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Uterine size and volume are associated with a higher clinical pregnancy rate in patients undergoing assisted reproduction technology

A longitudinal study (A STROBE-compliant article)

Hong Gao, MD[a,b], Dong-e Liu, MM[c], Yumei Li, MD[c], Jing Tang, MM[c], Shimin Hu, MD[a], Xinrui Wu, MD[a], Zhengwen Tian, MM[a], Hongzhuan Tan, MD, PhD[a,*]

Abstract

The aim of this study was to investigate the relationships between uterine size and volume and clinical pregnancy rate.

This longitudinal study was conducted among patients undergoing assisted reproduction technology (ART) treatment at the Reproductive Medicine Center from January 2010 to May 2017, all of whom provided informed consent to participate in the study. The uterine size, for all patients, was measured by transvaginal ultrasonography before ovarian stimulation. Clinical pregnancy was diagnosed by ultrasound confirmation of at least an intrauterine gestational sac and fetal cardiac activity 4 weeks after embryo transfer.

A total of 11,924 patients were enrolled in this study. Compared to patients with uterine lengths of 50 to 59 mm (referent), patients with uterine lengths ≥60 mm had a lower clinical pregnancy rate. Compared to patients with uterine widths of 30 to 39 mm (referent), patients with uterine widths of 40 to 49 mm and those with uterine widths of ≥50 mm had a lower clinical pregnancy rate. Compared with those with a uterine anteroposterior diameter of <30 mm (referent), patients with uterine anteroposterior diameters of ≥50 mm had a lower clinical pregnancy rate. Compared with those with a uterine volume of 30 to 49 mL (referent), patients with a uterine volume ≥70 mL had a lower clinical pregnancy rate.

The patients with an optimal uterine length, width, anteroposterior diameter, and volume had a higher clinical pregnancy rate than those with suboptimal uterine measurements. Uterine sizes and volumes that were too large reduced the clinical pregnancy rate.

Abbreviations: ART = assisted reproduction technology, E_2 = estradiol, FSH = follicle-stimulating hormone, HCG = human chorionic gonadotropin, HMG = human menopausal gonadotropin, ICSI = intracytoplasmic sperm injection, IVF = in vitro fertilization, LH = luteinizing hormone, RR = relative risk.

Keywords: assisted reproduction technology, clinical pregnancy, female infertility, uterine size, uterine volume

1. Introduction

With the development of human society, there is a great difference in the geographical distribution of the incidence of infertility, which is 1% to 18% in China[1–3] and 2% to 26% in the United Kingdom.[2,4,5] Infertility is a worldwide problem and significant issue in the field of human reproduction. Infertility has increased negative effects on human society and life, such as its role in causing divorce, depression, anxiety, and other issues.[6–8] Therefore, an increased number of infertility patients ask for assisted reproduction technology (ART), but not every ART outcome is successful. The outcome of ART is influenced by many determinants, such as sperm quality, oocyte quality, hormone level, and so forth.[9–11] In normal conditions, gynecologists have eliminated the cause of congenital uterine malformation, with little consideration for uterine factors, including uterine length, width, anteroposterior diameter, and total volume, are predictive of clinical pregnancy rate.

Actually, one of the most important determinants of infertility is the function and morphology of the uterus. At present, it is clear that congenital uterine malformations and uterine fibroid can lead to infertility.[12,13] Some studies have focused on the relationships between uterine length and human reproduction, such as uterine length and ectopic pregnancy, in vitro fertilization (IVF) outcomes, comparisons among different study subjects, and so on.[14–16] However, studies on the relationships between uterine size (including length, width, anteroposterior diameter), total volume, and clinical pregnancy in infertile patients are rare. Defining these relationships will assist in identifying effective counseling and management strategies for patients undergoing ART treatment.

Editor: Daryle Wane.

HG and DEL were considered as co-first authors.

The authors have no funding and conflicts of interest to disclose.

[a] Department of Epidemiology and Health Statistics, Xiangya School of Public Health, Central South University, Changsha, [b] School of Nursing, University of South China, Hengyang, [c] Reproductive Medicine Center, Xiangya Hospital, Central South University, Changsha, Hunan, China.

