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GENERAL GYNECOLOGY

Analysis of the reproductive outcomes and the size of the unicornuate uterus measured by magnetic resonance imaging and their relationship

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Abstract

Purpose To evaluate the relationship between the uterine size measured by pelvic magnetic resonance and reproductive outcome in women with a unicornuate uterus.

Methods This was a retrospective study including 140 patients affiliated with unicornuate uterus diagnosed by the pelvic MR prior to their first pregnancy in the Obstetrics and Gynecology Hospital of Fudan University from April 2010 to December 2017. All the length of the unicornuate uterus were re-measured and recorded by skilled radiologists during the study period. We divided all the 140 participants with complete pelvic MR imaging into four groups by the best reproductive outcomes, which refers to Group 1 (primary infertility, $n=21$), Group 2 (<24 weeks' gestation, $n=34$), Group 3 (preterm delivery, 24–35 weeks' gestation, $n=13$), Group 4 (≥ 35 weeks' gestation, $n=72$), followed them up and then analyzed the data.

Results Measurements of 140 patients with hemi-uteri were retrieved for analysis. The mean length of the uterine was 4.90 $\pm$ 0.56 cm. There were no significant differences in the uterine cavity length, cervical length, endometrial thickness and uterine wall thickness between the four groups while the uterine length ($P=0.001$) was statistically significant. Women with uterine lengths $\geq$ 4.5 cm were more likely to experience full-term delivery compared with the other group ($P=0.001$). Ordinal multiple logistic regression analysis showed that the uterine length [OR = 9.03 (95% CI: 2.90–28.13)] and uterine cavity length [OR = 0.32 (95% CI: 0.06–2.04)] were independent protective factors for better obstetric outcomes

Conclusion The uterine length is a reliable prognostic factor for the gestational week of delivery and an appropriate antenatal surveillance factor of women with unicornuate uterus.

Keywords Unicornuate uterus · Hemi-uterus · Reproductive outcome · Obstetric outcomes · Uterine size · Uterine length

Introduction

Congenital malformation of female genital tract results from formation, fusion, and absorption disorders of the bilateral Müllerian or paramesonephric ducts [1], the prevalence of which is reported to be 0.1–3.8% in the general population and 3.5–6.3% in infertile women. Unicornuate uterus accounts for 5–20% of congenital uterine anomalies [2, 3]. It is quite difficult to calculate or estimate the incidence of a unicornuate uterus since many women are clinical silent. The unicornuate uterus is classified as a type II of the system of American Fertility Society (AFS) [4] or U4 according to the European Society of Human Reproduction and Embryology/ European Society for Gynaecological Endoscopy (ESHRE/ESGE) [5] classification system of female genital tract malformation. According to the ESHRE/ESGE classification system [5], Class U4 or hemi-uterus incorporates all

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cases of the unilateral formed uterus. Hemi-uterus is defined as the unilateral uterine development while the contralateral part could be either incompletely formed or absent [5] the hemi-uterus was further divided into two sub-classes: hemi-uterus with a communicating or non–communicating (functional) rudimentary cavity (U4aC0V0); hemi-uterus without a rudimentary cavity (U4bC0V0) [5].

For those women afflicted with hemi-uterus, the congenital uterus malformation may show extreme impact on fertility, obstetrical outcomes, and gynaecologic health, and even serve as a point of great anxiety and affecting sexual functioning. Several studies have reported that patients afflicted with a unicornuate uterus have increased the incidence of gynecologic symptoms like infertility, endometriosis, and chronic pelvic pain and obstetric complications such as spontaneous miscarriage, preterm delivery, and breech presentation [6–9]. What's more, the reproductive performance of the unicornuate and didelphys uteri was pretty poor, while that of the septate and bicornuate uteri was much better than expected and the arcuate uterus had no impact on reproduction [10].

To date, studies have shown the influence of the uterine length or uterine cavity length on the implantation and clinical pregnancy rates in IVF [11–13]. Chun et al. [14] reported that the implantation rates and the clinical pregnancy rates were significantly higher in the patients with increased depth of the uterine cavity. Hawkins et al. [12] showed that women at extremes of pre-cycle uterine length (cervical canal included) (<7.0 or >9.0 cm) were less likely to achieve live birth and women with uterine lengths <6.0 cm were also more likely to experience spontaneous abortion in IVF patients.

However, to date, the influence of the size and length of unicornuate uteri on the adverse pregnancy outcomes has not been explored.

So the aim of this study was to evaluate the relationship between the uterine size measured by pelvic magnetic resonance imaging and reproductive outcome in women with hemi-uterus.

