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Diagnostic value and efficacy evaluation value of transvaginal color doppler ultrasound parameters for uterine scar pregnancy and sub-type after cesarean section

Yuting Peng[1*], Jia Liu[1], Jun Xie[1] and Quanlv Li[2]

Abstract

Objective We aimed to probe the diagnostic value of transvaginal color Doppler ultrasound (TV-CDU) parameters in cesarean scar pregnancy (CSP) and CSP sub-types, and the relevant factors affecting patients' surgical effects.

Methods Seventy-five CSP patients (all requested termination of pregnancy) were selected as the observation group, and 75 normal pregnant women with a history of cesarean section were selected as the control group. All the study subjects underwent TV-CDU and their cesarean scar muscle (CSM) thickness, minimum sagittal muscle thickness and resistance index (RI) of blood flow in the anterior wall of the lower uterine segment were calculated. The diagnostic value of CSM, minimum sagittal muscle thickness, and RI for CSP and CSP sub-types was analyzed. The patients in the observation group were grouped into the effective group and the ineffective group according to whether the surgical treatment was effective or not, and the independent factors affecting CSP efficacy were analyzed.

Results The observation group had lower CSM, minimum sagittal muscle thickness and RI than the control group. CSM, RI, and minimum sagittal thickness in patients with type II CSP were lower than those in patients with type I, and these indicators in patients with type III were lower than those in patients with type II. The area under the curve (AUC) of CSM, RI and minimum sagittal muscle thickness in combination for CSP diagnosis and the AUC for CSP sub-types were higher than those of each indicator alone. Gestational sac size and CSM were independent factors affecting CSP treatment.

Conclusion Changes in TV-CDU parameters facilitates CSP diagnosis after cesarean section. CSM, minimum sagittal muscle thickness changes, and RI in combination possesses high value for CSP diagnosis and CSP sub-types. Gestational sac size and CSM are independent factors affecting CSP treatment.

Keywords Cesarean scar pregnancy, Cesarean scar muscle, Resistance index, Minimum sagittal muscle thickness, Transvaginal color doppler ultrasound, Gestational sac size

*Correspondence:
Yuting Peng
Pengyuting8145@163.com
[1]Department of Obstetrics, Yueyang People's Hospital, No. 263, Baling East Road, Yueyang 414000, Hunan, China
[2]Department of Gynaecology, Yueyang People's Hospital, Yueyang 414000, Hunan, China

Introduction

Cesarean scar pregnancy (CSP) is a rare variant of ectopic pregnancy [1], which can be defined as partial or full implantation of gestational sac in the scar of the previous cesarean Sect [2]. This disease is life-threatening or threatens patients' functional prognosis owing to early uterine rupture or hemorrhage [3]. Moreover, CSP confers serious risk and serious morbidity [4], whose rate is rising globally, in parallel with the rising cesarean delivery rates [5].

Early recognition of CSP is of great significance because of the risk for long-term reproductive complications involved in this condition [6]. CSP possesses significant risks without prompt diagnosis [7], and it shows substantial risks for serious maternal morbidity due to challenges in securing a prompt diagnosis. Ultrasound is considered as the primary imaging modality for the diagnosis of CSP [8]. Ultrasonography is demonstrated to enable early diagnosis and successful preservation of uterus [9]. An ultrasound scan and Doppler examination are useful tools in early detection of asymptomatic CSP, which enables effective fertility treatment and preservation [10]. Doppler ultrasound is reported to provide accurate and qualitative diagnosis of cesarean section scar pregnancy, and have higher clinical value in the evaluation of the treatment efficacy of cesarean section scar pregnancy by utilizing high intensity focused ultrasound [11]. The use of ultrasound and transvaginal imaging have taken the guesswork out of ectopic pregnancy diagnosis [12]. Transvaginal ultrasonography is a key tool utilized in the identification of CSP [13]. Transvaginal ultrasound imaging has been utilized as an essential tool in prenatal evaluation of lower uterine segment and cervix anatomy. In addition, transvaginal ultrasound examination makes contributions to both prenatal management and prediction of surgical results in patients with a previous history of cesarean delivery, which suggests that transvaginal ultrasound examination of the lower uterine segment and cervix should be regarded as clinical protocols for the preoperative evaluation of patients at a risk of complicated cesarean delivery [14]. Furthermore, measurement of lower uterine segment thickness by ultrasound is implemented in the evaluation of the quality of uterine scar after cesarean delivery and has an association with uterine rupture risk [15]. Considering the above researches, we realize that the effects of TV-CDU parameters on CSP are of great significance. Therefore, this study was aimed at ascertaining the effects of TV-CDU parameters on CSP diagnosis and CSP sub-types, and the relevant factors affecting patients' surgical effects.

