

Risk factors for respiratory assistance in premature infants

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Abstract. Premature infants are prone to dyspnea after birth due to immature development, and some infants require respiratory assistance. However, the risk factors for respiratory assistance in premature infants are rarely reported. The present study enrolled 3,394 premature infants (665 infants had been provided with respiratory assistance and 2,729 had not used respiratory assistance) to retrospectively analyze the risk factors associated with respiratory aid. The multivariate logistic regression analysis demonstrated that placental abnormality [odds ratio (OR)=1.284; P=0.048], the male sex (OR=0.696; P=0.001), delivery via cesarean section (OR=1.538; P<0.001), low 1-min Apgar score (OR=0.727; P<0.001), low birth weight (OR=0.999; P=0.005) and low gestational age (OR=0.616; P<0.001) were independent risk factors for respiratory assistance in premature infants. Overall, a number of risk factors, including placental abnormality, cesarean section, low 1-min Apgar score, low birth weight and small gestational age, were identified for respiratory assistance in premature infants. By conducting a risk assessment of risk factors at birth and using this information to provide timely respiratory assistance, the survival rates of premature infants may increase.

Introduction

The prevalence of premature delivery is on the rise worldwide, and in 2019 it was estimated that premature birth accounted for 10.6% of all live births (1). With economic development and an increase in medical knowledge, the survival rate of premature infants is increasing, reaching >90%, and the survival rate of infants with an extremely low birth weight (ELBW) with gestational age <28 weeks increased from 0 to 35-70% in

high-income countries during the previous two decades (1-4). However, premature infants that survive may develop detrimental conditions, such as neurodevelopmental disabilities and bronchopulmonary dysplasia (BPD) (5).

The pulmonary cellular structure, thoracic structure and muscle strength mature in the last trimester (6), and metabolic substances that are important for effective breathing, such as pulmonary surfactant and antioxidant enzyme, are highly reserved in the last trimester (7). Therefore, pulmonary disease is a major cause of mortality in premature infants, especially in extremely premature infants (8). These infants require respiratory assistance to clear lung fluid, aerate the lungs and establish a consistent functional residual capacity to ensure gas exchange (9). Prior to the 1970s, neonatal respiratory distress syndrome (NRDS) was the most common cause of mortality in premature infants until the emergence of assisted ventilation, which resulted in a significant increase in the survival rate of patients with the disease (10). Respiratory assistance is also an important treatment for other complications that are common in premature infants, including BPD and respiratory failure (8,11,12).

Respiratory assistance includes mechanical ventilation, nasal continuous positive airway pressure (CPAP) and nasal intermittent positive pressure ventilation. A previous study has revealed that extremely preterm births require positive pressure ventilation if infants have spontaneous breathing and the use of nasal or mask CPAP is recommended (13). CPAP failure is defined as hypoxia, severe respiratory distress or apnea when $FiO_2 > 0.6$ and $pCO_2 > 65$ mmHg (14-16), and often requires mechanical ventilation. Due to the underdeveloped body function and organ development of premature infants who exhibit hyp immunity, long-term respiratory assistance may also result in a number of complications. For example, an Australian study revealed that 24% of 500 pediatric patients who used respiratory assistance developed complications, including croup, epiglottitis, lung atelectasis, infection and others (17). Despite the continuous advancement of medical care, ventilator-associated pneumonia, infection and retinopathy of prematurity occur occasionally, resulting in prolonged hospital stay of newborns, of which severe cases can be life-threatening (1,18,19). Therefore, investigating the risk factors of respiratory assistance in premature infants may reduce the use of ventilators and the incidence of complications via targeted pregnancy and prenatal education and can strengthen medical skills. Furthermore, using the correct personalized respiratory management in a timely manner (by

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determining whether premature infants require respiratory assistance as early as possible) will be of great significance in improving survival rates of premature infants. However, to the best of our knowledge, there are few relevant studies at present.

The current study retrospectively analyzed the factors associated with the use of ventilators in the treatment of premature infants to investigate risk factors for respiratory assistance. The results of the current study may provide evidence for the clinical early judgment of respiratory assistance contributing to an increase in survival rate of premature infants by effectively managing risk factors of respiratory assistance.

