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PROBLEMS IN DIAGNOSTIC IMAGING

Pictorial Essay of Ultrasound-Reconstructed Coronal Plane Images of the Uterus in Different Uterine Pathologies

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Imaging in the major planes (horizontal, coronal, and sagittal) of the uterus is important for determining anatomy and allowing the findings to be standardized, and for evaluating and diagnosing different pathological conditions in clinical practice. Examination of the coronal plane is an important step in identifying uterine pathologies and their relationships to the endometrial canal. Three-dimensional (3D) ultrasound reveals the normal anatomy better and improves the depiction of abnormal anatomy, as the coronal plane of the uterus can easily be obtained using 3D reconstruction techniques. Our pictorial essay demonstrates that adding 3D ultrasound to a routine gynecological workup can be beneficial for clinicians, enabling a precise diagnosis to be made. In addition, the volumes obtained and stored by 3D ultrasound can allow students or residents to become more familiar with normal and abnormal pelvic structures. Clin. Anat. 31:373–379, 2018.

Key words: uterus anatomy; coronal plane; three-dimensional plane; uterine pathology; education; arcuate uterus; didelphe uterus; unicorn uterus; uterine anomalies; endometrial polyp; isthmoceles; cesarean scar defect

INTRODUCTION

Imaging in the major planes (horizontal, coronal, and sagittal) of the uterus is important for determining its anatomy and allowing the findings to be standardized, and for evaluating and diagnosing different pathological conditions in clinical practice (Bocca and Abuhamad, 2013). For example, the diagnosis of a benign uterine pathology is usually based on both clinical symptomatology and imaging investigations. Although two-dimensional (2D) ultrasound is routinely used, the examination of the uterus and its lesions is limited to the sagittal and axial planes (Figs. 1a and 1b). In several uterine pathologies, an examination of the coronal plane is particularly important. Unfortunately, 2D ultrasound has limited ability to assess uterine pathology in the coronal plane. The ultrasound examination is performed similarly in 2D and three-dimensional (3D) examinations and the vaginal probes have the same size.

3D ultrasound reveals the normal anatomy better than 2D ultrasound and improves the depiction of abnormal anatomy, as the coronal plane of the uterus can easily be obtained using 3D reconstruction techniques. The coronal plane clearly outlines the external

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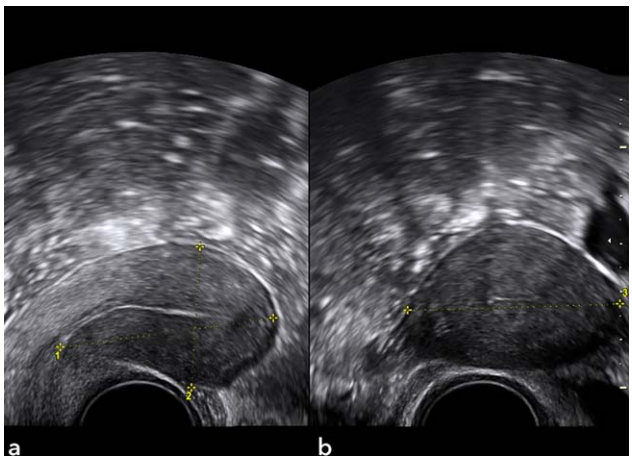

Fig. 1. (a) Normal uterus—longitudinal plane. (**b**) Normal uterus—transverse plane. [Color figure can be viewed at wileyonlinelibrary.com]

contour of the uterus and provides accurate information regarding the shape of the uterine cavity (Fig. 2). On the coronal plane, the normal shape of the uterine cavity is triangular, with a smooth contour, while the normal shape of the fundus is convex. The coronal plane enables the endometrial–myometrial junction (also called the uterine junctional zone, endometrial–subendometrial unit, subendometrial myometrium, archimetra, archimyometrium, or inner myometrium) to be visualized; this is an important anatomical landmark to assess in several uterine conditions. The endometrial–myometrial junction appears on a reconstructed coronal plane ultrasound as a hypoechoic zone around the endometrium (Fig. 3).

