# Predictive values of cervix length measurement based on transvaginal ultrasonography combined with pathological examination of placenta for premature delivery and correlation between premature delivery and infection

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**Abstract. – OBJECTIVE: The predictive values of cervix length (CL) measurement based on transvaginal ultrasonography (TVUS) and pathological examination of placenta for premature delivery (PTD) were investigated, and the correlation between PTD and infection was analyzed.**

**PATIENTS AND METHODS: A total of 120 pregnant women with PTD or high-risk factors for PTD admitted to Hengyang Maternal and Child Health Hospital, between February 2020 and March 2022 were included in this retrospective study. There were 36 subjects in the PTD group and 84 in the normal delivery group (control group). They underwent pathological examination of the placenta and TVUS for CL measurement. The final gestational age was set as the standard for the evaluation of the predictive values of pathological examination of the placenta and TVUS. Moreover, a pathological examination of the placenta was used to analyze the correlation between PTD and infection.**

**RESULTS: The sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) of joint inspection were remarkably superior to those of single CL or pathological examination of the placenta (*p*<0.05). The proportion of pregnant women with CL ≤30 mm and positive placental pathology was higher than that of pregnant women with CL >30 mm and negative placental pathology (*p*<0.05). In addition, the incidence of Ureaplasma urealyticum (UU), Chlamydia trachomatis (CT), and chorioamnionitis (CA) in the vaginal discharge of the PTD group was markedly superior to that of the control group (*p*<0.05).**

**CONCLUSIONS: The combination of CL ≤30 mm and positive placental pathology could effectively predict PTD, and placental infection was notably correlated with the occurrence of PTD.**

*Key Words:*
Transvaginal ultrasonography, Cervix length, Pathological examination of placenta, Premature delivery, Infection.

## Introduction

In recent years, the incidence of premature delivery (PTD) becomes more and more higher due to the development of auxiliary reproduction and ovulation induction technologies and the changes in pregnant women's lifestyle and physical quality[1-3]. PTD not only affects postpartum recovery and causes great physical pains, but it also has adverse effects on the birth state of neonates and even leads to neonatal death[4,5]. In most cases, premature infants who are born before week 32 can only survive for less than 1 year. Survivors suffer from various complications, such as cerebral palsy, pulmonary diseases, and visual and hearing disorders, bringing about huge economic burdens to their families[6,7]. PTD can be predicted through various examination methods, and early evaluation of pregnant women's delivery status can effectively prevent PTD and improve neonatal survival rate[8,9]. Based on PTD prediction, early detection and intervention and the prolongation of gestational weeks can reduce premature infant mortality and improve prognosis[10]. At

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present, the common clinical methods for PTD prediction mainly include cervix length (CL) measurement, neonatal fibronectin examination, and human chorionic gonadotropin (HCG) examination. Transvaginal ultrasonography (TVUS) is the main method for CL measurement, which is widely applied in clinical practice[11]. It is characterized by simple operation, low price, and little trauma to pregnant women. Based on TVUS, fetal physical health, and pregnant women's cervix status can be better understood. TVUS is not harmful to pregnant women and fetuses with high sensitivity and specificity[12]. PTD can be reliably predicted, and intervention is performed in time through TVUS-based CL measurement, which plays a positive role in preventing and controlling PTD[13]. Progressive stretching and shortening of the cervical canal and progressive dilation of the internal cervical orifice mark the beginning of labor[14,15]. Before cervical dilation, cervical images can be generated through TVUS. In addition, intervention can be performed on any abnormality before cervical dilation is detected. Hence, ultrasonography and CL measurement can be carried out to obtain basic data on the cervix for PTD prediction and the reduction in PTD incidence[16,17]. Moreover, pathological examination of the placenta can also be applied to PTD prediction for obtaining general data on parturients and neonates[18]. Intrauterine infection may result in PTD and is related to various complications among premature infants. The investigation into the relationship between PTD and infection is of great significance in clinical practice[19,20].

This study was conducted to explore the predictive values of CL based on measurement TVUS combined with pathological examination of the placenta for PTD and analyze the correlation between PTD and infection. In addition, CL and placental pathology of PTD patients and pregnant women with normal delivery were compared. The prediction effects of different examination methods on PTD were analyzed. The incidence of postpartum and neonatal complications in different groups was investigated to provide guidance and references for normal delivery and clinical references for the prevention and control of PTD.

## Patients and Methods

### Subjects

After excluding 9 people according to the exclusion criteria, 120 pregnant women with PTD or high-risk factors for PTD admitted to Hengyang Maternal and Child Health Hospital between February 2020 and March 2022 were included in this retrospective study. They were divided into two groups based on pregnancy outcomes, including the PTD group (36 cases) and the control group (84 with normal delivery). All subjects underwent pathological examination of the placenta and TVUS for CL measurement. The final gestational age was set as the standard for the evaluation of the predictive values of pathological examination of the placenta and TVUS for PTD. Moreover, the predictive values of single examination and joint inspection for pregnancy outcomes were analyzed, and the postpartum and neonatal outcomes of the two groups were compared. No statistical differences but comparability was detected in age and years of education between the two groups. The Medical Ethics Committee had approved the implementation of this research. All subjects have signed informed consent forms. The flow diagram of this study is shown in Figure 1.