Materials and methods

Subjects. The subjects were selected from 3,578 premature infants ranging from 24 to 36 week of gestational age (mean, 33.73; SD, 2.29). They were born in Changzhou Maternal and Child Health Care Hospital (Changzhou, China) between January 1, 2013 and December 31, 2016 and were hospitalized in the neonatology department. In total, 56.48% of participants were male, 43.46% were female and 0.06% were unknown. The inclusion criteria were as follows: i) Born in Changzhou Maternal and Child Health Care hospital; ii) gestational week of delivery <37 weeks. The exclusion criteria were as follows: i) Patients with hospice care; ii) missing data on maternal pregnancy period or perinatal period; iii) pediatrics who were readmitted for various reasons after recovery from neonatology department; and iv) congenital abnormalities including fatal fetal anomaly, such as Edwards syndrome, anencephaly, Patau Syndrome, Renal Agenesis/Potter Syndrome, triploidy, serious open spina bifida, severe encephalocele, monocardian, severe fatal achondroplasia and severe cleft lip and palate.

The included subjects were divided into two groups: The respiratory assistance group, which had a history of ventilator use during neonatal hospitalization, including invasive ventilator, non-invasive ventilator and high-frequency ventilation; and the no ventilator use group, of which patients had no history of ventilator use during hospitalization.

The indications for non-invasive ventilation were: i) Early prophylactic application in the delivery room for premature infants with spontaneous breathing (gestational age 25-28 weeks); ii) preterm infants at high risk of respiratory distress syndrome (RDS); iii) when the fraction of inspired oxygen (FiO_2) >0.3, arterial oxygen saturations (PaO_2) <50 mmHg (1 mmHg=0.133 kpa) or transcutaneous oxygen saturations ($TcSO_2$) <90%; iv) premature infant apnea; v) the condition of children with RDS was stable following pulmonary surfactant treatment, and the tracheal tube was removed; and vi) after conventional mechanical ventilation or high-frequency ventilation was removed, there were obvious tri-retraction signs and/or respiratory distress (20-22).

The indications of conventional mechanical ventilation (CMV) were as follows: i) Frequent apnea, with no effect after medication or CPAP intervention; ii) children with RDS who require PS treatment; iii) FiO_2 >0.6-0.7, PaO_2 <50-60 mmHg or $TcSO_2$ <85% (except the cyanotic congenital heart disease); iv) $PaCO_2$ >60-65 mmHg, accompanied by persistent acidosis (pH <7.20); and v) newborns under general anesthesia (22).

High-frequency ventilation is often used for the following situations (22-25): i) Pulmonary air leak syndromes, including pneumothorax, interstitial emphysema or bronchopleural fistula; ii) some congenital diseases, such as diaphragmatic hernia, pulmonary dysplasia and severe thoracic deformity; iii) persistent pulmonary hypertension, especially for those requiring inhalation of NO; iv) lung diseases with severe non-uniform changes, such as meconium inhalation syndrome and severe pneumonia; and v) premature infant RDS, and can be used as the first choice after CMV failure.

The current study protocol followed the ethical guidelines of the Declaration of Helsinki (26) and was approved by the Ethics Committee of Changzhou Women and Children Health Care Hospital.

Patient information collection. Using the hospital's information system, a retrospective study was conducted to collect factors that may be associated with the use of ventilators in 3,578 patients. The data are anonymous, and the requirement for informed consent was therefore waived. Data included the general information and complication condition of mothers during the maternal pregnancy period, including the mothers' hospital number, age, polyembryony or not, gravidity and parity, the complications of pregnancy and delivery (such as anemia, hypertension, diabetes, infection, scarred uterus, cholestasis, hypoproteinemia, thrombocytopenia, uterine fibroid and hypothyroidism), whether the fetal position, placenta and umbilical cord were abnormal and whether the preterm birth was *in vitro* fertilization and embryo transfer. Furthermore, data regarding the condition of pediatric patients during the perinatal period was collected, and included the following: Whether there was premature rupture of membranes, the mode of delivery, the gestational age (weeks), 1-min and 5-min Apgar score (27), sex, birth weight and whether a ventilator was used. After removing unqualified cases, 3,394 subjects were included, of which 19.59% (665/3,394) required a ventilator (Fig. 1).