Material and methods

Study design and population

In this retrospective case series study, we searched our MRI clinic database from April 2010 to December 2017 to identify all patients who had been diagnosed with unicornuate uterus with magnetic resonance imaging (MRI) in the Obstetrics and Gynecology Hospital of Fudan University, regardless of their indications for the visit. All the patients with a unicornuate uterus were included. The diagnosis of hemi-uterus was based on ESHRE/ ESGE classification system published in 2013 [5, 15], and hemi-uterus was defined as the unilateral uterine development; the contralateral part could be either incompletely formed or absent [5].

The selection criteria were that women who were (1) diagnosed by pelvic MR prior to their first pregnancy (2) at least 18 years of age (3) planning to become pregnant at least 12 months of unprotected intercourse (4) with singleton pregnancies and (5) willing to comply with schedule for visits. The exclusion criteria were: (1) without requirement of reproduction or asexual (2) multiple pregnancies/gestation (3) patients with incomplete follow-up data or lack of pelvic MR images (4) pelvic MR or sonographic findings with presence of associated extragenital tract anomalies (5) history of severe cardiac, respiratory, renal, hepatic or adrenal disease (6) history-indicated cerclage (7) uterine fibroids distorting uterine cavity or adenomyosis diagnosed by trans-vaginal sonography or MR (8) endometrial lesions (polyps, endometrial hyperplasia, and intrauterine adhesions). Finally, 167 patients diagnosed with unicornuate uteri were involved in our study, among which 140 patients had complete pelvic MR images.

Maternal characteristics

Maternal demographic, menstrual patterns, pregnancy history, medical history and delivery data from previous pregnancies were collected by interviewer-administered questionnaire at the recruitment visit, including details about pregnancy complications, delivery indications, and neonatal outcomes. After initial inspection of our data, we divided all the 140 participants with complete pelvic MR imaging into four groups by the best reproductive outcomes (the gestation week of delivery),Group 1 (primary infertility, $n=21$), Group 2 (<24 weeks' gestation, $n=34$), Group 3 (preterm delivery, 24–35 weeks' gestation, $n=13$), Group 4 (≥ 35 weeks' gestation, $n=72$), followed them up and then analyzed the data. Preterm birth was defined as that occurring after 24 weeks and before 37 completed weeks of gestation, as births before 23 weeks are unlikely to survive and hence clinically very different from those delivered after 23 weeks. Birth after 35 weeks of gestation are more likely to survive, so we combined preterm deliveries after 35 weeks and term pregnancy together as a group.

Uterine size measurement

Data of the pelvic MR images were obtained from hospital MR imaging clinic database. Pelvic MR was performed in the secretory phase (days 24–28) of the menstrual cycle. In addition, all the length measurements were re-measured and recorded by experienced radiologists using standard technique according to the standard procedure at our hospital during the study period and the diagnosis of

hemi-uterus was based on ESHRE/ ESGE classification published in 2013 [5]. The uterine length was defined as the distance from the internal cervical os to the uterine fundus. We defined the uterine wall thickness as a mean value of the anterior and posterior uterine wall thickness on a longitudinal section [15]. Uterine cavity length was the length between the fundal part of the uterine cavity and the internal cervical os. The uterine volume was measured using a geometric formula for prolate ellipsoid volume (g) = length × width × depth × 0.52 [16].

Clinical outcome measurement

In this study, we define infertility as being infertile after unsuccessfully attempting to achieve pregnancy for 1 year. Infertility is termed primary when it occurs without any prior pregnancy and secondary when it follows a previous conception. Preterm birth was defined as that occurring after 24 weeks and before 37 completed weeks of gestation, as births before 23 weeks are unlikely to survive and hence clinically very different from those delivered after 23 weeks. Live birth was defined as the delivery of a baby after at least 24 weeks' gestational age. The term malpresentation encompasses any fetal presentation other than vertex, including brow, breech, shoulder, face, and compound presentations. Intrauterine growth restriction (IUGR) by definition occurs when the birth weight (g) of a newborn infant is below the tenth percentile for a given gestational age. Intrauterine fetal demise (IUFD) is fetal death after 20 weeks' gestation but before the onset of labor.

Statistical analysis

All statistical analyses were performed using SPSS version 25.0 (IBM, Armonk, NY, USA). Continuous variables were presented as mean values ± standard deviation (mean ± SD), while categorical variables were expressed as numbers (percentages). One-way ANOVA and Chi-square test were performed to compare the pregnancy outcomes among the four groups, Fisher exact test was used when appropriate. One-way ANOVA was used for analyses of continuous variables while Chi-square tests and Exact Fisher test were used for ordinal categorical variables. A P value of < 0.05 was considered statistically significant. Ordinal multivariate logistic regression models were performed to assess the risk factors for adverse reproductive outcomes in women with unicornuate uterus and estimate the odds ratios (ORs) and 95% confidence intervals for expects (CIs) adjusting for confounding variables.