The inclusion criteria are listed below.

1. Patients with complete medical records.
2. Patients over 18 years old.
3. Patients without contraindications to TVUS.
4. Patients without a surgical history.
5. Patients who had volunteered to participate in the research and signed informed consent forms.

The exclusion criteria are listed below.

1. Patients with incomplete medical records.
2. Patients with major organ diseases.
3. Patients with mental disorders or dementia.
4. Patients who were unwilling to cooperate with the research.
5. Patients with other diseases during pregnancy.
6. Patients who had to withdraw due to severe complications and specific physiological changes.

### Methods

The pregnant women in both groups received TVUS. Color Doppler ultrasound diagnosis instrument (HITACHI Preirus, Japan) was utilized, and probe frequency ranged from 4 MHz to 9 MHz. After that, TVUS was carried out to measure the subjects' CL. Pregnant women were instructed to take the vesical calculus position after emptying the bladder. Consequently, the structures of internal and external cervical orifices were displayed. Next, CL was measured. Measurements were taken by two senior ultrasonographers after uniform training using the same

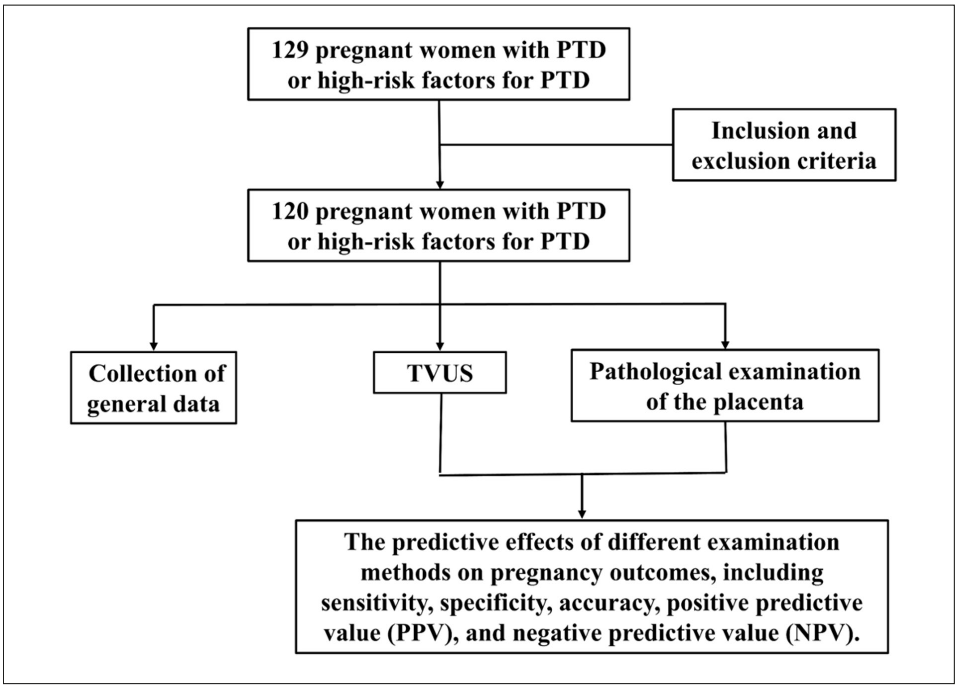


**Figure 1.** The flow diagram of this study.

criteria. The average of the measurements taken by the two doctors was taken as the final result. Finally, all subjects underwent a pathological examination of the placenta.

### Observation Indicators

The general data on the two groups were summarized, mainly including years of education, average age, body mass index (BMI), and number of pregnancies. The calculation method for BMI was displayed as equation (1).

$$BIM = \frac{Weight}{Height^2} \quad (1)$$

CL of the two groups was compared and analyzed.

The placental pathology of the two groups was compared and analyzed.

The incidence of Ureaplasma urealyticum (UU), Chlamydia trachomatis (CT), and chorioamnionitis (CA) in two groups was compared and analyzed.

The predictive effects of different examination methods on pregnancy outcomes were compared and analyzed, including sensitivity, specificity, accuracy, positive predictive value (PPV), and negative predictive value (NPV). The gold standard for the diagnosis was final gestational age. The calculation methods for sensitivity, specificity, accuracy, PPV, and NPV were shown as equations (2), (3), (4), (5), and (6), respectively. PB, PM, YDB, YDM, DB, and DM represented the number of patients with negative outcomes, positive outcomes, negative PTD, positive PTD, negative outcomes, and positive outcomes in cervical examination or pathological examination of the placenta, respectively.

$$Sensitivity = \frac{DM}{PM} \times 100\% \quad (2)$$

$$Specificity = \frac{DB}{PB} \times 100\% \quad (3)$$

$$\text{Accuracy} = \frac{\text{DM+DB}}{\text{PB+PM}} \times 100\% \quad (4)$$

$$\text{Positive predictive value} = \frac{\text{DM}}{\text{YDM}} \times 100\% \quad (5)$$

$$\text{Negative predictive value} = \frac{\text{DB}}{\text{YDB}} \times 100\% \quad (6)$$