Materials and methods

Ethics statement

The study was approved by the Ethic Committee of Yueyang People's Hospital. All participants were aware of this study and signed the written informed consent form.

Study subjects

Seventy-five CSP patients admitted to Yueyang People's Hospital from January 2021 to April 2022 (all requested termination of pregnancy) were selected as the observation group, and 75 normal pregnant women with a history of cesarean section during the same period were selected as the control group. All the study subjects underwent TV-CDU.

Inclusion criteria: (1) all study subjects had a history of cesarean section; patients in the observation group met the diagnostic criteria for CSP; (2) all study subjects agreed to undergo ultrasonography; (3) those with singleton pregnancy; (4) those with complete clinical data.

Exclusion criteria: (1) those combined with other reproductive system diseases; (2) those with a history of pregnancy hypertensive disorders, placenta implantation, placenta praevia, premature rupture of membranes, preterm labor, and intrauterine growth restriction of the fetus; (3) those with other types of ectopic pregnancies; (4) those with speech and communication disorders, cognitive dysfunction, and psychiatric disorders that prevented cooperation with the examination.

Methods

The examination was performed by implementing a SIEMENS 1000 color Doppler ultrasound (CDU) diagnostic machine with the ultrasound probe frequency set as 3–5 MHz, and the study subjects were instructed to empty their bladder before the examination. With the bladder in the lithotomy position, the ultrasound probe was covered with a condom and medical coupling agent, and slowly pushed into the vagina to observe the uterine wall, uterine scar, and uterine cavity, mainly focusing on the site of gestational implantation, the thickness of the incisional muscular layer, and the cervix. The echo size, morphology, internal echo, and blood flow at the cesarean incision on the anterior wall of the lower uterine segment were observed, and cesarean scar muscle (CSM) thickness, minimum sagittal muscle thickness and resistance index (RI) of blood flow in the anterior wall of the lower uterine segment were calculated. All ultrasound findings were analyzed by two experienced imaging physicians, and qualitative diagnoses were made after deliberation in case of disagreement.

Observation indicators

CSM thickness, minimum sagittal muscle thickness and RI of blood flow in the anterior wall of the lower uterine

segment of the two groups of patients were calculated. The differences in ultrasound parameters between CSP and normal pregnancy were assessed.

Patients in the observation group were categorized into patients with different CSP sub-types based on ultrasound findings. Criteria for CSP sub-types: Type I: thickness ≥ 3 mm, thinning of the gestational sac and intervesical musculature, elongated or sharply angled lower end of the gestational sac, most of the gestational tissues deposited in the scarred area, with a small portion in uterine cavity floor, and the majority in the uterine cavity; Type II: thickness < 3 mm, thinning of the gestational sac and intervesical musculature, elongated or sharply angled lower end of the gestational sac, some of the gestational tissue deposited in the scarred area with most in the uterine cavity; Type III: thickness < 3 mm, thinning or even loss of gestational sac and bladder interstitial muscle layer, gestational sac fully attached to the uterine scar site, convex towards the bladder. CSM thickness, minimum sagittal muscle thickness and RI of the anterior wall of the lower uterine segment in patients with different sub-types were compared.

According to the typing results of the patients in the observation group, the corresponding treatment plans (methotrexate systemic administration + complete curettage of uterine cavity, uterine artery embolization + ultrasound-guided complete curettage of uterine cavity) were given. The treatment was rated as effective when all the pregnancy tissues were removed during the operation with less bleeding and a decrease in the postoperative blood β-hCG levels and there was no need for other surgical treatments, and when the above criteria were not met, the treatment was rated as ineffective.

