



Value of three-dimensional transvaginal ultrasonography and contrast-enhanced ultrasonography in assessing prognosis of lauromacrogol sclerotherapy for cesarean scar pregnancy

Značaj transvaginalne trodimenzionalne ultrasonografije i ultrasonografije sa kontrastom u proceni prognoze skleroterapije lauromakrogolom kod trudnoće u ožiljku carskog reza

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Abstract

Background/Aim. When cesarean scar pregnancy (CSP) is diagnosed, it is proposed in clinical practice to remove the pregnancy tissue as soon as possible. Contrast-enhanced ultrasonography (CEUS) has higher diagnostic value for CSP compared to three-dimensional transvaginal ultrasonography (3D-TVUS). The aim of the study was to assess the efficiency of combining 3D-TVUS with CEUS in the prognosis of lauromacrogol sclerotherapy (LSC) for CSP. **Methods.** The study included patients with CSP admitted to our hospital and treated with LSC from January 2023 to January 2024 (CSP group, $n = 150$), and women with normal pregnancy after cesarean section (normal pregnancy group, $n = 150$). The CSP group was additionally divided into good and poor prognosis groups. Both groups received 3D-TVUS and CEUS, with quantitative parameters measured [3D-TVUS parameters: vascular index (VI), flow index (FI), and vascular FI (VFI)]. CEUS parameters included the area under the

time-intensity curve (AUC_{TIC}), arrival time (AT), time to peak (TTP), and peak intensity (PI). **Results.** After treatment, both CSP and normal pregnancy groups exhibited significant decreases in VI, FI, VFI, PI, and AUC_{TIC} , alongside a significant increase in TTP compared with baseline ($p < 0.05$). Conversely, compared with the good prognosis CSR group, the poor prognosis CSR group demonstrated higher VI, FI, VFI, PI, and AUC_{TIC} , as well as a shorter TTP, both before and after treatment ($p < 0.05$). The combined parameters of 3D-TVUS and CEUS showed the best predictive performance of LSC prognosis in CSP, significantly outperforming any single parameter. **Conclusion.** A considerable proportion of patients with CSP had poor short-term prognosis after LSC. Pretreatment 3D-TVUS and CEUS parameters may help in the early evaluation of short-term prognosis.

Keywords:

cesarean section; polidocanol; pregnancy, ectopic; prognosis; sclerotherapy; ultrasonography, prenatal.

Apstrakt

Uvod/Cilj. Kada se dijagnostikuje trudnoća u ožiljku od prethodnog carskog reza (*cesarean scar pregnancy* – CSP), u kliničkoj praksi se predlaže što ranije uklanjanje tkiva embriona. Ultrasonografija sa kontrastom (*contrast-enhanced ultrasonography* – CEUS) ima veću dijagnostičku vrednost za CSP u poređenju sa transvaginalnom trodimenzionalnom ultrasonografijom (*three-dimensional transvaginal ultrasonography* – 3D-TVUS). Cilj rada bio je da se proceni efikasnost kombinacije 3D-TVUS i CEUS u prognozi skleroterapije lauromakrogolom (*lauromacrogol sclerotherapy* – LSC) kod CSP. **Metode.** Istraživanje je uključilo pacijentkinje koje su imale CSP, primljene u našu bolnicu i lečene pomoću LSC od januara 2023. do januara 2024.

godine (grupa CSP, $n = 150$), kao i žene sa normalnom trudnoćom posle carskog reza ($n = 150$). Grupa CSR je dodatno podeljena na grupu sa dobrom i grupu sa lošom prognozom. Obe grupe su pregledane pomoću 3D-TVUS i CEUS, uz određivanje kvantitativnih parametara [parametri 3D-TVUS: vaskularni indeks (*vascular index* – VI), indeks protoka (*flow index* – FI) i indeks vaskularnog protoka (*vascular FI* – VFI)]. Parametri CEUS uključivali su *area under the time-intensity curve* (AUC_{TIC}), *arrival time* (AT), *time to peak* (TTP) i *peak intensity* (PI). **Rezultati.** Nakon tretmana, u obe grupe (CSP i sa normalnom trudnoćom) zabeleženo je značajno smanjenje vrednosti VI, FI, VFI, PI i AUC_{TIC} , uz značajno povećanje TTP u poređenju sa početnim vrednostima ($p < 0.05$). Nasuprot tome, u poređenju sa CSR grupom sa dobrom

prognozom, CSR grupa sa lošom prognozom pokazala je više vrednosti VI, FI, VFI, PI i AUC_{TIC} , kao i kraće TTP, kako pre tako i posle tretmana ($p < 0,05$). Kombinovani parametri 3D-TVUS i CEUS pokazali su najbolje prediktivne performanse u proceni prognoze LSC za CSP, značajno nadmašujući bilo koji pojedinačni parametar. **Zaključak.** Značajan broj pacijentkinja koje su

imale CSP imao je lošu kratkoročnu prognozu posle LSC. Parametri 3D-TVUS-a i CEUS pre tretmana mogu pomoći u ranoj proceni kratkoročne prognoze.

