Risk factors and predictive model for abdominal wound dehiscence in neonates: a retrospective cohort study

Shouxing Duan¹⁺⁻, Xuan Zhang³, Xuewu Jiang³, Wenhui Ou², Maxian Fu², Kaihong Chen², Xinquan Xie², Wenfeng Xiao², Lian Zheng², Shuhua Ma² and Jianhong Li²

¹Department of Pediatric Surgery, The First Affiliated Hospital of Shantou University Medical College, Shantou, China; ²Department of Pediatric Surgery, The Second Affiliated Hospital of Shantou University Medical College, Shantou, China; ³Department of Pediatric Surgery, Shenzhen Pingshan District Woman’s and Children’s Hospital, Southern Medical University, Shenzhen, China; ²Department of Radiology, The First Affiliated Hospital of Shantou University Medical College, Shantou, China

ABSTRACT

Background: Abdominal wound dehiscence (AWD) is a major complication of abdominal surgery, and neonates are a group with a high risk of AWD, which has serious consequences or can even result in death. The purpose of this study is to explore the risk factors for neonatal AWD and construct a predictive model.

Methods: The clinical data of 453 cases that underwent neonatal laparotomy from June 2009 to June 2020 were retrospectively analyzed, among which 27 cases of AWD were identified. Nine factors, including gender, age at admission, weight at admission, preterm delivery, level of preoperative anaemia, hypoalbuminemia, operation time, incision length, and incision type, were analyzed to explore their correlation with neonatal AWD.

Results: The incidence of neonatal AWD was 6.0% (27/453), among which partial wound dehiscence accounted for 4.9% (22/453) and complete wound dehiscence accounted for 1.1% (5/453). Hypoproteinemia and incision type were the independent risk factors for neonatal AWD, and weight at admission was a protective factor for AWD in the multivariate models. All these factors were incorporated to construct a nomogram, and a calibration curve was plotted. The result indicated that the actual risk was close to the predicted risk when the predicted risk rate was greater than about 35%.

Conclusions: Neonatal AWD is closely related to hypoproteinemia and incision contamination. Our predictive model showed the potential to provide an individualized risk estimate of AWD for neonatal patients undergoing abdominal surgery.

KEY MESSAGES

- Neonatal abdominal wound dehiscence (AWD) has a serious consequence and the incidence of neonatal AWD was about 6.0% and the complete AWD morbidity is 1.1%.
- Hypoproteinemia and incision type were the independent risk factors for neonatal AWD.
- Our predictive model showed the potential to provide an individualized risk estimate of AWD for neonatal patients undergoing abdominal surgery.

Introduction

With the rapid development of modern neonatal surgery, an increasing number of operations are carried out during the neonatal period, especially abdominal surgeries [1]. Abdominal wound dehiscence (AWD) is a major complication of abdominal surgery, and it is accompanied by high morbidity and mortality in neonates [2]. Because of the unique pathophysiological and anatomical characteristics of newborns, the situation of abdominal wound rupture is more complex and the consequences are more serious, as compared to those in children and adults [3]. The thin abdominal wall of a newborn is more likely to rupture again, with the possibility of causing systemic infection and endangering life [2,4,5]. AWD includes both partial and complete wound dehiscence, partial wound dehiscence means when the skin and/or deep tissue is

CONTACT Lian Zheng 284274042@qq.com Department of Pediatric Surgery, The First Affiliated Hospital of Shantou University Medical College, NO. 57 Changping Road, Shantou, 515041, China; Shuhua Ma shuhua6633@163.com Department of Radiology, The First Affiliated Hospital of Shantou University Medical College, NO. 57 Changping Road, Shantou, 515041, China; Jianhong Li jianhongli2013@163.com Department of Pediatric Surgery, The Second Affiliated Hospital of Shantou University Medical College, NO. 69 Dongxiabei Road, Shantou, 515041, China

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dehiscent, but the fascia layer is intact, no viscera and omentum can be seen; complete wound dehiscence is considered present when intestine, omentum or other viscera are seen through the abdominal wound. However, there are few reports describing the risk factors for AWD.

Therefore, we sought to investigate the risk factors for neonatal AWD and construct a predictive model, so as to identify effective measures to better prevent and control wound dehiscence.