The patients in the observation group were separated into two subgroups, the effective group and the ineffective group, according to whether the criteria for effective surgical treatment were met. The patients' preoperative general data and ultrasound-related parameters were compared: CSM thickness, minimum sagittal muscle thickness and RI of blood flow in the anterior wall of the lower uterine segment. The independent factors affecting the treatment of patients with CSP were analyzed.

Statistics

SPSS 22.0 software (SPSS Inc, Chicago, IL, USA) and GraphPad Prism 6.0 software (Graph Pad Inc., La Jolla, CA, USA) were applied for data processing. Measurement data conformed to normal distribution were expressed as mean ± standard deviation ($\overline{x} \pm s$). Numeration data were depicted as n (%). Two-by-two comparisons of measurement data between groups were analyzed by the t-test, and numeration data were analyzed by the χ^2 test. Diagnostic value of ultrasound parameters for CSP diagnosis and CSP sub-types was analyzed by the receiver operating characteristic (ROC) curve. Logistic regression was employed to analyze the independent factors affecting the treatment of patients with CSP. The test level was $\alpha = 0.05$ and $P < 0.05$ was considered statistically significant.

Table 1 Comparison of general information between two groups of patients

Indicator	The control group ($n = 75$)	The observation group ($n = 75$)	*P* value
Age (years)	32.11 ± 3.43	31.43 ± 3.20	0.211
Body mass index (kg/m^2)	24.17 ± 1.35	24.16 ± 1.28	0.966
Number of pregnancies (times)	2.03 ± 0.54	1.88 ± 0.52	0.093
Time to previous pregnancy (year)	2.27 ± 0.68	2.21 ± 0.74	0.648

Table 2 TV-CDU parameters of the two groups of patients

Grouping	CSM (mm)	Minimum sagittal muscle thickness (mm)	RI
The control group ($n = 75$)	6.93 ± 2.00	8.01 ± 1.96	0.69 ± 0.16
The observation group ($n = 75$)	4.77 ± 1.35	5.56 ± 1.73	0.52 ± 0.13
P value	< 0.001	< 0.001	< 0.001

Results

General information

There was no statistically significant difference in general information such as age, body mass index, number of pregnancies, and time to previous pregnancy in patients between the control group and the observation group, indicating comparability ($P > 0.05$; Table 1).

TV-CDU parameters

CSM, minimum sagittal muscle thickness and RI in the observation group were lower than those in the control group ($P < 0.05$), suggesting that there was a significant change in TV-CDU parameters in CSP patients (Table 2).

TV-CDU parameters in CSP patients with different sub-types

There were significant differences in CSM, RI, and minimum sagittal muscle thickness in patients with different CSP sub-types. Patients with type II CSP had lower CSM, RI, and minimum sagittal muscle thickness than those with type I, and patients with type III patients possessed lower CSM, RI, and minimum sagittal muscle thickness than those with type II ($P < 0.05$), which suggested that with the increase of CSP sub-types, each examination parameter revealed a tendency of reduction, showing a negative correlation (Table 3).

Table 3 TV-CDU parameters in CSP patients with different sub-types

Grouping	CSM (mm)	Minimum sagittal muscle thickness (mm)	RI
Type I ($n=23$)	5.87 ± 1.25	6.78 ± 1.54	0.62 ± 0.14
Type II ($n=36$)	4.56 ± 1.03[a]	5.42 ± 1.30[a]	0.50 ± 0.10[a]
Type III ($n=16$)	3.69 ± 1.01[ab]	4.13 ± 1.67[ab]	0.42 ± 0.07[ab]

Note: [a]$P<0.05$ vs. Type I; [b]$P<0.05$ vs. Type II

Diagnostic value of TV-CDU parameters for CSP after cesarean section

The area under the curve (AUC) of CSM, RI and minimal sagittal muscle thickness in combination (AUC: 0.826, 95% CI: 0.761–0.890) was higher than that of the single detection of each indicator, which indicated that the combination of CSM, RI and minimum sagittal muscle thickness for CSP diagnosis can effectively compensate for the insufficiency of single indicator detection and have higher value (Table 4; Fig. 1).