Ključne reči:

carski rez; polidokanol; trudnoća, ektopična; prognoza; skleroterapija; ultrasonografija, prenatalna.

Introduction

Cesarean scar pregnancy (CSP), a familiar complication after cesarean section (CS), displays no specific clinical manifestations in the early stage. Symptoms such as painless vaginal bleeding and lower abdominal pain may occur in only a few patients, which, if not diagnosed and intervened in time, increase the risk of events such as uterine rupture, placenta implantation, and uncontrollable intraperitoneal hemorrhage, serving as a serious threat to the safety of patients. In clinical practice, therefore, it is proposed to remove pregnancy tissues as soon as possible once CSP has been diagnosed^{1,2}. At present, curettage is a crucial method for treating CSP; however, vascular rupture easily occurs since tissues at the incision sites of CS in the lower uterine segment are weak, with poor flexibility and *vasa vasorum* going deep into the muscular layer, thus elevating the risk of massive hemorrhage³. Lauromacrogol, a foam hardener, exhibits high affinity for vascular endothelial cells and exerts a sclerosing effect by triggering vascular inflammation, thereby promoting cell fibrosis and necrosis after injection⁴. Considering its pharmacological characteristics, lauromacrogol is used clinically for the treatment of CSP. It is believed that satisfactory efficacy can be achieved by combining lauromacrogol sclerotherapy (LSC) to block local blood vessels at the scar site with curettage within 24 hrs⁵. At our center, LSC combined with curettage is a preferred treatment option for eligible type I/II CSP because it can directly reduce local trophoblastic blood supply before evacuation, thereby potentially decreasing intraoperative bleeding risk. Compared with more invasive surgical procedures or uterine artery embolization, this approach is minimally invasive, relatively easy to perform under ultrasound guidance, and may help preserve uterine integrity and reproductive potential in selected patients. Based on our institutional experience and available evidence, patients with type I/II CSP and suitable clinical conditions were managed using this treatment strategy. However, outcomes vary among patients because the implantation depth of the gestational sac within the scar differs⁶. Therefore, early assessment of LSC prognosis in patients with CSP has become a critical focus of current clinical research.

Currently, the evaluation of CSP relies predominantly on conventional two-dimensional (2D) transvaginal ultrasonography (TVUS) – 2D-TVUS. However, this method is limited in its ability to fully evaluate overall blood flow at the pregnancy site, so it fails to make an accurate assessment. In contrast, three-dimensional (3D) TVUS – 3D-TVUS can reflect the overall blood supply around scars, thus making a

more objective evaluation⁷. Contrast-enhanced ultrasonography (CEUS), a novel ultrasonic examination approach in which microbubble contrast agents enhance the backscatter of ultrasonic sound waves, has a stronger ability to assess microvascular perfusion at the site of CSP, offering higher diagnostic value for CSP⁸. The above studies have shown that 3D-TVUS and CEUS have high sensitivity and specificity for diagnosing CSP, but whether they can predict LSC prognosis in patients with CSP remains unclear.

Therefore, 3D-TVUS and CEUS were utilized in this study for the first time to predict LSC prognosis in patients with CSP, aiming to provide a reference for future research.

Methods

Subjects

A total of 150 patients with CSP, treated with LSC in our hospital from January 2023 to January 2024, were selected as the CSP group. Our hospital is a regional tertiary maternal and child health center receiving referred CSP cases from surrounding hospitals. They had undergone 1–3 previous CSs. As to disease types, there were 65 type I and 85 type II cases of CSP. The study was approved by the Ethics Committee of the Affiliated Maternal and Child Health Hospital of Nantong University, Nantong, Jiangsu, China (from January 18, 2023).

Inclusion and exclusion criteria

Patients were included if they met the following criteria: a documented history of CS with type I/II CSP confirmed by color Doppler ultrasonography or pelvic magnetic resonance imaging (MRI); an amenorrhea duration of ≥ 6 weeks with positive urine beta-human chorionic gonadotropin (β -HCG); normal cervical morphology and length; and a request for pregnancy termination *via* LSC, with written informed consent provided prior to study enrollment.