**Methods**

**Study design and patient population**

This retrospective observational cohort study consisted of all patients (n = 453) who underwent neonatal laparotomy between June 2009 and June 2020, and 27 of these 453 cases developed AWD. All 27 patients with AWD were included. Exclusion criteria were as follows: Discharged without treatment; Patient records were incomplete. The clinical data for all children with AWD were compiled, and they included gender, age at admission, weight at admission, preterm delivery, preoperative anaemia, hypoalbuminemia, operation time, incision length, and incision type. This retrospective study was registered at researchregistry.com (NO.: RR-5350). The study was approved by the Ethics Committee at the Affiliated Hospital of Shantou University Medicine College (NO.: 2016-16) and individual consent for this retrospective analysis was waived.

**Data investigation criteria**

AWD includes both partial and complete wound dehiscence. Partial wound dehiscence is a condition characterized by rupture of a surgical incision along the suture so that the skin and/or deep tissue of an abdominal wound are exposed, but the fascial layer is intact and viscera and omentum cannot be seen. Complete wound dehiscence is considered to have occurred when the intestine, omentum or other viscera are seen through the abdominal wound.

In China, a neonate is defined as a baby aged less than 28 days. A preterm infant is defined as a baby born at a gestational age (GA) <37 weeks, and a term infant is defined as a baby born at a GA ≥37 weeks. The hypoproteinemia standard is albumin <35 g/L. Neonatal anaemia is characterized by venous haemoglobin (HB) <130 g/L or peripheral blood HB <145 g/L within 2 weeks of birth; after 2 weeks of birth, anaemia is characterized by venous blood HB ≤115 g/L. Neonatal anaemia is classified as follows: if the infant’s age is less than or equal to 2 weeks and the HB level is between 100 and 145 g/L, the condition is classified as mild to moderate anaemia; if the HB level is less than 100 g/L, it is classified as severe anaemia. If the infant’s age is more than 2 weeks and the HB level is between 80 and 115 g/L, it is classified as mild to moderate anaemia; if the HB level is less than 80 g/L, it is considered to be severe anaemia. Surgical incision type can be divided into the following three categories: type I incision (clean incision): sterile incision that can be sutured; type II incision (possibly contaminated incision): sterile incision that may be contaminated during surgery; and type III incision (contaminated incision): refers to the adjacent infected area or tissue directly exposed to the infection [6].

**Management after AWD**

The abdominal wounds were examined from the third postoperative day onwards on a daily basis to identify the signs of wound infection, dehiscence including redness (erythema), seroma formation, discharge of serous fluid or pus from one or more sites and subsequently partial or complete wound dehiscence.

The patients with partial wound dehiscence were managed conservatively by laying open the wound, and daily wound washing and dressing along with intravenous antibiotics according to culture and sensitivity. It can be cured by conservative treatment, but complications, such as incisional hernia, could occur in some patients.

In cases of complete wound dehiscence, the wound was immediately covered with sterile cotton pads to protect the bulge and fissure once the intestinal and/or omental prolapse were visible. At the same time, the patients were sedated to avoid an increase in abdominal pressure and release more intestinal tubes caused by continuous crying. The patients were transferred to the operating room for extended suturing under general anaesthesia. During surgery, the intestine was washed out, any residual suture in the wound was removed, the necrotic tissue was removed, and an entire layer of decompression suture was added. The application of antibiotics and local dressing changes were strengthened after the operation. The sutures were removed 2 to 3 weeks later. Table 1 presents the intraoperative findings and treatment of cases with complete wound dehiscence.
Statistical analysis

SPSS software 22.0 (IBM, USA) was used for statistical analysis. Categorical variables were expressed as frequencies and percentages. Categorical variables were compared using the Chi-squared test or Fisher's exact test, as appropriate. Univariate and multivariate binary logistic regression analyses were conducted to identify independent predictors of AWD, and the odds ratio (OR) and 95% confidence intervals (CI) were computed using binary logistic regression analysis. A nomogram and calibration curve were established using R software (version 4.0.4) and Rstudio (version 1.1.383). The level of significance was set at \( p < .05 \).