Diagnostic value of TV-CDU parameters in CSP sub-types after cesarean section

The AUC of CSM, minimal sagittal muscle thickness, and RI in combination for the diagnosis of type III CSP (AUC: 0.861, 95% CI: 0.768–0.954) was higher versus that of each indicator alone, revealing that the combination

Table 4 Diagnostic value of TV-CDU parameters for CSP diagnosis

Items	AUC	95% CI		Sensitivity	Specificity	Truncation value
		Lower limit	Upper limit			
CSM	0.804	0.735	0.873	75.30	64.70	≥ 6 mm
Minimum sagittal muscle thickness	0.819	0.754	0.884	77.40	69.30	≥ 7 mm
RI	0.786	0.715	0.857	71.60	62.30	≥ 0.65
Combined diagnosis	0.826	0.761	0.890	80.70	71.60	-

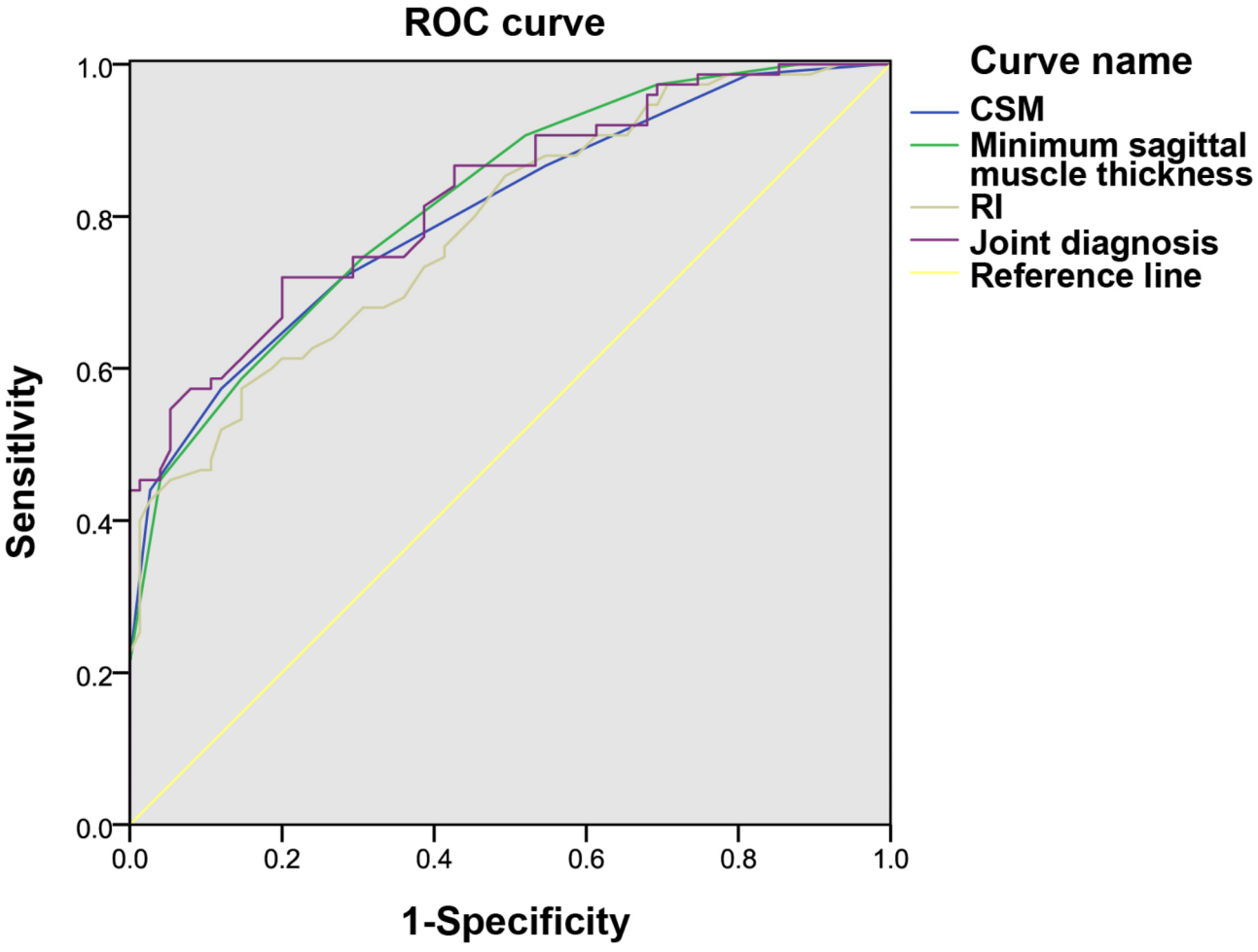

Fig. 1 ROC curves of TV-CDU parameters for the diagnosis of CSP

Table 5 Diagnostic value of TV-CDU parameters in CSP sub-types

Items	AUC	95% CI		Sensitivity	Specificity	Truncation value
		Lower limit	Upper limit			
CSM	0.796	0.674	0.917	81.20	64.40	≥3 mm
Minimum sagittal muscle thickness	0.786	0.647	0.925	78.00	62.50	≥4 mm
RI	0.804	0.705	0.903	87.50	67.80	≥0.50
Combined diagnosis	0.861	0.768	0.954	88.10	74.60	-

