THE SONOGRAPHIC DETECTION OF UTERINE ANOMALIES

INTRODUCTION
Uterine malformations result from partial or complete failure of one of three mechanisms either separately or combined - agenesis, fusion, and resorption. Agenesis results in either a complete absence of the uterus or a unicornuate uterus; a failure to fusion gives rise to uterine didelphys or a bicornuate uterus; and a septated uterus is due to a failure of resorption. The incidence of muellerian anomalies has historically varied widely due to the different populations studied, small sample sizes, prospective versus retrospective study designs, different classification systems, and the type of test used to make the diagnosis. The need for a standard classification of muellerian anomalies was self-evident. The American Fertility Society (AFS) classified muellerian anomalies according to the major uterine anatomic types. It was hoped that by appropriately defining uterine anomalies, reliable pregnancy, as well as fetal wastage rates, could be obtained. The AFS classes of muellerian anomalies are:
1. Hypoplasia/agenesis
2. Unicornuate
3. Didelphys
4. Bicornuate
5. Septate
6. Arcuate
7. DES drug related
None of these categories are strictly defined; they are based upon the subjective impression of the examiner. This system, by necessity, has simplified the categorization of muellerian anomalies. However, some uterine anomalies may have characteristics of one or more categories. Despite its flaws, the American Fertility Society classification provides a basis for communication and comparison between investigators.
Since the muellerian and Wolffian systems are embryologically closely linked, the kidneys should be evaluated whenever a uterine anomaly is detected. In one series, renal agenesis was present in 28% of cases with a unicornuate uterus.

PREVALENCE OF UTERINE ANOMALIES
The prevalence of muellerian anomalies in women with normal fertility and infertility is between 1% and 5.6%. In women with a history of repeated pregnancy loss, the rate of muellerian anomalies increases to between 3% and > 25%.

OBSTETRICAL COMPLICATIONS
All uterine anomalies negatively affect the live birth rate and result in a higher frequency of obstetrical
complications. Depending upon the type of muellerian anomaly, cervical incompetence, spontaneous miscarriage, preterm delivery, breech presentation, abnormal fetal lie and intrauterine growth restriction are all increased to a variable degree\textsuperscript{1,6,7}.

**UNICORNUATE UTERUS**

Approximately 20\% of uterine anomalies are unicornuate.

A unicornuate uterus occurs when one muellerian duct develops normally and the other does not - 1/3 are isolated (Fig. 1); 1/3 have a non-cavitary rudimentary horn; and 1/3 have a cavitary rudimentary horn that may or may not communicate with the unicornuate cavity.

Figure 1 - 3-dimensional coronal image of a unicornuate uterus.

Resection of a cavitary rudimentary horn is recommended because of the substantial risk that a pregnancy in a non-communicating horn will rupture; even in a communicating horn a viable pregnancy is rarely achieved\textsuperscript{4}. In one study the reproductive outcome of women with a unicornuate uterus consisted of a live born rate of 29.2\%; a prematurity rate of 44\%; a miscarriage rate of 29\%; and an ectopic rate of 4\%\textsuperscript{3}.

**UTERINE DIDELPHYS**

Uterine didelphys accounts for 5\% of muellerian anomalies. This uterine anomaly is due to an almost complete failure of muellerian duct fusion - there are two hemiuteruses and two cervices (Fig 2). A longitudinal and transverse vaginal septum may also be present\textsuperscript{4} Widely divergent uterine horns are imaged on 2D ultrasound. The distance between the uterine horns frequently prevents their visualization on a single 3D ultrasound image.
Obstetrical complications associated with a didelphys uterus include: a miscarriage rate of 32% - 52%; a prematurity rate of 20% - 45%; and a fetal survival rate of 41% - 64%.

BICORNUATE UTERUS

Ten percent of uterine anomalies are bicornuate. Incomplete fusion of the uterine horns results in a bicornuate uterus (Fig 3). The intervening myometrium extends for a variable length from the fundus to the cervix. A complete bicornuate uterus may have a single (bicornuate unicollis) or duplicated (bicornuate bicollis) cervix.

On 3D ultrasound a large fundal cleft may be visualized. The depth of the cleft is > 1.0 cm. Patients with a bicornuate uterus have a miscarriage rate of 28% - 35%; a prematurity rate of 14% - 23%; and a fetal survival rate of between 57% and 63%.
It is important to differentiate between a partially septated and a partially bicornuate uterus. While hysteroscopic resection is the treatment of choice for a subseptate uterus, it is contraindicated for a bicornuate uterus 9.