Results

Among the 453 patients included in this study, 27 cases developed AWD. These 27 infants were 1–28 days old, and they weighed 1.9–3.5 kg. There were 17 males and 10 females, and 19 term infants and 8 preterm infants. The patient demographics are shown in Table 2.

Analysis of risk factors

After univariate analysis of risk factors, we found that gender, age at admission, weight at admission, preterm delivery, operation time, and incision length were not the risk factors for AWD, and the difference was not statistically significant (\( p > .05 \)); however, the level of preoperative anaemia, hypoproteinemia, and incision type were the potential risk factors for AWD (\( p < .05 \)) (Table 3). Significant variables after univariate correlation analysis were further analysed by binary logistic regression analysis and the results of multivariate stepwise logistic regression analysis indicated that hypoproteinemia and incision type were the potential risk factors for AWD (\( p < .05 \)).

Table 1. The intraoperative findings and treatment of complete wound dehiscence cases.

| Case | Disease | Condition during the first operation | The first operation | Wound orientation | Dehiscence after surgery (d) | Condition during the second operation | The second operation | Length of stay (d) |
|------|---------|--------------------------------------|---------------------|------------------|-----------------------------|---------------------------------------|---------------------|------------------|
| 1    | Congenital intestinal atresia | Type II atresia, approximately 40 cm from the flexion ligament | Bowel resection and anastomosis | Horizontal | 5 | No anastomotic fistula | Debridement and tension suture | 29 |
| 2    | Ileal perforation | An idiopathic perforation was located at approximately 50 cm from the ileocecal area | Bowel repair | Vertical | 8 | Intestinal repair healed well | Debridement and tension suture | 37 |
| 3    | Meconium peritonitis | Intestinal adhesions were severe during surgery, and fistulization was made 35 cm from the ileocecal area | Enterostomy | Vertical | 6 | Unexplored abdominal cavity | Debridement and tension suture + stoma replacement | 23 |
| 4    | Congenital intestinal malrotation | Bowel rotation 270° clockwise | Ladd operation and appendectomy | Horizontal | 5 | The thread that ligated the appendix became untied, and pus was seen in the abdominal cavity, but there was no fistula of the appendix | Abdominal lavage + debridement and tension suture | 27 |
| 5    | Neonatal necrotizing enterocolitis with perforation | Multiple perforations of the colon and fistulization was made 10 cm from the ileocecal area | Enterostomy | Vertical | 7 | Unexplored abdominal cavity | Debridement and tension suture + stoma replacement | 74 |
factors associated with AWD and the overall events are shown in Figure 1.

**Nomogram construction and validation**

Multivariate analyses demonstrated that the variables, such as hypoproteinemia and incision type, were independent risk factors for AWD, but the weight at admission (OR 0.081, 95% CI 0.020–0.324) was a protective factor for AWD. A nomogram including all significant independent factors for predicting AWD was established (Figure 2). Each variable assigned a score on a point scale; by adding the scores of each selected variable, we could easily estimate the probability of AWD in an individual patient. The C-index for the nomogram to predict AWD was 0.760 (95% CI, 0.668–0.851). Then we performed calibration of the nomogram internally with bootstrap sampling 1000 times and a calibration curve (Figure 3) was plotted.

**Table 2. Patient demographics.**

| Parameter                  | Data (number)          |
|----------------------------|------------------------|
| Sex                        | Males (298); females (155) |
| Gestational age (week)     | 38.51 ± 1.59           |
| Age of admission (d)       | 7.79 ± 8.40 (1–28)     |
| Bodyweight (kg)            | 2.80 ± 0.51 (1.9–3.8)  |
| Wound orientation          | Horizontal (337)       |
|                            | Vertical (116)         |
| AWD types                  | Partial wound dehiscence (22) |
|                            | Complete wound dehiscence (5) |
| Etiology                   | Congenital intestinal atresia/stenosis (117) |
|                            | Intestinal perforation (51) |
|                            | Meconium peritonitis (12) |
|                            | Congenital intestinal malrotation/twist (105) |
|                            | Congenital hypertrophic pyloric stenosis (62) |
|                            | Congenital defects of gastric musculature (12) |
|                            | Mesenteric/omental cyst (16) |
|                            | Neonatal necrotizing enterocolitis with perforation (23) |
|                            | Residual diseases of omphalomesenteric duct (55) |