[*] Correspondence: Hongzhuan Tan, Department of Epidemiology and Health Statistics, Xiangya School of Public Health, Central South University, No 110 Xiangya Road, Changsha, Hunan 410008, China (e-mail: tanhz99@qq.com).

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Medicine (2019) 98:8(e14366)

Received: 18 September 2018 / Received in final form: 21 December 2018 / Accepted: 9 January 2019

http://dx.doi.org/10.1097/MD.0000000000014366

We aim to explore the relationships between uterine length, width, anteroposterior diameter, and total volume and clinical pregnancy rate in ART patients. We hypothesize that uterine size and volume are associated with a higher clinical pregnancy rate in Chinese Han ART patients.

2. Materials and methods

This longitudinal study was conducted on patients undergoing ART treatment at the Reproductive Medicine Center, all of whom provided informed consent for inclusion in the study. This study was performed in accordance with all relevant guidelines and regulations. The Reproductive Medicine Center of Xiangya Hospital is an important integrated ART treatment center in South China that treats patients who come from all over China.

2.1. Study population

All patients who presented to the Reproductive Medicine Center, Xiangya Hospital of Central South University, Hunan, China, for planned ART treatment from January 2010 to May 2016 and who signed the informed consent were enrolled in our study. Exclusion criteria included patients with congenital uterine malformation, uterine septum, uterus duplex, uterine cancer, rudimentary horn of uterus, hysteromyoma, adenomyosis, and intrauterine adhesions, all of the uteri after surgical operation, or psychiatric illness, contraindications of pregnancy, or no embryo transfer.

2.2. Data collection

All data of the patients were recorded in the electronic medical records (Haitai, Nanjing, China) of Xiangya Hospital Central South University. We continued to follow-up with patients for 12 months until May 2017. All patients were interviewed face to face, and data on age, sociodemographic factors, and history of disease were collected from them. Height, weight, and BMI were measured. Precycle uterine size was measured by transvaginal ultrasonography. We collected all data from theirs and their partners' health records, including diagnosis of infertility, treatment process of ART, treatment outcomes of ART, etc. Recorders of the data included attending gynecologists, fellows, and nurses.

2.3. Uterine size measurements

Uterine size of each patient was measured by 3-dimensional transvaginal ultrasonic imaging examination before ovarian stimulation. All ultrasonic scans were performed with 5.0 to 8.0 MHz scanners (DC-6 Expert; Shenzhen Mindray Bio-medical Electronics Co. Ltd., China) by gynecologists with specialized training in gynecological ultrasonography. In our whole study, there were 3 senior gynecologists with specialized training in gynecologic ultrasonography who took the uterine measurements. By 2010, they had at least 15 years of work experience. Therefore, the uterine measurement results were reliable.

The following parameters were analyzed: uterine longitudinal diameter (length), transverse diameter (width), and anteroposterior diameter. The longitudinal diameter was measured from the cervical internal os to the fundus in the sagittal plane; the transverse diameter was measured by the maximum diameter from the right side of the uterine corpus to the left side of the uterine corpus in the transverse plane; the anteroposterior diameter was measured from the anterior serosa to the posterior serosa at the point at which the uterus appeared to be at its thickest and perpendicular to the endometrial line in the sagittal plane.[16] The uterine volume was calculated according to the following formula for ellipsoid bodies: V = Longitudinal diameter $\times$ Anteroposterior diameter $\times$ Transverse diameter $\times$ 0.5233.[17]

2.4. ART treatment

The protocols for ovarian stimulation mainly included a long, short, antagonist, and mini-stimulation.

Long protocol: On day 21 of the menstrual cycle, patients were injected with gonadotropin releasing hormone agonist (triptorelin), 0.05 to 0.1 mg/d, and they continued treatment until the day of human chorionic gonadotropin (HCG) triggering. After reaching the standards of downregulation (follicle-stimulating hormone [FSH] $<$ 5 IU/L, $E_2 <$ 50 pg/mL, LH $<$ 5 IU/L, a follicular diameter $<$ 8 mm, and an endometrium $<$ 5 mm), gonadotropin (Gn) stimulation was initiated using human menopausal gonadotropin (HMG, Menogon; Ferring, Germany) or recombinant FSH (rFSH, Gonal-f; Merck Serono, Darmstadt, Germany) 150 to 300 IU/d. The dose of gonadotropin was adjusted according to follicular growth, endometrial thickness, and serum sex hormone levels. After 5 days, the growth and development of follicle and endometrium were monitored daily or on alternate days with transvaginal ultrasonography. When B ultrasonography showed the mean diameter of 1 to 2 follicles as $\geq$20 mm, or as 2 follicles having a diameter $\geq$18 mm, patients were injected with HCG (Livzon, Guangdong, China) at a dose of 10,000 IU.