Exclusion criteria were as follows: type III CSP; severe hepatic, renal, or cardiopulmonary dysfunction or severe underlying systemic comorbidities; active local or systemic infection; history of prior CSP; other ectopic pregnancy locations (e.g., tubal or ovarian); those allergic to contrast agents; those intolerant to vaginal ultrasonography; or those with mental or communication disorders.

Recent imaging and vascular studies indicate that implantation into a previous CS scar is associated with

altered local vascular supply and scar niche formation⁹. In addition, the presence of a scar niche in the lower uterine segment may affect uterine perfusion and endometrial-myometrial integration¹⁰. Therefore, by selecting women with prior CS but with a current normal intrauterine pregnancy as the control group, we aimed to balance the surgical scar background while isolating the specific effect of scar-site implantation.

One hundred and fifty women with normal pregnancy after CS were included as a normal pregnancy group (NPG). They had undergone 1–3 previous CS and had a normal pregnancy confirmed by ultrasonography. All patients in the CSP group successfully completed LSC and the scheduled follow-up. No patient was lost to follow-up, and none were excluded after enrollment.

Three-dimensional transvaginal ultrasonography and contrast-enhanced ultrasonography

All subjects were examined using a color Doppler ultrasound system (Resona 7S, Mindray) equipped with a V11-3Hu intracavitary probe at a probe frequency of 5–9 MHz. Specifically, the gestational sac size, yolk sac, embryo, and fetal heart were observed first. Then, the 3D energy Doppler scanning was started in the uterus to obtain 3D blood flow imaging of the *vasa vasorum* at the implantation site of the gestational sac. The vascular index (VI), flow index (FI), and vascular FI (VFI) were calculated using VOCAL software, and the mean of three measurements was taken. Thereafter, the contrast mode was started: SonoVue contrast agent (Bracco, Italy) was mixed with 5 mL of 0.9% sodium chloride injection to prepare an ultrasonic microbubble contrast agent, and 1.2 mL of that agent was then injected through the elbow vein. Afterwards, the muscular layer at the scar underneath the serosa of the anterior isthmus was selected as the region of interest, in which the whole process of contrast agent perfusion was analyzed; a time-intensity curve was plotted, and CEUS parameters were obtained, including the area under the time-intensity curve (AUC_{TIC}), arrival time (AT), time to peak (TTP), and peak intensity (PI). The results were judged by two radiologists with 5 years of experience.

Lauromacrogol sclerotherapy

LSC was performed as follows: before LSC, patients underwent routine blood and urine examinations, coagulation function examination, hepatic and renal function examination, and gynecological examination, and were instructed to empty their bladder. Then, lauromacrogol was slowly injected into the muscular layer and peripheral contraction points around the gestational sac by transvaginal puncture in patients in a lithotomy position. The volume of raw lauromacrogol solution was 10–20 mL. The injection was stopped when the gestational sac showed sheet or annular enhancement with scarce peripheral blood flow. Curettage was performed within 24 hrs after LSC by the same team of physicians. After that, conventional postoperative anti-infection therapy, oxytocin-

induced uterine contraction, symptomatic fluid replacement, and other supportive treatments were carried out. In addition, patients were followed up by outpatient visits after surgery, during which postoperative vaginal bleeding, menstruation recovery, and β -HCG decline were monitored, and ultrasonography was conducted.

Evaluation of prognosis of lauromacrogol sclerotherapy

In this study, prognosis referred to short-term treatment response within one month after LSC. All patients with CSP followed the same follow-up protocol. Pre-treatment ultrasonography was performed within 24 hrs before lauromacrogol injection, and follow-up assessment was performed one month after the procedure. During follow-up, vaginal bleeding, menstrual recovery, serum β -HCG decline, and ultrasonographic findings were recorded.

Poor short-term prognosis was defined as the presence of residual gestational tissue with visible blood-flow signals on ultrasonography at one month after treatment, accompanied by an unsatisfactory decline in serum β -HCG and the need for additional treatment. The decision for retreatment was made by two experienced gynecologists based on the predefined clinical, serological, and ultrasonographic criteria. Patients without residual vascularized tissue and without the need for additional treatment were classified as having a good short-term prognosis.

Ultrasonographic images and parameters were evaluated by two radiologists with 5 years of experience. When disagreement occurred, a final decision was reached by discussion and consensus. According to this definition, 150 patients with CSP were divided into a good prognosis group (GPG; $n = 108$) and a poor prognosis group (PPG; $n = 42$).