Neonatal outcomes of the two groups were compared and analyzed, mainly including neonatal asphyxia, neonatal pneumonia, and pathologic jaundice. The calculation method for the incidence of neonatal complications ($\text{Complication}_N$) was presented as equation (7). Number of $\text{complications}_N$ and $\text{Total}_N$ referred to the number of neonates with complications and total number of neonates, respectively.

$$\text{ComplicationN} = \frac{\text{Number of complicationsN}}{\text{TotalN}} \quad (7)$$

Postpartum outcomes of the two groups were compared and analyzed, mainly including postpartum infection, postpartum hemorrhage, and difficult wound healing. The calculation method for the incidence of postpartum complications among pregnant women ($\text{Complication}_P$) was displayed as equation (8). The number of $\text{complications}_P$ and $\text{Total}_P$ represented the number of pregnant women with postpartum complications and a total number of pregnant women, respectively.

$$\text{ComplicationP} = \frac{\text{Number of complicationsP}}{\text{TotalP}} \quad (8)$$

### Statistical Analysis

Statistical Package for the Social Sciences (SPSS) v. 20 (IBM Corp., Armonk, NY, USA) was utilized for data statistics and analysis. Measurement data were denoted by means ± standard deviation (SD) and analyzed using a Student's *t*-test. Enumeration data were denoted by percentage (%) and analyzed using the $\chi^2$ test. $p<0.05$ demonstrated statistical differences.

## Results

### Comparison of the General Data on Two Groups

As illustrated in Table I, years of education, average age, BMI, and the number of pregnancies of control and PTD groups amounted to 12.14±3.62 *vs.* 12.23±3.81, 30.66±5.21 *vs.* 30.19±5.58, 25.38±3.15 kg/m$^2$ *vs.* 25.46±3.58 kg/m$^2$, and 2.19±1.28 *vs.* 2.23±1.45, respectively. No statistical differences but comparability were detected in the above general data between the two groups ($p>0.05$).

### Comparison and Analysis of CL in Two Groups

Figures 1 and 2 show the number and proportion of cases with different CLs, respectively. The number of pregnant women with CL greater than 30 mm, between 20 and 30 mm, and less than 20 mm in control and PTD groups amounted to 69 (82.14%) *vs.* 7 (19.44%), 11 (13.1%) *vs.* 19 (52.78%), and 4 (4.76%) *vs.* 10 (27.78%), respectively ($p<0.05$).

### Comparison and Analysis of Placental Pathology of the Two Groups

Figure 3 presents the proportion of pregnant women with positive and negative outcomes in two groups, respectively. The number of positive and negative cases in the control and PTD groups amounted to 18 (21.43%) *vs.* 29 (80.56%) and 66 (78.57%) *vs.* 7 (19.44%), respectively ($p<0.05$).

### Comparison and Analysis of the Incidence of CT, UU, and CA in two Groups

Figures 4A and 4B show the incidence of CT, UU, and CA, respectively. The incidence of CT,

**Table I.** The general data on two groups.

| Groups | Years of education (years) | Age (years) | BMI (kg/m$^2$) | Number of pregnancies |
|---|---|---|---|---|
| Control group | 12.14 ± 3.62 | 30.66 ± 5.21 | 25.38 ± 3.15 | 2.19 ± 1.28 |
| PTD group | 12.23 ± 3.81 | 30.19 ± 5.58 | 25.46 ± 3.58 | 2.23 ± 1.45 |

BMI: body mass index; PTD: premature delivery.