Ethical approval

Before our study initiation, approval by the Ethics Committee of the Obstetrics and Gynecology Hospital of Fudan University was obtained.

Results

After exclusions, 167 eligible participants with a unicornuate uterus were enrolled in our study and recruitment and follow-up flow chart was shown in Fig. 1. Among them, 140 participants with complete MR image were included.

The demographic maternal characteristics of the 167 patients are presented in Table 1. More than three-quarters of the patients were diagnosed as U4bC0V0 (87.4%, 146/167). None of the enrolled patients with hemi-uteri had any evidence of cervical or vaginal anomalies. In this study, we found that 14 patients (8.3%) had associated contralateral renal agenesis contralateral to the unicornuate uterus, including ectopic, horseshoe kidney and double renal pelvis. The maternal age of the patients is 32.26 ± 4.15 years old. Eleven patients (6.6%) had undergone rudimentary horn excision among which two patients had emergency laparotomy resection because of pregnancy in the rudimentary horn with the functional cavity. Furthermore, nearly 58 patients (34.8%) had undergone the assistant reproductive technology (ART), among which 10.8% of patients had previous ART attempts more than once.

Reproductive outcomes are summarized in Table 2. Nine patients (5.3%) had IUFD and 98 patients (58.7%) had live birth, among which abnormal fetal position at delivery occurred in 37 patients. Approximately 13.2% of the participants suffered from primary infertility, and the main cause of infertility was tubal factor (42.5%). Ectopic pregnancy occurred in 22 patients (13.2%), among which two pregnancies in rudimentary horn were included. Preterm delivery, premature rupture of membrane, preterm premature rupture of membrane, IUGR, and cesarean section delivery rates were 13.2%, 9.6%, 5.3%, 6.0%, 42.5%, respectively. Cervical incompetence was diagnosed in two pregnant women (1.2%). Among 98 patients who had live birth, 24 patients (24.5%) were pregnancy after successful ART.

The distribution of the uterine length (A), uterine cavity length (B), uterine wall thickness (C), uterine volume (D) measured by pelvic MR in 140 patients with hemi-uterus is shown in Fig. 2. The mean length of the uterine of the whole patients was 4.90 ± 0.56 cm and the mean length of the uterine cavity was 3.77 ± 0.61cm (Table 3). There were no significant differences in the uterine cavity length, cervical length, endometrial thickness and uterine wall thickness between the four groups while the uterine length ($P = 0.001$) was statistically significant (Table 4).

