International Journal of Nursing Studies Advances 8 (2025) 100326

Contents lists available at ScienceDirect

International Journal of Nursing Studies Advances

journal homepage: www.sciencedirect.com/journal/international-journal-of-nursing-studies-advances

Analysis of risk factors and prediction model construction for poor healing of perineal wounds after vaginal delivery: A retrospective case-control study

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ARTICLE INFO

Keywords:
Perineal wound
Poor healing
Risk prediction
Nomogram

ABSTRACT

Background: Perineal wounds after vaginal delivery are very common, but the existing evidence for poor healing of perineal wounds is limited. Although some studies have analyzed the risk factors for poor perineal wound healing, there are currently no simple and practical predictive tools available for clinical use.

Objective: To retrospectively analyze the independent risk factors for poor perineal wound healing after vaginal delivery and to establish a risk prediction model for poor perineal wound healing.

Design: A Retrospective Case-Control Study.

Data Source: A total of 167 cases of poor perineal wound healing after vaginal delivery who visited the emergency department from May 2021 to September 2023 in our hospital were selected as the poor perineal wound healing group. The control group was randomly selected by the random number table method at a ratio of 1:2 from those with normal perineal wound healing during the same period.

Methods: Clinical indicators of the two groups were analyzed, and the risk factors for poor perineal wound healing were analyzed using univariate and multivariate Logistic regression analysis, and a risk prediction model was constructed. A nomogram was drawn, and the model was evaluated by discrimination and calibration.

Results: This study ultimately included four independent risk factors to construct the risk prediction model, including primiparity, perineal laceration, perineal laceration combined with laceration, and vaginal hematoma. The model formula was $Z = 2.256 + 2.7 \times$ (episiotomy with laceration) $+ 1.5 \times$ (episiotomy) $+ 1.321 \times$ (vaginal hematoma) $+ 0.904 \times$ (primiparity). The area under the ROC curve of the constructed model was 0.757 (95 % CI: 0.712–0.803), and the optimal cutoff value was 0.194, at which the model sensitivity was 0.952 and specificity was 0.759.

Conclusions: The risk prediction model for poor perineal wound healing after vaginal delivery can reasonably predict the risk of poor incision healing, providing a basis for obstetric medical staff to

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https://doi.org/10.1016/j.ijnsa.2025.100326
Received 24 November 2024; Received in revised form 19 March 2025; Accepted 7 April 2025
Available online 8 April 2025

take preventive management measures for high-risk groups before the discharge of parturient women, thereby reducing the occurrence of poor perineal wound healing.

What is already known:

Many factors can contribute to poor perineal wound healing, and evidence-based prevention strategies remain unclear.

To date, no predictive model has been established to screen high risk populations.

What this paper adds:

Logistic regression models can be developed to potentially help predict the incidence of poor perineal wound healing after birth.

The nomogram established included minimal factors and may be an effective tool for perineal wound management.

1. Background

Perineal injury is common during vaginal delivery, with estimates suggesting that over 85 % of women who give birth vaginally will experience some degree of perineal laceration (Okeahialam et al., 2024). These perineal wounds sometimes fail to heal due to infection or dehiscence, leading to poor wound healing rates ranging between 0.1–23.6 % and 0.2–24.6 % (Jones et al., 2019). Delayed wound healing is particularly common after episiotomy, although it can also occur in a minority of natural lacerations. This can lead to perineal pain, fecal incontinence, sexual dysfunction, pelvic floor dysfunction in patients, and may also trigger anxiety or even depression in mothers, severely affecting the quality of life and postpartum breastfeeding (Shi et al., 2018a). Additionally, it can cause extended hospital stays, low patient satisfaction, and increased patient expenditure and medical resource pressure due to multiple returns to the hospital for wound care (Guo et al., 2021).

The poor healing of perineal wounds has been studied both with prospective and retrospective design in the developed countries, and various factors affecting wound healing have been analyzed meticulously. At present, most common risk factors include advanced age, fever, pour nutrition, BMI > 35 kg/m^2, diabetes, smoking, forceps delivery, birthweight > 4000 g, obstetric anal sphincter injuries, suture skill of birth attendants. Yet in China, due to the lack of proper understanding of the wound healing process among obstetric midwifery and nursing staff, the vast majority believe that poor healing of perineal wounds is primarily caused by poor suturing techniques rather than objective factors, thus unwilling to reveal related data. Although the National Health Commission (2024) has listed "reducing the incidence of vaginal delivery complications" as one of the top ten goals for national medical quality and safety improvement, perineal complications have not received enough attention. The limited numbers of retrospective studies focused primarily on women with episiotomy. However, the episiotomy rate has dropped dramatically from over 70 % in 2001 (Qian et al., 2001) in the eastern region to 33 % in nulliparity and 10 % in multiparity in 2016 (Ye et al., 2021), with the concept of restrictive episiotomy been widely accepted today. Under this trend, the known risk factors may be applied to only a relatively small portion of the whole population.