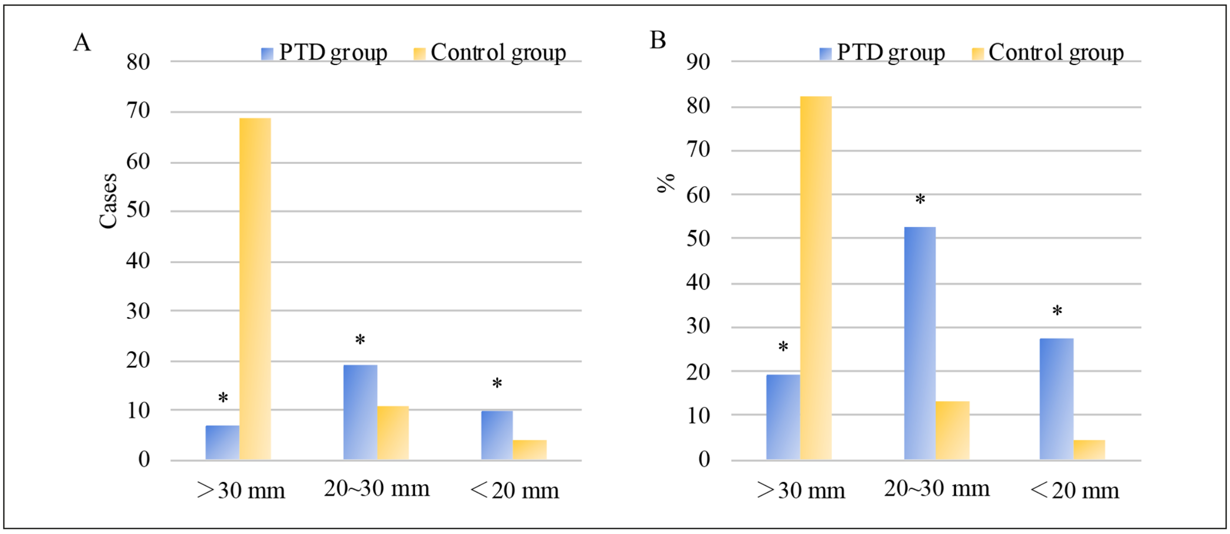


**Figure 2.** CL of the two groups. **A**, The number of patients with different CL. **B**, Proportions of patients with different CL. *Revealed that the differences between the two groups suggested $p < 0.05$.

UU, and CA in control and PTD groups amounted to (3.57%, 26.19%, and 19.05%) *vs.* (13.89%, 52.78%, and 58.33%), respectively ($p<0.05$).

Comparison and Analysis of the Predictive Effects of Different Examination Methods on Pregnancy Outcomes

As illustrated in Table II, the sensitivity of pathological examination of the placenta, CL examination, and joint inspection among pregnant women undergoing delivery for less than 3 d, 7 d, and 37 weeks amounted to (100%, 100%, 100%), (83.33%, 77.78%, 88.89%), and (66.67%, 66.67%, 77.78%), respectively. The sensitivity of joint inspection was notably superior to that of single examination ($p<0.05$). Moreover, the predictive sensitivity was the highest among those undergoing delivery for less than 3 d, which was followed by that among those receiving delivery for less than 7 d.

As presented in Table III, the specificity of pathological examination of the placenta, CL examination, and joint inspection among pregnant women undergoing delivery for less than 3 d, 7 d, and 37 weeks amounted to (72.22%, 77.78%,

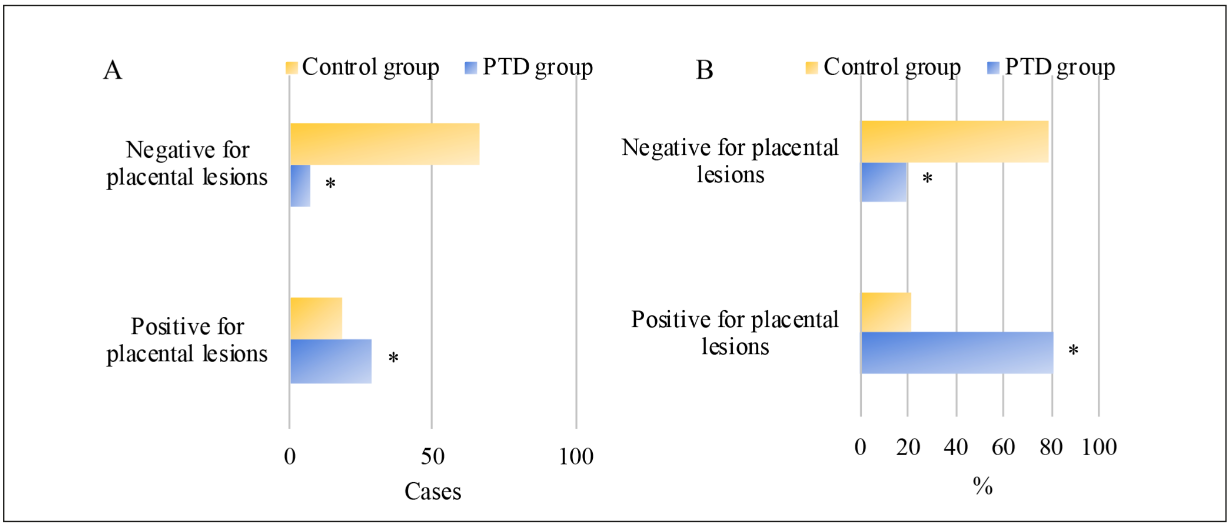


**Figure 3.** Placental pathology of two groups. **A**, Number of positive and negative cases. **B**, Proportions of positive and negative cases. *Revealed that the differences between the two groups suggested $p < 0.05$).