Statistical analysis

SPSS 25.0 software was used for statistical analysis. Measurement data were expressed as mean $\pm$ standard deviation and compared using the independent-samples *t*-test between groups and the paired *t*-test within groups. Count data were expressed as frequency and percentage and compared using the χ^2 test. Receiver operating characteristic (ROC) curves were plotted with poor short-term prognosis after LSC as the state variable to evaluate the predictive performance of 3D-TVUS and CEUS parameters. Collinearity among candidate ultrasonographic parameters was assessed using the variance inflation factor (VIF), with $VIF < 5$ indicating no obvious multicollinearity. Multivariable logistic regression analysis was performed to identify independent predictors of poor short-term prognosis. The combined model was constructed using the predicted probability derived from the multivariable logistic regression equation. Internal validation was performed using 1,000 bootstrap resampling procedures, and calibration was assessed using the Hosmer-Lemeshow goodness-of-fit test and the Brier score. A two-sided $p < 0.05$ was considered statistically significant.

Results

Patients with CSP were 25–36 years old, with a mean age of 30.12 ± 2.54 years, while women with normal pregnancy were 25–35 years old, with a mean age of 30.19 ± 2.42 years. The baseline data showed no significant differences between the two groups ($p > 0.05$).

The CSP group had higher VI, FI, and VFI, as well as PI and AUC_{TIC}, and shorter TTP than the NPG ($p < 0.05$), whereas no significant difference was shown in the AT value between the two groups ($p > 0.05$) (Table 1).

Baseline characteristics, including age, BMI, gravidity, number of previous CSs, type of CSP, time since the last CS, days of amenorrhea, gestational sac diameter, myometrial thickness between the gestational sac and bladder, and β -HCG levels, showed no statistically significant differences ($p > 0.05$) between the GPG and PPG, indicating good comparability between the two cohorts (Table 2).

The VI, FI, and VFI dropped in both the PPG and the GPG after treatment compared with those before treatment ($p < 0.05$), and they were higher in the PPG than in the GPG both before and after treatment ($p < 0.05$) (Table 3).

Table 1

Parameters of 3D-TVUS and CEUS in normal pregnancy and CSP groups

Group	Parameter of 3D-TVUS			Parameter of CEUS			
	VI	FI	VFI	AT, s	TTP, s	PI, dB	AUC _{TIC} , dB×s
Normal pregnancy (n = 150)	8.21 ± 0.37	29.90 ± 3.11	4.13 ± 0.29	15.63 ± 2.31	23.76 ± 2.31	18.92 ± 2.13	190.09 ± 54.63
CSP (n = 150)	21.98 ± 2.43	43.54 ± 4.65	12.19 ± 2.14	15.21 ± 2.14	16.49 ± 1.78	27.87 ± 3.42	657.76 ± 54.56
t-test	68.610	29.860	45.710	1.672	30.530	27.210	74.190
p-value	< 0.001	< 0.001	< 0.001	0.095	< 0.001	< 0.001	< 0.001

3D-TVUS – three-dimensional transvaginal ultrasonography; **CEUS** – contrast-enhanced ultrasonography; **CSP** – cesarean scar pregnancy; **VI** – vascular index; **FI** – flow index; **VFI** – vascular flow index; **AT** – arrival time; **TTP** – time to peak; **PI** – peak intensity; **AUC_{TIC}** – area under the time-intensity curve; **n** – number. Values are given as mean $\pm$ standard deviation.

Table 2

Baseline data of CSP patients with different outcomes of LSC

Baseline characteristics	Poor prognosis group (n = 42)	Good prognosis group (n = 108)	χ^2/t	p-value
Age, years	30.19 ± 2.67	30.23 ± 2.85	0.079	0.938
BMI, kg/m ²	23.87 ± 2.19	23.90 ± 2.31	0.072	0.942
Gravidity				
2	16 (38.10)	39 (36.11)		
3	14 (33.33)	39 (36.11)	0.106	0.949
4	12 (28.57)	30 (27.78)		
Previous CS frequency				
1	16 (38.10)	62 (57.41)		
2	26 (61.90)	45 (41.67)	5.174	0.075
3	0	1 (0.93)		
CSP type				
I	19 (45.24)	46 (42.59)		
II	23 (54.76)	62 (57.41)	0.086	0.769
Time from the last CS, years	3.42 ± 0.29	3.49 ± 0.30	1.295	0.197
Number of amenorrhea days	46.56 ± 3.98	46.92 ± 4.12	0.485	0.628
Average diameter of the gestational sac, mm	20.12 ± 1.67	19.97 ± 1.85	0.458	0.648
Thickness of the gestational sac and bladder myometrium, mm	3.00 ± 0.12	3.02 ± 0.16	0.733	0.465
Blood β -HCG value, mIU/mL	$4,235.54 \pm 387.96$	$4,238.98 \pm 390.90$	0.048	0.961