REEDA scale is a tool commonly used in developed countries to assess the healing status of perineal episiotomy wounds for postpartum women, employing five dimensions—Redness (R), edema (E), ecchymosis (E), discharge (D), and approximation of the perineal tissues (A) (Carey, 1971). Each dimension is scored on a scale of 0 to 3, with a total score of 11 to 15 indicating poor healing. While it is a commonly used tool to observe the postpartum condition of episiotomy tissue wounds, it could not provide prospective prediction of the healing outcome. According to Hill (1990), this tool had several limitations: it included only width dimension without considering length and depth of the induration, and there can be overlapping between redness and ecchymosis. In addition, the Kappa coefficient of the scale, which represents inter-rater reliability, shows only moderate correlation across items (Alvarenga et al., 2015). This means that different evaluators may assign different scores for the same wound, thereby limiting its clinical application to some extent.

So far, there is also a lack of prediction model or evidence-based clinical guidelines related to poor healing of perineal wounds in existing literature (Shamy et al., 2022). Therefore, this study aims to explore the key factors affecting wound healing of perineal trauma after birth and establishing a risk prediction model for poor health. This will provide guidance for early wound prediction and targeted intervention for high-risk groups and is expected to fill the gap in the relevant research field.

2. Methods

2.1. Study setting and participants

A case-control study was conducted in a specialized tertiary teaching hospital in eastern China. This study has been approved by the hospital ethics committee (No. KS23358). Informed consent was obtained from participants routinely on admissions as a general informed consent.

Participants include women who gave birth vaginally from May 2021 to September 2023 at our hospital. During labor management, preventative antibiotics were prescribed 12 h on the rupture of the membrane. In addition, women with positive Group B Streptococcus (GBS) and fever also accepted antibiotics. In the second stage of labor, the women were provided with perineal warm

compression for 10 min to decrease the risk of laceration, using red bean packs with a national patent restored in a heated incubator at 60 °C. Warm compression was contradicted under circumstance of any perineal infection or inflammation. Episiotomy was implemented for the following indications: previous anal surgeries, poor elasticity in the perinium, vaginal wall laceration before delivery, possible macrosomia, and category III fetal heart rate, using a delivery assessment scale (Zhuang et al., 2013) registered at the Shanghai Copyright Bureau with registration number 2018-A-01188766. Perineal analgesics were implemented for episiotomy indication or those who did not have epidural anesthesia. Perineal edema after birth was managed with cold compression with cool pack twice daily, for half an hour to one hour each time. Epidural anesthesia was discontinued 2–3 h postpartum if the women's conditions were stable. Analgesics were not routinely prescribed for postpartum perineal pain control due to cultural traditions.

Cases were defined as postpartum women who followed up for perineal wounds in the emergency department (ED) and were confirmed to have poor wound healing. After screening and verification of outpatient medical records, these patients' intrapartum and postpartum medical history information was collected by matching hospital numbers in the hospitalization system. Controls, matched 1:2 with cases concurrently by month using random digital method, were defined as those that had normal perineal wound healing after vaginal delivery. Inclusion Criteria: Age>18 years; full-term singleton vaginal delivery; perineal injury or episiotomy occurred during childbirth. Exclusion Criteria: Those who had regular prenatal examinations in other hospitals; twins and multiple births; preterm delivery cases.

2.2. Clinical data

The research team reviewed the literature (Guo et al., 2021; Okeahialam et al., 2021; Shi et al., 2018a) on factors affecting perineal wound healing and determined the indicators, including age, gravidity and parity, gestational age, pregnancy complications, pre-pregnancy and prenatal body mass index (BMI), pre-pregnancy and postpartum hemoglobin, pre-pregnancy and postpartum albumin, detection of microorganisms in the reproductive tract including human papilloma virus (HPV), number of sutures used, premature rupture of membranes, perineal wound type, mode of delivery, epidural analgesia, neonatal weight, delivery attendants, and existence of perineal edema.

