7 The Septate Uterus

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Incidence

A septate uterus is a type of congenital uterine malformation whereby there is a midline, longitudinal band dividing the uterus either partially (incomplete or subseptate) or completely. This septation may continue caudally, and be associated with a longitudinal vaginal septum. The septate uterus is the most common type of uterine anomaly, with a mean incidence of 35 % amongst all uterine abnormalities, and accounting for ~55 % of uterine malformations when including both septate and arcuate uteri [1]. When looking at the ratio of septate to bicornuate uteri in different patient populations, septate uteri are always more common at a ratio of 4:1, 5:1, and 7:1 in the infertile, general, and recurrent miscarriage populations, respectively [2]. A septate uterus is frequently associated with a complete or partial longitudinal vaginal septum [3], with 94 % of complete septate uteri associated with a concurrent vaginal septum in one series [4].

The true incidence of a septate uterus is difficult to determine, as the majority of cases go undiagnosed. Most women with a septate uterus will not have any clinical consequences, and therefore, a work-up and evaluation will never be performed. In addition, the criteria for diagnosis are not consistent and all diagnostic testing methods are not equally optimal. The majority of studies are based on women with pregnancy loss and/or infertility, and therefore do not reflect the underlying prevalence in the general population.

The incidence of congenital uterine malformations varies between studies, and has been reported as low as 0.1 % and as high has 12 % [5]. According to a recent systematic review by Chan et al. in 2011, when utilizing optimal tests for diagnosing uterine anomalies (three-dimensional transvaginal sonography, magnetic resonance imaging (MRI), saline infusion vaginal sonohysterography, laparoscopy/laparotomy plus hysteroscopy, or hysterosalpingogram), the overall prevalence of all uterine anomalies was 5.5 % in an unselected population verses 24.5 % in an infertility plus recurrent miscarriage population, and the prevalence of a septate uterus was 2.3 % in an unselected population verses 15.4 % in an infertility plus recurrent miscarriage population [6]. In studies looking at women without infertility or recurrent miscarriage, 5.5–9.8 % were found to have a uterine anomaly, and 2.2–4.3 % were found to specifically have a septate

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uterus, either partial or complete, by three-dimensional transvaginal sonography or saline infusion vaginal sonohysterography, respectively [7, 8]. Furthermore, it is estimated that 1 % of fertile women have a septate uterus [9]. Amongst women seeking treatment for subfertility, 10–15 % will have an intracavitary abnormality [10], and of those women with a diagnosis of unexplained infertility, 1–3.6 % will have a septate uterus [2]. According to the systematic review sited above, utilizing optimal tests, the prevalence of a septate uterus was consistent with prior studies, finding 3 % in an infertility population, and 5.3 % in a recurrent miscarriage population [6].

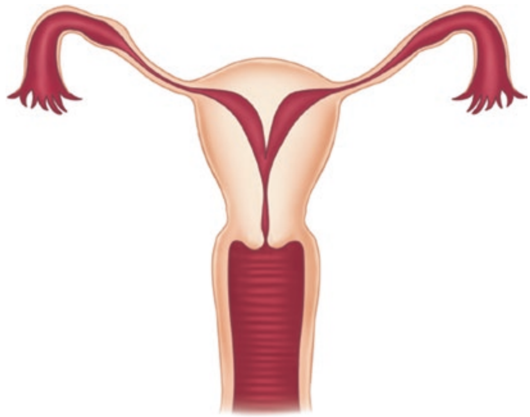

Fig. 7.1 Partial uterine septum: narrow or thin

Etiology

Uterine anomalies are testaments to defects that occur during embryological development, and the septate uterus is no exception. The vast majority of woman with congenital uterine anomalies have normal 46, XX karyotypes, although abnormal karyotypes can be found in 7.7 % of woman with uterine anomalies [11]. To understand the etiology of the septate uterus, it is important to understand normal Müllerian development. Embryonic development of the uterus and surrounding structures takes place between weeks 6 and 16, but can continue as late as week 20. Initially, there are two Müllerian ducts and two Wolffian ducts, both of which are present by week 6. By week 9, the Müllerian ducts have elongated to consist of three segments: (1) the cranial vertical portion which will eventually develop into the fimbriated ends of the Fallopian tubes; (2) the horizontal portion that becomes the isthmus of the Fallopian tubes; and (3) the caudal vertical portion which will migrate to join its contralateral pair to form the uterovaginal primordium (UVP). The UVP will become the uterus, cervix, and upper third of the vagina. The migration of the Fallopian tubes, followed by fusion and internal canalization of the two Müllerian ducts, resulting in two cavities divided by a septum, occurs between weeks 9 and 12 in most cases. This is followed by a period of regression of the partition between the two cavities, thought to be a product of Bcl-2 regulated apoptosis, usually occurring between week 12 and 16 and resulting in a single cavity [12]. The resorption of the septum is completed by week 20. Thus, normal uterine development involves a complex series of events including Müllerian duct elongation, fusion, canalization, and septal resorption.

A septate uterus results from failure of resorption of the midline partition between the two Müllerian ducts resulting in a fibromuscular septum with a normal external uterine contour. The extent of the septum is variable, from involving the superior aspect of the endometrial cavity (incomplete septum, partial, or subseptate uterus) to a septum that extends the total length of the uterine cavity down to the internal cervical os and including either a cervical septum or complete duplicated cervix (compete septum). A complete or partial longitudinal vaginal septum is found most frequently in concert with a complete septate uterus [3], with 94 % of complete septate uteri associated with a concurrent vaginal septum in one series [4] (Figs. 7.1, 7.2, 7.3, and 7.4).