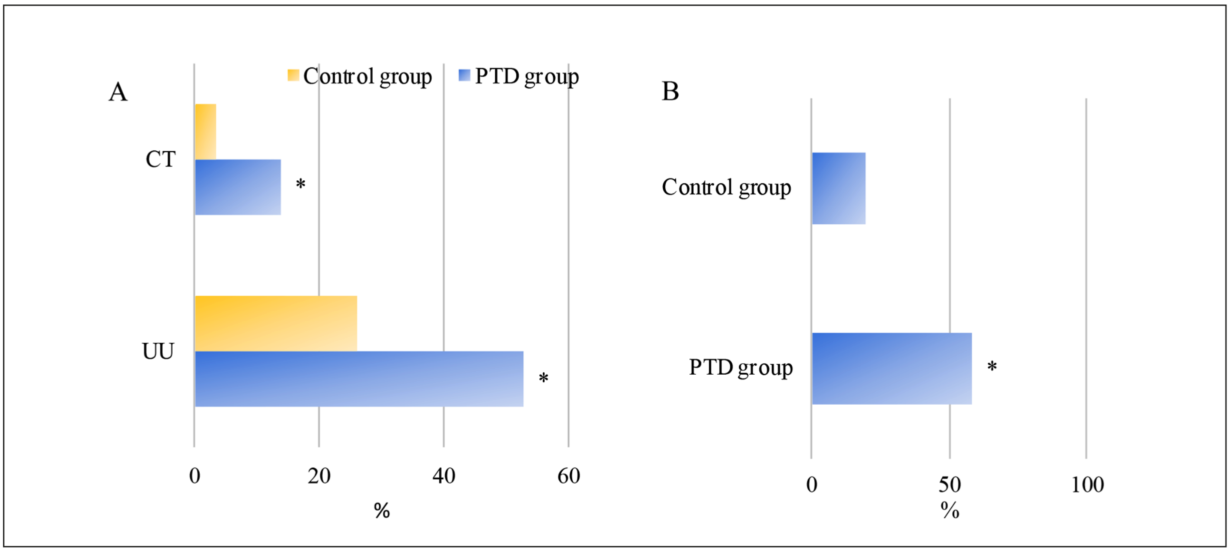


**Figure 4.** The incidence of CT, UU, and CA in two groups. **A**, CT, and UU. **B**, CA. * revealed that the differences between the two groups suggested $p < 0.05$.

**Table II.** Sensitivity of the prediction of pregnancy outcomes by different examination methods.

| Delivery time | Sensitivity (%) | | |
|---|---|---|---|
| | Pathological examination of the placenta | CL | Joint inspection |
| < 3 days | 100 | 100 | 100 |
| < 7 days | 83.33 | 77.78 | 88.89 |
| < 37 weeks | 66.67 | 66.67 | 77.78 |

**Table III.** Specificity of the prediction of pregnancy outcomes by different examination methods.

| Delivery time | Specificity (%) | | |
|---|---|---|---|
| | Pathological examination of the placenta | CL | Joint inspection |
| < 3 days | 72.22 | 77.78 | 83.33 |
| < 7 days | 88.57 | 85.71 | 91.43 |
| < 37 weeks | 90.32 | 87.1 | 93.55 |

83.33%), (88.57%, 85.71%, 91.43%), and (90.32%, 87.1%, 93.55%), respectively. The specificity of joint inspection was remarkably superior to that of single examination ($p<0.05$). The predictive specificity was the highest among those undergoing delivery for less than 37 weeks, which was followed by that among those receiving delivery for less than 7 d.

As displayed in Table IV, the accuracy of pathological examination of the placenta, CL examination, and joint inspection among pregnant women undergoing delivery for less than 3 d, 7 d, and 37 weeks amounted to (81.48%, 85.19%, 88.89%), (86.79%, 83.02%, 90.57%), and (85%, 82.5%, 90%), respectively. The accuracy of joint inspection was notably superior to that of single examination ($p<0.05$).

As illustrated in Table V, PPV of pathological examination of the placenta, CL examination, and joint inspection among pregnant women undergoing delivery for less than 3 d, 7 d, and 37 weeks amounted to (64.29%, 69.23%, 75%), (78.95%, 73.68%, 84.21%), and (66.67%, 60%, 77.78%), respectively. PPV of joint in-

**Table IV.** Accuracy of the prediction of pregnancy outcomes by different examination methods.

| Delivery time | Accuracy (%) | | |
|---|---|---|---|
| | Pathological examination of the placenta | CL | Joint inspection |
| < 3 days | 81.48 | 85.19 | 88.89 |
| < 7 days | 86.79 | 83.02 | 90.57 |
| < 37 weeks | 85 | 82.5 | 90 |

**Table V.** PPV of the prediction of pregnancy outcomes by different examination methods.

| Delivery time | Positive predictive value (%) | | |
|---|---|---|---|
| | Pathological examination of the placenta | CL | Joint inspection |
| < 3 days | 64.29 | 69.23 | 75 |
| < 7 days | 78.95 | 73.68 | 84.21 |
| < 37 weeks | 66.67 | 60 | 77.78 |

spection were dramatically superior to those of single examination ($p<0.05$). PPV was the highest among those undergoing delivery for less than 7 d.

As displayed in Table VI and Figure 5, NPV of pathological examination of the placenta, CL examination, and joint inspection among pregnant women undergoing delivery for less than 3 d, 7 d, and 37 weeks amounted to (100%, 100%, 100%), (91.18%, 88.24%, 91.43%), and (90.32%, 90%, 93.55%), respectively. NPV of joint inspection was much superior to those of single examination ($p<0.05$), and NPV was the highest among those undergoing delivery for less than 3 d.