Specifically for microbial test results: if the report detects in the second and third trimesters any type of microorganism such as bacteria, fungi, etc., it is considered positive. Pre-pregnancy hemoglobin and albumin were based on the results of the hospital admission blood routine examination. Postpartum hemoglobin and albumin: the blood routine examination results on the first day after delivery were used, whereas if it was <24 h after delivery, the examination results on the second day after delivery were used. The Perineal wound type was categorized into laceration, episiotomy, and episiotomy combined with laceration. Delivery attendants were divided into doctors and midwives, and the level of the midwife was divided into 3 levels according to the years of specialized work. Junior midwives were those with under five years of experience on completion of the midwifery residency program, and were responsible for the delivery of low-risk pregnant woman with a single fetus in cephalic presentation, as well as performing episiotomy. Those with 5~10 years midwifery experience fell into the category of mid-level midwives, and were capable of delivery of certain level of technique difficulty, such as vaginal wall laceration <2 cm without active bleeding before birth. Senior midwives had >10 years of midwifery experience and managed complicated cephalic presentation delivery, such as previous anal surgery, hematoma or laceration with active bleeding before birth. Obstetricians were responsible for assisted vaginal delivery, breech presentation or twin delivery.

The primary outcome was perineal wound healing. In the case group, poor healing was defined by the criteria (Ernstmeyer et al., 2021) as follows: ① Secondary intention healing and tertiary intention healing; ②Wound infection: Local tissue tenderness, redness, swelling accompanied by purulent or watery discharge; ③Wound dehiscence: the separation of the edges of the wound. In contrast, the control group underwent normal perineal wound healing.

2.3. Data collection

The hospital information system was adopted to export clinical data. Two independent researchers (Liu & Yao) proceeded with data cleansing using Microsoft Excel. 20.0 % of the collected data were randomly selected for review to ensure the authenticity and accuracy of the data. To reduce bias and avoid the possibility that some participants in the control group might have experienced poor perineal wound healing but did not seek medical attention, we conducted telephone follow-ups to confirm that all individuals in the control group had normal healing.

2.4. Data analysis

SPSS 26.0 software was used for statistical analysis, and multiple imputations were used for missing values. Measurement data were described using the mean ± standard deviation for data conforming to a normal distribution, and non-normal distribution measurement data were described using the median and quartiles, and counting data were expressed as a percentage. Univariate Logistic regression analysis was used to screen factors with statistical differences, with collinearity diagnosis performed. Factors without collinearity were further included in the multivariate Logistic regression model to finally screen out independent risk factors. $P < 0.05$ was considered statistically significant. The nomogram was further drawn using R 4.3.3 software, the model's discrimination was evaluated using the area under the ROC (Receiver Operating Characteristic) curve, and the model's calibration was evaluated using the Hosmer-Lemeshow goodness-of-fit test. $P > 0.05$ indicates that the model has good calibration.

3. Results

3.1. Distribution characteristics of poor perineal wound healing after vaginal delivery

A total of 230 women who visited the emergency department for wound follow-up were collected in this study, of which 83 cases had wound dehiscence (36.1 %), 72 cases had wound infection (31.3 %), 63 cases had suture reaction (27.4 %), 6 cases had wound hematoma (2.6 %), 4 cases had wound bleeding (1.7 %), and 2 cases had granulation tissue growth (0.9 %). 63 cases excluded due to non-absorbable sutures (Fig. 1). 167 people complained of obvious pain when visiting (72.6 %). The median postpartum visit interval was 13 days after delivery (IQR1, IQR3=8, 29).

3.2. Clinical indicator analysis of the two groups of subjects

In this study, 167 subjects who experienced wound dehiscence and non-Phase I healing were included in the analysis. A control group of 323 women with normal healing of vaginal delivery wounds was matched. Detailed clinical data of the study subjects in both groups are presented in Table 1.

3.3. Univariate and multivariate analysis of perineal wound healing complications after vaginal delivery

A univariate Logistic regression analysis was conducted to identify factors associated with poor perineal wound healing following vaginal delivery. The analysis revealed that mode of delivery, advanced maternal age, primiparity, postpartum hemoglobin, postpartum albumin, the difference in hemoglobin levels before and after delivery, the difference in albumin levels before and after delivery, the number of 2–0 and 0–0 sutures, the level of the accoucheur, mediolateral episiotomy, combined episiotomy and laceration, vaginal hematoma, and epidural analgesia were statistically significant (see Table 2 for details). A diagnosis of multicollinearity was performed on the variables with statistical differences, with variance inflation factors (VIF) <10, indicating no multicollinearity among the independent variables. Further multivariate Logistic regression analysis indicated that primiparity, mediolateral episiotomy, combined episiotomy and laceration, and vaginal hematoma were independent risk factors for poor perineal wound healing after vaginal delivery ($P < 0.05$) (see Table 2 for details).