The current American Society for Reproductive Medicine (ASRM) classification system [13] is based on the classification described by Buttram in 1979 [14] and follows the unidirectional theory of caudal-to-cranial Müllerian duct resorption [13–15]. While this unidirectional theory explains the majority of septate uteri, whereby partial septate uteri contain only the more cephalad portion of the septum, it does not explain the less common anomaly of a complete uterine septum, double cervix, and longitudinal

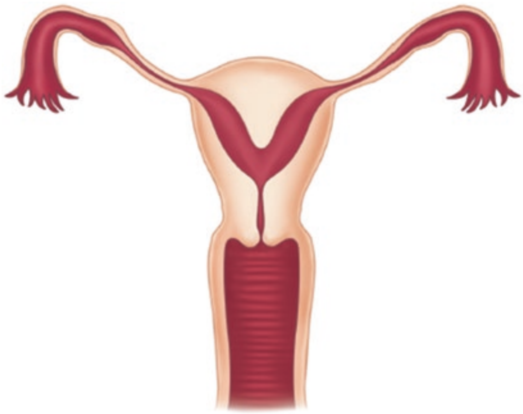

Fig. 7.2 Partial septum: wide or thick

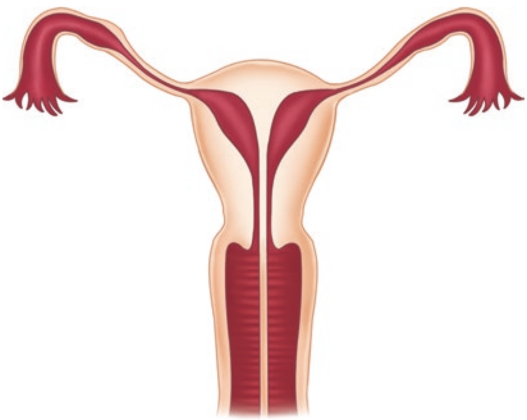

Fig. 7.3 Complete septate uterus with septum extending down through the cervix and associated with a longitudinal vaginal septum

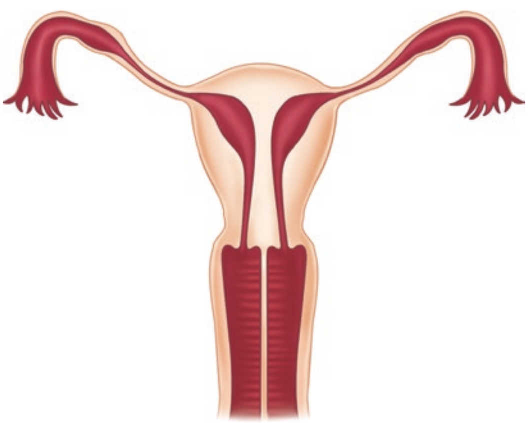

Fig. 7.4 Complete septate uterus with duplicated cervix and longitudinal vaginal septum

vaginal septum first described in 1994 [16]. This less frequent anomaly lends support to the bidirectional/segmental theory of fusion and resorption described by Musset and Muller [17], and championed by Acién in his categorization based on embryological origin [18, 19]. The double cervix is a failure of fusion, occurring between weeks 9 and 12, while the uterine septum is a regression failure during weeks 12–16. Taken together, the complete septate uterus with a double cervix likely results from an insult that occurs around week 12, while a complete septate uterus occurs from a later insult somewhere early between week 12 and 16, and a partial septate uterus ensues from an even later defect as far out as 20 weeks. Additionally, segmental septa also exist, resulting in partitioned uterus with partial communications, and further challenging the unidirectional theory of development [11].

Differential Diagnosis

The differential diagnosis for a septate uterus includes other congenital uterine malformations and is dependent upon which diagnostic test is utilized and which classification system is employed. The European Society of Human Reproduction and Embryology/European Society for Gynaecological Endoscopy (ESHRE/ESGE) classification will overdiagnose septate uteri as compared with the ASRM classification system, diagnosing many uteri as septate that would be considered arcuate or normal by the ASRM classification system [20]. Not only would the ESRE/ESGE system lead to a relative overdiagnosis of septate uteri, but this overdiagnosis may lead to unnecessary treatment without proven benefit [20].

Therefore, the arcuate uterus needs to be distinguished from a true septate uterus. Definitions between the two anomalies are not standardized, and the arcuate uterus has been variably classified as normal, bicornuate, or septate [20, 21]. The arcuate uterus contains a slight residual cranial septum, sometimes with minimal external fundal cavity indentation [21].

Utilizing the ASRM classification system alone is solely subjective. However, several authors have proposed supplementing the ASRM

Table 7.1 AFS Classification system supplemented with proposed additional morphometric criteria [7, 13, 23]

	ASRM Classification	Internal uterine cavity indention (cm)	External uterine contour cleft (cm)
Septate uterus	Class V	≥1.5	<1
Arcuate uterus	Class VI	1–1.5	<1
Bicornuate uterus	Class IV	≥1.5	≥1

classification with additional morphometric criteria [7, 22] (Table 7.1). These additional criteria proposed describe a septate uterus as Class V with an internal uterine cavity indentation ≥1.5 cm and an external uterine contour cleft of <1 cm. Similarly, an arcuate uterus is Class VI with an internal indentation of 1–1.5 cm and an external cleft of <1 cm [7, 20, 22–24]. The indentations are measured using a coronal view on imaging and drawing a horizontal line between the intramural parts of both Fallopian tubes. These strict absolute measurement criteria may not allow for the best classification of all size uteri. Utilizing the ESHRE/ESGE criteria, internal fundal indentations of >50 % of the uterine wall thickness are considered a Class U2 septate uterus, as long as the external cleft is <50 % of the largest wall thickness measured in the sagittal plane [20, 25]. There is no distinct arcuate uterus anomaly within the ESHRE/ESGE classification system.