CSP – cesarean scar pregnancy; **LSC** – lauromacrogol sclerotherapy; **n** – number; **BMI** – body mass index; **CS** – cesarean section; **β -HCG** – beta-human chorionic gonadotropin; **IU** – international units. Values are given as mean $\pm$ standard deviation and numbers (percentages).

Table 3

Parameters of 3D-TVUS in CSP patients with different outcomes of LSC before and after treatment

Group	VI		FI		VFI	
	before	after	before	after	before	after
Good prognosis (n = 108)	18.65 ± 2.23	$9.19 \pm 0.76^*$	39.65 ± 4.53	$30.42 \pm 2.98^*$	9.12 ± 1.03	$5.00 \pm 0.43^*$
Poor prognosis (n = 42)	23.43 ± 2.31	$13.32 \pm 1.85^*$	47.67 ± 6.98	$37.87 \pm 3.41^*$	14.34 ± 2.51	$7.18 \pm 0.26^*$
t-test	11.670	19.430	8.286	13.190	18.110	30.710
p-value	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001

3D-TVUS – three-dimensional transvaginal ultrasonography; **CSP** – cesarean scar pregnancy; **LSC** – lauromacrogol sclerotherapy; **VI** – vascular index; **FI** – flow index; **VFI** – vascular flow index; **n** – number. Values are given as mean $\pm$ standard deviation.

Note: * $p < 0.05$ vs. before treatment.

Table 4**Parameters of CEUS in CSP patients with different outcomes of LSC before and after treatment**

Group	AT, s		TTP, s		PI, dB		AUC _{TIC} , dB×s	
	before	after	before	after	before	after	before	after
Good prognosis (n = 108)	15.34 ± 1.22	15.24 ± 1.09	20.12 ± 2.07	23.41 ± 2.21*	22.12 ± 2.19	19.43 ± 1.75*	500.32 ± 54.64	231.23 ± 25.46*
Poor prognosis (n = 42)	15.28 ± 1.31	15.11 ± 1.17	12.32 ± 1.54	21.08 ± 1.32*	30.14 ± 3.45	20.28 ± 2.14*	700.98 ± 76.69	307.86 ± 54.59*
t-test	0.265	0.643	22.140	6.395	16.960	2.210	17.930	11.710
p-value	0.791	0.522	< 0.001	< 0.001	< 0.001	0.029	< 0.001	< 0.001

CEUS – contrast-enhanced ultrasonography; CSP – cesarean scar pregnancy; LSC – lauromacrogol sclerotherapy; AT – arrival time; TTP – time to peak; PI – peak intensity; AUC_{TIC} – area under the time-intensity curve; n – number.

Values are given as mean ± standard deviation.

Note: **p* < 0.05 vs. before treatment.

Table 5**Early predictive value of 3D-TVUS and CEUS parameters for LSC prognosis in CSP**

Index	AUC (95% CI)	Cut-off	Sensitivity, %	Specificity, %	<i>p</i> -value
VI	0.850 (0.793–0.925)	20.76	84.29	80.42	< 0.001
FI	0.804 (0.756–0.893)	43.12	81.50	76.90	< 0.001
VFI	0.800 (0.734–0.904)	11.47	81.00	76.87	< 0.001
TTP	0.869 (0.793–0.930)	16.56 s	85.45	81.43	< 0.001
PI	0.823 (0.734–0.912)	25.45 dB	82.13	80.98	< 0.001
AUC _{TIC}	0.887 (0.768–0.934)	589.92 dB×s	87.76	83.32	< 0.001
Combination	0.923 (0.856–0.987)	-	90.41	87.98	< 0.001

3D-TVUS – three-dimensional transvaginal ultrasonography; CEUS – contrast-enhanced ultrasonography; LSC – lauromacrogol sclerotherapy; CSP – cesarean scar pregnancy; AUC – area under the curve; CI – confidence interval; VI – vascular index; FI – flow index; VFI – vascular flow index; TTP – time to peak; PI – peak intensity; AUC_{TIC} – area under the time-intensity curve.