3.4. Predictive performance of the perineal wound healing complications risk prediction model after vaginal delivery

A risk prediction model for perineal wound healing complications after vaginal delivery was constructed using four independent risk factors: primiparity, mediolateral episiotomy, combined episiotomy and laceration, and vaginal hematoma as independent variables. The regression model is represented as $Z = 2.256 + 2.7 \times$ (episiotomy with laceration) $+ 1.5 \times$ (episiotomy) $+ 1.321 \times$ (vaginal hematoma) $+ 0.904 \times$ (primiparity). The discriminative ability of the prediction model was evaluated, and the results showed that the area under the ROC curve was 0.757 (95 % CI: 0.712–0.803, $P = 0.000$), indicating good discriminative power of the model. The optimal cutoff value of this ROC curve was 0.194, with a sensitivity of 0.952 and a specificity of 0.759 at this point; further confirming the model's reliability and effectiveness, see Fig. 2. The calibration of the prediction model was evaluated using the Hosmer-Lemeshow goodness-of-fit test, which indicated no significant difference between the predicted risk and the actual risk (χ^2=0.572, $P = 0.903$). A nomogram was plotted using the four independent risk factors, as shown in Fig. 3. To use this nomogram, the four independent risk factors were screened for a postpartum woman. Draw an upward vertical line to the "Points" bar to calculate points for each existing factor. Based on the sum, draw a downward vertical line from the "Total Points" line to calculate the probability of poor wound

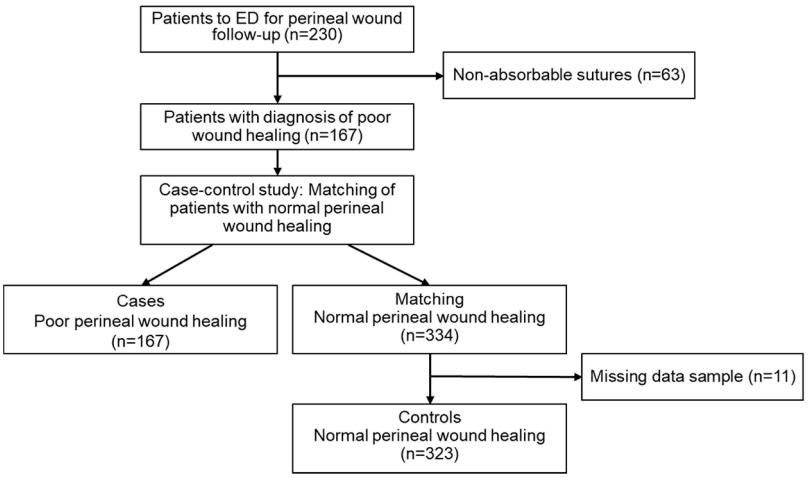

Fig. 1. Flow diagram of the case-control study.

Table 1
Characteristics of participants in both groups.