The most important anomaly that needs to be differentiated from a septate uterus is a bicornuate uterus. Both the septate and the bicornuate uterus have a partitioned cavity. Subsequently, on hysteroscopy the appearance of both the septate and bicornuate uterus is similar. However, the external contour of these two uterine abnormalities is different, and a misdiagnosis can result in complications if a septum resection is performed hysteroscopically on a bicornuate uterus without realizing where the external surface is. The septate uterus has an external counter with a smooth appearance at the fundus, whereas the bicornuate uterus has an external counter with an indented appearance at the fundus that is often described as heart shaped [26]. Utilizing the ASRM classification system supplemented with distinct morphometric criteria (Table 7.1), the bicornuate uterus is Class IV with an internal indentation of ≥1.5 cm and an external cleft of ≥1 cm [7, 20, 22–24]. Without the morphometric criteria, the distinction between septate and bicornuate uteri was subjective.

It is also important to distinguish between a complete and a partial uterine septum. Resection of a complete uterine septum requires a slightly different surgical technique, which is described below. Patients can also have different variations of complete septate uteri that may include a double cervix and a longitudinal vaginal septum. When two distinct cervices are noted on pelvic examination, the most common diagnosis is uterus didelphys, but one must consider the less common anomaly of a complete uterine septum, double cervix, and longitudinal vaginal septum, first described in 1994. Both of these abnormalities would be treated differently with regard to reproductive outcomes [16]. In addition, it is important to distinguish between a true cervical duplication verses a complete uterine septum through the cervix [27]. If a longitudinal vaginal septum is present, it is commonly resected at the time of uterine septum resection and may even be resected earlier for the indication of dyspareunia or to allow effective tampon use. When a longitudinal vaginal septum is diagnosed in a patient during a basic gynecological well-woman exam, further imaging for any other Müllerian anomalies should be performed.

Diagnosis (Table 7.1)

The diagnosis of a uterine septum, like all uterine anomalies, can be made by utilizing different diagnostic modalities. Diagnostic modalities include both radiologic imaging and surgical procedures. Radiologic modalities include: two-dimensional (2D) and three-dimensional (3D) ultrasound (via transvaginal, transabdominal, or transperineal route), hysterosalpingography (HSG), sonohysterography (SIS), and MRI. According to

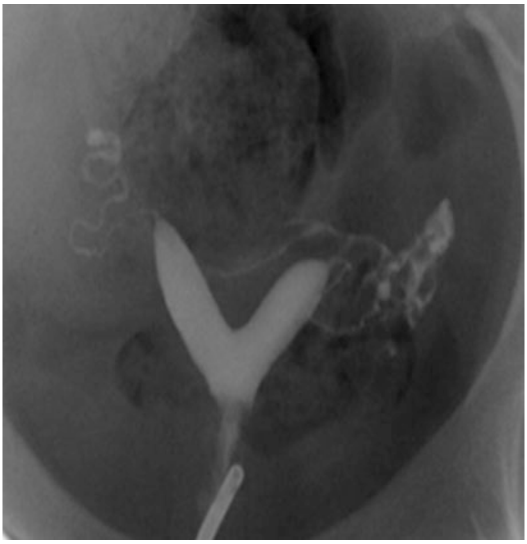

Fig. 7.5 HSG of partial septate uterus. The septum depicted here is wide. Note that HSG cannot differentiate between septate and bicornuate uterus (*Image provided by David E Reichman MD*)

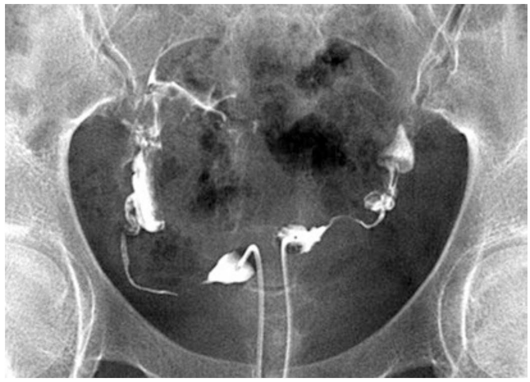

Fig. 7.6 HSG of complete septate uterus. Note the two separate cervical canals and the disparate uterine horns. HSG cannot reliably differentiate complete septate from didelphys uterus (*Image provided by Samantha M. Pfeifer MD*)

a recent systematic review by Chan et al. in 2011, diagnostic modalities may be grouped into optimal tests and suboptimal tests, according to their diagnostic accuracy [6]. Optimal tests include 3D transvaginal ultrasound, MRI, SIS, and laparoscopy or laparotomy plus hysteroscopy or hysterosalpingogram; while suboptimal tests include 2D ultrasound, hysteroscopy alone, HSG, and assessment during Cesarean section [6].