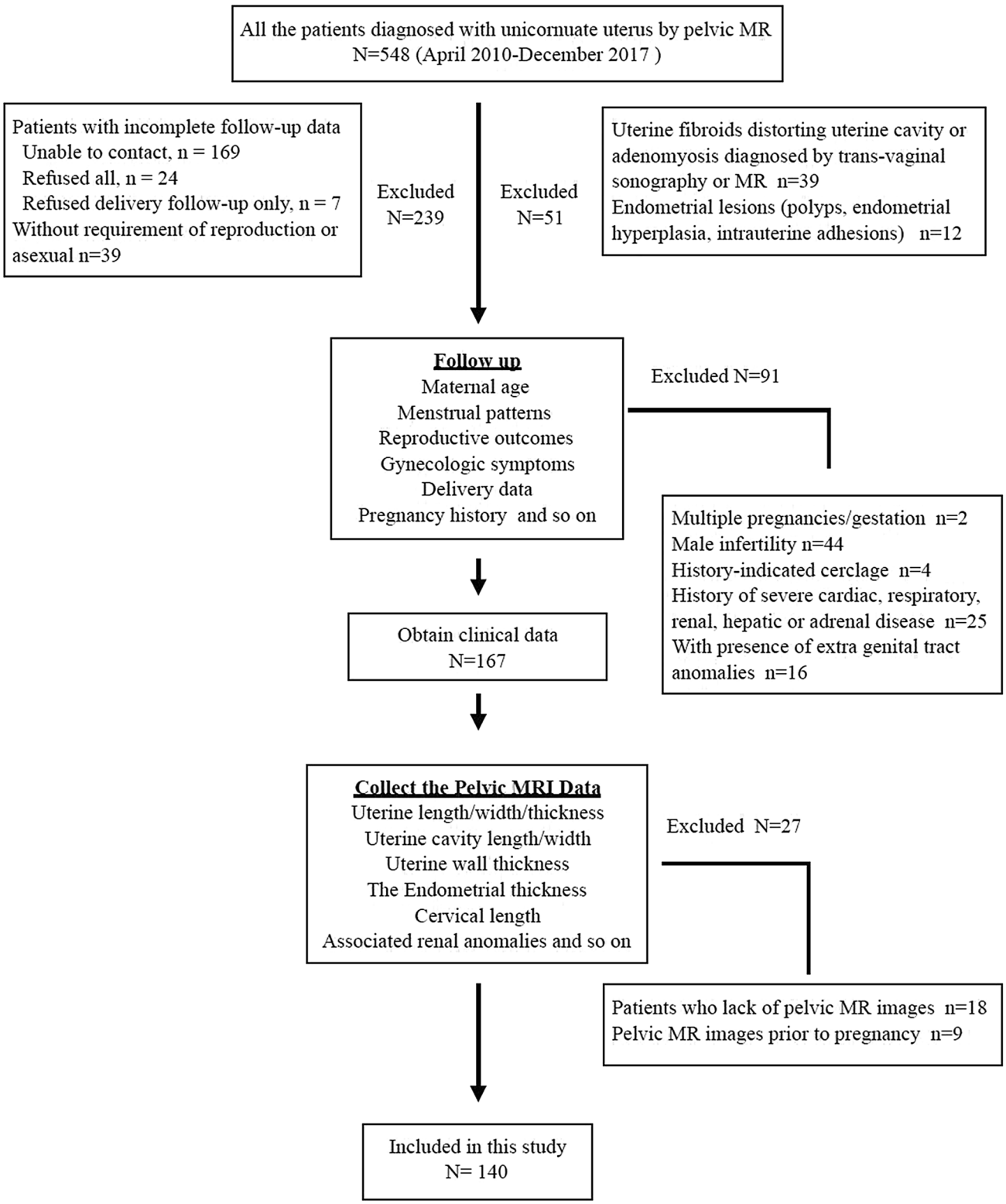

Fig. 1 Recruitment and follow-up flow chart

Table 1 Demographic maternal characteristics of 167 women with congenital unicornuate uteri

Parameters	Mean ± SD (range or percentage)
Maternal age, (years)	32.26 ± 4.15
Subtypes of hemi-uterus	
U4aC0V0, *n* (%)	21 (12.6%)
U4bC0V0, *n* (%)	146 (87.4%)
Removal of rudimentary horn with or without salpingectomy, *n* (%)	11 (6.6%)
Associated renal anomalies, *n* (%)	14 (8.3%)
Ectopic or absent ovarian tissue, *n* (%)	13 (7.8%)
Endometriosis, *n* (%)	26 (15.6%)
Severe dysmenorrhea, *n* (%)	44 (26.3%)
Spontaneous abortions ≥ 2, *n* (%)	22 (13.2%)
Previous IVF attempts	
1, *n* (%)	40 (24.0%)
≥ 2, *n* (%)	18 (10.8%)

SD standard deviation

The women were divided into two groups according to the length of the uterine length: < 4.5 cm and ≥ 4.5 cm. The majority (113/140, 80.7%) of patients had uterine lengths ≥ 4.5 cm, while less than a fifth (27/140, 19.3%) had uterine lengths < 4.5 cm. We compared reproductive outcomes across the two groups, and the results are listed in Table 5. Women with uterine lengths ≥ 4.5 cm were more likely to experience full-term delivery compared with the other group. However, no significance was observed in the comparison of reproductive outcomes between uterine cavity length < 3.9 cm and ≥ 3.9 cm ($P = 0.051$) (Table 6).

Ordinal multiple logistic regression analysis showed that the uterine length ($P = 0.00$) and uterine cavity length ($P = 0.01$) were independent protective factors for better obstetrics outcomes (Table 7). The odds ratios for uterine length and uterine cavity length were 9.03 (95% confidence interval: 2.90–28.13) and 0.32 (95% confidence interval: 0.06–2.04), respectively (Table 7).

Discussion

Our study demonstrates that the mean length of the uterine was 4.90 ± 0.56 cm, and that women with longer uterine lengths (≥ 4.5 cm) were more likely to achieve full-term delivery. The uterine length and uterine cavity length were independent protective factors for better obstetric outcomes.