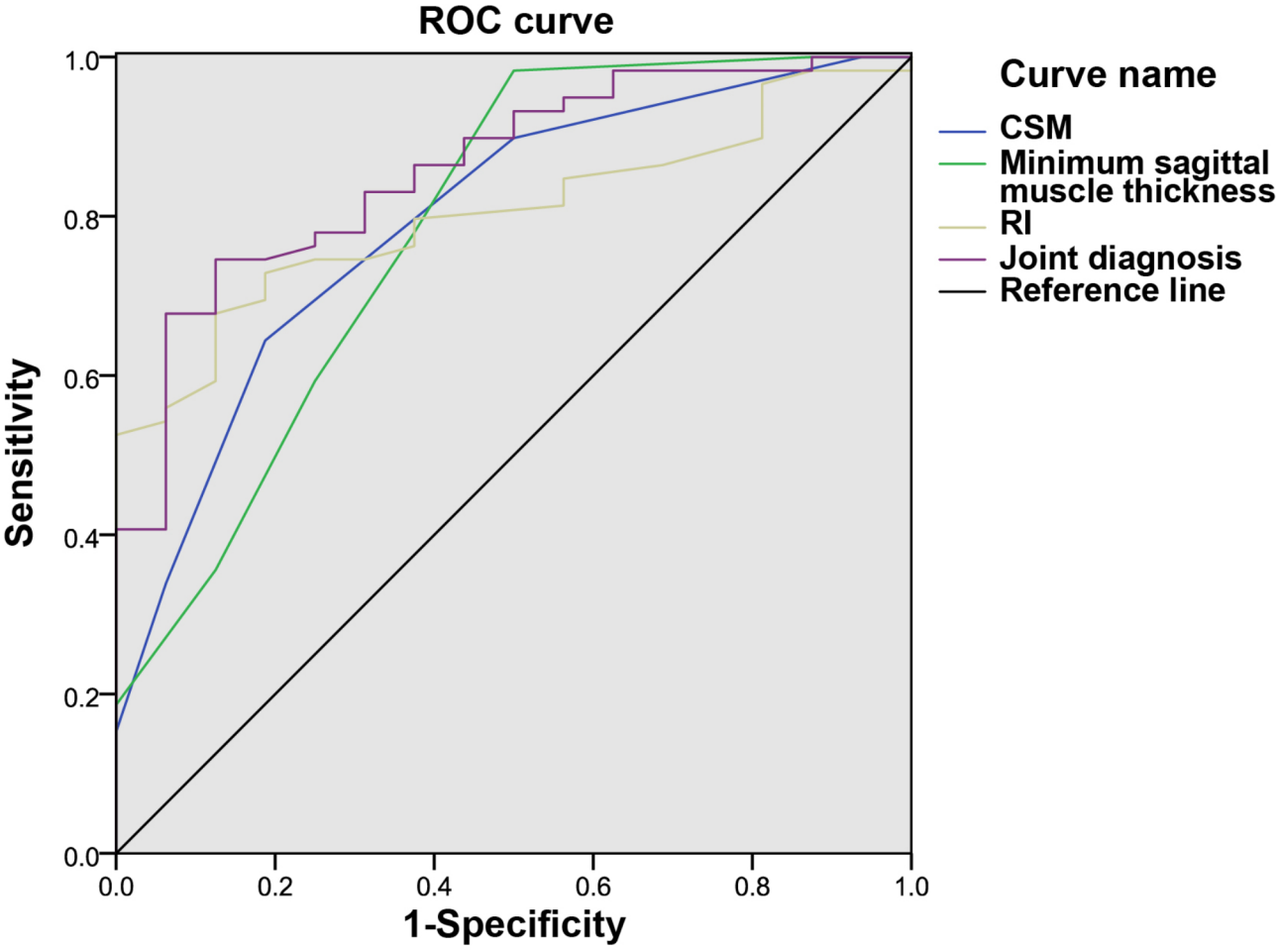

Fig. 2 ROC curves of TV-CDU parameters for the diagnosis of CSP sub-types

of CSM, RI and minimum sagittal muscle thickness was of higher value in diagnosing CSP sub-types (Table 5; Fig. 2).

Factors influencing CSP treatment

Age, BMI, pregnancy number, CSM, minimum sagittal muscle thickness, RI, gestational sac size, and CSP sub-types were selected as factors that may influence the treatment of patients with CSP. Whether the treatment was effective or not was set as the outcome variable, and uni-variate analysis unearthed that pregnancy number, CSM, minimum sagittal muscle thickness, and gestational sac size were the relevant factors impacting the treatment of patients with CSP ($P<0.05$), while the other factors did not have a significant influence on the treatment of CSP ($P>0.05$). Further analysis unraveled that gestational sac size and CSM were independent factors influencing the treatment of patients with CSP ($P<0.05$) (Tables 6 and 7).

Discussion

CSP is a severe complication of cesarean delivery [16]. The impact of CSP on fertility has emerged as a clinical issue in gynecology and obstetrics in China because of the rising rate of cesarean section over the past 30 years [17]. CSP, an ectopic pregnancy with embryo implanted in the cesarean scar, can pose significant risks when lack of prompt diagnosis and treatment [7]. Therefore,