Surgery was historically the gold standard before more advanced imaging techniques were developed. Surgery, specifically simultaneous laparoscopy and hysteroscopy, can aid in the diagnosis of a uterine septum, and enables the provider to treat the uterine malformation at the same time. Hysteroscopy visualizes the intrauterine septum, and laparoscopy visualizes the external counter of the fundus, aiding in the differentiation between a septate and bicornuate uterus. The laparoscopy also enables assessment of the pelvis, including the ovaries and Fallopian tubes. The diagnostic accuracy for the two procedures is 100 % [5]. Surgery, however, is invasive and expensive. With the advent of more advanced imaging modalities, MRI has replaced surgery as the gold standard for the diagnosis of uterine anomalies, such as septums [28].

HSG can assess the uterine cavity and Fallopian tube patency (Figs. 7.5 and 7.6). It cannot, however, assess the external uterine contour and thus has limitations in differentiating between uterine anomalies. The intercornual angle can be determined from an HSG, which will help direct the diagnosis. The angle for a bicornuate uterus is said to be greater than 105° and the angle for a septate uterus is less than 75° [29]. Cases with an angle between 75 and 105° create a diagnostic dilemma, where further diagnostic tools are needed to determine a diagnosis. Unfortunately, accuracy has been cited as only 44 % for an HSG diagnosing different anomalies [29]. Valle and et al. similarly cites the diagnostic accuracy of HSG as 55 % in differentiating a bicornuate from a septate uterus [5]. In addition, a complete septum may be falsely diagnosed as a unicornuate uterus, if the catheter only enters on one side of the septum.

A 2D transvaginal ultrasound can be used as an initial screening test, with its reported sensitivity of up to 90–92 % for uterine anomalies [29]. The sensitivity for diagnosing a septum has been reported as high as 81 % [5]. The ultrasound is best performed during the secretory phase, as this will aid in visualization of the endometrium due to its hyperechoic appearance [30]. A diagnosis of bicornuate uterus is made when the internal indentation is ≥1.5 cm and external contour reveals a fundal cleft of ≥1 cm. Even more sensitive is a 3D ultrasound, which creates a rendering

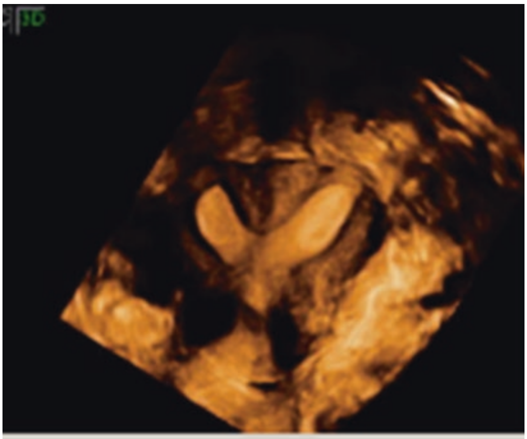

Fig. 7.7 3D US of septate uterus depicted on HSG in Fig. 7.5 (*Image provided by David E Reichman MD*)

image from the typical sagittal and transverse planes (Fig. 7.7). The rendering image provides evaluation of both the internal cavity and the external contour in the coronal plane, thus improving the diagnostic accuracy [29]. A 3D ultrasound can provide a diagnostic accuracy of 92 % for a septum and 100 % for a bicornuate uterus [5]. In addition to having high diagnostic accuracy, the 3D ultrasound is easy to perform, noninvasive, convenient for patients, and can be performed in an office setting [31].

An adjuvant to routine sonography is the SIS, which is best performed during the proliferative phase of the cycle when the endometrium is thin, and involves the introduction of fluid into the cavity to enhance internal delineation. An SIS can be done in either a 2D or a 3D modality [29]. A 3D SIS has improved accuracy and is superior to MRI or office hysteroscopy for classifying uterine anomalies [32]. It is important to note that SIS is a more invasive procedure than 2D or 3D sonography, and except in cases where the endometrial lining is thin, it is unclear if SIS offers any diagnostic advantage over 3D ultrasound [33].

MRI remains the current gold standard for the diagnosis of uterine anomalies for most, with a 100 % sensitivity and accuracy [29] (Fig. 7.8). For distinguishing a bicornuate uterus, MRI uses a greater than 1 cm fundal external cleft, similar to ultrasound morphometric criteria. MRI has advantages of also being able to simultaneously

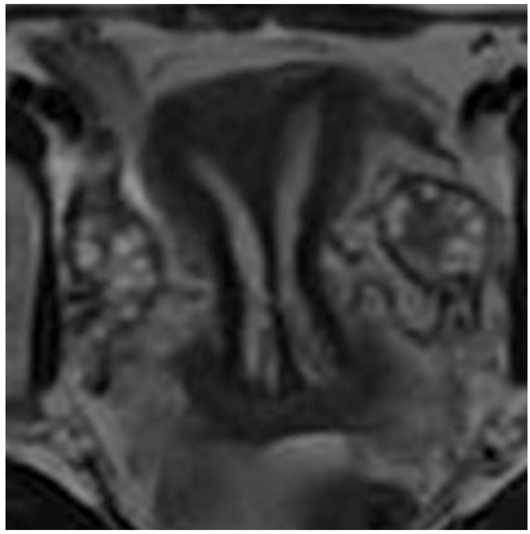

Fig. 7.8 MRI of complete septate uterus. Note the uterine fundus is convex and unified with two separate endometrial cavities. This is the same patient with HSG in Fig. 7.5 (*Image provided by Samantha M. Pfeifer MD*)

assess the renal system, which can be effected in many congenital uterine anomalies. While MRI provides an accurate diagnosis, the imaging test is expensive and can be difficult for claustrophobic patients. Berger and et al. concluded that a 3D ultrasound and a 3D SIS provide similar diagnostic accuracy compared to an MRI and do so at decreased cost [29]. Faivre et al. found 3D ultrasound to have improved diagnostic accuracy above MRI [32]. Therefore, 3D ultrasounds may replace MRI as the gold standard for diagnosing uterine anomalies, such as uterine septums [29].