### *Comparison and Analysis of Neonatal Outcomes in Two Groups*

As presented in Figure 6, the number of neonates with asphyxia, pneumonia, and pathologic jaundice in control and PTD groups amounted to 2 (2.38%) *vs.* 2 (5.55%), 1 (1.19%) *vs.* 7 (19.44%), and 8 (9.52%) *vs.* 4 (11.11%), respectively ($p<0.05$).

### *Comparison and Analysis of Postpartum Outcomes in Two Groups*

As illustrated in Figure 7, the number of pregnant women with postpartum infection, hemorrhage, and difficult wound healing in control and PTD groups amounted to 8 (9.52%) *vs.* 9 (25%), 10 (11.9%) *vs.* 11 (30.56%), and 5 (5.95%) *vs.* 6 (16.67%), respectively ($p<0.05$).

## Discussion

In this study, we investigated the predictive values of cervix length (CL) measurement based on transvaginal ultrasonography (TVUS) and pathological examination of placenta for premature delivery (PTD), and the correlation between PTD and infection was analyzed. We found that the combination of CL≤30 mm and positive placental pathology could effectively predict PTD, and placental infection was notably correlated with the occurrence of PTD.

Premature infants are light in weight and weak in constitution, and most of their organs are not

**Table VI.** NPV of the prediction of pregnancy outcomes by different examination methods.

| Delivery time | Negative predictive value (%) | | |
|---|---|---|---|
| | Pathological examination of the placenta | CL | Joint inspection |
| < 3 days | 100 | 100 | 100 |
| < 7 days | 91.18 | 88.24 | 91.43 |
| < 37 weeks | 90.32 | 90 | 93.55 |

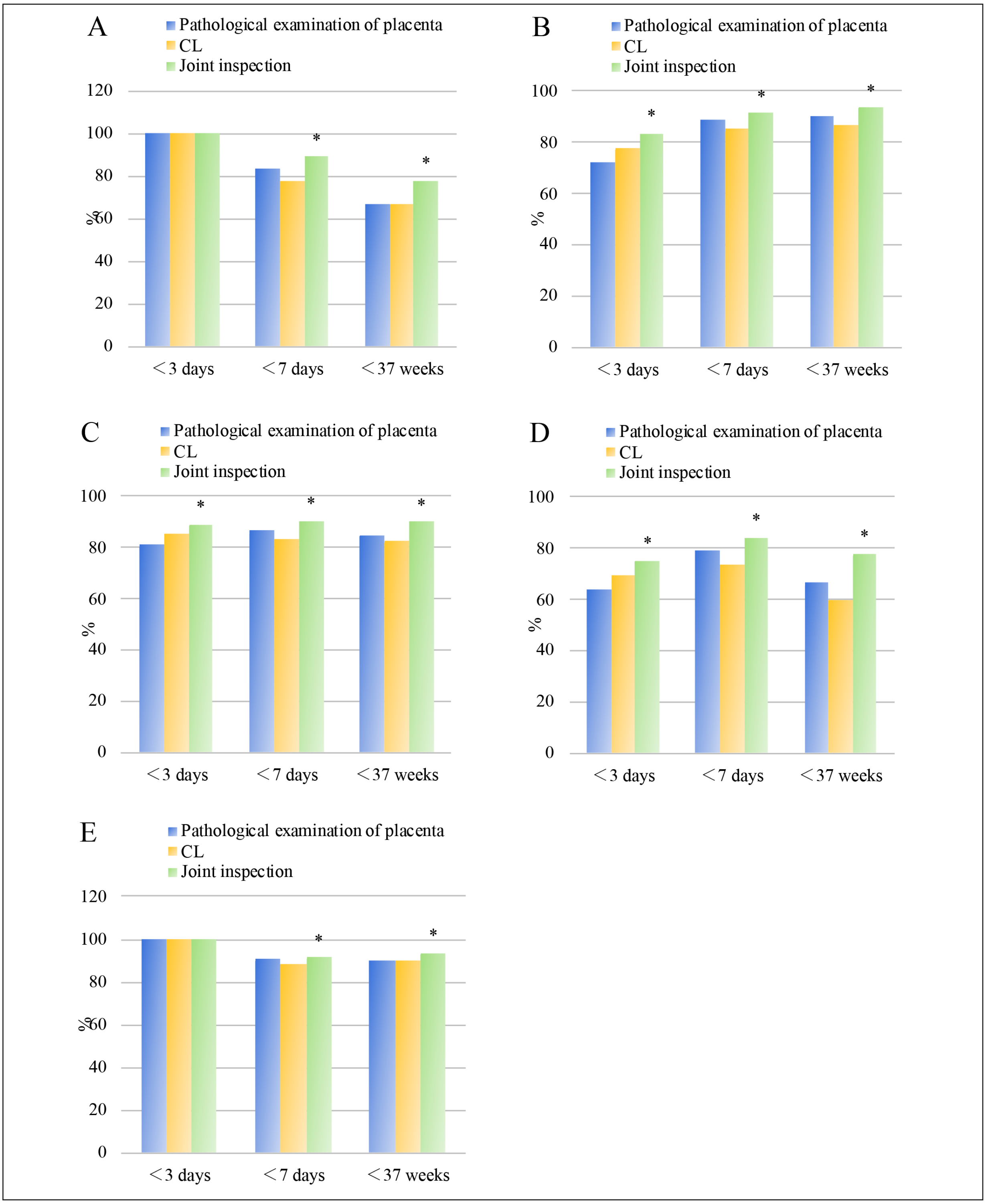


**Figure 5.** Predictive effects of different examination methods on pregnancy outcomes. **A**, Sensitivity. **B**, Specificity. **C**, Accuracy. **D**, PPV. **E**, NPV. *Revealed that the differences among the three examination methods suggested $p < 0.05$.