Table 2 Reproductive outcomes of 167 women with congenital unicornuate uterus

Obstetrics outcomes	Mean ± SD (range or percentage)
Primary infertility, *n* (%)	22 (13.2%)
Secondary infertility, *n* (%)	46 (27.5%)
Ectopic pregnancy	
Rudimentary horn pregnancy (RHP), *n* (%)	2 (1.2%)
Tubal pregnancy, *n* (%)	20 (12.0%)
Live birth, *n*	98 (58.7%))
Intrauterine fetal demise(IUFD), *n* (%)	9 (5.3%)
Intrauterine growth restriction(IUGR), *n* (%)	10 (6.0%)
Mode of pregnancy	
Assistant productive technology, *n* (%)	26 (15.6%)
Natural pregnancy, *n* (%)	72 (43.1%)
Cesarean delivery, *n* (%)	71 (42.5%)
Cervical incompetence	2 (1.2%)
Malpresentation at delivery, *n* (%)	37 (22.2%)
Preterm birth, *n* (%)	22 (13.2%)
Pregnancy complications	
Preterm premature rupture of membrane (PPROM), *n* (%)	9 (5.3%)
Premature rupture of membrane (PROM), *n* (%)	12 (9.6%)
Cord entanglement, *n* (%)	25 (14.9%)
Asphyxia neonatorum	1 (0.6%)
Gestational diabetes mellitus	11 (6.6%)
Hypertension in pregnancy	6 (3.6%)
Placenta previa	1 (0.6%)

SD standard deviation

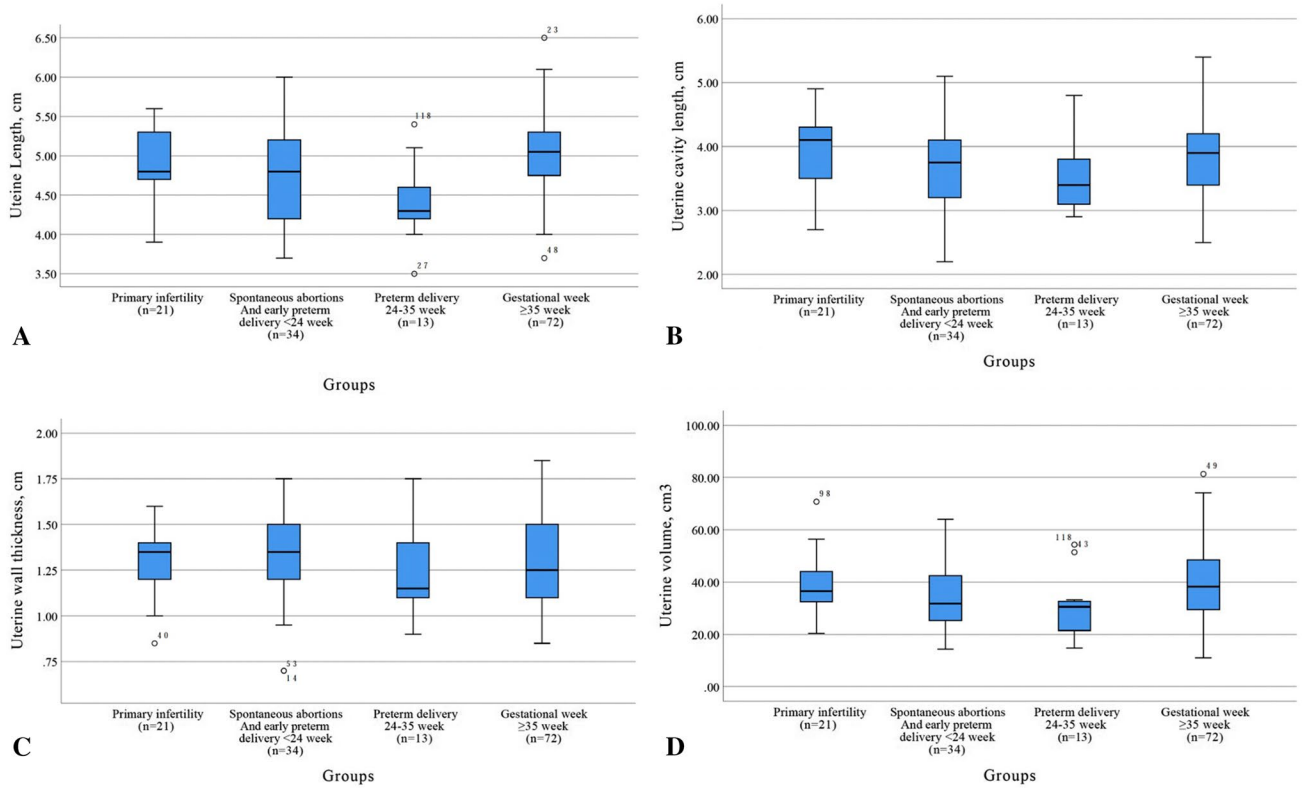

Fig. 2 The distribution of the uterine length (**a**), uterine cavity length (**b**), uterine wall thickness (**c**), uterine volume (**d**) measured by pelvic MR in 140 patients with hemi-uterus