Table 6 Uni-variate analysis of factors influencing CSP treatment

Items	The effective group ($n=52$)	The ineffective group ($n=23$)	*P* value
Age (years)	31.52 ± 3.18	31.22 ± 3.29	0.709
BMI (kg/m^2)	24.30 ± 1.23	23.84 ± 1.36	0.156
Pregnancy number (times)	1.71 ± 0.46	2.26 ± 0.45	< 0.001
Time from previous pregnancy (years)	2.31 ± 0.76	2.00 ± 0.67	0.097
CSM (mm)	5.31 ± 1.21	3.57 ± 0.73	< 0.001
Msinimum sagittal muscle thickness (mm)	5.92 ± 1.21	4.74 ± 1.79	0.005
RI	0.54 ± 0.12	0.47 ± 0.14	0.028
Gestational sac size (cm)	3.77 ± 0.72	2.84 ± 0.68	< 0.001
CSP sub-types			0.749
Type I	17 (32.69%)	6 (26.09%)	
Type II	25 (48.08%)	11 (47.82%)	
Type III	10 (19.23%)	6 (26.09%)	

Table 7 Multi-variate analysis of factors influencing CSP treatment

Items	β	SE	Wald	*P* value	Exp (B)	95% CI	
						Lower limit	Upper limit
Pregnancy number	-1.948	0.918	1.450	0.298	2.883	0.427	9.169
CSM	3.134	1.224	6.557	0.010	22.966	2.086	25.288
Minimum sagittal muscle thickness	1.114	0.887	1.576	0.209	3.045	0.535	17.318
RI	0.068	0.914	0.005	0.941	1.070	0.178	6.424
Gestational sac size	-3.123	1.155	7.303	0.007	22.706	2.358	21.862

this study was aimed at probing the effects of TV-CDU parameters in CSP diagnosis and CSP sub-types, and the relevant factors affecting patients' surgical effects.