Short protocol: On days 1 to 3 of the menstrual cycle, patients were injected with gonadotropin releasing hormone agonist (triptorelin), 0.05 to 0.1 mg/d, and they continued treatment until the day of HCG. On day 3, Gn stimulation was initiated using HMG or rFSH at a dosage of 225 to 300 IU/d. Follow-up treatment was the same as that in the long protocol.

Antagonist protocol: On day 2 of the menstrual cycle, patients were injected with rFSH daily. After reaching at least one standard (1 or more follicles with a diameter $\geq$14 mm, $E_2 \geq$ 600 pg/mL, and LH $\geq$ 10 IU/L), cetrorelix (Cetrotide; Merck Serono) treatment was initiated at a dosage of 0.25 mg/d. Then, continue to use antagonist and rFSH every day until the day of HCG.

Ovum pickup was conducted under transvaginal ultrasonography guidance at 36 to 38 hours after the HCG injection.

The oocytes were evaluated in metaphase II. Selection of fertilization methods relied on the condition of the patient's partner and mainly included IVF and intracytoplasmic sperm injection. The quality of embryo was assessed according to the degree of multinucleation, the degree of fragmentation and the number of blastomeres.[18] The number of embryo transfers was no more than 3. Types of embryo transfer included fresh and frozen-thawed embryos.

2.5. Outcome measures

Clinical pregnancy was diagnosed by ultrasound confirmation of at least an intrauterine gestational sac and fetal cardiac activity 4 weeks after embryo transfer.

2.6. Statistical analysis

All data were managed and analyzed using Statistical Package for Social Sciences (SPSS) software, version 17.0 (SPSS Inc, Chicago, IL), and Excel (Microsoft Corp, Redmond, WA). Measurement data were described by the mean $\pm$ standard deviation, and enumeration data were described by the number (percentage). A

Table 1

The variable assignment in multivariate logistic regression analysis.

Risk factors	Variable names	Assignment statements*
Uterine length, mm	X_1	1 = <40, 2 = 40∼, 0 = 50∼, 4 = ≥ 60
Uterine width, mm	X_2	1 = <30, 0 = 30∼, 3 = 40∼, 4 = ≥50
Uterine anteroposterior diameter, mm	X_3	0 = <30, 2 = 30∼, 3 = 40∼, 4 = ≥50
Uterine volume, mL	X_4	1 = <30, 0 = 30∼, 3 = 50∼, 4 = ≥70
Infertility diagnosis	X_5	1 = male factor, 2 = ovulation dysfunction, 3 = decreased ovarian reserve, 4 = tubal factor, 5 = endometriosis, 0 = polycystic ovarian syndrome, 7 = chromosome abnormality, 8 = unexplained, 9 = male + female factors.
Total no. of transferred embryos	X_6	1 = 1, 0 = 2, 2 = 3
The quality of transferred embryos	X_7	1 = I, 2 = II, 3 = III
Types of transferred embryos	X_8	0 = fresh embryo, 1 = frozen-thawed embryo
Artificial insemination technologies*	X_9	0 = IVF, 1 = ICSI, 2 = IVF + ICSI
Stimulation protocol	X_{10}	0 = long protocol, 1 = short protocol, 2 = antagonist protocol
Endometrial thickness before embryo transfer, mm	X_{11}	1 = <8, 2 = 8∼, 3 = 10 ∼, 4 = ≥12
Clinical pregnancy	Y	1 = nonclinical pregnancy, 0 = clinical pregnancy

ICSI = intracytoplasmic sperm injection, IVF = in vitro fertilization.

* For X_1, X_2, X_3, X_4, X_5, X_6, X_8, X_9, X_{10}, the group with the highest clinical pregnancy rate was selected as the reference group, all of which were assigned "0," all these variable was used as dummy variable in multivariate logistic regression.