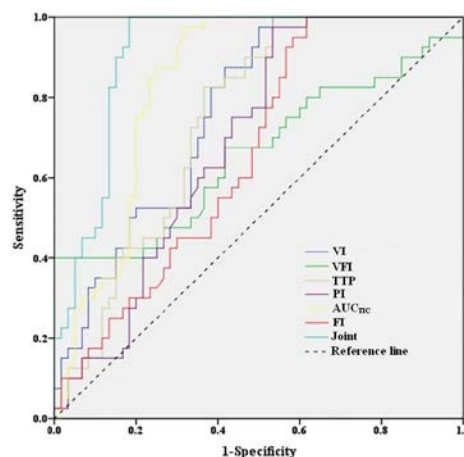


Fig. 1 – Receiver operating characteristic curves of parameters of three-dimensional transvaginal ultrasonography and contrast-enhanced ultrasonography in evaluating prognosis of lauromacrogol sclerotherapy for cesarean scar pregnancy.

VI – vascular index; VFI – vascular flow index; TTP – time to peak; PI – peak intensity; AUC_{TIC} – area under the time-intensity curve; FI – flow index.

Compared with pre-treatment, TTP was prolonged, while PI and AUC_{TIC} decreased in both groups after treatment (*p* < 0.05). In contrast to the GPG, the PPG showed shorter TTP (*p* < 0.05), higher PI and AUC_{TIC} (*p* < 0.05), and a comparable AT value (*p* > 0.05) before and after treatment (Table 4).

Collinearity analysis showed that the VIF values of the candidate ultrasonographic parameters were < 5, indicating no obvious multicollinearity. Therefore, VI, FI, VFI, TTP, PI, and AUC_{TIC} were included in the multivariate logistic regression model. The results showed that VI [odds ratio (OR) = 1.38, 95% confidence interval (CI): 1.12–1.69, *p* = 0.003], TTP (OR = 0.82, 95% CI: 0.71–0.94, *p* = 0.005), and AUC_{TIC} (OR = 1.015, 95% CI: 1.006–1.024, *p* = 0.001) were independent predictors of poor short-term prognosis after LSC.

The combined model was constructed using the predicted probability derived from the multivariable logistic regression equation. According to the ROC curves plotted with the prognosis of LSC in patients with CSP as the state variable and the ultrasonic parameters of significant differences between the PPG and the GPG (VI, FI, VFI, TTP, PI, and AUC_{TIC}) as the test variables, AUC_{TIC} performed the best in prediction among all the parameters, with AUC, sensitivity, and specificity of 0.887, 87.76%, and 83.32%, respectively. It was further found that the performance of the combination of all parameters in predicting the LSC prognosis in CSP was superior to that of any single parameter, and its AUC, sensitivity, and specificity were 0.923, 90.41%, and 87.98%, respectively (*p* < 0.05) (Table 5 and Figure 1). After 1,000

bootstrap resampling procedures, the optimism-corrected AUC was 0.911, suggesting good internal stability of the model. The calibration curve showed acceptable agreement between predicted and observed probabilities. Hosmer-Lemeshow test showed no significant lack of fit ($p = 0.428$), and the Brier score was 0.086, indicating acceptable calibration performance.

Discussion

According to the investigation, the incidence rate of CSP is about 6% among females with a history of CS, which is increasing annually. It is now accepted that the development of CSP is associated with endometrial injury and poor postoperative incision healing¹¹. In the case of CSP, the risks of uterine rupture and massive hemorrhage are relatively high due to the relatively thin myometrium where CSP develops and due to the relatively poor contractility of scar tissue. Even if a few pregnant patients successfully enter the third trimester, most of them suffer from dangerous complications such as placenta previa, placenta implantation, and other serious adverse events¹². Currently, the treatment of CSP mainly aims to terminate pregnancy as soon as possible to avoid the occurrence of serious adverse events. LSC, a common treatment for CSP, involves injecting lauromacrogol near veins to damage vascular endothelial cells and trigger an aseptic inflammatory response. This leads to venous occlusion and blocks local blood supply^{13–15}. The results of this study revealed that among the 150 patients with CSP, 42 had a poor prognosis after LSC, signifying that LSC is effective for CSP, but some patients still have a poor prognosis and recovery. This is attributed to the fact that scar tissue is weak, leading to deeper villous implantation.