Characteristic		All Participants ($n = 490$)	Poor Healing Group ($n = 167$)	Normal Healing Group ($n = 323$)
Advanced Maternal Age (>35)		66(13.5 %)	12(7.2 %)	54(16.7 %)
Gravidity				
	1	290(9.2 %)	121(72.5 %)	169(52.3 %)
	2	135(27.6 %)	33(19.7 %)	102(31.6 %)
	≥3	65(13.2 %)	13(7.8 %)	52(16.1 %)
Parity				
	1	401(81.8 %)	158(94.6 %)	243(75.2 %)
	≥2	89(18.2 %)	9(5.4 %)	80(24.8 %)
Gestational Age		39.3 ± 1.4	39.5 ± 1.0	39.2 ± 1.5
Pre-pregnancy BMI (kg/m2)		21.0 ± 2.5	21.0 ± 2.4	21.1 ± 2.5
Pre-delivery BMI (kg/m2)		26.2 ± 2.7	25.9 ± 2.8	26.3 ± 2.6
Premature Rupture of Membranes		125(25.5 %)	35(21.0 %)	90(27.9 %)
Gestational Diabetes		59(12.4 %)	16(9.6 %)	43(13.3 %)
Microbial Test Results				
	Mycoplasma	89(18.2 %)	29(17.4 %)	60(18.6 %)
	HPV	5(1.0 %)	2(1.2 %)	3(1.0 %)
	Candida	12(2.4 %)	6(3.6 %)	6(1.9 %)
	GBS	18(3.7 %)	2(1.2 %)	16(5.0 %)
	Gram-Positive Bacteria	20(4.1 %)	6(3.6 %)	14(4.3 %)
Blood Test Results				
	Postpartum Hemoglobin	109.6 ± 12.2	106.9 ± 11.7	111.1 ± 12.3
	Postpartum White Blood Cell Count	13.5 ± 2.8	13.7 ± 2.7	13.5 ± 2.9
	Postpartum Albumin	30.2 ± 2.3	29.8 ± 2.3	30.4 ± 2.3
	Difference in Hemoglobin Before and After Delivery	12.1 ± 10.8	14.8 ± 10.1	10.7 ± 11.0
	Difference in Albumin Before and After Delivery	5.4 ± 2.4	6.0 ± 2.4	5.1 ± 2.4
Epidural Analgesia		401(81.8 %)	150(89.8 %)	251(77.7 %)
Mode of Delivery				
	Forceps Delivery	53(10.8 %)	28(16.8 %)	25(7.7 %)
	Spontaneous Delivery	437(89.2 %)	139(83.2 %)	298(92.3 %)
Delivery Attendant				
	Obstetrician	61(12.4 %)	31(18.6 %)	30(9.3 %)
	Senior Midwife	52(10.6 %)	18(10.8 %)	34(10.5 %)
	Mid-level Midwife	260(53.1 %)	85(50.9 %)	175(54.2 %)
	Junior Midwife	117(23.9 %)	33(19.8 %)	84(26.0 %)
Wound Type				
	Laceration	275(56.1 %)	34(20.4 %)	241(74.6 %)
	Episiotomy	196(40.0 %)	115(68.9 %)	81(25.1 %)
	Episiotomy with Laceration	19(3.9 %)	18(10.8 %)	1(0.3 %)
Number of 2–0 Sutures				
	1	343(70.0 %)	97(58.1 %)	246(76.2 %)
	≥2	133(27.1 %)	67(40.1 %)	66(20.4 %)
Number of 1–0 Sutures				
	1	34(6.9 %)	19(11.4 %)	15(4.6 %)
	≥2	28(5.7 %)	20(12.0 %)	8(2.5 %)
Neonatal Weight		3286.9 ± 391.4	3311.8 ± 367.4	3274.0 ± 403.2
Vaginal Hematoma		14(2.9 %)	9(5.4 %)	5(1.5 %)
Perineal Edema		94(19.2 %)	36(21.6 %)	58(18.0 %)

healing.

4. Discussion

4.1. Significance of constructing a risk prediction model for perineal wound healing complications after vaginal delivery

Poor perineal wound healing, a common postpartum complication following vaginal delivery, significantly impact the quality of life for women after childbirth. However, due to the lack of a unified concept definition, diagnostic tools, and core outcome indicators, the exact incidence of perineal wound healing complications remains unclear (Jones et al., 2019). Qualitative studies have shown that some women may experience a temporary improvement in symptoms within days after discharge, only to have a sudden deterioration with symptoms such as fever, malaise, and acute perineal pain; meanwhile, some physicians may fail to timely recognize wound abnormalities due to inconspicuous local infection symptoms (Wiseman et al., 2019). Most perineal infections occur within 14 days postpartum (Dudley et al., 2017), but the identification and treatment of wound healing complications are often delayed due to insufficient attention to perineal wounds by midwives and physicians, and an over-reliance on external signs of wound infection during diagnosis. Additionally, some women may feel embarrassed discussing perineal wound symptoms and vaginal health issues, making it

Table 2
Univariate and multivariate analysis results of poor perineal wound healing after vaginal delivery.