Statistical analysis. A total of 3,394 patients were included in the statistical analysis, 2,729 cases did not require ventilator use and 665 cases used a ventilator. Continuous variables were tested for normality using the Kolmogorov-Smirnov test. Data are presented as the mean \pm standard deviation or median (percentile 25 to percentile 75). When appropriate, continuous variables, including maternal age, birth weight and gestational age, were compared using unpaired Student's t-test or Mann-Whitney U test. Pregnancy times, 1-min and 5-min Apgar scores were compared using the Wilcoxon signed rank test. The remaining categorical variables were summarized using frequency and percentage and compared using χ^2 test or Fisher's exact test. For all possible determinants of treatment with a ventilator or not, univariate logistic regression analysis was performed. All variables with a $P < 0.1$ (defined '*a priori*') were considered relevant and included into the multivariate logistic regression analysis. Multivariate logistic regression analysis was used to define the factors that were independently associated with using a ventilator. Statistical analyses were performed with R version 3.4.1 (www.R-project.org). $P < 0.05$ was considered to indicate a statistically significant difference.

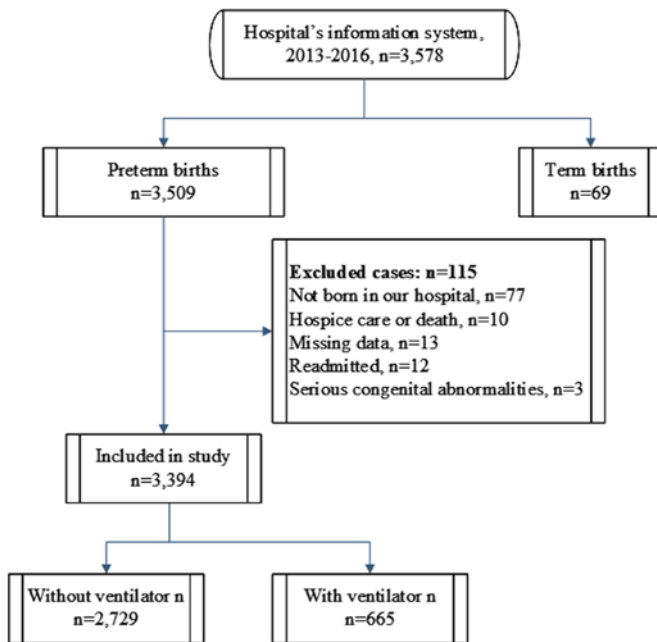


Figure 1. Flow chart outlining the protocol of the present study.

Results

Demographics and clinical characteristics. The results identified that among the factors during the maternal pregnancy period, there were significant differences between the two groups in terms of maternal anemia, abnormal fetal position, pregnancy with diabetes, placental abnormality, maternal infection, abnormality of umbilical cord, cholestasis during the maternal pregnancy period and neonates conceived by IVF (Table I). However, there were no statistically significant differences between the two groups in terms of maternal hypertension, scarred uterus, hypothyroidism and thrombocytopenia (Table I). Among the perinatal factors, the proportion of male infants who received ventilator rescue was significantly higher compared with the number of female infants. Furthermore, the patients who received ventilator rescue exhibited a lower 1-min and 5-min Apgar score, lower birth weight and smaller gestational age compared with those who did not receive ventilator treatment. There were significant differences between the groups in terms of whether the weight was suitable for gestational age (SGA/AGA/LGA), the mode of delivery (eutocia/caesarean section), pregnancy times, and premature rupture of membranes.

Risk factors associated with preterm infants who used ventilation. Univariate and multivariate logistic regression were used to analyze the risk factors for respiratory assistance in pediatric patients. The results demonstrated that placental abnormality, being male, cesarean section, low 1-min Apgar score, low birth weight and small gestational age were the independent risk factors for using respiratory assistance in rescue of premature infants (Table II).