Herein, we provide a pictorial essay focused on the gynecological clinical applications of coronal plane images of the uterus obtained via 3D ultrasound using a Voluson 730 Pro (General Electric, Zipf, Austria) and

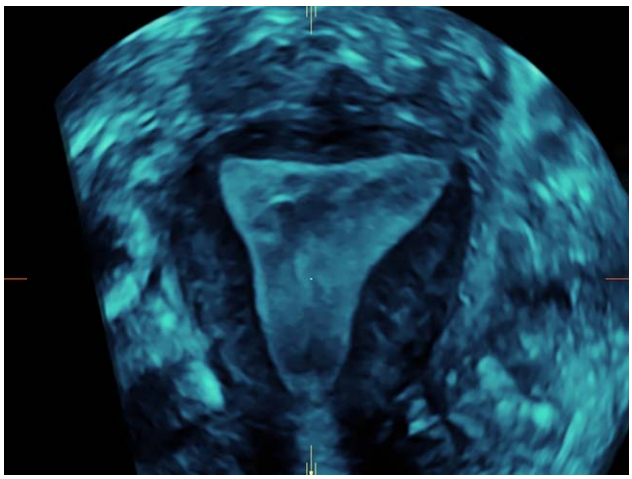

Fig. 2. Coronal or C-plane of the normal uterus (rendered image). [Color figure can be viewed at wileyonlinelibrary.com]

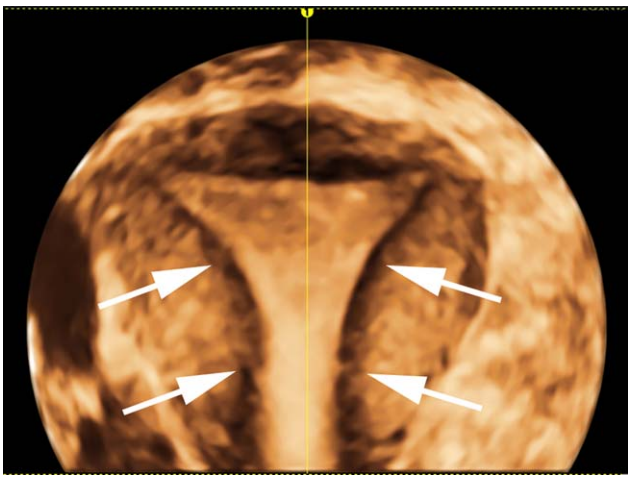

Fig. 3. Coronal or C-plane of the normal uterus (rendered image)—endometro–myometrial junction (white arrows). [Color figure can be viewed at wileyonlinelibrary.com]

a Voluson E8 (General Electric, Zipf, Austria) with volumetric transvaginal transductors.

UTERINE ANOMALIES

Uterine anomalies are related to the unsuccessful development and/or fusion of the Müllerian ducts, or a failure in resorption of the uterovaginal septum. The reported prevalence of congenital uterine anomalies is 5.5% in the general population, 8% in the infertile population, and 13.3% in women with recurrent miscarriages (Chan et al., 2011). In the past, uterine anomalies were often investigated via routine 2D sonography or contrast hysterosalpingography. However, 3D ultrasound has proved very powerful for diagnosing uterine anomalies by obtaining the coronal plane of the uterus (Propst and Hill, 2000; Faivre et al., 2012). It is possible that 3D ultrasound will become the gold standard for diagnosing uterine anomalies in future, sidelining magnetic resonance imaging (MRI).

The septate uterus, the most common Müllerian duct anomaly, results from a partial or complete failure of resorption of the uterovaginal septum after the paramesonephric ducts fuse (Fig. 4). Since the paramesonephric ducts fuse prior to the resorption failure, the serosa of the uterine fundus is intact. The septum arises in the midline of the cavity, starting from the fundus, and can extend partially or completely to the external cervical os (Carrington, 1990). The external uterine contour can be convex, flat, or mildly concave (Troiano and McCarthy, 2004). A serosal indentation of >1 cm indicates a bicornuate uterus, which results from an incomplete fusion of the uterine horns (Grigore et al., 2009). The bicornuate uterus consists of two symmetrical cornua with communication of the endometrial cavities, usually at the level of the uterine isthmus. A complete bicornuate uterus can have a single (bicornuate unicollis) or a duplicated (bicornuate