**Table 3. Correlation analysis of risk factors for neonatal AWD.**

| Factors                      | Total cases (N = 453) | AWD (N = 27) | Rate (%) | Chi-squared value | p-value |
|------------------------------|-----------------------|--------------|----------|-------------------|---------|
| Gender                       |                       |              |          |                   |         |
| Male                         | 298                   | 17           | 63.0     | 0.101             | .750    |
| Female                       | 155                   | 10           | 37.0     |                   |         |
| Admission age                |                       |              |          |                   |         |
| <7 days                      | 283                   | 14           | 51.9     | 1.381             | .240    |
| 7–28 days                    | 170                   | 13           | 48.1     |                   |         |
| Admission weight             |                       |              |          |                   |         |
| <2500g                       | 113                   | 8            | 29.6     | 0.337             | .562    |
| ≥2500g                       | 340                   | 19           | 70.4     |                   |         |
| Preterm delivery             |                       |              |          |                   |         |
| Premature infant             | 54                    | 4            | 14.8     | 0.229             | .632    |
| Term infant                  | 399                   | 23           | 85.2     |                   |         |
| Preoperative anaemia         |                       |              |          |                   |         |
| Severe anaemia               | 30                    | 5            | 18.5     | 8.216             | .004    |
| Mild and moderate anaemia    | 68                    | 6            | 22.2     |                   |         |
| No anaemia                   | 355                   | 16           | 59.3     |                   |         |
| Hypoproteinemia              |                       |              |          |                   |         |
| Preoperative hypoproteinemia | 117                   | 14           | 51.9     | 10.150            | .001    |
| No hypoproteinemia           | 336                   | 13           | 48.1     |                   |         |
| Operation time               |                       |              |          |                   |         |
| <2 h                         | 337                   | 19           | 70.4     | 0.244             | .621    |
| ≥2 h                         | 116                   | 8            | 29.6     |                   |         |
| Incision length              |                       |              |          |                   |         |
| <5 cm                        | 155                   | 9            | 33.3     | 0.010             | .921    |
| ≥5 cm                        | 298                   | 18           | 66.7     |                   |         |
| Incision type                |                       |              |          |                   |         |
| I                            | 106                   | 2            | 7.4      | 12.259            | .002    |
| II                           | 246                   | 12           | 44.4     |                   |         |
| III                          | 101                   | 13           | 48.1     |                   |         |

**Table 4. Significant variables after binary logistic regression analysis.**

| Variable                  | Wald  | Odds ratio  | 95% CI       | p-value |
|---------------------------|-------|-------------|--------------|---------|
| Hypoproteinemia           | 6.206 | 2.841       | 1.249–6.460  | .013    |
| Incision type             | 7.350 | 2.274       | 1.256–4.118  | .007    |
and it showed the relationship between the actual probability and predicted probability. When the predicted risk rate was greater than about 35%, the baseline and the reference line basically coincided, and the actual risk was close to the predicted risk.

Discussion
With the development of modern medical approaches and anaesthesia, there has been a significant increase in the number of neonatal abdominal surgical operations in some developing countries due to the recognition and detection of neonatal gastrointestinal malformations [1,7]. Because of the immature development of organ function in neonates, low immune function and rapid change in disease are more prominent. Newborns are a high-risk group for AWD compared to older children and adults [2,8]. Wound dehiscence is the result of multiple factors, and it usually occurs within 1 week after surgery [9,10]. In the current study, 9 factors, including gender, age at admission, weight at admission, preterm delivery, level

![Figure 1. Clinical outcomes in patients with independent risk factors and the overall events.](image)

![Figure 2. Nomogram for predicting AWD rate. The red and green indicate the confidence interval.](image)
of preoperative anaemia, hypoalbuminemia, operation

time, incision length, and incision type were analyzed
to explore their relationship with neonatal AWD.

In the current study, we found that the incidence

of neonatal AWD was 6.0% (27/453) and that AWD

occurred 3 to 8 days after surgery, mostly within

7 days. Through the analysis of the above-related fac-
tors, we found that hypoalbuminemia and incision
type were the independent risk factors for neo-
natal AWD.