Analysis of receiver operating characteristic (ROC) curve. The results from the multivariate regression analyses, which included birth weight, gestational age, 1-min Apgar, mode of

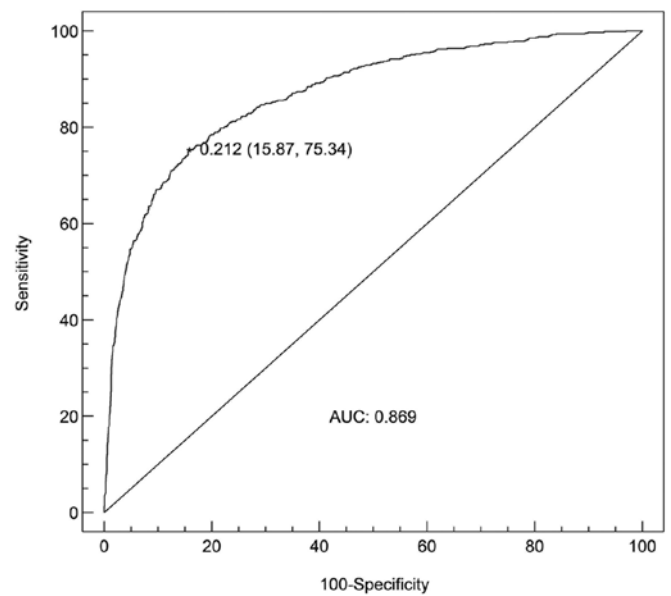


Figure 2. Received operator characteristic curve for the risk factors associated with respiratory assistance. AUC, area under the curve.

delivery (cesarean section/vaginal delivery), sex and placental abnormality, were used to construct the ROC curve analysis that predicted the use of infant ventilator in preterm infants. The area under the curve of the prediction model constructed in the present study was 0.869 and the cut-off value was 0.212, which indicated that the prediction ability and discrimination of the model were generally effective (Fig. 2).

Discussion

Ventilator-assisted ventilation, which is an important treatment tool used in the Neonatal Intensive Care Unit (NICU), has developed rapidly and aided a number of premature infants (13). However, if respiratory assistance is delayed, the rescue outcomes for newborn patients whose conditions are continuously changing and difficult to predict may be unfavorable. The present study investigated the risk factors for the use of ventilation in advance, and whether it is possible to predict if preterm births will require ventilator support or not, which will determine whether the relevant equipment should be prepared and a pediatrician made available in order to rescue infants quickly and improve their chances of survival. In addition, the economic cost of treatment for premature infants is high, and with the improvement of medicine, more premature infants of decreased gestational ages survive, which increases this cost (28-30). Ventilator support involves a number of different pieces of equipment, medical workers and expenses, which can be reduced if the risk factors of ventilator support are managed effectively.

As an effective method to solve high-risk pregnancy, dystocia and other obstetric critical illness, the use of a cesarean section has been increasing each year, and in 2015, an estimated 29.7 million (21.1%) births globally were by CS, which represented almost a doubling in the proportion since 2000, when 16.0 million (12.1%) births were by CS (31). Although cesarean delivery can reduce the incidence of neonatal asphyxia and meconium inhalation, the risk of

Table I. Demographics and clinical characteristics in premature babies with or without ventilator use.

A, Maternal pregnancy period			
Factor	Without ventilator, n=2,729	With ventilator, n=665	P-value
Anemia			0.001 ^b
Yes	1,234	347	
No	1,495	318	
Hypertension			0.118
Yes	545	115	
No	2,184	550	
Abnormal fetal position			0.045 ^a
Yes	441	129	
No	2,288	536	
Diabetes			0.018 ^a
Yes	368	67	
No	2,361	598	
Placental abnormality			<0.001 ^b
Yes	544	234	
No	2,185	431	
Infection			<0.001 ^b
Yes	603	219	
No	2,126	446	
Abnormality of umbilical cord			0.004 ^b
Yes	423	74	
No	2,306	591	
Scarred uterus			0.243
Yes	274	77	
No	2,455	588	
Cholestasis			0.004 ^b
Yes	305	49	
No	2,424	616	
Hypoproteinemia			0.776
Yes	269	68	
No	2,460	597	
Conceived by IVF			0.013 ^a
Yes	364	65	
No	2,365	600	
Thrombocytopenia			0.405
Yes	73	14	
No	2,656	651	
Uterine fibroid			0.786
Yes	53	14	
No	2,676	651	
Hypothyroidism			0.573
Yes	41	12	
No	2,688	653	
Maternal age (years) ^c	28.18±4.94	28.42±5.07	0.266
B, Perinatal period			
Factor	Without ventilator, n=2,729	With ventilator, n=665	P-value
Age (days) ^c	1.12±0.86	1.10±0.77	0.571
Sex, female/male			<0.001 ^b
Female	1,231	250	
Male	1,498	415	

Table I. Continued.