As the preferred examination method for CSP, TVUS is characterized by easy operation, non-invasiveness, and high sensitivity, and does not require bladder filling compared with traditional transabdominal ultrasonography¹⁶. In 3D ultrasonography, 3D images are acquired based on 2D ultrasonography, in which the Y and Z planes are obtained from the X plane, thereby revealing the coronal section that cannot be displayed by 2D ultrasonography. As a result, relationships among the uterine cavity, gestational sac, mass, and incision are revealed from multiple sections^{17–19}. Huang et al.²⁰ compared the diagnostic efficacy of 3D-TVUS and MRI in CSP and discovered no significant difference in the detection rate of CSP between the two examination methods. Nevertheless, the detection rates of the yolk sac, embryo, and heartbeat with 3D-TVUS were significantly higher than those with MRI. In the present study, women with normal intrauterine pregnancies after CS were included as an external physiological reference. This design aimed to provide baseline values for 3D and CEUS parameters under normal conditions. By contrasting these physiological parameters with those observed in scar pregnancies, we were able to better characterize the abnormal vascularization and perfusion associated with scar implantation and further explore their

relationship with clinical prognosis in patients treated with LSC. Using this approach, 3D-TVUS was performed in both groups. The results revealed that the VI, FI, and VFI values were significantly higher in patients with CSP than in those with NPG. Possible reasons include the following: the gestational sac is implanted near the incision site of the previous CS, and the villi erode peripheral tissues to form a venous fistula. In addition, the muscle wall at the incision is thin, but blood vessels and fibrous tissues in this region are rich. As a result, the VI at this site is high, and there is more blood flow, increasing FI. Moreover, differences in 3D-TVUS parameters in patients with different LSC outcomes were further analyzed in this study. It was found that the VI, FI, and VFI rose in patients with poor prognosis, indicating more vessels and deeper implanted villi at the implantation location of the gestational sac in patients with poor prognosis. The ROC curves were plotted in this study to analyze the cut-off value of 3D-TVUS parameters in the early prediction of the LSC prognosis. The results showed that the optimal prediction performance was obtained when the values of VI, FI, and VFI were 20.76, 43.12, and 11.47, respectively, suggesting that in clinical practice, the prognosis of LSC can be predicted early by analyzing the quantitative parameters of 3D-TVUS before treatment.

CEUS can effectively distinguish the difference in blood perfusion between lesions and normal tissues, identify blood flow signals that conventional ultrasonography cannot distinguish, and inhibit peripheral tissue signals under a low mechanical index, thereby judging the relationship between the gestational sac and the perimetrium layer^{21, 22}. After CS, adhesion is observed in the fundus and abdominal wall, and the uterus and cervix are elongated, thereby limiting the application of TVUS²³. However, the above phenomena do not restrict the application of CEUS, i.e., the blood flow in the trophoblast can be displayed in CEUS. The results of the present study showed that the AT was not significantly different between the CSP group and the NPG, whereas shorter TTP and higher PI and AUC_{TIC} were found in the CSP group compared with the NPG. These results officially reflected the rich blood flow of the gestational sac at the incision in CSP. Wu et al.²⁴ found that CEUS could guide the selection of the location of lauromacrogol injection for patients with CSP, and the postoperative morphological indices could fully predict the curative effect after curettage and guide clinical treatment. In this study, CEUS was used to evaluate the prognosis of LSC in patients with CSP. The results revealed that TTP was prolonged, and PI and AUC_{TIC} declined after treatment compared with before treatment, demonstrating that LSC is markedly effective in the treatment of CSP. The PPG displayed shortened TTP and higher PI and AUC_{TIC} than the GPG both before and after treatment. It is possibly because patients with poor prognosis have more blood vessels in and around the gestational sac, as well as faster local blood flow, so part of the injection may flow away rapidly through the villous space when LSC is performed. As a result, complete

sclerosis fails, resulting in poor prognosis. Furthermore, to determine the cut-off values of CEUS parameters for predicting LSC prognosis, ROC curves were plotted, and it was found that when TTP, PI, and AUC_{TIC} were 16.56 s, 25.45 dB, and 589.92 dB×s, respectively, the optimal predictive performance was obtained. Among them, AUC_{TIC} displayed the best prediction performance, and its AUC, sensitivity, and specificity were 0.887, 87.76%, and 83.32%, respectively. These results suggest that early prediction of the prognosis of LSC can be achieved clinically by observing blood vessels and local blood flow.