Treatment

Indications

The indications for metroplasty of a septate uterus are controversial, as few have evidence of benefit. Metroplasty may be performed by the transabdominal or hysteroscopic route. However, with advances in the less invasive hysteroscopic techniques, the abdominal approaches have largely been abandoned. The most accepted indication for surgical correction is recurrent pregnancy loss, which usually occurs in the first trimester. Of note, pregnancy loss occurs in only 20–25 % of patients with a septate uterus [5]. Other indications have included infertility or subfertility; however, the strength of this indication is weaker given the fact that a septate uterus does not usually contribute to the etiology of infertility [5]. Observational studies have demonstrated improved spontaneous pregnancy rates after hysteroscopic metroplasty [34], and three observational studies found benefit for removing a uterine septum by hysteroscopic metroplasty in subfertile and infertile women with a uterine septum [35–37].

Patients undergoing assisted reproductive technology (ART) may also undergo resection of a uterine septum prior to their planned treatment. Few quality studies evaluating the benefit of this exist. A retrospective study evaluating pregnancy and live birth rates in women undergoing in vitro fertilization (IVF)/intracytoplasmic sperm injection (ICSI) found lower pregnancy rates, lower live birth rates, and higher miscarriage rates in women with complete septate or partial septate or arcuate uteri, as compared with normal uteri; these differences in reproductive outcomes disappeared after hysteroscopic septum resection [37]. In a historical cohort study of women undergoing IVF, reproductive outcomes were no different between women with normal uterine cavities and women treated with hysteroscopic metroplasty for either a complete uterine septum, incomplete uterine septum, or arcuate uterus [38]. These studies suggest that metroplasty prior to undergoing ART could be indicated in patients with a uterine septum, and that such treatment is not detrimental to reproductive outcomes.

Surgical Adjuvants

Regardless of indication, when surgery is planned, the best timing for the surgery is in the early follicular phase, as the endometrial lining will be thin and therefore aid in surgical visualization. Although combined oral contraceptives and progestins are commonly used preoperatively to thin the lining, Danazol and gonadotropin-releasing hormone (GnRH) agonists have also been used [5, 39].

Various hormonal treatments have been utilized postoperatively to promote endometrial healing and reduce scarring with no proven benefit, although there are no randomized controlled trials evaluating this and the published studies are small and usually retrospective [40]. Nonetheless, postoperative estrogen is often used to induce endometrial growth, followed by a progestin to induce a withdrawal bleed [5]. Of note, complete healing occurs within 8 weeks of hysteroscopic metroplasty [41].

The utilization of intrauterine anti-adhesion agents, stents, Foley catheters, and intrauterine devices (IUDs) were all originally utilized with the intent to prevent adhesion formation. However, although the published literature is relatively poor on this topic, none have been found to be superior to no treatment following hysteroscopic metroplasty and are not routinely used [5]. In addition, the incision of a uterine septum does not usually result in intrauterine adhesion formation, unlike hysteroscopic lysis of synechiae where adhesion reformation is common [5]. In 2010, Tonguc et al. performed a randomized, prospective trial on 100 women who had undergone hysteroscopic metroplasty and were randomized to one of four postoperative treatments: no treatment, daily estradiol + norgestrel (synthetic progestin), copper IUD, or daily estradiol + norgestrel + copper IUD [42]. There was no statistically significant difference in adhesion formation nor pregnancy rates amongst any of the post-surgery treatment regimens although the study was substantially underpowered [42]. One prospective randomized study in 16 patients undergoing hysteroscopic metroplasty evaluated the use of intrauterine auto-crosslinked hyaluronic acid gel administered immediately following incision compared to no therapy [43]. The incidence of postoperative adhesions assessed by hysteroscopy was lower in the gel group compared to controls (12.5 % vs. 37.5 %, respectively, $P<0.05$).

While prophylactic antibiotics are often used, there are no randomized trials examining the use of prophylactic antibiotics in the setting of hysteroscopic metroplasty, nor any randomized trials examining the use of prophylactic antibiotics to reduce infectious morbidity during transcervical intrauterine procedures, and their use is provider preference based [5, 44]. There is one randomized controlled trial looking at prophylactic antibiotics during hysteroscopic procedures, which found no benefit in terms of reducing bacteremia [45]. This taken together with the low risk of infection after metroplasty questions the utility of the use of prophylactic antibiotics to lower the risk of febrile morbidity during hysteroscopic metroplasty [40]. However, it is important to note that no study has looked at subsequent fertility as an outcome after prophylactic antibiotics, and the role of prophylactic antibiotics for this indication is unknown.