Pearson Chi-square test was used in the univariate analysis. Binary logistic regression was used in the multivariate analysis. All *P*-values corresponded to 2-sided tests, and $P < .05$ was considered to indicate statistical significance. The variable assignments in the multivariate logistic regression analysis are listed in Table 1.

2.7. Ethical approval

This study was approved by the ethics committee of Xiangya Hospital of Central South University.

3. Results

3.1. General information

This study included 13,033 infertile patients. About 1109 (8.5%) patients had missing data and were thus excluded, which left 11,924 (91.5%) patients included in the final analysis. There were 3 main reasons for missing patient data: no embryo transfer, which was shown in 615 (55.5%) patients, loss to follow-up, which was shown in 294 (26.5%) patients, and incomplete or missing data for the size of the uterus, which was shown in 200 (18.0%) patients. The demographic and clinical characteristics of the infertile Chinese Han patients are summarized in Table 2.

3.2. Uterine length and clinical pregnancy

We analyzed the relationship between uterine length and clinical pregnancy. In the multivariate analysis, the determination of the influencing factors was performed through single factor analysis and multiple collinearity among influencing factors. The main influencing factors were infertility diagnosis, total number of transferred embryos, quality of transferred embryos, types of transferred embryos, and artificial insemination technologies. Table 3 shows that, compared with the patients with uterine lengths of 50 to 59 mm (referent), the patients with uterine lengths of ≥60 mm had a lower clinical pregnancy rate (RR = 1.202).

3.3. Uterine width and clinical pregnancy

We analyzed the relationship between uterine width and clinical pregnancy. In the multivariate analysis, the determination of the influencing factors was performed through single factor analysis and multiple collinearity among influencing factors. After adjusting for infertility diagnosis, total number of transferred embryos, quality of transferred embryos, endometrial thickness before embryo transfer, types of transferred embryos, stimulation protocol, and artificial insemination technologies, we found that compared to patients with uterine widths of 30 to 39 mm (referent), patients with uterine widths of 40 to 49 mm and those with uterine widths of ≥50 mm had a lower clinical pregnancy rate (RR = 1.312 and 1.473, respectively) (Table 4). A uterine width of ≥50 mm was the most unsuitable of all uterine widths for pregnancy.

3.4. Uterine anteroposterior diameter and clinical pregnancy

The relationship between uterine anteroposterior diameter and clinical pregnancy is shown in Table 5. In the multivariate analysis, the determination of the influencing factors was performed through single factor analysis and multiple collinearity among influencing factors. The main influencing factors were infertility diagnosis, quality of transferred embryos, types of transferred embryos, endometrial thickness before embryo transfer and artificial insemination technologies. Compared to patients with uterine anteroposterior diameters of <30 mm (referent), patients with uterine anteroposterior diameters of ≥50 mm had a lower clinical pregnancy rate (RR = 1.495).

3.5. Uterine volume and clinical pregnancy

Table 6 presents the data for the relationship between uterine volume and clinical pregnancy in ART patients. In the multivariate analysis, the determination of the influencing factors was performed through single factor analysis and multiple collinearity among influencing factors. After adjusting for infertility diagnosis, total number of transferred embryos, quality of transferred embryos, endometrial thickness before embryo transfer, types of transferred embryos, and artificial insemination technologies, we found that compared to patients with uterine volumes of 30 to 49 mL (referent), patients with uterine volumes of ≥70 mL had a lower clinical pregnancy rate (RR = 1.391).

Table 2

Demographic and clinical characteristics of 11,924 infertile patients (mean ± standard deviation or N [%]).