Table 3 Descriptive statistics of the size of the uterine measured by pelvic MR in 140 patients

Variable	Mean ± SD or interquartile range (IQR)
Uterine length, (cm)	4.90 ± 0.56
Uterine width, (cm)	3.94 ± 0.64
Uterine thickness, (cm)	3.62 ± 0.53
Uterine cavity length, (cm)	3.77 ± 0.61
Uterine cavity width, (cm)	1.29 ± 0.40
Uterine wall thickness, (cm)	1.30 ± 0.25
Cervical length, (cm)	3.10 ± 0.55
Endometrial thickness, (cm)	1.00 ± 0.35
Uterine volume, (cm^3)	(27.14, 46.36)[#]
Uterine cavity volume, (cm^3)	(1.37, 3.88)[#]

SD standard deviation

[#]*IQR* interquartile range

It was reported that the prevalence of cervical os insufficiency was significantly higher in women with a uterine malformation than in the control group, that women with uterine anomalies have an increased risk to develop pregnancy complications that arise from cervical dysfunction [17] and that uterine anomalies have a strong association with cervical insufficiency according to multivariate analysis [17]. However, in our research, the proportion of the cervical incompetence was quite low (2/167, 1.2%), and the cervical length was long (3.10 ± 0.55 cm on average) in patients with the unicornuate uterus, and the difference for the length of the cervix was not statistically significant between the four groups. This may suggest that the cervical incompetence is not the main reason for abortion and preterm labor in patients with unicornuate uterus.

Various studies reported that a unicornuate uterus was associated with a rudimentary horn in 70–90% of cases [18, 19], 6.6% patients of which underwent removal of a rudimentary horn and showed no uterine rupture before or after labor [2]. In our study, there were 139 (86.6%) patients affiliated with rudimentary corn, including 21 (12.6%) patients with functional cavity. Above all, 11 patients (6.6%) had undergone rudimentary horn excision, among which two patients had emergency laparotomy resection because of pregnancy in the rudimentary horn with functional cavity. We found that a patient who underwent resection of a rudimentary horn did not present a high risk for uterine rupture.

Urinary tract-malformations are usually associated with unicornuate uteri [20, 21]. We found that 14 patients (8.3%)

Table 4 Comparison of uterine size measured by pelvic MR between four groups ($n=140$) (mean ± SD, cm/cm^3)

Variable	Primary infertility ($n=21$)	Spontaneous abortions and early preterm delivery < 24 week ($n=34$)	Preterm delivery 24–35 week ($n=13$)	Gestational week ≥ 35 week ($n=72$)	*P* value
Uterine length, (cm)	4.85 ± 0.48	4.78 ± 0.64	4.44 ± 0.50	5.05 ± 0.51	0.001*
Uterine width, (cm)	4.04 (0.52)	3.84 (0.71)	3.72 (0.51)	3.99 (0.66)	0.362
Uterine thickness, (cm)	3.65 ± 0.47	3.52 ± 0.56	3.37 ± 0.62	3,70 ± 0.51	0.138
Uterine cavity length, (cm)	3.95 ± 0.54	3.65 ± 0.72	3.52 ± 0.52	3.82 ± 0.56	0.111
Uterine cavity width, (cm)	1.38 ± 0.28	1.20 ± 0.44	1.25 ± 0.42	1.32 ± 0.39	0.382
Uterine wall thickness, (cm)	1.33 ± 0.21	1.33 ± 0.26	1.28 ± 0.26	1.29 ± 0.26	0.818
Cervical length, (cm)	3.09 ± 0.56	3.02 ± 0.53	3.14 ± 0.76	3.13 ± 0.52	0.803
Endometrial thickness, (cm)	1.07 ± 0.25	0.89 ± 0.36	0.89 ± 0.31	1.05 ± 0.36	0.065
Uterine volume, (cm^3)	38.24 ± 12.35	35.39 ± 14.78	30.15 ± 11.94	40.23 ± 14.76	0.081#
Uterine cavity volume, (cm^3)	3.18 ± 1.54	2.40 ± 1.97	2.31 ± 1.66	3.05 ± 1.98	0.224#