Item	Univariate Analysis		Multivariate Analysis	
	P	OR (95 %CI)	P	OR (95 %CI)
Mode of Delivery	0.003	2.401 (1.350–4.270)		
Advanced Maternal Age	0.004	0.386 (0.200–0.743)		
Primiparity	<0.001	5.780 (2.820–11.846)	0.022	2.470 (1.139–5.538)
Gestational Diabetes	0.231	0.690 (0.376–1.266)		
Pre-delivery BMI	0.212	0.956 (0.891–1.026)		
Postpartum White Blood Cell Count	0.505	1.023 (0.957–1.093)		
Postpartum Hemoglobin	<0.001	0.972 (0.957–0.987)		
Postpartum Albumin	0.008	0.895 (0.824–0.972)		
Difference in Hemoglobin Before and After Delivery	<0.001	1.036 (1.018–1.055)		
Difference in Albumin Before and After Delivery	<0.001	1.160 (1.071–1.256)		
Mycoplasma Infection	0.742	0.921 (0.565–1.502)		
Candida Infection	0.247	1.969 (0.625–6.202)		
GBS Infection	0.054	0.233 (0.053–1.024)		
Number of 2–0 Sutures	<0.001	1.896 (1.363–2.637)		
Number of 0–0 Sutures	<0.001	2.015 (1.453–2.794)		
Delivery Attendant	0.004	0.743 (0.606–0.911)		
Episiotomy	<0.001	6/607 (4.372–9.986)	<0.001	4.484 (2.859–7.033)
Episiotomy with Laceration	<0.001	38.899 (5.145–294.121)	0.009	14.890 (1.942–114.191)
Vaginal Hematoma	0.023	3.623 (1.194–10.990)	0.043	3.750 (1.043–13.479)
Perineal Edema	0.338	1.256 (0.788–2.000)		
Epidural Analgesia	0.001	2.531 (1.437–4.457)		

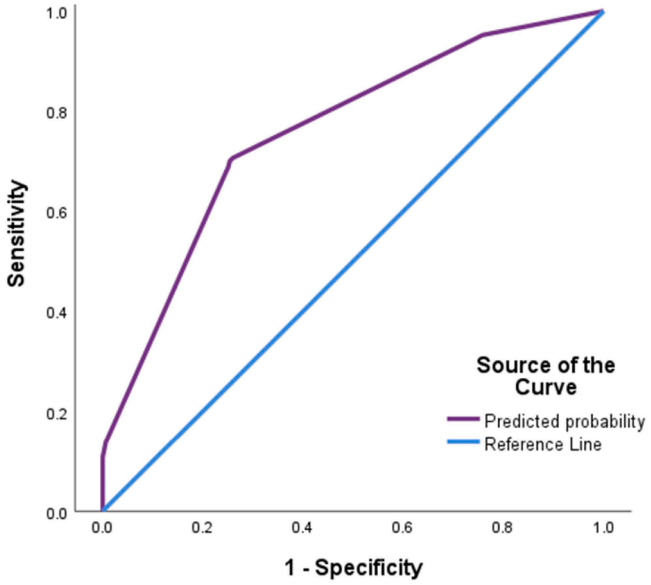

Fig. 2. ROC curve of the prediction model for perineal wound healing complications after vaginal delivery.

difficult for them to seek medical help in a timely manner when complications arise (Wiseman et al., 2019). Other extrinsic factors also include poor education about wound healing after surgery and lack of use of technology to connect patients and care givers (Sandy-Hodgetts et al., 2018). In China, postpartum perineal wound assessment is usually conducted by community doctors or nurses, but due to the lack of effective linkage and follow-up from delivery institutions, not all women receive wound assessments during home visits. The management of perineal wound healing complications often takes place in emergency rooms with simple debridement, lacking systematic tracking and follow-up, which results in a lack of standardization and scientific management of postpartum perineal wounds.

Currently, both domestic and international research on perineal wounds after vaginal delivery mainly focuses on identifying risk factors for wound healing complications (Cui et al., 2022; Saad et al., 2023; Shi et al., 2018a; Wiseman et al., 2019) but has not yet developed regression models or risk prediction nomograms, which to some extent hinders the clinical identification of high-risk groups and early intervention. This study, based on the analysis of risk factors, further constructs a predictive model aimed at predicting the risk of perineal wound healing complications through pre- and intrapartum clinical indicators. Compared to previous studies, this

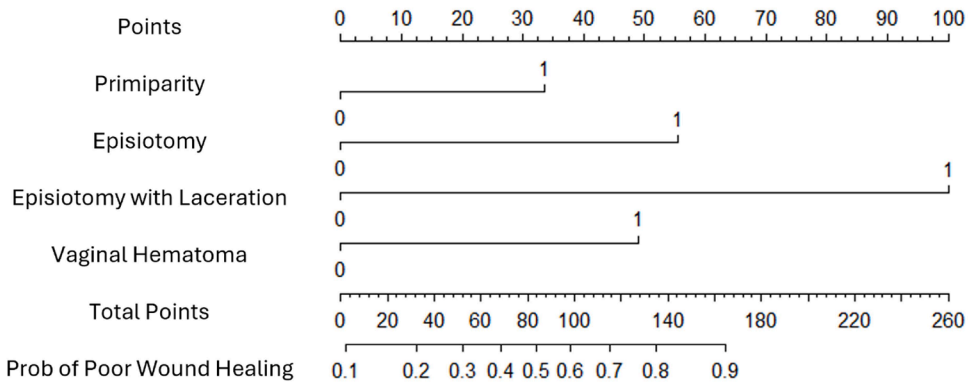

Fig. 3. Nomogram predictive model for perineal wound healing complications after vaginal delivery.

study has a larger sample size and includes more refined predictive factors in the model, which improves the predictive accuracy. The study results also indicate that women at the highest risk of perineal wound dehiscence will benefit from close follow-up (Wilkie et al., 2018). Since the predictive entries included in this model can be assessed immediately after delivery, it helps guide early intervention and follow-up postpartum, thus having significant clinical application value.