	Clinical pregnancy	Nonclinical pregnancy	*P*-value
Age, yrs	30.70 ± 4.52	33.42 ± 5.58	<.001
BMI, kg/m^2	21.68 ± 3.02	21.94 ± 2.97	<.001
Total number of transferred embryos	1.97 ± 0.29	1.86 ± 0.47	<.001
Endometrial thickness before embryo transfer, mm	10.48 ± 2.10	9.82 ± 2.10	<.001
Uterine length, mm	50.43 ± 7.09	50.70 ± 7.37	.052
Uterine width, mm	41.51 ± 7.33	42.15 ± 7.63	<.001
Uterine anteroposterior diameter, mm	46.20 ± 8.54	46.51 ± 8.68	.052
Uterine volume, mL	52.01 ± 20.67	53.71 ± 22.89	<.001
Infertility diagnosis			<.001
Male factor	967 (64.00)	544 (36.00)	
Ovulation dysfunction	43 (65.15)	23 (34.85)	
Decreased ovarian reserve	28 (25.93)	80 (74.07)	
Tubal factor	4529 (61.76)	2804 (38.24)	
Endometriosis	71 (49.65)	72 (50.35)	
Polycystic ovarian syndrome	230 (72.78)	86 (27.22)	
Chromosome abnormality	14 (41.18)	20 (58.82)	
Unexplained	50 (51.02)	48 (48.98)	
Male + female factors	1388 (59.91)	929 (40.09)	
Stimulation protocol			<.001
Long protocol	3539 (72.67)	1331 (27.33)	
Short protocol	697 (49.36)	715 (50.64)	
Antagonist protocol	21 (38.89)	33 (61.11)	
Artificial insemination technologies			<.001
IVF	4942 (64.42)	2730 (35.59)	
ICSI	1407 (58.41)	1002 (41.59)	
IVF + ICSI	421 (59.13)	291 (40.87)	
The quality of transferred embryos*			<.001
I	6577 (65.27)	3500 (34.73)	
II	411 (42.81)	549 (57.19)	
III	94 (26.33)	263 (73.67)	

BMI = body mass index, ICSI = intracytoplasmic sperm injection, IVF = in vitro fertilization.

* The quality of transferred embryos: I is the best quality embryo, and follow by II and III.

Table 3

Uterine length and clinical pregnancy in patients undergoing assisted reproduction technology.

Uterine length, mm	N	Number of clinical pregnancy	Rate of clinical pregnancy, %	RR (95% CI)*	aRR (95% CI)†
<40	591	360	60.91	1.043 (0.876–1.242)	1.149 (0.940–1.403)
40∼	4902	3023	61.67	1.009 (0.931–1.093)	1.018 (0.928–1.116)
50∼	5166	3198	61.90	1 (referent)	1 (referent)
≥60	1267	739	58.33	1.161 (1.025–1.316)	1.202 (1.041–1.387)

aRR = adjusted RR, CI = confidence interval, RR = relative risk.

* RR calculated from univariate binary logistic regression.

† Adjusted RR (aRR) calculated from multivariate binary logistic regression adjusted for infertility diagnosis, total number of transferred embryos, the quality of transferred embryos, types of transferred embryos, and artificial insemination technologies.

Table 4

Uterine width and clinical pregnancy in patients undergoing assisted reproduction technology.

Uterine width, mm	N	Number of clinical pregnancy	Rate of clinical pregnancy, %	RR (95% CI)*	aRR (95% CI)†
<30	445	270	60.67	1.140 (0.933–1.393)	1.334 (0.972–1.830)
30∼	4326	2758	63.75	1 (referent)	1 (referent)
40∼	5400	3279	60.72	1.138 (1.048–1.236)	1.312 (1.143–1.506)
≥50	1755	1013	57.72	1.288 (1.150–1.443)	1.473 (1.214–1.788)

aRR = adjusted RR, CI = confidence interval, RR = relative risk.

* RR calculated from univariate binary logistic regression.

† aRR calculated from multivariate binary logistic regression adjusted for infertility diagnosis, total number of transferred embryos, the quality of transferred embryos, endometrial thickness before embryo transfer, types of transferred embryos, stimulation protocol, and artificial insemination technologies.

Table 5

Uterine anteroposterior diameter and clinical pregnancy in patients undergoing assisted reproduction technology.

Uterine anteroposterior diameter, mm	N	Number of clinical pregnancy	Rate of clinical pregnancy, %	RR (95% CI)*	aRR (95% CI)†
<30	176	115	65.34	1 (referent)	1 (referent)
30~	2431	1503	61.83	1.162 (0.843–1.601)	1.312 (0.902 -1.909)
40~	5247	3242	61.79	1.166 (0.851–1.598)	1.349 (0.932–1.952)
≥50	4072	2460	60.41	1.235 (0.900–1.696)	1.495 (1.031–2.167)

aRR = adjusted RR, CI = confidence interval, RR = relative risk.