Abdominal Procedures

Historically, metroplasty was performed via an abdominal approach using the Jones method or the Tompkins method. Compared to the currently preferred hysteroscopic approach, the abdominal approach had more limitations, including need for laparotomy, greater estimated blood loss, longer hospital stay, prolonged recovery, mandatory cesarean section in succeeding pregnancies, and increased risk of abdominal-pelvic adhesions, which could affect future fertility [5, 39]. The Jones metroplasty involves a wedge resection, which removes a portion of the uterine fundus and the septum [46]. The two uterine halves are then approximated and closed in multiple layers. On the other hand, the Tompkins metroplasty does not remove a portion of the uterine fundus. An incision is made in the anterior–posterior plane, the septum is then removed from each uterine half, and the two halves approximated and closed starting at the base anteriorly and posteriorly [5, 46]. The modified Tompkins metroplasty involves just incising the septum rather than excising it once the uterus is opened as the septal tissue retracts in a similar fashion to the hysteroscopic procedures. To reduce bleeding, diluted vasopressin may be injected into the myometrium or a tourniquet applied around the uterine or uterine and infundibulopelvic vessels. These techniques have been largely replaced by the hysteroscopic techniques described below.

Hysteroscopic Procedures

The hysteroscopic, minimally invasive, approach has since replaced the abdominal approach. This approach offers patients outpatient surgery with shorter recovery time, decreased complication rates, and the possibility of a subsequent vaginal delivery [5, 39]. There are several different hysteroscopic instruments and tools that can be used for a septum resection. The most commonly used are hysteroscopic scissors and electrosurgical instruments, but other techniques include the use of lasers (argon and neodymium:yttrium-aluminum-garnet (Nd:YAG) lasers), vaporizing or bipolar electrodes, and mechanical morcellators [40]. Regardless of tool used, typically, the septum is incised to the level of the myometrium or until bleeding is noted within the tissue, representative of myometrium, and/or the surgeon is able to visualize both tubal ostia within the same panoramic view [40].

Different techniques offer various benefits, but only limited studies have examined superiority of different techniques with regard to reproductive outcomes. Hysteroscopic metroplasty utilizing scissors afforded more pregnancies than when utilizing the resectoscope, according to a study of 81 women by Cararach et al. [47]. Scissors have the disadvantage of being delicate and needing to be changed, adding to the cost, however their use requires minimal dilation and may be done in the outpatient setting. Fedele et al. found no difference between hysteroscopy done with the scissors, the argon laser, or the resectoscope, but this is contradicted by other studies [9].

The simplicity, speed, low cost, and low complication rate lead to electrosurgical procedures being commonly utilized, including the resectoscope [38]. Common electrosurgical instruments include the monopolar resectoscope and the bipolar Versapoint (Gynecare, Ethicon, Somerville, NJ). In a study comparing the resectoscope (knife electrode) and the Versapoint (twizzle-tip electrode) during hysteroscopic metroplasty on 160 women, Colacurci et al. found similar reproductive outcomes between the two groups, including pregnancy rates, abortion rates, gestational age at delivery, and method of delivery [48]. However, patients in the resectoscope group required greater cervical dilation (Hegar size 10 dilator to fit a 26F resectoscope verses often no dilation with the 5 mm Versapoint), had longer operative times (23.4 ± 5.6 vs. 15.7 ± 4.7 min), higher complication rates (total of 7 cases verses 1 case), and greater mean fluid absorption (486.4 ± 169.9 vs. 222.1 ± 104.9 mL) compared to the Versapoint group [48]. A second study by Litta et al. also compared the resectoscope and Versapoint for hysteroscopic metroplasty, with similar findings of equivalent reproductive outcomes but longer operating times and higher complication rates for the resectoscope group [49]. More recent studies found that utilizing the resectoscope with a 0° semicircular loop, as opposed to the 90° Collin's loop, is more manageable and faster [40].

Laser techniques have also been used for hysteroscopic metroplasty but are less widely used. The fiberoptic Nd:YAG laser offers the ability to perform surgery under local anesthesia in the office setting and with minimal cervical dilation to 6.5 mm, but its use is limited by its high cost [50, 51]. While the Nd:YAG laser offers as much as a 98 % success rate according to a study by Yang et al. on 46 patients, the argon laser was found to be less effective than the scissors in a study by Candiani et al. on 21 patients [50, 51].

Historically, the hysteroscopic metroplasty always required concurrent laparoscopy to avoid uterine perforation, and to distinguish between a septate and bicornuate uterus. Today, if the diagnosis of a uterine septum is not confirmed and there is still a possibility of a bicornuate uterus, a simultaneous laparoscopy can be performed with the hysteroscopy to help distinguish between the two diagnoses. A concurrent laparoscopy can also be helpful during a hysteroscopic metroplasty to monitor the depth of the resection in order to minimize the risk of uterine perforation. The hysteroscope light can also be visualized laparoscopically when the resection is closer to the outer myometrium and serosa [39]. Additionally, the laparoscopy can diagnosis any other pelvic pathology that could be contributing to the infertility etiology. However, simultaneous transabdominal ultrasound monitoring may be preferred to the laparoscopic observation in those in whom the diagnosis is known, and there is no indication for evaluation of the pelvis at the time of hysteroscopic metroplasty. Simultaneous ultrasound has the advantage of being less invasive than laparoscopic observation and provides better ability to gauge the septal division depth in relation to the outer contour of the uterus thereby reducing the risk of uterine perforation [5]. Bettocchi et al. have suggested that by adopting three criteria, a safe, outpatient hysteroscopic metroplasty can distinguish between a septate and bicornuate uterus, without laparoscopic or ultrasound guidance, in approximately 80 % of cases; these three criteria are the presence of vascularized tissue, sensitive innervation, and the appearance of tissue at the site of supposed septum incision [40, 52].