4.2. Analysis of factors influencing perineal wound healing complications after vaginal delivery

4.2.1. Systemic risk factors

In this study, despite differences in groups for factors such as advanced maternal age, gestational diabetes, pre-delivery BMI, postpartum white blood cell count, postpartum hemoglobin, postpartum albumin, the difference in hemoglobin levels before and after delivery, the difference in albumin levels before and after delivery, mycoplasma infection, fungal infection, GBS infection, etc., these differences did not show statistical significance in multivariate analysis, and thus no systemic risk factors were included in the final regression model. This is consistent with the results of Puissegur et al. (2023), which suggests that early dehiscence of perineal wounds may be more influenced by obstetric factors. This may be because the population of women included in this study did not have extreme cases in terms of age, BMI, and other characteristics, and the impact of these recognized factors on wound healing in this population is not as significant as in certain specific groups. For example, a Danish study found that the risk of perineal wound healing complications increased by 6.66 times in severely obese individuals (BMI>35 kg/m^2) (Gommesen et al., 2019), but Asian women are generally smaller in stature than Western populations, and this BMI range classification is not suitable for Asian populations. In the domestic population of this study, BMI distribution is more uniform, so BMI did not become a factor in the prediction model. Shi et al. (2018a) compared the characteristics of perineal wound healing complications in women who underwent forceps-assisted delivery and found that in systemic factors, postpartum fever and postpartum anemia both increased the risk of perineal wound healing complications after forceps delivery. However, these factors only showed group differences and did not enter the regression equation in this study. This further suggests that obstetric factors rather than systemic factors may be more likely to lead to perineal wound healing complications.

Additionally, this study analyzed various microorganisms that may cause vaginal infections but found that their impact on perineal wound healing complications was not significant, even in individuals with multiple microorganism infections. In fact, multiple bacteria can be found on swabs of perineal wounds (Tharpe, 2008), and perineal wound infections are not caused by a single bacterial group. Nevertheless, since the vaginal flora changes during pregnancy (Zhang et al., 2022), this may lead to changes in the local microecological environment, causing inflammation such as perineal mucosal congestion, edema, and increased vaginal discharge, which may be one of the causes of complex perineal lacerations.

4.2.2. Obstetric risk factors

The results of this study confirm that perineal laceration combined with episiotomy is a major independent risk factor for perineal wound healing complications and increases the risk of infection. Compared to spontaneous lacerations, episiotomy usually involves more bleeding, which may lead to poor nutritional status postpartum, thereby delaying the wound healing process. Moreover, due to the perineum not being fully dilated during episiotomy or the actual effective incision not being large enough, this may cause the wound to extend deeper and upward. A single-center study covering different types of perineal wounds also confirmed that the infection and dehiscence rates of spontaneous second-degree perineal lacerations are lower than those of perineal third and fourth-degree lacerations and episiotomies (Wiseman et al., 2019). Therefore, preventive measures during pregnancy and childbirth, such as perineal massage and pelvic floor function training in the late pregnancy (Chen et al., 2024), perineal hot compresses during childbirth (World Health Organization, 2018), lateral position delivery, and controlling the speed of fetal head delivery, can reduce the occurrence of episiotomy, complex perineal lacerations, and severe perineal lacerations, fundamentally avoiding the occurrence of perineal wound healing complications. Additionally, one of the main causes of perineal laceration combined with complex lacerations is forceps-assisted delivery, which is also prone to obstetric anal sphincter injuries (OASIS) (Shi et al., 2018b). In contrast, studies have

also found that vacuum-assisted delivery does not increase the risk of perineal incision extension and tearing, significantly reducing the chances of perineal wound healing complications (1.4 % VS 5.5 %) (Wilkie et al., 2018). Although OASIS was not included as a risk factor in this study, this does not mean that OASIS is not a risk factor for delayed wound healing. Rather, it was not included because OASIS did not occur in the sample population of the study. In fact, the incidence of wound complications in OASIS women can occur in 7.3 % of the total patients (Stock et al., 2013). Studies have also found that the prophylactic use of antibiotics during and after vaginal delivery can effectively reduce the risk of perineal wound healing complications (Gommesen et al., 2019; Knight et al., 2019).