Additionally, we found that for predicting the LSC prognosis in CSP, the combination of 3D-TVUS and CEUS was more effective than single parameters. This shows that 3D-TVUS with CEUS is more helpful for improving the early evaluation of the prognosis of LSC in CSP. This is possibly ascribed to the following facts: the blood supply to the pregnancy focus is reflected by various blood flow parameters in 3D-TVUS, whereas CEUS reveals blood flow information in smaller vessels. The two examination methods complement each other's advantages, thereby enhancing prediction performance. From a clinical perspective, these ultrasound parameters may help translate imaging findings into individualized perioperative management. Higher VI, FI, VFI, PI, and AUC_{TIC} values, together with shortened TTP, indicate richer local vascularization and faster perfusion around the gestational sac, suggesting a higher risk of incomplete devascularization, residual vascularized tissue, and unsatisfactory β -HCG decline after LSC. Therefore, patients with parameters exceeding the proposed cut-off values, especially those with elevated AUC_{TIC} or a high combined ultrasound assessment, may be considered at higher risk of poor short-term response. In practical management, such patients may benefit from more detailed preoperative counseling, closer preparation for possible bleeding, treatment by an experienced operator, and more intensive post-treatment monitoring of serum β -HCG and ultrasonographic residual blood-flow signals²⁵. In contrast, patients with lower-risk ultrasound features may undergo routine follow-up after treatment. Thus, the combined use of 3D-TVUS and CEUS may provide a practical imaging-based framework for early risk stratification, although treatment decisions should still be made comprehensively according to clinical symptoms, β -HCG trends, and follow-up ultrasound findings²⁶.

These findings should also be interpreted in the context of recent international guidelines and expert recommendations. The 2022 Society for Maternal-Fetal Medicine – SMFM Consult Series #63 recommends against expectant management of CSP and suggests operative resection or ultrasound-guided uterine aspiration as potential surgical approaches, while sharp curettage alone should be avoided. Intra-gestational methotrexate may be administered with or without other treatment modalities, whereas systemic methotrexate alone is not recommended²⁵. Since this guideline does not specifically evaluate LSC and acknowledges that the optimal treatment strategy remains uncertain, the present findings provide

complementary evidence for pretreatment risk stratification and post-treatment monitoring within a minimally invasive sclerotherapy protocol, rather than establishing a universally preferred treatment approach. Meanwhile, an international Delphi consensus on the sonographic assessment of first-trimester CSP recommends TVUS at 6–7 weeks of gestation and standardized documentation of gestational-sac size, vascularity, its relationship with the uterine vessels, residual myometrial thickness, and its location relative to the uterine cavity and serosa; routine MRI was not considered to provide additional diagnostic value²⁷. Our findings extend this standardized anatomical assessment by demonstrating the potential prognostic value of quantitative 3D vascular indices and CEUS perfusion parameters. More recently, the 2026 Royal College of Obstetricians and Gynaecologists Green-Top Guideline recognized CSP as a potential precursor of placenta previa and placenta accreta spectrum and emphasized expert counseling regarding these risks when a live pregnancy persists beyond the first trimester²⁸. Although the patients in the present study underwent pregnancy termination and the continuation of pregnancy was not evaluated, this guideline perspective further reinforces the importance of early diagnosis, individualized counseling, and preparedness for severe hemorrhage in patients with marked vascularity. Therefore, the proposed ultrasonographic cut-off values should complement, rather than replace, comprehensive assessment based on clinical symptoms, serum β -HCG trends, residual myometrial thickness, gestational characteristics, and local treatment expertise.

Limitations of the study

This study has several limitations. First, this was a single-center retrospective study with a relatively limited sample size, which may restrict the generalizability of the findings. Second, the NPG was used only as a physiological reference group for ultrasonographic perfusion characteristics, rather than as a true prognostic control group. Therefore, the main prognostic conclusions should be interpreted based on the comparison between good- and poor-prognosis patients within the CSP cohort. Third, the follow-up period was limited to one month, so the outcome evaluated in this study should be regarded as short-term treatment response rather than final long-term treatment success. Longer follow-up is needed to assess complete lesion resolution, recurrence, and reproductive outcomes. Fourth, although ultrasound assessment was performed by experienced radiologists and disagreements were resolved by consensus, formal interobserver variability analysis was not conducted. Finally, although multivariable logistic regression, internal validation, and calibration analysis were added, this was still a single-center retrospective study without external validation. Further prospective multicenter studies with larger samples are required to confirm the independent predictive value and generalizability of these parameters.

Conclusion

A considerable proportion of patients with cesarean scar pregnancy had poor short-term prognosis after lauromacrogol sclerotherapy. Pretreatment transvaginal three-dimensional ultrasonography and contrast-enhanced

ultrasonography parameters may help in the early evaluation of short-term prognosis after lauromacrogol sclerotherapy.

Conflict of interest

The author declares no conflict of interest.

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