* RR calculated from univariate binary logistic regression.

† aRR calculated from multivariate binary logistic regression adjusted for infertility diagnosis, the quality of transferred embryos, endometrial thickness before embryo transfer, types of transferred embryos, and artificial insemination technologies.

4. Discussion

In this study, our hypotheses were verified, the uterine size, and volume are associated with a higher clinical pregnancy rate in Chinese Han ART patients. There are 4 major findings in this study. First, the optimal length of the uterus in regard to being suitable for clinical pregnancy was <60 mm, and those with uterine lengths of ≥60 mm had a lower pregnancy rate than those with these shorter uterine lengths. Second, the optimal width of the uterus in regard to being suitable for pregnancy was <40 mm, and those with uterine widths ≥40 mm had a lower pregnancy rate than those with these shorter uterine widths. Third, the optimal anteroposterior diameter of the uterus in regard to being suitable for pregnancy was <50 mm, and those with uterine anteroposterior diameters of ≥50 mm had a lower pregnancy rate than those with these shorter anteroposterior diameters. Finally, the optimal volume of the uterus in regard to being suitable for pregnancy was <70 mL, and those with uterine volumes of ≥70 mL had a lower pregnancy rate than those with lower uterine volumes.

In our study population, the majority of patients had uterine lengths of <60 mm, which was the most favorable for pregnancy. Hawkins *et al* reported that uterine lengths of 70 to 79 mm are beneficial to pregnancy, accounting for 55.5% of uterine lengths of the total IVF population. These results demonstrate two important points: the uterine length has an impact on pregnancy outcomes, and an optimal uterine length can increase the pregnancy rate. However, the mean length and the optimal lengths of the uterus vary greatly in the 2 studies. This may be due to the inclusion of different races of patients or utilization of different measurement methods.[19]

The uterine widths of <40 mm, anteroposterior diameters of <50 mm, and volumes of <70 mL were suitable for clinical pregnancy and led to the highest clinical pregnancy rate in the infertile Chinese Han population. Until now, the relationships between uterine width, anteroposterior diameter, and volume and clinical pregnancy or human reproduction were not reported.

Some studies indicated that a smaller uterine size was associated with an increased risk of miscarriage and failed implantation[20–21] and that the uterine volume or ratio of uterine dimensions was a significant parameter controlling the outcomes of pregnancy and parturition.[22] Furthermore, an animal study showed a negative correlation between a larger uterus and fertility success in cows.[23] These results were partly consistent with the results of our research. Too large of a size and volume of a uterus may result in partial or complete dysfunction. Previous studies have reported that uterine size was influenced by congenital abnormalities in HOX and Wnt gene expression, production or action of GH, estrogen, progesterone, and IGFs.[21,24,25] Hence, the causes and mechanisms for uterine size and volume affecting fertility may be explained by 2 aspects: an inappropriate size or volume of the uterus induces a decline in human female fertility and hormone levels, genes, or other unknown factors not only affect uterine size and volume but also affect female reproductive health.

The strength of our study indicated for the 1st time that there are inherent relationships between uterine size and volume and clinical pregnancy in infertile patients, adjusted for the main influencing factors. We found that the optimal size and volume ranges of the uterus were conducive to clinical pregnancy in infertile patients. Our findings indicate a possible prospective use of uterine size and volume as predictive variables for the clinical pregnancy rate. Thus, these data may provide a reference for gynecologists in the diagnosis and treatment of infertility and assist in the counseling and management of patients undergoing ART treatment. Furthermore, our sample was sufficiently large to produce reliable results with high statistical power.

The main limitations of this study include three aspects. First, we only studied these uterine measurements in infertile Chinese Han patients and did not include a healthy control group as a comparison group. Second, the samples of this study mainly come from the south of China, not from the whole country. Finally, these findings may not be appropriate for women who are

Table 6

Uterine volume and clinical pregnancy in patients undergoing assisted reproduction technology.