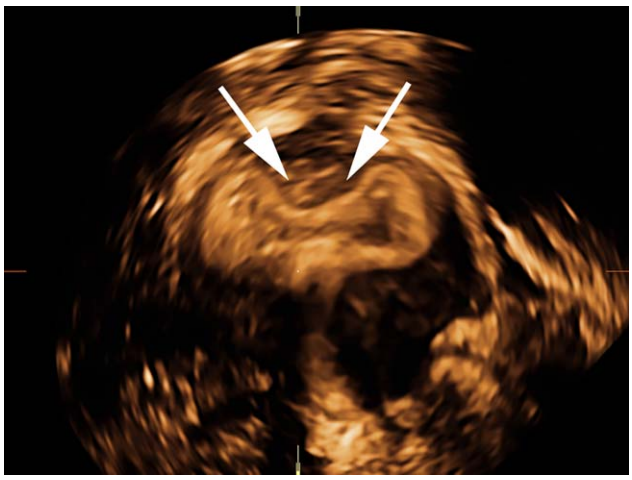

Fig. 4. Coronal plane—Septate uterus—incomplete septate uterus. [Color figure can be viewed at wileyonlinelibrary.com]

bicollis) cervix (Uğur et al., 1995). The incidences of spontaneous abortion and premature delivery in women with a bicornuate uterus are 28–35% and 14–23%, respectively (Carrington, 1990). From a clinical point of view, it is important to differentiate a septate from a bicornuate uterus, as different clinical and therapeutic approaches are used for the two anomalies. One differentiating anatomical feature is the angle between the uterine horns; imaging in the coronal plane allows this angle to be measured. An angle of $<75^{\circ}$ between the uterine horns suggests a septate uterus, while an angle of $>105^{\circ}$ is more consistent with a bicornuate uterus.

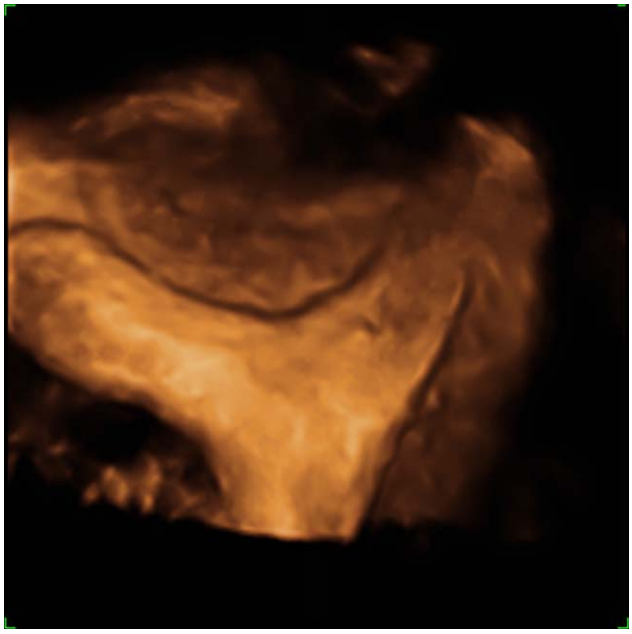

Fig. 5. Coronal plane—Arcuate uterus. [Color figure can be viewed at wileyonlinelibrary.com]

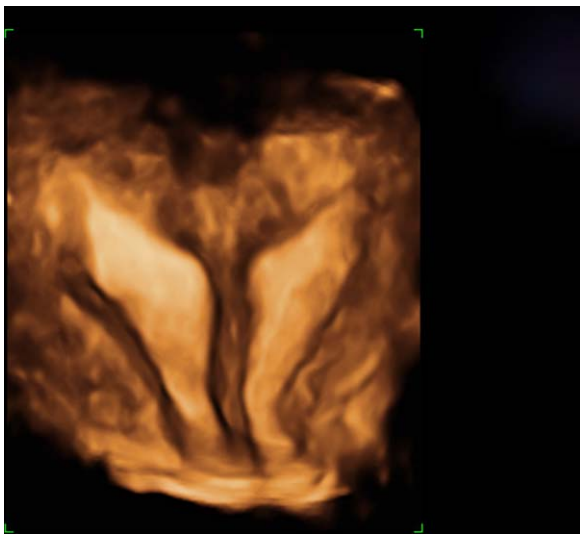

Fig. 6. Coronal plane—Unicorn uterus. [Color figure can be viewed at wileyonlinelibrary.com]

An arcuate uterus has a broad indentation in the fundal endometrium resulting from near-complete resorption of the uterovaginal septum (Fig. 5). The depth of the indentation that distinguishes an arcuate uterus from a small partial septum is not yet well defined (Grigore et al., 2009); thus, its differential diagnosis from a septate uterus can be difficult.