SEPTATED UTERUS
Fifty-five percent of uterine anomalies are septated. A septated uterus is derived from incomplete resorption of the uterovaginal septum. Since the paramesonephric ducts have previously fused, the serosa of the uterine fundus is intact. A serosal indentation up to 1.0 cm may be present with a septated uterus; a serosal indentation > 1.0 cm is indicative of a bicornuate uterus 4. While this cut-off was arbitrarily selected, it accurately distinguishes between a septated and a bicornuate uterus 10.

It has not yet been determined why some patients with a septated uterus carry a pregnancy to term and others have recurrent miscarriages 9.

Some septa are thin, while others are more broad-based and, therefore, result in smaller uterine cavities. A septum consists of varying amounts of muscle and fibrous tissue. Salim et al 11 have reported that the more complete the septum, the higher the pregnancy failure rate. Kupesic and Kurjak 12 have found that the length of the septum does not affect the pregnancy complication rate. In general, septated uteri have the poorest reproductive outcomes of muellerian anomalies 12,13.

Hysteroscopic septum resection attempts to restore normal uterine anatomy and function. Pregnancy outcome after hysteroscopic resection approaches normal controls 5. A residual uterine septum of <= 1.0 cm does not impair reproductive function 6.

The endometrial mucosa covering the septum does not respond appropriately to estrogen. The distribution of vessels within the septum is deficient 8. The muscular fibers in the septum may cause irregular contractions 9,14. All of these factors may play a role in the poor reproductive outcomes reported with a septated uterus 9,11,14.

Since it is not always associated with a poor obstetrical history, the incidental finding of a uterine septum is not an indication for hysteroscopic incision 9,15. Hysteroscopic incision of a septum is indicated in women with a longstanding history of unexplained infertility 15.

ARCUATE UTERUS
It remains controversial as to whether an arcuate uterus is a normal variant or a true muellerian anomaly 16. The signal intensity of the indentation on MRI is consistent with normal myometrium 8. An arcuate uterus has a broad indentation of the fundal endometrium (Fig. 4). The depth of the indentation that would distinguish and arcuate from a small partial septum has yet to be defined 4. As result, it is not surprising that both poor and good obstetric outcomes have been reported in patients with an arcuate shaped uterus 17. Hysteroscopic incision has been performed in patients with an arcuate shaped uterus and recurrent pregnancy loss 8.
DETECTION OF UTERINE ANOMALIES

Hysterosalpingograms (HSG) have historically been utilized to evaluate the uterine cavity (Fig 5). However, this test has a false negative rate of between 18% and 44% and a false positive rate of 10% to 44%.\textsuperscript{18} For example, a fundal leiomyoma can have the appearance of a bicornuate uterus on hysterosalpingography.\textsuperscript{19} Since the uterine serosal contour is not imaged, HSG cannot distinguish between a bicornuate and a septated uterus; laparoscopy was, therefore, frequently utilized to obtain a definitive diagnosis.\textsuperscript{20}
While transvaginal sonography (Fig 6) is an excellent screening examination for uterine anomalies, it is not as effective as 3D ultrasound in distinguishing specific malformations. For example, Jurkovic et al\textsuperscript{20} reported a 100% sensitivity and specificity for the three-dimensional ultrasound detection of uterine anomalies in contrast to 100% sensitivity and 95% specificity for two-dimensional ultrasound. However, the positive predictive value of three-dimensional and two-dimensional ultrasound for muellerian anomalies was 100% and 50%, respectively.

![Figure 6 - 2-dimensional transverse view of the uterine fundus showing two distinct endometrial cavities (arrows). A subsequent 3-dimensional examination confirmed that this was a partially septated uterus.](image)

The use of a sufficient amount of saline with hysterography improves the sensitivity of transvaginal sonography by permitting visualization of the outer uterine surface\textsuperscript{21,22}. Uterine position, the location of leiomyomas, and the interference of adjacent bowel can affect the success of this technique. The advent of 3D ultrasound has made this procedure obsolete. MRI has been the "gold standard" for categorizing uterine anomalies because of its 98% - 100%\textsuperscript{23} accuracy (Fig. 7). While ultrasound will remain the primary modality utilized to evaluate muellerian anomalies, MRI can offer additional diagnostic information in patients with equivocal ultrasound findings. As a result, laparoscopy or open surgery are no longer required to make a definitive diagnosis of a uterine anomaly\textsuperscript{24}. 