fully mature. Even worse, some neonates die during the perinatal stage. Furthermore, various short- and long-term complications seriously affect normal neonatal development[21,22]. TVUS-based CL measurement plays a positive role in PTD prediction. During TVUS, cervical

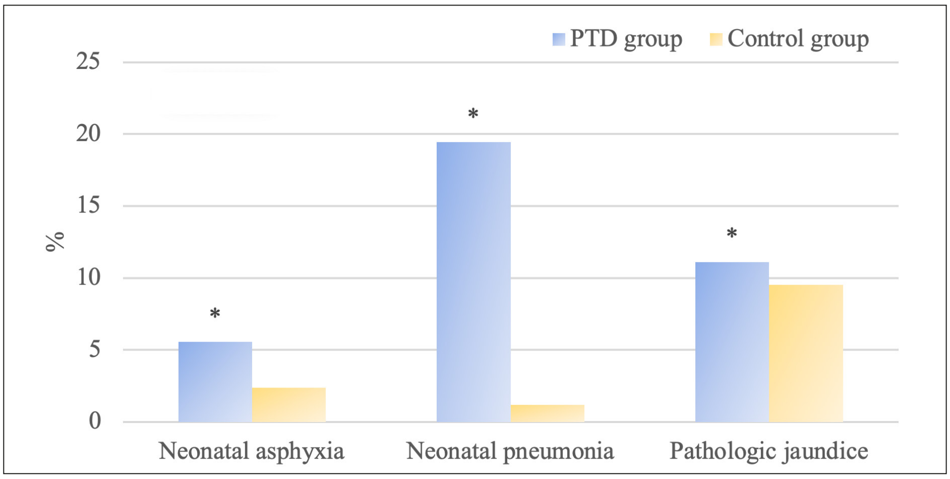


**Figure 6.** Neonatal outcomes in two groups. *Revealed that the differences between the two groups suggested $p < 0.05$.

compression should be avoided to prevent the deformity of anatomical morphology. In addition, the cervical sagittal plane is scanned to show the length of endocervical mucosa, observe internal and external cervical orifices, and measure the distance between them[23,24]. TVUS can not only be adopted for CL measurement, but it is also applied in the observation of cervical morphology and internal and external orifices[25,26]. With the advent of an expected date of delivery, the uterus continuously dilates so that the cervical canal is compressed and the cervix is gradually shortened. CL is an important predictor for PTD through which labor and fetal status can be understood and delivery time can be estimated[27,28]. In addition, PTD can be predicted based on placental pathology. The joint inspection is more specific and sensitive in PTD prediction, so it is widely recognized by patients and shows remarkable clinical application values.

Thain et al[29] analyzed the relationship between PTD and CL and found that the CL of the PTD group was much shorter than that of the term group during pregnant metaphase (weeks 18 to 22) and late pregnancy (weeks 28 to 32). Furthermore, the CL of the PTD group was shorter during early pregnancy (weeks 11 to 14). According to the analysis of receiver operating characteristic (ROC) curves of CL of the PTD group (weeks 18 to 22 and weeks 28 to 32), CL of the PTD group was notably shortened during the 2$^{nd}$ and 3$^{rd}$ trimesters of pregnancy. CL is a moderate predictor for PTD with good NPV and relatively good specificity.

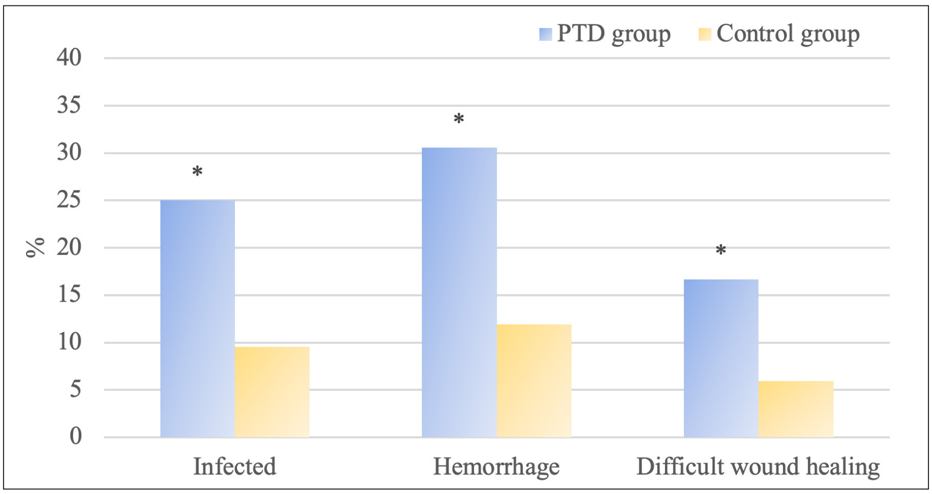


**Figure 7.** Postpartum outcomes in two groups. *Revealed that the differences between the two groups suggested $p < 0.05$.