Uterine didelphys represents 5% of Müllerian duct anomalies and is caused by an almost complete failure of Müllerian duct fusion. There are two hemiuteri and two cervices, with no communication between the duplicated endometrial cavities (Fig. 6). The spontaneous abortion rate ranges from 32% to 52%, the premature birth rate from 20% to 45%, and the fetal survival rate from 41% to 64% (Goldberg and Falcone, 1999). The retrograde menstrual flow in patients with

Fig. 7. Coronal plane—Didelphe uterus. [Color figure can be viewed at wileyonlinelibrary.com]

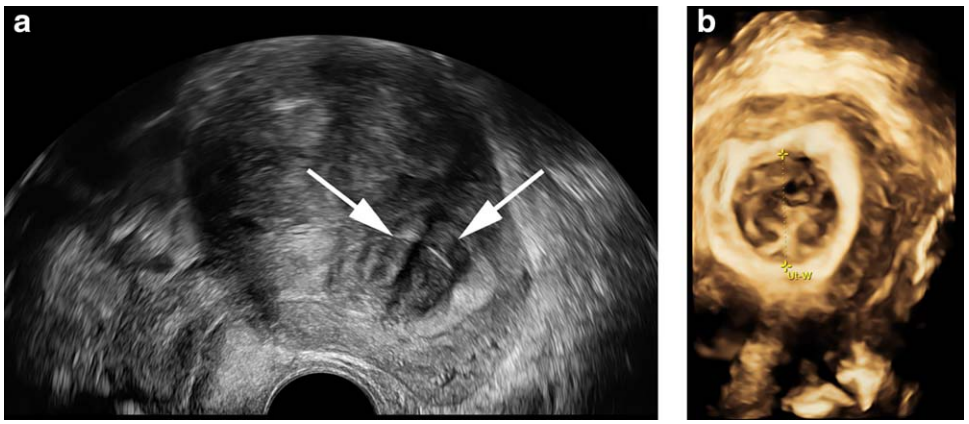

Fig. 8. (**a**) Type 0 uterine myoma—2D ultrasound image, longitudinal plane. (**b**) Type 0 uterine myoma—3D, coronal plane. [Color figure can be viewed at wileyonlinelibrary.com]

obstruction increases the prevalence of endometriosis and pelvic adhesions (Heinonen, 1997).

A unicornuate uterus occurs (Fig. 7) when one Müllerian duct develops normally and one does not. One-third of such cases are isolated, one-third have a non-cavitary rudimentary horn, and one-third have a cavitary rudimentary horn that may or may not communicate with the unicornuate cavity (Uğur et al., 1995). Unicornuate uteri are associated with increased incidences of spontaneous abortion, premature birth, and intrauterine growth retardation (Carrington, 1990). These complications are caused by inadequate vascularization and compromised uteroplacental blood flow in the unicornuate uterus, resulting from a decreased vascular contribution of the uterine and utero-ovarian arteries from the abnormal side (Goldberg and Falcone, 1999).

A T-shape uterus is usually associated with diethylstilbestrol (DES) exposure and is characterized by a small hypoplastic uterus, constriction bands, a widened lower uterine segment, a narrowed fundal segment of the endometrial canal, and irregular endometrial margins. Women exposed to DES are predisposed to cervical incompetence secondary to structural and histological changes such as an abnormal smooth muscle-to-collagen ratio and decreased cervical elastin (Bromley et al., 2000).

