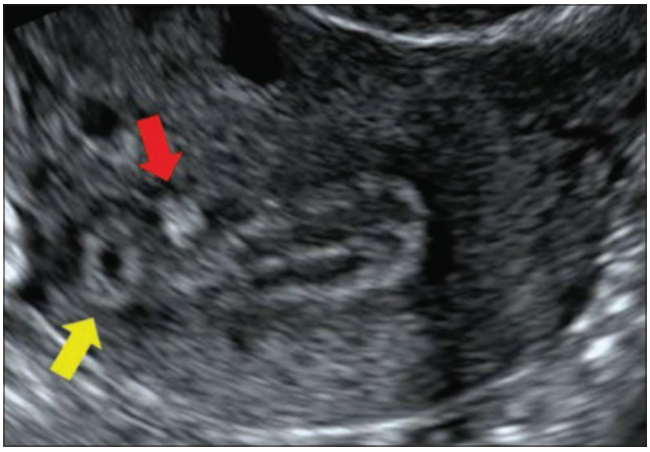

Figure 9: Adenomyosis sonographic finding[2]

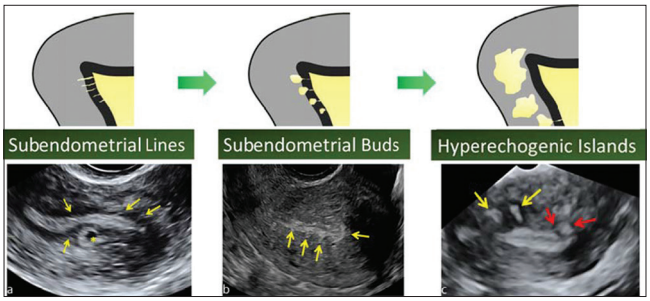

Figure 10: Sub-endometrial Lines, Buds, and Hyperechogenic Island in Adenomyosis [15]

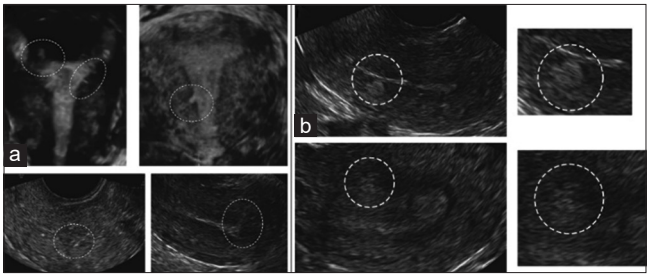

Figure 11: Sub-endometrial echogenic lines (a) and buds (b)[3]

the total uterine wall thickness (measured perpendicular to the endometrium). Both should be measured on the same image. The *extent* of an ill-defined lesion is reported as *localized,* if less than 50% of the total uterine

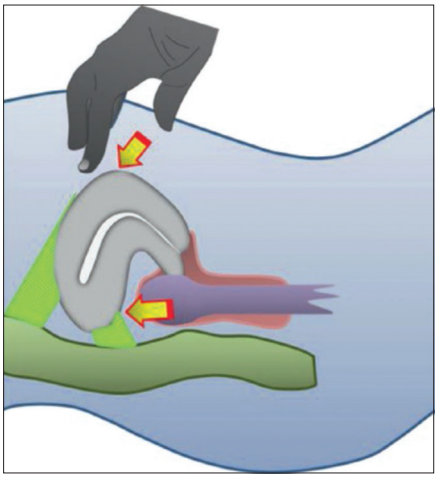

Figure 12: Sliding Sign[3]

is involved, or as *diffuse,* if at least half of the uterine volume is involved. The extent may also be recorded as the percentage of the myometrium involved [2].

Echogenicity

The *echogenicity* of a myometrium lesion is reported as *uniform* or *non-uniform*. A uniform lesion may be *hypo-*, *iso-*, or *hyperechogenic* as compared with the surrounding (unaffected) myometrium. For research purposes, the relative echogenicity can be scored as very hypoechogenic (−−), hypoechogenic (−), isoechogenic, hyperechogenic (+), or very hyperechogenic (++). As stated before, the overall myometrial echogenicity may be heterogeneous, making the *reference echogenicity* less reliable. The subjectivity of the scoring system had to be taken into account in the interpretation of the report [2].