Transvaginal ultrasound reveals that uterine scar thickness and gestational sac or uneven mass size have differences among various surgical methods, suggesting that transvaginal ultrasound might offer valuable reference for CSP clinical surgical procedures [18]. The monitoring of cesarean section scar muscle layer thickness is significant in the prevention of uterine rupture in late pregnancy [19]. Measurement of lower uterine segment thickness is a proposed test method to measure the risk factors of uterine rupture in women who undergo trial of labor after cesarean [20]. The lower uterine segment thickness is reported to correlated with transvaginal ultrasound. Moreover, transvaginal ultrasound is an accurate tool in the assessment of lower uterine segment thickness [21]. In our paper, we compared TV-CDU parameters between the two groups of patients, and we found that CSM, minimum sagittal muscle thickness and RI in the observation group were lower in contrast with those in the control group, which revealed that there was a significant change in TV-CDU parameters in patients with CSP. Furthermore, we compared TV-CDU parameters in CSP patients with different sub-types and significant differences were found in terms of CSM, RI, and minimum sagittal muscle thickness in CSP patients with different sub-types. Patients with type II CSP possessed lower CSM, RI, and minimum sagittal muscle thickness versus those with type I, and patients with type III patients possessed lower CSM, RI, and minimum sagittal muscle thickness in comparison with those with type II, which unearthed that with the increase of CSP sub-types, each examination parameter revealed a tendency of reduction, showing a negative correlation.

Subsequently, we analyzed the diagnostic value of TV-CDU parameters in CSP diagnosis and CSP sub-types, and found that the AUC of CSM, RI and minimal sagittal muscle thickness in combination was higher than that of the single detection of each indicator, suggesting that the combination of CSM, RI and minimum sagittal muscle thickness for CSP diagnosis can effectively compensate for the insufficiency of single indicator detection and have higher value. It was also found that the AUC of CSM, minimal sagittal muscle thickness, and RI in combination for the diagnosis of type III CSP was higher versus that of each indicator alone, suggesting that the combination was of higher value in the diagnosis of CSP sub-types. Further, factors influencing CSP treatment were analyzed and it was found that pregnancy number, CSM, minimum sagittal muscle thickness, and gestational sac size were the related factors affecting CSP treatment and gestational sac size and CSM were independent factors affecting the treatment of patients with CSP. A previous study has demonstrated that gestational sac size can be considered as a meaningful factor in the prediction of the efficacy and safety of high intensity focused ultrasound treatment [22]. It has been revealed that monitoring CSM is of great importance for the prevention of uterine rupture in late pregnancy [19]. The study by Hu Hongyan et

al. showed that the minimum sagittal muscle thickness in CSP patients was significantly lower than that in normal prenatal examination pregnant women, and the thickness gradually decreased with the increase of pregnancy cycle, further confirming the diagnostic value of minimum sagittal muscle thickness for CSP [23]. The research results of Pan Changxia et al. showed that calculating the blood flow RI of CSP patients through transvaginal ultrasound can effectively evaluate the treatment effect. When the RI changes from low resistance to medium resistance, it indicates significant treatment effect, further indicating that blood flow RI is closely related to CSP [24].

In summary, this research demonstrated that changes in TV-CDU parameters facilitated CSP diagnosis. There was a correlation between the CSM, minimum sagittal muscle thickness changes, and RI with CSP sub-types, and the three ultrasound parameters in combination possessed high value for CSP diagnosis and CSP sub-types. Gestational sac size and CSM were independent factors affecting CSP treatment. This study lays a foundation to explore the effects of TV-CDU parameters in CSP diagnosis and CSP sub-types, and the relevant factors affecting patients' surgical effects. The scar pregnancy in type I CSP patients is relatively mild. We will further explore the research on its ability to restore normal pregnancy under expected conditions and its combination with the placenta accreta spectrum in future studies.

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Author contributions
Yuting Peng contributed to study design; Jia Liu contributed to manuscript editing; Jun Xie contributed to experimental studies; Quanlv Li contributed to data analysis. All authors read and approved the final manuscript.

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Data availability
The data that support the findings of this study are available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate
The study was approved by the Ethic Committee of Yueyang People's Hospital (approval number: 20201116) and followed the tenets of the Declaration of Helsinki. All participants were aware of this study and signed the written informed consent form.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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