UTERINE MYOMAS

Leiomyomas are the most common benign tumors in women and are classified as intramural, subserosal, or submucosal according to their location. Submucosal fibroids are a common cause of abnormal uterine bleeding, subfertility, and early pregnancy loss. Submucosal fibroids can be classified into three groups on the basis of their protrusion into the endometrial cavity: Type 0 (the myoma is entirely in the cavity), Type I (<50% contained within the myometrium), and Type II (>50% contained within the myometrium). It is sometimes difficult to differentiate a submucosal from an intramural leiomyoma, or to establish its relationship to the endometrial cavity, using 2D ultrasound (Fig. 8a). The correct mapping of multiple myomas can also be difficult with 2D ultrasound. In contrast, 3D ultrasound can delineate the location of the leiomyomas precisely and depict their intramural and

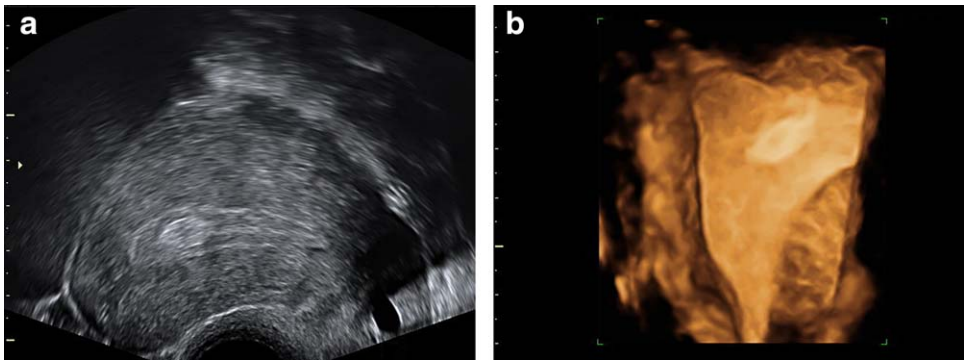

Fig. 9. (**a**) Endometrial polyp—2D ultrasound image, longitudinal plane. (**b**) Endometrial polyp—3D ultrasound image, coronal plane. [Color figure can be viewed at wileyonlinelibrary.com]

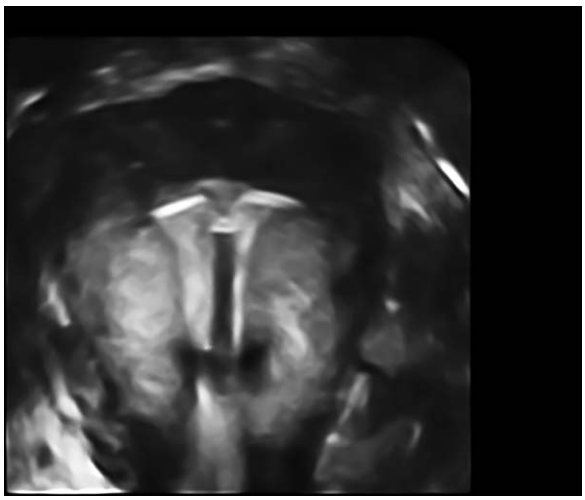

Fig. 10. Coronal plane—T-shaped intrauterine device (IUD) in the correct intrauterine position.

submucosal components (Fig. 8b). This information is very useful for clinical decision-making in women with fertility problems and recurrent pregnancy failures, when it is very important to preserve the uterus. The visualization of the coronal plane enables good candidates for hysteroscopic resection to be carefully selected, avoiding classic or laparoscopic surgery.

ENDOMETRIAL POLYPS

Endometrial polyps are localized overgrowths of the endometrial glands and stroma and are more common in women with infertility (Shokeir et al., 2004). The current consensus is that endometrial polyps should be screened for and removed prior to any assisted reproduction treatment (Kodaman, 2016). 3D ultrasound can be useful because it gives a precise mapping of the lesion, and this information is useful in planning the subsequent hysteroscopic procedure (Saravelos et al., 2017) (Figs. 9a and 9b).

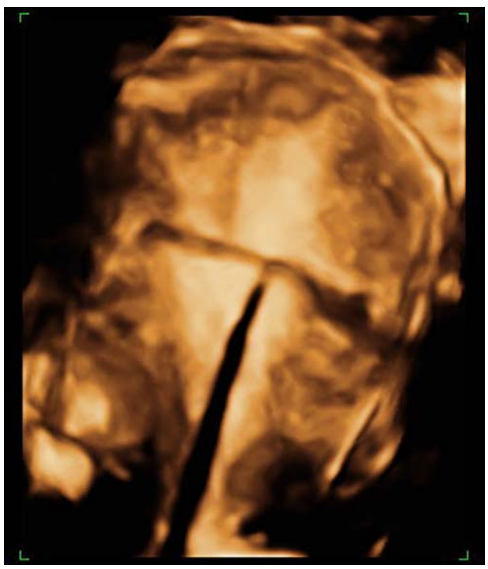

Fig. 11. Coronal plane—a descended IUD. [Color figure can be viewed at wileyonlinelibrary.com]