B, Perinatal period			
Factor	Without ventilator, n=2,729	With ventilator, n=665	P-value
AGA or not			0.007 ^b
SGA	321	72	
AGA	2,328	587	
LGA	81	6	
Mode of delivery			<0.001 ^b
Eutocia	1,142	329	
Cesarean	1,587	336	
1-min Apgar score ^d	8 (8-9) ^c	7 (6-8)	<0.001 ^b
5-min Apgar score ^d	8 (8-9) ^c	8 (7-8)	<0.001 ^b
Monocyesis			0.005 ^b
Yes	1,949	511	
No	780	154	
Pregnancy times			0.010 ^a
1	1,208	262	
2	710	176	
3	403	108	
≥4	408	119	
Parity			0.767
Primiparous	1,265	304	
Multiparous	1,464	361	
Birth weight (g) ^c	2339.83±473.06	1735.64±523.24	<0.001 ^b
Gestational age (weeks) ^c	34.29±1.62	31.24±2.59	<0.001 ^b
Premature rupture of membrane			0.001 ^b
Yes	1124	229	
No	1605	436	

^aP<0.05; ^bP<0.01; ^cvalues are presented as mean (standard deviation); ^dvalues are presented as median (range). SGA, small for gestational age; AGA, appropriate for gestational age; LGA, large for gestational age.

respiratory morbidity and the probability of admission into the NICU are significantly higher (32,33). Furthermore, previous studies have reported that cesarean section is a risk factor for respiratory diseases, such as respiratory distress syndrome (34-36), transient shortness of breath (37) and pulmonary hypertension (38), but few of these studies examine the association between ventilator use and cesarean section. In the present study, cesarean section was demonstrated to be an independent risk factor for ventilator use.

Fetuses need to overcome the viscosity resistance, surface tension and tissue resistance of the lung fluid by accelerating their breathing rate after delivery, but fetuses delivered by cesarean section have significant restricted ventilatory dysfunction within 12 h of birth due to the lower tidal volume and minute ventilation volume compared with fetuses born via vaginal delivery (39). It has been previously suggested that the clearance of fetal lung fluid begins before birth, and neonates born via cesarean section without uterine contractions may have difficulty in removing fluid from their lungs, which can result in obstruction of ventilation (39). In addition, cesarean delivery makes infants more susceptible to

Table II. Analysis of risk factors for using a ventilator in preterm infants.

A, Maternal pregnancy period						
Variables	Univariate regression analysis			Multivariate regression analysis		
	OR	95% CI	P-value	OR	95% CI	P-value
Anemia, yes/no	1.322	1.116-1.566	0.001 ^b	1.021	0.819-1.273	0.854
Hypertension, yes/no	0.838	0.671-1.046	0.118			
Abnormal fetal position, yes/no	1.249	1.005-1.552	0.045 ^a	0.778	0.581-1.042	0.092
Diabetes, yes/no	0.719	0.546-0.947	0.019 ^a	0.864	0.613-1.217	0.402
Placental abnormality, yes/no	2.181	1.813-2.623	<0.001 ^b	1.284	1.002-1.646	0.048 ^a
Infection, yes/no	1.731	1.438-2.083	<0.001 ^b	1.151	0.901-1.471	0.259
Abnormality of umbilical cord, yes/no	0.683	0.525-0.888	0.004 ^b	0.832	0.605-1.145	0.259
Scarred uterus, yes/no	1.173	0.897-1.534	0.243			
Cholestasis, yes/no	0.632	0.462-0.866	0.004 ^b	0.992	0.675-1.457	0.967
Hypoproteinemia, yes/no	1.042	0.787-1.379	0.776			
Conceived by IVF, yes/no	0.704	0.533-0.930	0.014 ^a	0.789	0.528-1.181	0.249
Thrombocytopenia, yes/no	0.782	0.439-1.395	0.406			
Uterine fibroid, yes/no	1.086	0.599-1.969	0.786			
Hypothyroidism, yes/no	1.205	0.630-2.305	0.574			
Maternal age (years)	1.010	0.993-1.027	0.258			