Rim and shape

Rim of the lesion may not be clear, hypoechogenic, or hyperechogenic compared to myometrium, and lesion shape may be round or not round. Not round lesions can be oval, lobulated, or irregular [3].

Shadowing

Shadowing originating from the myometrium may present as edge shadows, internal shadows, or fan-shaped shadowing. The degree of shadowing is recorded as slight, moderate, or strong [2], [3].

Cyst

Myometrial cysts may be present. Cyst may be caused by adenomyosis, atrophy, and necrosis or may be drug induced (e.g., tamoxifen). The cyst size may vary considerably. At least in the presence of larger cysts, the number of cysts and the maximal diameter of the largest cyst are recorded. In

adenomyosis, numerous small cysts may be present. In this case, it is not feasible to record the exact number nor the size of the cysts. A typical adenomyosis cyst has an echogenic rim caused by endometrial tissue surrounding the cyst cavity. Adenomyosis is a common gynecological disorder characterized by the presence of heterotopic endometrial glands and stroma in the myometrium with adjacent smooth muscle hyperplasia [2], [3], [13], [14].

Hyperechogenic island

Hyperechogenic islands (Figure 6b) are the hyperechogenic areas within the myometrium and they may be regular, irregular, or ill-defined. In adenomyosis, the presence of endometrium tissue within the myometrium may be seen as *hyperechogenic islands.* Endometrial and myometrial damage allowing the growth of ectopic endometrial glands and stroma into the myometrium may explain ultrasound findings of sub-endometrial lines and buds with expansion to hyperechogenic islands in the myometrium [2], [3], [15]. This is shown in Figure 10.

Sub-endometrial echogenic lines and buds

Hyperechogenic sub-endometrial lines or buds may be observed disrupting the JZ. Hyperechogenic sub-endometrial lines are (almost) perpendicular to the endometrial cavity and are in continuum with the endometrium. These buds and lines should be distinguished from small hyperechogenic spots seen in the sub-endometrium. For research purposes, the number and location of the sub-endometrial lines or buds should be reported [3]. This is shown in Figure 11.

Vascularization of myometrium and myometrial lesion

The *vascularity* of the myometrium using color or power Doppler imaging starts with the assessment of the overall vessel pattern within the uterine walls, reported as *uniform* or *non-uniform*. The amount of color in a lesion is reported as a *color score*. Both the percentage of the lesion being vascularized and the color hue are taken into account. The color score ranges from 1 to 4: *Score 1* meaning no color, *Score 2 min*imal color, *Score 3* moderate color, and *Score 4* abundant flow. The l*ocation* of vessels is reported as *circumferential*, *intralesional*, or *translesional.* The *vessel morphology* can further be described as to vessel *number*, *size*, *branching*, and *direction*. The number of vessels is recorded as *single* or *multiple*. The vessel size may be *large and equal*, *small and equal*, or *unequal*. Vessels may exhibit *regular* or *irregular branching*, or no branching. The direction of the vessels is recorded as *perpendicular* or *not perpendicular* to the uterine cavity [2].

Reporting in Clinical Practice

In general clinical practice, reporting findings in myometrial evaluation through sonographic assessment can be done more briefly. The report is shown in Table 5. For addition, general differences to help determine between adenomyosis and uterine fibroids in clinical background are also provided in Table 6 [3].

Table 5: Sonographic report in general clinical practice[3]

Feature to be described	Description/term
Uterine corpus	Length, anteroposterior diameter, transverse diameter
Myometrial walls	Symmetrical/asymmetrical
Overall echogenicity	Homogeneous/heterogeneous
Myometrial lesions	Well-defined/ill-defined
Number	Number (1, 2, 3, or estimation in case>4 lesions)
Location	Location of the largest/clinically relevant lesion (s): Anterior, posterior, fundal, right lateral or left lateral, global
Site	Site (for well-defined lesions) of the largest/ clinically relevant lesion (s): FIGO classification 1–7
Size	Maximum diameter of the largest/clinically relevant lesion (s)
Shadowing	
Edge shadows	Present/absent
Internal shadows	Present/absent
Fan-shaped shadowing	Present/absent
Cysts	Present/absent
Hyperechogenic islands	Present/absent
Sub-endometrial echogenic lines and buds	Present/absent
Junctional zone	Regular/poorly defined
Vascularity of myometrium	
Overall vessel pattern (in whole uterus)	Uniform/non-uniform
Amount of color (in a lesion): color score	(1) No color; (2) minimal color; (3) moderate color; (4) abundant color

An adequate reporting will give major benefits in choosing treatment, as well as in research background, since fibroids and adenomyosis are two of the most frequent findings in gynecologic practices, as members of abnormal uterine bleeding (AUB). In a study conducted in Haji Adam Malik General Hospital in Medan, North Sumatra, it was found that most AUB patients based on age group was older adults (36–45 years old), followed by the early elders (46–55 years old), with the most common lesion found was fibroids (23,0%) [16], [17].