It has been reported that the incidence of wound
dehiscence after infection is 5–10 times as high as
that after primary healing [11]. It has been noted that
infection is an important cause of wound dehiscence.
In the group of neonates included in the current
study, contaminated incisions (types II and III)
accounted for 92.6% (25/27) of AWD cases. The chan-
ces of contamination of the surgical field are higher
than in aseptic surgery. The incidence of incision
dehiscence increases with an increase in the degree of
contamination. All 5 cases of complete wound dehis-
cence had undergone intestinal tract surgery, and all
of them received more than a type II incision. In 2
cases of enterostomy, the stoma was placed at the ori-
ginal wound made during the first surgery, and the
intestinal fluid contaminated the wound and caused
infection; in 1 case of congenital intestinal malrotation,
the second abdominal exploration showed that the
thread used to ligate the appendix became loose, and
pus was found in the abdominal cavity; and in the
other 2 patients, the abdominal cavity was contami-
nated by faeces. Contamination occurred in the
above-mentioned patients, indicating that wound con-
tamination is an important risk factor for AWD. There
was a positive correlation between the incision type

and AWD, and the incidence increased with the aggra-
vation of contamination.

Malnutrition is an important factor affecting post-

operative recovery [12,13]. Albumin is the most com-
monly used index to evaluate nutritional status, and

hypoproteinemia is closely related to the surgical out-

come and postoperative complications [13–15]. In our

study, we found that the incidence of AWD in patients

with preoperative hypoproteinemia was 12%, while

the incidence of AWD in patients without preoperative

hypoproteinemia was only 3.9%; the former percentage

was 3 times more than the latter percentage. The results

indicated that preoperative hypoproteinemia is
closely related to AWD because the condition is not

conducive to the healing of an abdominal wound.

Healing becomes hindered because hypoproteinemia
can reduce the synthesis of collagen and collagenase
and the growth of granulation tissue on the wound

surface, resulting in poor wound healing [16]. In

patients with hypoproteinemia, the colloid osmotic
pressure is low, and wound exudation is increased,
which provides a medium for the growth and repro-
duction of bacteria and causes poor wound healing

[17]. In addition, hypoproteinemia will lead to the

hypofunction of several system organs, especially

immune function, causing a decrease in the ability

of the injured skin to protect against infection, which

can lead to wound infection and dehiscence [18,19].

Vigilance is required to prevent neonatal AWD dur-
ing the entire perioperative period [20,21]. Because of
the lack of nutritional reserve and the poor tolerance
of surgery by neonates, perioperative nutritional sup-
port should be strengthened to improve the surgical
success rate [22,23]. The presence of anaemia or elec-
trolyte disorders should be corrected before surgery,
and for those infants who are not able to accept oral
liquid nourishment after surgery, total venous nutri-
tion and albumin should be used to provide positive
nitrogen balance [23,24]. In addition to adequate
washing in patients who have a severe abdominal cav-
ity infection, effective antibiotics should also be used
for the control of infection [25]. In patients who
develop fistulization, another incision can be created
for stoma replacement to prevent the first wound
from being contaminated by the intestinal fluid. In
patients with multiple risk factors, a preventive tension
suture can be used [26,27].

Hypoproteinemia and incision type were identified
as the independent risk factors for neonatal AWD in
our study, but the weight at admission was a protect-
ive factor for AWD in the multivariate models. We
established a nomogram including all significant
independent factors for predicting AWD, from which the probability of AWD in an individual patient can be easily estimated. Likewise, we plotted a calibration curve that can show the relationship between the actual probability and predicted probability. Our predictive model showed the potential to provide an individualized risk estimate of AWD for neonatal patients undergoing abdominal surgery. It could provide satisfactory predictions when the predicted risk was greater than 35%.

Conclusions

In conclusion, our predictive model has the potential to provide an individualized risk estimate of AWD for neonatal patients undergoing abdominal surgery. Hypoproteinemia and incision type were the independent risk factors for the occurrence of neonatal AWD. Therefore, it is very important to clean the abdominal cavity and incision thoroughly during the operation and strengthen the nutritional support and infection control after the operation in the high-risk population of neonates.

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Disclosure statement

No potential conflict of interest was reported by the author(s).

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Data availability statement

The datasets generated in this study are available from the corresponding author on reasonable request.

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