B, Perinatal period						
Variables	Univariate regression analysis			Multivariate regression analysis		
	OR	95% CI	P-value	OR	95% CI	P-value
Sex, female/male	0.733	0.616-0.872	<0.001 ^b	0.696	0.558-0.869	0.001 ^b
Gestational age, SGA/AGA	0.892	0.680-1.170	0.41	0.887	0.579-1.356	0.579
Gestational age, LGA/AGA	0.294	0.128-0.667	0.004 ^b	1.182	0.432-3.235	0.745
Delivery method: Cesarean section/eutocia	0.735	0.620-0.871	<0.001 ^b	1.538	1.197-1.977	<0.001 ^b
1-min Apgar score	0.479	0.443-0.518	<0.001 ^b	0.727	0.638-0.828	<0.001 ^b
5-min Apgar score	0.300	0.261-0.343	<0.001 ^b	0.908	0.740-1.114	0.356
Polyembryony, yes/no	0.753	0.618-0.918	0.005 ^b	0.763	0.571-1.018	0.066
Pregnancy times	1.105	1.024-1.192	0.01 ^a	1.005	0.911-1.109	0.916
Parity, ≥2/1	1.026	0.866-1.216	0.767			
Birth weight (g)	0.997	0.997-0.998	<0.001 ^b	0.999	0.999-1.000	0.005 ^b
Gestational age (weeks)	0.519	0.493-0.546	<0.001 ^b	0.616	0.560-0.678	<0.001 ^b
Premature rupture of membrane, yes/no	0.750	0.628-0.895	0.001 ^b	0.966	0.769-1.214	0.769

^aP<0.05; ^bP<0.01. OR, odds ratio; CI, confidence interval; SGA, small for gestational age; AGA, appropriate for gestational age; LGA, large for gestational age.

NRDS and its accompanying increase in endothelin-1 levels, which may indirectly result in the occurrence of Persistent Pulmonary Hypertension of Newborn (38). Exposure of newborns delivered via caesarean section with the combined effect of these pathophysiological events may result in the occurrence of respiratory distress, hypoxia, acidosis and transition-delay (34). Therefore, the risk of respiratory diseases in premature infants delivered by caesarean section is higher, which suggests that the indications for elective caesarean section should be strictly controlled when selecting this

method of delivery for premature infants in clinical practice, thus reducing their risk of ventilator use.

A previous study which measured the association between fetal sex and preterm birth in four original datasets found that premature birth is more common in males, with ~55% of premature births occurring in male infants (40). In addition, male infants exhibit a higher mortality rate compared with female infants born in the same gestation period (41). The results of the present study suggested that the male sex is an independent risk factor for ventilator use, which is consistent

with previous studies reporting that the incidence of certain respiratory-related diseases in male newborns is significantly higher compared with that of female infants. For example, the incidence of NRDS in late-stage premature infants with different sexes is statistically different (male infants have a higher incidence compared with female infants) (42,43). Another study compared 130 premature male infants with 106 premature female infants and revealed that 60.8% of male infants required machinery ventilation support compared with only 46.2% of female infants, and the incidence of Chronic Lung Disease in male infants was higher compared with that of female infants (44). A previous study reported that after birth, male infants express less transforming growth factor (TGF)- β compared with female infants, and low levels of TGF- β are important indicators for predicting aerobic therapy, and at 36 weeks, male infants require a higher oxygen supply compared with female infants, which may cause premature male infants to lack oxygen, thus deepening and accelerating the breathing and aggravating damage to the respiratory system (45). Another previous study indicated that the carbon dioxide partial pressure of male infants is lower compared with female infants within 24 h after birth (46), while the low level of carbon dioxide partial pressure is associated with a low level of pulmonary surfactant, which may account for the sex difference in respiratory diseases. In addition, genetic factors may be responsible for sex differences. For example, a previous study revealed that allele 186 Asn and haploid 138 Asn-186 Asn are independent risk factors for RDS (47), and the association between allele 186 Asn and RDS was observed among male infants (48).