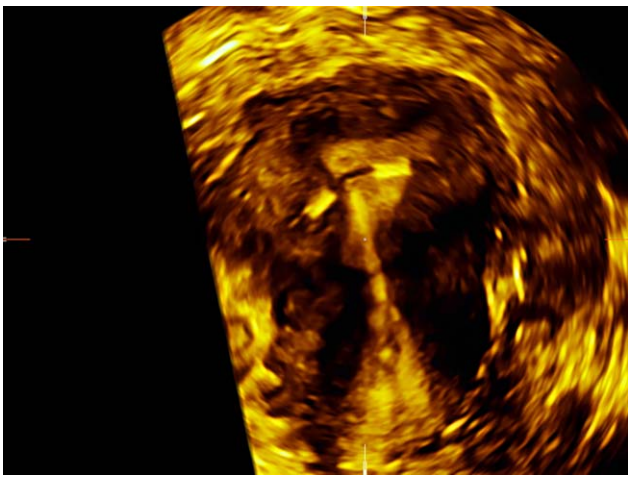

Fig. 12. Coronal plane—An IUD embedded in the myometrium. [Color figure can be viewed at wileyonlinelibrary.com]

INTRAUTERINE DEVICES

Intrauterine devices (IUDs) are a popular and reversible form of contraception. Imaging is crucial in managing patients with IUDs, especially in cases with clinical complications such as pelvic pain, abnormal bleeding, or absent retrieval strings. Standard endovaginal 2D ultrasound usually identifies the stem of the IUD as a linear echogenic structure, but cannot provide information regarding the arms or the correct positioning of the IUD inside the cavity. Adding a 3D

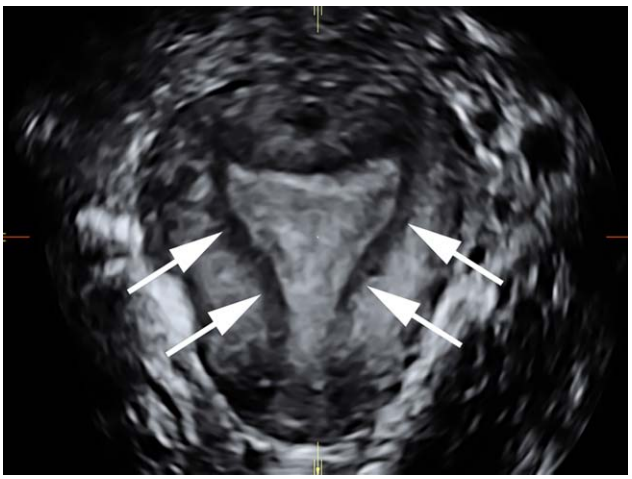

Fig. 13. Adenomyosis—3D-disruption of the endometro–myometrial junction. [Color figure can be viewed at wileyonlinelibrary.com]

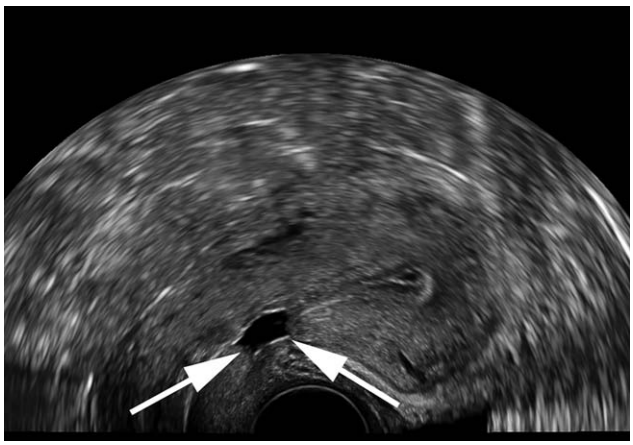

Fig. 14. Cesarean scar defect—longitudinal plane.

ultrasound scan to a conventional examination can be beneficial, as the coronal plane of the uterus can be obtained easily (Fig. 10). Furthermore, 3D ultrasound allows both the IUD type and its position inside the uterine cavity to be determined. In addition, it has proven more sensitive than 2D ultrasound, revealing more subtle findings of malposition, particularly side-arm embedment, by showing the coronal plane of the uterus (Figs. 11 and 12). Abnormally positioned IUDs can be associated with higher incidences of failed contraception, pain, and bleeding.