Uterine volume, mL	N	Number of clinical pregnancy	Rate of clinical pregnancy, %	RR (95% CI)*	aRR (95% CI)†
<30	1115	690	61.88	1.024 (0.896–1.170)	1.062 (0.908–1.242)
30~	5110	3191	62.45	1 (referent)	1 (referent)
50~	3756	2325	61.90	1.023 (0.938–1.116)	1.094 (0.987–1.212)
≥70	1945	1114	57.28	1.240 (1.115–1.379)	1.391 (1.226–1.579)

aRR = adjusted RR, CI = confidence interval, RR = relative risk.

* RR calculated from univariate binary logistic regression.

† aRR calculated from multivariate binary logistic regression adjusted for infertility diagnosis, total number of transferred embryos, the quality of transferred embryos, endometrial thickness before embryo transfer, types of transferred embryos, and artificial insemination technologies.

currently receiving hormone therapy and for women with hormone-induced uterine dysplasia and pregnancy. Our study focused on the effect of uterine size and volume on clinical pregnancy before the ART treatment cycle. Anyhow, our results provide new knowledge for reproductive medicine.

This study was conducted at one of the most important research centers of reproductive medicine in Hunan, China. The subjects of study come from Hunan and its surrounding areas, from different geographical, occupational and age groups, which are representative of the Han people. At the same time, our findings are reasonable in the pathophysiology of reproduction. Therefore, they may have some significance to other nationalities, but further research of this is needed.

5. Conclusion

In conclusion, this study suggests that there are significant correlations between uterine size and volume and clinical pregnancy in infertile patients. The optimal uterine length, width, and volume led to the highest clinical pregnancy rates. Uterine sizes and volumes that are too large can reduce the clinical pregnancy rate. Our findings may stimulate further research on the relationships between uterine size and volume and partus maturus, premature birth, and abortion.

Acknowledgments

The authors acknowledge the Guojun Wang, MD (Department of Social Medicine and Health Service Management, XiangYa School of Public Health) for proofreading this article and Xiao Gao, MD (Department of Epidemiology and Biostatistics, XiangYa School of Public Health) for assistance in the data analysis of this article.

Author contributions

HG jointly conceptualized and designed the study, devised the linkage protocol, supervised the linkage and carried out the analysis, drafted the initial manuscript and approved the final manuscript for submission. DEL jointly conceptualized and designed the study, interpreted the data, reviewed and revised the manuscript, and approved the final manuscript for submission. HZT jointly conceptualized and designed the study, devised the linkage protocol, jointly supervised the linkage and carried out the analysis, reviewed and revised the manuscript, and approved the final manuscript for submission. YML jointly conceptualized and designed the study, interpreted the data, reviewed and revised the manuscript, and approved the final manuscript for submission. JT jointly conceptualized and designed the study, review data linkage, interpreted the data, reviewed and revised the manuscript, and approved the final manuscript for submission. XRW jointly conceptualized and designed the study, interpreted the data, reviewed and revised the manuscript, and approved the final manuscript for submission.

Conceptualization: Hong Gao, Dong-e Liu, Hongzhuan Tan.
Data curation: Hong Gao, Dong-e Liu, Shimin Hu, Xinrui Wu.
Formal analysis: Hong Gao, Dong-e Liu, Hongzhuan Tan.
Investigation: Hong Gao, Dong-e Liu, Yumei Li, Jing Tang, Hongzhuan Tan.
Methodology: Hong Gao, Dong-e Liu, Yumei Li, Jing Tang, Shimin Hu, Xinrui Wu, Hongzhuan Tan.
Project administration: Hong Gao, Dong-e Liu, Yumei Li, Jing Tang, Hongzhuan Tan.
Resources: Hong Gao. Hongzhuan Tan.
Software: Hong Gao, Shimin Hu, Xinrui Wu, Hongzhuan Tan.
Supervision: Hong Gao, Dong-e Liu, Yumei Li, Jing Tang, Zhengwen Tian, Hongzhuan Tan.
Validation: Hong Gao, Dong-e Liu, Hongzhuan Tan.
Visualization: Hong Gao, Dong-e Liu, Hongzhuan Tan.
Writing – original draft: Hong Gao.
Writing – review & editing: Hong Gao, Dong-e Liu, Zheng wen Tian, Hongzhuan Tan.

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