THREE-DIMENSIONAL ULTRASOUND

3D ultrasound permits an accurate assessment of the size and shape of the endometrial cavity. It is best performed during the secretory phase of the menstrual cycle so the endometrial cavity is easier to outline (Fig. 8). Since the uterine serosa, as well as the endometrial cavity, can be visualized, the coronal plane is the most valuable in the detection of uterine anomalies. This view shows the entire endometrial canal, the relationship of the endometrium to myometrium and the uterine serosa. Multiple planes can be constructed regardless of uterine position. The sensitivity, specificity, positive and negative predictive values of 3D ultrasound in the detection of a septated uterus is 98.4%, 100.0%, 100.0% and 96.0%, respectively9. The 3D coronal view of a septated uterus can also confirm or exclude the diagnosis of a septated cervix19.
Figure 8 - 3-dimensional coronal view of a normal uterus during the secretory phase of the menstrual cycle.

The multiplanar display shows the plane of acquisition in the left upper box (Figs 9, 10) and the two perpendicular planes in the right upper and left lower box. In Figure 9 the image was obtained parasagittally; the transverse image is in box b and the coronal image is in box c. The fourth image is a surface rendering of the acquisition image.

Figure 9 - Multiplanar display of a normal uterus: a) sagittal; b) axial; c) coronal; and d) surface rendering.
Figure 10 - Multiplanar display of the same image as in Figure 9. The field of view in the sagittal image begins on the endometrial lining, resulting in an image of the uterine serosa and endometrium on the surfaced rendering image (d).

The three planes can be correlated by placing the image point (Fig 11) or the intersection of the two perpendicular views (Fig 9) at the region of interest. By scrolling the upper line of the field of view into the endometrial cavity, surface rendering of the serosa and endometrial cavity are visualized (Fig 10). Surface rendering is helpful in evaluating the fundal notch of a bicornuate uterus (Fig. 12)\textsuperscript{25}.

Figure 11 - 3-dimensional coronal multiplanar display of a normal uterus. Note the “dot” (arrow) that orients the observer to the same spot in the sagittal, transverse and coronal planes.
Because of the limited views that are required, the learning curve for obtaining appropriate images to detect uterine malformations is faster than for obtaining obstetric 3D images. The additional equipment and training that 3D ultrasound requires necessitates that it is a second tier examination after a standard two-dimensional study suspects the presence of a possible uterine anomaly. By convention during 2-dimensional scanning the right side of the patient is on the right side of the image. The continuation of this orientation during 3D scanning is necessary, not only for standardization, but also to ensure that detected abnormalities are properly oriented in the uterus.

The acquisition of a 3D image can be either freehand or automated. In the former, the sonographer manually sweeps through the region of interest. The drawback of this technique is that accurate measurements cannot be obtained. In the automated method, a dedicated 3D probe with a mechanical drive obtains the image. Since the sweep is at a predetermined speed, measurements of specific structures can be obtained.

In order to accurately measure the endometrial extension of a septum, a true coronal plane through the fundus and cervix must be obtained (Fig 11). If the plane is off center, an arcuate uterus may not be detected, the measurement of a septum will be inaccurate, and the detection of the serosal indentation of a bicornuate uterus may be missed.

The region of interest in the uterus must fit within the volume "box". The horns of a didelphic uterus are generally too far apart to be imaged with 3D ultrasound.

A 3D ultrasound image in the coronal plane can be used to measure the distance between the two internal tubal ostia, the length of a septum (Fig 13), the remaining cavity length, and the depth of an external fundal indentation. Quantification of these parameters provides a reproducible standard that can be used to compare studies from different institutions. Cut-off values for distinguishing arcuate, bicornuate, and septated uteri on 3D coronal images have, to date, been arbitrarily selected. By defining 3D diagnostic criteria, inter and intra-observer variability in detecting uterine malformations is quite
The accumulation of data on specifically defined uterine anomalies will provide reliable incidence figures for uterine anomalies and outcome data that may result in anomaly-based management schemes.

Figure 13 - 3-dimensional coronal view of a septated uterus (a) distance between ostia (+. .+); (b) length of septum (x . . x).

REFERENCES
9. Kupesic S. Clinical implications of sonographic detection of uterine anomalies for reproductive