ADENOMYOSIS

Adenomyosis is a common gynecological disease, characterized by non-neoplastic ectopic endometrial glands and stroma within the myometrium and associated with a reactive overgrowth of the musculature. Numerous studies have established a role for 2D ultrasound in the diagnosis of adenomyosis (Atri et al., 2000; Osser et al., 2009). However, 3D ultrasound not only allows the endometro–myometrial junction to be visualized, but also distinguishes all the other criteria revealed by 2D ultrasound: anechoic foci, striation, and heterogeneous myometrium. The coronal plane can reveal the thickening of the endometro–myometrial junction and its disruption by the infiltration of hyperechoic endometrial tissue (Fig. 13).

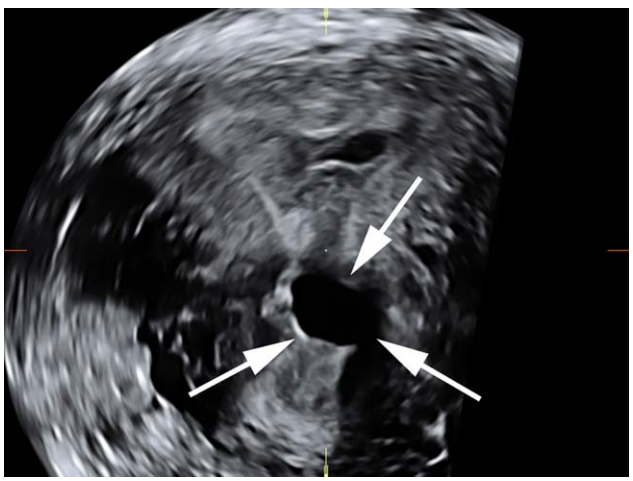

Fig. 15. Cesarean scar defect—coronal plane—white arrows show the surface of the defect in coronal plane. [Color figure can be viewed at wileyonlinelibrary.com]

CAESAREAN SCAR DEFECTS

Caesarean scar defects, also known as isthmoceles, are an emerging condition affecting women with a history of caesarean section. Their presence is a novel, under-recognized cause of abnormal postmenstrual uterine bleeding, pelvic pain, and infertility. On 2D ultrasound, a myometrial-thinning defect can be observed at the level of the previous cesarean section (Fig. 14). In clinical practice, measuring the remaining myometrial thickness over the defect is important for assessing cesarean hysterotomy scars in non-pregnant women (O'Rahilly, 1997). When a hysteroscopic repair is planned, imaging the coronal plane allows the defect to be measured in all three dimensions, which provides useful information (Fig. 15).

This pictorial essay demonstrates that adding 3D ultrasound to a routine gynecological workup can be beneficial for clinicians, enabling a precise diagnosis to be made. Furthermore, 3D ultrasound can replace several investigations that are invasive (hysteroscopy, laparoscopy), involve exposure to radiation (hysterosalpingography), or require expensive MRI. Another important advantage of 3D ultrasound concerns the storage of volumes for subsequent processing and analysis. These volumes can be processed later to gain a more in-depth picture of the normal or pathological anatomy of the uterus. In addition, the volumes can allow students or residents to become more familiar with normal and abnormal pelvic structures (Popovici et al., in press). A major limitation of 3D ultrasound is that a learning curve is involved, even for sonographers and sonologists who are experienced in 2D ultrasound. In addition, spatial orientation can be challenging for less experienced practitioners (Rodriguez et al., 2014).

CONCLUSIONS

Examination of the coronal plane of the uterus is an important step in evaluating uterine disorders and their relationships to the endometrial canal. 3D sonography is an easy and cost-effective method that allows the coronal plane to be reconstructed.

CONFLICTS OF INTEREST

There are no conflicts of interest to declare.

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