Additional Technical Tips

Measuring the *total length of the uterus* is not always easy due to the flexion of the uterus. Unless the uterus is outstretched, the true size of the uterine length will be underestimated using a straight line. Clinician should be aware of such limitations. In clinical follow-up, it is important to use the same methodology [12].

A *3D acquisition* enables to visualize all three section planes: The sagittal, transverse, and coronal planes. The frontal or coronal section is essential in the

Table 6: Typical differences between adenomyosis and fibroids findings[3]

Feature	Typical fibroid	Adenomyosis
Serosal contour of uterus definition of lesion	Lobulated or regular well-defined	Often globally enlarged uterus ill-defined in diffuse adenomyosis (adenomyoma may be well-defined)
Symmetry of uterine walls lesion	Asymmetrical in presence of well-defined lesion (s)	Myometrial anteroposterior asymmetry
Outline	Well-defined	Ill-defined
Shape	Round, oval, lobulated	Ill-defined
Contour	Smooth	Irregular or ill-defined
Rim	Hypo- or hyperechogenic	No rim
Shadowing	Edge shadows, internal shadows (often fan-shaped shadowing)	No edge shadows, fan-shaped shadowine
Echogenicity	Uniform: hyper-, iso-, hypoechogenic Non-uniform: mixed echogenicity	Non-uniform: mixed echogenicity67,68 Cysts2°-24,62, hyperechogenic islands, sub-endometrial lines and buds203
Echogenicity	Circumferential flow	Translesional flow69
JZ thickness, regularity JZ interruption	Not-thickened; regular or not visible Interrupted or overstretched JZ in areas with lesions of FIGO types 1–3 [Figure 3]	Thickened; irregular or ill-defined9,61-63 Interrupted JZ (even in absence of localized lesions) [9]

FIGO, International Federation of Gynecology and Obstetrics'.

diagnosis of congenital uterine anomalies as well as in the assessment of the junctional zone [2], [18].

The *outer border* of the myometrium is the uterine serosa, the *inner border* the endometrium. The serosa is usually seen as a regular white line. It is of clinical importance to assess the mobility of the uterus against the surrounding organs (bowel and bladder). This has been referred to as the *sliding sign*, being a marker for the presence of adhesions caused by endometriosis, infection, or cancer. For the assessment of the *sliding sign*, the examiner applies some gentle pressure on the uterus with the vaginal probe and uses his/her freehand push on the patient's lower abdomen [as shown in Figure 12 [2], [19], [20].

It is not always easy to identify the *JZ* on USG examination. The use of volume contrast imaging set at 2 mm after 3D volume acquisition has been reported to yield the best ultrasound images of the JZ. If the endometrium is not clearly visible, the junctional zone cannot be evaluated neither. In those cases, fluid instillation may be helpful [2], [21].

Future Perspective

Various radiologic devices and techniques are available to detect and evaluate several uterine lesions. Future studies will address the value of USG and color Doppler imaging in the prediction of fibroid growth. USG may prove to be a key examination in the management of fibroids and in the choice between expectant management, medical therapy, ablation, and selective embolization [22].

A better understanding of the association between adenomyosis and pain or bleeding symptoms as well as the role of adenomyosis in infertility and adverse obstetrical outcome should be addressed in future research. The exact correlation between ultrasonographic features and histological findings also deserves more attention. These issues should be solved before deciding on the place – if any – of surgery in the management of adenomyosis [2], [23].

Conclusion

The need for a standardized terminology to describe sonographic findings of myometrium, both normal and pathological, has given MUSA protocol an advantage to show its benefit, that is, not only just for clinical background but also for research purposes. Researchers and clinicians should continue to further develop and study the relevance and use of the consensus, especially the correlation of sonographic findings with clinical and histological features.

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