In the present study, it was revealed that placental abnormalities, such as placental abruption, placenta previa, placental adhesions and abnormal invasion placenta (AIP), may also increase the risk of ventilator use. Ahn *et al* (49) studied newborns born by 2,067 mothers with placenta previa and demonstrated that newborns whose anterior placenta previa in the second and third trimesters was correlated with NRDS. Furthermore, a previous study reported that AIP increased the risk of NRDS, and AIP cases required longer respiratory assistance compared with the control group, which was consistent with the results of the current study (50).

Apgar score includes heart rate, respiratory effort, muscle tone, reflex irritability and color, which is the standard evaluation method of checking the health condition of the infant immediately after birth (27). This score has been used as a predictive index for neonatal mortality and morbidity, and for later neurologic or developmental disability (51). Numerous factors can influence Apgar score, such as maternal education and BMI, gestational age, pathological obstetrics, longer duration of the second stage of labor, neonatal weight and meconium-stained amniotic fluid (52). The present results suggested that 1-min Apgar score was a risk factor for respiratory assistance in premature infants, indicating that weight control in pregnant women, reduction of the preterm birth and other measures may reduce the use of ventilators.

As aforementioned, lung-related structures and metabolites mature in the last trimester, and thus premature infants often require respiratory assistance (6,7,53). In the current study, the ventilator utilization rates of gestational age <28 weeks, 28-31 weeks and 32-36 weeks were 89.58% (43/48),

65.38% (321/491) and 10.54% (301/2,855), respectively (data not shown); therefore, it was suggested that the younger the gestational age, the more ventilator support is required. Birth weight is also a risk factor for numerous respiratory diseases (54,55). To avoid these diseases, the pregnancy period should be extended as soon as possible, as well as ensuring good nutrition, and timely and regular antenatal visits during pregnancy. However, multiple sociodemographic, nutritional, biological and environmental factors can increase the risk of preterm birth and low birth weight (56,57). Therefore, methods for appropriate interventions to reduce the incidence of premature infants and low birth weight remain challenging.

With the increasing incidence of premature infants, how to reduce the use of ventilators, and use the ventilators correctly and timely is of great concern (1). However, there is limited research on the risk factors of ventilator use in premature infants worldwide, and there are few predictive models constructed for its use. The high-risk factors associated with respiratory assistance observed in the present study, including placental abnormality, being male, cesarean section, low 1-min Apgar score, low birth weight and small gestational age, may reduce the use of respiratory assistance by developing strategies to decrease these factors, and to clinically guide medical staff to identify pediatric patients with high risk factors, which will allow advanced preparation of the ventilator and ensure the availability of a pediatrician. Collectively, these actions could help to minimize the time of hypoxia within newborns, which will increase their survival.

There are some limitations of the present study that require discussion. Firstly, the current study used data from a single-center that has not been validated in other hospitals. Secondly, there was no in-depth discussion of the individual risk factors, such as a stratified analysis based on gestational age, which would provide more accurate risk factor analysis for the respiratory assistance of premature infants in different gestational age groups. This should be performed in future studies in order to provide a basis for preparing for the respiratory assistance of premature infants.

In conclusion, the present results suggested that cesarean section, male neonates, placental abnormality, low 1-min Apgar score, low birth weight and lower gestational age represented independent risk factors for the use of ventilators in premature infants. Thus, increased effort to reduce the use of ventilators and provide early detection of those requiring assistance should be performed for premature infants who require respiratory assistance to improve their survival rate and quality of life. Firstly, the indications for elective cesarean section should be strictly controlled when selecting cesarean section for premature infants in clinical practice. Secondly, ensuring nutrition and the timely and regular antenatal visits during pregnancy are important, as well as the pregnancy period should be extended as soon as possible. Finally, for premature infants who have risk factors for using the ventilator, ventilator support such as the relevant equipment and personnel should be prepared in time to improve their chances of survival.

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Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Authors' contributions

HXL, ZLM and HYW were study investigators and participated in study design, patient recruitment, acquisition of data, and/or analysis and interpretation of the findings. HXL, ZLM, HYW, CJG and SC contributed to data analysis, drafting and revising the article, gave final approval of the version to be published, and agree to be accountable for all aspects of the work. All authors read and approved the final version of the manuscript.

Ethics approval and consent to participate

The present study protocol followed the ethical guidelines of the Helsinki Declaration revised in 2008 and was approved by the Ethics Committee of Changzhou Women and Children Health Care Hospital (Changzhou, China).

Patient consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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