In this study, primiparity was identified as a predictive factor for perineal wound healing complications, which is consistent with the results of Jallad et al. (2016). This may be because the likelihood of perineal injury in primiparous women is much higher than in multiparous women (91 % VS 71 %) (Smith et al., 2013), especially the rate of episiotomy, which is more than four times higher in primiparous women than in multiparous women (Blanc-Petitjean et al., 2020). The wide confidence interval for this variable is likely mainly due to the higher proportion of primiparous women in the case group (94.6 %) compared to the control group (75.2 %). Similar results were also observed for the variables of episiotomy with laceration and vaginal hematoma, with even wider confidence intervals. This might also be due to the smaller number of positive samples in the control group, indicating further study on these factors and the validation of this nomogram. Although in China, perineal wound healing complications are often attributed to poor suturing techniques by midwives, this study and other related studies have found that suturing techniques are not risk factors for perineal wound dehiscence (Puissegur et al., 2023). This may be because, to ensure high-quality suturing techniques, our hospital requires that the suturing process must be completed under the supervision of a charge midwife when training junior midwives, and regardless of the midwife's experience, dual verification of wound conditions is required. In addition, perineal wound care plays an indispensable role in the healing process (Sandy-Hodgettes et al., 2020), and maintaining cleanliness and dryness of postpartum perineal wounds is a must-emphasize point in postpartum health education by midwives. Wilkie et al.'s retrospective study also found that the use of postpartum anesthetics is strongly correlated with perineal wound dehiscence (OR value 21.29) (Wilkie et al., 2018). However, since epidural anesthesia drugs are routinely discontinued after delivery in this study, this factor could not be included in the group comparison.

4.3. Strengths and limitations of the study

The strengths of this study lie in the large sample size included, which improves statistical power, and the construction of a predictive model for clinical application. The study also has some limitations, mainly due to data collection from a single-center retrospective survey, which may omit certain postpartum-related factors, such as the self-care of wounds by women. Only intrapartum perineal protection measurements were discussed in this study, without adequate control of antepartum factors, such as perineal massage and pelvic floor function training. The use of antibiotics and frequency of postpartum hygiene were not included, which might also be sources of bias. At the same time, the study lacks an assessment of the model's prospective application effect. Therefore, future research plans will include conducting prospective follow-ups and applying this model to clinical practice to verify its actual predictive effectiveness. In addition, future research can further explore early intervention measures for high-risk groups of perineal wound healing complications and the issue of secondary suturing after perineal wound dehiscence. These studies will provide more reference and evidence for the systematic and scientific management of perineal wounds after vaginal delivery.

5. Conclusions

In this study, primiparity, episiotomy, perineal laceration combined with episiotomy, and vaginal hematoma are independent risk factors for perineal wound healing complications after vaginal delivery. The risk prediction model based on these factors not only fills the gap in existing research but also has significant importance for early identification of high-risk groups for perineal wound healing complications. This helps medical workers to take timely targeted intervention measures before women are discharged from the hospital, thereby reducing the incidence of perineal wound healing complications and has certain clinical application value.

Funding program

Shanghai First Maternity and Infant Health Hospital "Reservoir" Talent Program; Shanghai Municipal Science and Technology Commission Technical Standard Project (22DZ2203800); Chinese Medical Association Magazine Nursing Science Research Project (CMAPH—NRP202204).

CRediT authorship contribution statement

Chunyu Cai: Writing – original draft, Investigation, Data curation. **Shanshan Shan:** Supervision, Project administration, Data curation. **Xiaoyan Chen:** Validation, Resources, Investigation. **Xiao Yao:** Validation, Resources, Investigation. **Ying Liu:** Writing – original draft, Software, Funding acquisition, Formal analysis, Conceptualization. **Hui Jiang:** Writing – review & editing, Supervision, Methodology, Funding acquisition.

Declaration of competing interest

All authors declare no conflicts of interest.

Acknowledgement

All authors gratefully acknowledge the financial supports by the Shanghai First Maternity and Infant Health Hospital "Reservoir" Talent Program; Shanghai Municipal Science and Technology Commission Technical Standard Project (22DZ2203800), and Chinese Medical Association Magazine Nursing Science Research Project (CMAPHNRP202204).

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