Ultrasound CL screening for Asian pregnant women during weeks 18 to 22 (cut-off length ≥ 2.48 cm) was conducive to predicting PTD risk. The identification of PTD was a clinical challenge. The shortening of CL during the whole trimester of pregnancy might be the predictor for spontaneous PTD. However, it remained unclear whether the shortening of CL from an asymptomatic to a symptomatic state could predict spontaneous PTD when patients suffer from PTD symptoms. Romero et al[30] analyzed the practicability of CL (the predictor for spontaneous PTD) from asymptomatic time points (anatomical ultrasound) to the occurrence of PTD. They found that the total incidence of spontaneous PTD amounted to 8.3%, and the length of 19% of cervixes was shortened by more than 10 mm. The incidence of spontaneous PTD was notably higher among patients with CL shortening greater than 10 mm than among those with CL shortening equal to or less than 10 mm. The sensitivity, specificity, PPV, and NPV of CL shortening greater than 10 mm amounted to 47.8%, 83.9%, 21.2%, and 94.7%, respectively. The above outcomes demonstrated that CL (more than 10 mm shorter than anatomical ultrasound) was related to the increasing risk of spontaneous PTD among PTD women. Khamees et al[31] analyzed the predictive effects of uterine cervix angle and CL on PTD and found that uterine cervix angle greater than 105° and CL less than 30 mm were the high-risk factors for PTD, which showed good performance in the diagnosis of high-risk patients. Muniz et al[32] evaluated the correlation between CL measurement parameters and PTD and found that postpartum total CL and upper cervix length were both associated with gestational age and PTD risk during delivery. After cervical cerclage during ultrasonography, total CL or upper cervix length could predict gestational age and PTD risk during delivery, which suggested that TVUS-based CL measurement played a positive role in PTD prediction so that it could be applied for pregnant women and parturients.

In this research, the predictive effects of pathological examination of placenta-based CL measurement on PTD were compared, and CL and placental pathology of PTD patients and pregnant women undergoing normal delivery were analyzed. Moreover, the effects of different examination methods on PTD prediction were compared, and the incidence of postpartum and neonatal complications in different groups was summarized. It was demonstrated that the proportion of cases with CL>30 mm was relatively lower in the PTD group, while the proportion of cases with CL<30 mm was higher ($p<0.05$). In addition, the proportion of positive cases was much higher, while that of negative cases was relatively lower in the PTD group ($p<0.05$). Moreover, the incidence of CT, UU, and CA in control and PTD groups amounted to 3.57% *vs.* 13.89%, 26.19% *vs.* 52.78%, and 19.05% *vs.* 58.33%, respectively. Joint inspection was more sensitive, specific, and accurate than single examination ($p<0.05$), and the sensitivity was the highest among pregnant women undergoing delivery for less than 3 d. In addition, the specificity was the highest among those undergoing delivery for less than 37 weeks. The incidence of asphyxia, pneumonia, and pathologic jaundice was higher in the PTD group ($p<0.05$), and so was the incidence of postpartum infection, hemorrhage, and difficult wound healing ($p<0.05$). It was verified that CL measurement with pathological examination of the placenta possessed more remarkable advantages in PTD prediction with high specificity, sensitivity, and accuracy. Therefore, it was worthy of clinical application.

### Limitations

The limitation of this research lies in the investigation into the predictive effects of CL and placental pathology on PTD without a comparative study on other prediction methods. In subsequent research, other prediction methods should be included for the comparison of predictive effects to provide references for successful pregnancy.

## Conclusions

This research was conducted to compare the predictive effects of different examination methods on PTD. It was found that TVUS-based CL measurement combined with pathological examination of the placenta was more effective with high specificity, sensitivity, and accuracy. Hence, it was an excellent prediction method and worthy of clinical application.

**Conflict of Interest**

The authors declare that they have no conflict of interests.

## Ethics Approval

This study is approved by the Ethics Committee of Hengyang Maternal and Child Health Hospital (No. HYMCH2020012).

## Informed Consent

Each subject included in the study signed an informed consent.

## Availability of Data and Materials

Data supporting the findings of this study are available from the corresponding author upon reasonable request.

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## Authors' Contribution

The conception and design of the study, acquisition of data, or analysis and interpretation of data: Hengfen Hu and Na Jiang; drafting the article or making critical revisions related to the relevant intellectual content of the manuscript: Lan Jiang and Yong Zhang; supervision: Ping Lu and Yanqing Xiao; validation and final approval of the version of the article to be published: all authors.

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