A partial uterine septum is the most common type of uterine septum. When a complete uterine septum or a complete uterine septum with duplicated cervix is present, a different hysteroscopic technique is required for treatment. Typically, a perforation is made in the complete septum, and then the septum is resected in a similar fashion to the partial septum, which was described above. There have been several different instruments described, such as a plastic dilator, Foley catheter, and metal dilator, that can aid the surgeon in finding a location to safely perform the primary septum perforation [53].

Complete septate uteri with cervical duplication also require special attention. Wang et al. performed hysteroscopic metroplasty on 25 women with complete septate uteri with cervical duplication, all who had concurrent laparoscopy and transabdominal ultrasound. A Hank dilator was inserted into one cervix and the 27F hysteroscopic resectoscope (with knife cutting or wire loop electrode) was inserted into the other cervix,

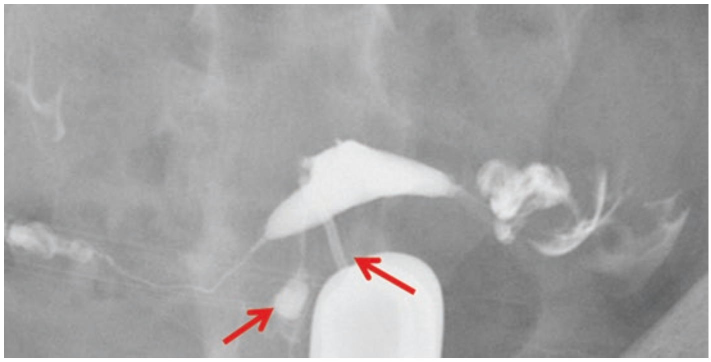

Fig. 7.9 HSG showing complete resection of a septum in complete septate uterus. *Arrows* point to the right and left cervical canals: the HSG cannula in the left cervical canal, the right cervical canal is filling retrograde from the common uterine cavity. Note the fundus of the endometrial cavity is unified and smooth *(Image provided by Samantha M. Pfeifer MD)*

with the Hank dilator serving as a visual marker when the perforation was made in the septum just above the internal os [54]. The Hank dilator also prevented leakage of the distension media through the second cervix [54]. There were no complications and 68.2 % of the cases had no residual septum [54]. Yang et al. compared dilator-guided and light-guided hysteroscopic resections of five complete uterine septums with cervical duplications, concluding that the light-guided instrument was superior in guiding location for the initial septum perforation [55]. Once the septum is resected, the uterine cavity should look normal, with the cervical duplication preserved. Following the procedure it is reasonable to confirm the septum has been satisfactorily resected using saline ultrasound, 3D US, HSG, or hysteroscopy (Fig. 7.9).

In the studies mentioned above, the portion of the septum creating the cervical duplication was preserved. This seems to be the consensus in the literature with the idea to protect the cervical integrity and avoid cervical incompetence in subsequent pregnancies [53–55]. In some situations, the complete uterine septum with duplicated cervix occurs in conjunction with a longitudinal vaginal septum. It is unclear whether this is considered a subset of the complete uterine septum classification or an anomaly that falls into a separate class. If this uncommon anomaly is diagnosed, resection of the vaginal septum can be performed at the same time as the hysteroscopy [53].

Complications

The abdominal metroplasty carries with it a longer operative time and a lengthier postoperative recovery period. Added complications of abdominal metroplasty include risks of bleeding with potential blood transfusion, infection with potential antibiotic therapy, postoperative adhesions that may cause infertility, intrauterine synechiae, full myometrial thickness scar rupture during subsequent pregnancy, and the need for cesarean section in subsequent pregnancy [5, 40].

The minimally invasive approach of a hysteroscopic metroplasty affords less morbidity, but complications can still occur with the minimally invasive route. The overall rate of intra- and post-operative complications is reported to be 1.7 %, according to a systematic review by Nouri et al. in 2010 [56]. These complications are similar to any surgical procedure, including bleeding, infection, and injury to surrounding structures. Intraoperative complications include endocervical or intracavitary injury, such as the creation of false paths, uterine perforation, uterine bleeding, fluid overload, allergic reactions to distending media (such as Dextran 70), and general anesthesia risks [40]. Patients undergoing a hysteroscopic procedure should be aware of the possible need for a laparoscopy or laparotomy if a uterine perforation occurs, in order to evaluate and repair any intra-abdominal injury, such as a bowel injury. As noted above, a conjoint laparoscopy or intraoperative ultrasound monitoring could help decrease the risk of uterine perforation. Volume overload can lead to electrolyte abnormalities and cerebral edema. The total allowable fluid deficit depends on the type of fluids used for the hysteroscopy, which is dependent upon whether monopolar or bipolar instruments are utilized, and an accurate fluid management system greatly aids in monitoring fluid deficits.