Data are presented as mean ± standard deviation unless otherwise specified

SD standard deviation

*$P < 0.05$

#Kruskal–Wallis test

Table 5 Comparison of uterine lengths ≥ 4.5 cm and uterine lengths < 4.5 cm across four groups

Variable	Primary infertility	Spontaneous abortions and early preterm delivery < 24 week	Preterm delivery 24–35 week	Gestational week ≥ 35 week	Total	*P* value
Uterine length < 4.5cm, *n* (%)	4 (2.90%)	9 (6.40%)	7 (5.00%)	7 (5.00%)	27 (19.30%)	
Uterine length ≥ 4.5cm, *n* (%)	17 (12.10%)	25 (17.90%)	6 (4.30%)	65 (46.40%)	113 (80.70%)	0.002*[a]
Total	21	34	13	72	140	

*$P < 0.05$

[a]Fisher's exact test

Table 6 Comparison of uterine cavity lengths ≥ 3.9 cm and uterine lengths < 3.9 cm across four groups

Variable	Primary infertility	Spontaneous abortions and early preterm delivery < 24 week	Preterm delivery 24–35 week	Gestational week ≥ 35 week	Total	*P* value
Uterine cavity length < 3.9 cm	6 (4.30%)	18 (12.90%)	10 (7.10%)	35 (25.00%)	69 (49.30%)	
Uterine cavity length ≥ 3.9 cm	15 (10.70%)	16 (11.40%)	3 (2.10%)	37 (26.40%)	71 (50.70%)	0.051[a]
Total	21	34	13	72	140	

*$P < 0.05$

[a]Fisher's exact test

had associated renal agenesis contralateral to the unicornuate uterus. In the literature, congenital renal agenesis was reported in the literature ranging from 16 to 38% in women with unicornuate uterus [22, 8], which was a little higher than that in our study.

Rarely, patients have absent gonads on the contralateral side of hemi-uterus [8]. In our study, we found ectopic or absent ovarian tissue in 13 patients (7.8%). Thus we should keep the possibility of ectopic ovarian in mind and an

Table 7 Ordinal multiple logistic regression analysis of factors related to reproductive outcomes among four groups

Group	OR	Sig.	95% Confidence interval	
			Lower bound	Upper bound
Uterine length	9.03	0.00*	2.90	28.13
Uterine cavity length	0.32	0.01*	0.13	0.77
Uterine wall thickness	0.28	0.12	0.06	1.39
Uterine width	0.73	0.47	0.31	1.73
Uterine cavity width	0.76	0.58	0.28	2.04

*$P < 0.05$

evaluation of the renal system is required when a unicornuate uterus is identified.

Several studies previously demonstrated the association between the unicornuate uterus and adverse obstetric outcomes and found that women with unicornuate uteri had an increased risk of miscarriage, preterm birth, and fetal malpresentation [23, 18, 24, 8, 25]. Our results were generally consistent with those of previous studies. First, with the help of IVF, patients with unicornuate uterus have a good chance to conceive. There were 26 patients who became pregnant successfully via IVF. In our study, the live birth, preterm delivery, ectopic pregnancy, and IUGR rates were 58.7%, 13.2%, 13.2%, and 6.0%, respectively. David and the co-workers had done a review examining 290 women with unicornuate uterus, and their results were similar to ours and they revealed that the rate of live birth, preterm delivery, ectopic pregnancy, IUFD was 49.9%, 20.1%, 2.7%, and 10.5%, respectively [8]. While Munire et al. reported that the poor reproductive outcomes among 55 women with unicornuate uterus and showed that the rate of the live birth, prematurity, ectopic pregnancy, miscarriage, was 29.2%, 44%, 4%, and 29%, respectively [26]. We believe that the high prevalence of the preterm delivery results from the limited capacity or the volume of the hemi-uterus and the restricted expansion of an abnormal endometrial cavity. We found that the frequency of cesarean delivery substantially increased (71/98, 72.4%) compared with other studies [2]. This was perhaps due to the high rate of fetal malpresentation (37/98, 37.8%), excessive worry of the parents and the high cesarean rate in China.