Uterine rupture is a rare, late complication of hysteroscopic metroplasty. In a 2005 retrospective literature review, Sentilhes et al. reported only 18 uterine ruptures during subsequent pregnancies following any operative hysteroscopy, and 16 of these had metroplasties [57, 58]. Of note, uterine perforation and/or the use of monopolar cautery increased the risk of subsequent uterine rupture [57, 58]. In a 2013 review and meta-analysis, Valle and Ekpo confirmed 18 reported cases of uterine rupture following hysteroscopic metroplasty [5]. Again of note, during each case of uterine rupture in the literature, there was a hysteroscopic surgical complication recorded, including uterine perforation, excessive septal excision, and excessive use of electrosurgical or laser energy [5].

The risk of intrauterine synechiae after hysteroscopic metroplasty appears to be low [5, 39]. Uterine septal width and surface area have been noted to be predictors of abnormal cavities postoperatively, but this finding is not uniformly noted [45]. Lastly, the need for reoperation after hysteroscopic metroplasty appears to be low, ranging from 0 to 23 %, and being 6 % in a pooled analysis from a systematic literature review [56].

Postoperative Uterine Cavity Evaluation

Postoperatively, the cavity typically is reexamined to evaluate for any residual septum, adhesions, or other anatomic abnormalities. This can be done with imaging or a diagnostic hysteroscopy. A prospective study by Fedele et al. in 1996 compared the reproductive outcomes in patients with a residual septum of between 0.5 and 1 cm to that of a group with no residual septum or a septum of <0.5 cm. There was no statistically significant difference in reproductive outcomes between the two groups, although the study was underpowered with only 17 patients in the residual septum of 0.5–1 cm arm and 51 patients in the group with no residual septum or septum of <0.5 cm [59].

Impact on Fertility and Reproduction

The presence of a uterine septum increases the risk of a miscarriage; however, many women with a septate uterus have uneventful reproductive function. Only about 20–25 % of patients with a septate uterus experience recurrent miscarriage, typically occurring in the late first and early second trimesters [5]. While the majority of women with septate uteri have successful pregnancies, the septate uterus is the anomaly most frequently associated with pregnancy wastage. Patients with uterine anomalies are at increased risk for obstetrical complications, including malpresentation, preterm labor and birth, premature rupture of membranes, cesarean section, low birth weight, retained placenta, and higher perinatal mortality rates [5, 60]. While a uterine factor can contribute to a patient's presentation of infertility, a uterine septum is not believed to cause infertility.

There have been numerous studies examining the reproductive outcomes in patients after metroplasty. Overall, the literature supports the conclusion that the spontaneous abortion rate is decreased in patients who have undergone surgical correction of a uterine septum [39, 60–62]. A meta-analysis by Venetis et al. in 2014 reported a decreased rate of spontaneous abortion in patients post-hysteroscopic metroplasty (RR 0.37, 95 % CI 0.25–0.55), but did not find any benefit in the likelihood of achieving a pregnancy [60]. A retrospective study from India in 2014 by Gundabattula et al. showed a statistically significant decreased miscarriage rate, increased term delivery rate, increased live birth rate, and increased take home baby rate in the post-resection pregnancies [61]. A retrospective study from Israel by Freud et al. in 2014 examined the reproductive outcomes before and after hysteroscopic metroplasty in 28 patients and showed improved reproductive outcomes in women who have a history of prior spontaneous miscarriage. After the septum resection, the authors noted lower rates of spontaneous miscarriage (12.5 % vs. 63.6 % $p<0.001$), increased mean gestational age at birth (38.47 ± 1.71 weeks vs. 33.73 ± 6.27, $p<0.05$), increased neonatal birth weights (3202.59 ± 630.21 g vs. 2520 ± 764.45, $p<0.05$), and lower risk of preterm delivery (OR = 0.073, 95 % CI 0.16–0.327, $p<0.01$) [62]. Homer et al. in 2000 found lower preterm delivery rates after hysteroscopic metroplasty (6 % vs. 9 %) [39]. While the majority of the studies support the utility of metroplasty in patients with recurrent miscarriages, there are no randomized controlled trials comparing hysteroscopic metroplasty to no intervention, thus limiting the data interpretation [63].

The literature is less clear on the value of metroplasty in treating infertility. While a uterine septum is not felt to cause infertility, metroplasty in women who have infertility appears to improve pregnancy rates. According to a systematic review by Nouri et al. in 2010, hysteroscopic metroplasty is an effective treatment for women with a septate uterus and a history of infertility, resulting in a 60 % pregnancy rate and 45 % live birth rate [56]. A retrospective study by Tehraninejad et al. in 2013 analyzed 203 patients, the majority being infertility patients, who underwent a septum resection. The spontaneous miscarriage rate decreased from 20.2 to 4.9 % after metroplasty ($p<0.0001$), and the rate of term delivery increased from 2.5 to 33.5 % ($p<0.0001$) [64]. A retrospective matched-control study by Tomaževič et al. in 2010 examined women before and after septum resection that were also undergoing ART treatments, with both IVF and ICSI cycles. The rates of pregnancy, live birth, and spontaneous abortion were all improved after metroplasty [37]. These studies suggest that infertility may be another indication for septum resection, besides a history of recurrent pregnancy losses, especially in those women who are planning to proceed with ART.

Conclusions

The septate uterus is the most common of all the uterine anomalies. It is associated with recurrent miscarriage and adverse pregnancy outcomes, including preterm delivery. The role of the septate uterus in infertility is controversial. The best modalities for diagnosing a septate uterus include a 3D ultrasound, with or without saline infusion, and an MRI. Hysteroscopic metroplasty improves reproductive outcomes in women with recurrent miscarriage, and is a simple, well-tolerated procedure with a low complication rate.

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