Previous studies had accessed the impact of the uterine size or uterine cavity length of the normal uterus on the IVF outcomes. Egbase and his colleagues conducted a prospective study comparing rates of implantation, clinical pregnancy, and ectopic pregnancy by pre-IVF uterine length among 807 women with an apparently normal uterus and showed that the highest implantation and clinical pregnancy rates were seen in women with a uterine cavity length of 7–9 cm, but the differences were not statistically significant [11]. While Sang et al. reported that patients who had a normal (7–8 cm) or longer uterine cavity length (> 8 cm) had a higher clinical pregnancy rate in the IVF-ICSI compared with the IVF-ICSI patients with a short uterine cavity length (< 7 cm) ($P < 0.005$) [14]. Hawkins et al. [12] performed a retrospective cohort study of all cycles performed after uterine length measurement (normal uterus) and found that women with uterine lengths < 6.0 cm were half as likely to achieve live birth [RR: 0.53; 95% confidence interval (CI): 0.35–0.81] and women with lengths of 6.0–6.9 cm were also less likely (RR: 0.91; CI: 0.85–0.98). In the literature, median uterine length, including the cervical canal, is 7.00 cm (7.00–7.75) and the majority (55.5%) of participants had a uterine length between 7.00 and 7.99 cm, while about a fourth (23.3%) had uterine lengths < 7.00 cm [12]. Based on our results, the size of unicornuate uterus is much smaller than the normal uterus, more than 60% of which was between 4.5 and 5.5 cm and the mean length of the hemi-uterus was 4.91 ± 0.55 cm. In addition, the authors mentioned above used different definition of the uterine size from us, both of which defined the uterine length as the distance from the external cervical os to the uterine fundus (uterine corpus length + uterine cervix length), while in our study we defined the uterine length as the distance from the internal cervical os to the uterine fundus (uterine corpus length only) and the uterine cavity length was the length between the fundal part of uterine cavity and the internal cervical os.

Though the earlier study has suggested that there was no difference in the length of uterine before or after term pregnancy in IVF population and increasing parity was unassociated with greater uterine length [27], our study still included only the patients who had their MRI examination before their first pregnancy, to rule out the potential bias. Accumulating studies have suggested that the challenges faced by patients with hemi-uterus lie in pregnancy maintenance rather than conception or impaired fertility ability. Pregnancy in a woman with hemi-uterus should be regarded as a high-risk expectant mother. It is uncertain whether interventions before conception or during pregnancy such as prophylactic cervical cerclage, prophylactic removal of the rudimentary horn and metroplasty of hemi-uterus and rudimentary horn with functional cavity decidedly improve reproductive outcomes. It is highly indicated that intensive monitoring of such pregnancy and delivery, as well as a package of preventive measures to avoid possible complications or other interventions, is needed. The findings in this study show that the uterine length of the unicornuate uterus is the independent risk factor of the poorer reproductive outcomes. The result implied that shorter uterine length did great harm to the reproductive outcomes. The reasons might be that the diminished uterine musculature, abnormal uterine blood flow and restricted expansion of an abnormal endometrial cavity [28]. Up to date, the influence

of the size and length of unicornuate uteri on the adverse pregnancy outcomes has not been explored before, and this is the first study that reported the relationship between the uterine length and the reproductive outcomes in patients with unicornuate uterus.

The main limitation of our study is that it was a retrospective study with a relatively small sample size and a larger sample size of prospective investigations are warranted in the future. The other potential weakness was the patient selection and confounding biases. All the patients who were enrolled in our study visited our hospital for some indications, such as infertility, pelvic pain, preterm delivery history, and so on.

There were no cases of the ruptured uterine in the enrolled patients with MR images. In the present study, the uterine rupture in hemi-uterus was not observed in the patients, possibly, due to the fact that there was a high percentage of preterm births or perhaps the number of cases was too small to access the risk of rudimentary horns or hemi-uterus rupture [2, 19]. However, there were several cases of uterine pre-ruptures in patients with unicornuate uterus during the past 10 years in our hospital.

In the clinical practice, we should keep the possibility of uterine rupture in mind, pay more attention to the early signs and make early diagnosis of pre-rupture of the unicornuate uterus or the rudimentary horns [18], and further studies are required to carry on to evaluate the incidence of the rupture of the hemi-uterus or the rudimentary horn, and the relationship between the uterine size or uterine wall thickness and the risk of uterine rupture.

In conclusion, our study demonstrates that women with longer uterine lengths (≥ 4.5 cm) were more likely to achieve full-term delivery, and that the uterine length and uterine cavity length were independent protective factors for better obstetrics outcomes, which implies that uterine length is a reliable prognostic factor for the gestational week of delivery and is an appropriate antenatal surveillance factor of woman with unicornuate uterus.

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Compliance with ethical standards

Conflict of interest All the authors declare that they have no competing interests.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. This study was approved by the Ethics Committee of the Department of Gynecology, the Obstetrics and Gynecology Hospital of Fudan University [2018–18] and informed consent was obtained from each individual.

Informed consent Informed consent was obtained from all individual participants included in the study.

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