www.jpnim.com Open Access eISSN: 2281-0692
Journal of Pediatric and Neonatal Individualized Medicine 2020;9(2):e090226
doi: 10.7363/090226
Received: 2019 Nov 02; revised: 2020 Feb 06; accepted: 2020 Feb 06; published online: 2020 Oct 31

Review

Risk factors for neonatal mortality in Neonatal Intensive Care Units (NICUs): a systematic literature review and comparison with scoring systems

Farzaneh Kermani[1,2], Abbas Sheikhtaheri[3], Mohammad Reza Zarkesh[4], Shahram Tahmasebian[5]

[1]Health Information Technology Department, School of Allied Medical Sciences, Semnan University of Medical Sciences, Semnan, Iran

[2]Department of Health Information Management, School of Health Management and Information Sciences, Iran University of Medical Sciences, Tehran, Iran

[3]Health Management and Economics Research Center, School of Health Management and Information Sciences, Iran University of Medical Sciences, Tehran, Iran

[4]Department of Neonatology, Yas Complex Hospital, Tehran University of Medical Sciences, Tehran, Iran

[5]School of Advanced Technologies, Shahrekord University of Medical Sciences, Shahrekord, Iran

Abstract

Objective: To identify neonatal death risk factors in NICUs and compare these factors with current scoring systems.

Data source: This review was conducted using Web of Science, PubMed/Medline, Scopus, and Cochrane library databases, considering papers published between 2007 and 2018.

Study selection: Studies conducted on the neonatal mortality risk factors in NICUs were included. We identified 3,642 unique citations; 69 full-text articles were included in the final review.

Data extraction: Data elements such as the first author, published year, country, purpose, data collection period, study design, sample size, and risk factors were extracted.

Data synthesis: Ninety factors were identified in three categories: 25 maternal factors, 59 neonatal factors, and six organizational factors. In total, delivery mode, non-use of steroid or corticosteroid, birth weight, gestational age, Apgar score, hospital/NICU level, and outborn status are the most cited risk factors for neonatal death. Well-known scoring systems did not consider many of the identified factors.

Conclusions: Determination of risk factors in neonatal death can help neonatologists identify sick neonates who are more likely to die in

NICUs and provide on-time care at their bedsides. Researchers interested in developing predictive neonatal mortality models may also use the results of this study to develop models for predicting neonatal death.

Keywords

Mortality, death, neonate, neonatal mortality, risk factors, Neonatal Intensive Care Unit.

Corresponding author

Abbas Sheikhtaheri, Health Management and Economics Research Center, School of Health Management and Information Sciences, Iran University of Medical Sciences, Tehran, Iran; email: sheikhtaheri.a@iums.ac.ir.

How to cite

Kermani F, Sheikhtaheri A, Zarkesh MR, Tahmasebian S. Risk factors for neonatal mortality in Neonatal Intensive Care Units (NICUs): a systematic literature review and comparison with scoring systems. J Pediatr Neonat Individual Med. 2020;9(2):e090226. doi: 10.7363/090226.

Introduction

The neonatal mortality rate, which refers to death occurring in the first 28 days of life, is an important indicator in evaluating public health services [1]. In 2017, nearly 2.5 million neonates died in their first month of life, of which about 36% died on the same day of birth and nearly three-quarters of them died in the first week of life [2, 3]. The neonatal death rate is 14 times lower in developed countries than in developing countries, mainly because of limited access to healthcare [4].

Early diagnosis and detection of at-risk neonates provide the possibility of timely treatment [5]. Initially, birth weight (BW) and Apgar scores were used in diagnosis, but they were not sufficiently accurate. Therefore, scoring systems like Clinical Risk Index for Babies (CRIB), Clinical Risk Index for Babies II (CRIB-II), Score for Neonatal Acute Physiology (SNAP), Score for Neonatal Acute Physiology with Perinatal Extension (SNAPPE), Score for Neonatal Acute Physiology II (SNAP-II), and Score for Neonatal Acute Physiology with Perinatal Extension II (SNAPPE-II) were developed [6-8]. Each of these models has several factors that are not necessarily common or comprehensive. The identification of risk factors for neonatal death is helpful in updating scoring systems or creating predicting models comprised of variables according to current healthcare systems and NICU equipment. Many studies have been done in this respect, but they are limited to a geographical area, a particular hospital, or a limited number of neonates. Therefore, it seems that no comprehensive study has been conducted to identify and classify all risk factors. In the only systematic review on predictive mortality factors published in 2011, studies related to the predictive performance of a model in terms of mortality on very premature or low birth weight (LBW) neonates were included and classified. In this review, factors related to neonatal death in Neonatal Intensive Care Units (NICUs) have not been comprehensively reported [9].

The primary aim of this study was to systematically review the literature to identify the risk factors affecting neonatal death or decreased survival rates among all live neonates in NICUs. The secondary aim was to compare the identified factors with current scoring systems dealing with neonatal death. In spite of the Medlock et al. study [9], we reviewed all the articles that determined the mortality risk factors on all neonates in NICUs.

Materials and methods

This review was performed according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [10]. The main steps are discussed in the following sections.

Inclusion and exclusion criteria

Papers with the following criteria were included:

- publication date between 2007 and 2018, even if the data collection period was before 2007;
- observational studies;
- papers published in English;
- articles related to neonates admitted to NICUs or level 1, 2, or 3 Neonatal Units;
- studies examining the risk factors for neonatal death or survival. Death/mortality or survival should be explicitly mentioned as one of the main outcomes of the study;
- the risk factors are related only to the neonatal period. Studies for other age groups were included only if results regarding the neonatal period were presented separately.

Papers with the following criteria were excluded:

- interventional studies;
- case studies, letters to editor, protocols, and papers published at conference proceedings without the full text;
- because the study population was neonates who had no anomalies or early diseases, papers related to neonates who had anomalies or early illnesses at the beginning of the study (for example renal or gastrointestinal disease, surgical history, heart surgery, or onset sepsis) were excluded. Case-control studies were included because a group of healthy neonates was included in the study;
- studies related to genetic factors;
- studies related to perinatal death, fetal death, or stillbirths based on the definitions: "perinatal mortality refers to death around the time of delivery and includes both fetal deaths and early infant death" [11] and it does not just include neonatal death; fetal death also refers to any death occurring at least "at 20 weeks' gestation" [12];
- studies that merely report mortality statistics.

Search strategy and information sources

The Web of Science, Scopus, Medline/PubMed and Cochrane Library databases were searched for articles published over the stated 11-year period. The search strategy included four term categories: "risk factor", "NICU", "neonate" and "mortality", along with synonyms, which were identified from Mesh and Emtree. Retrieved articles were added to EndNote.

Study selection

Two Authors (Sh, Kr) independently reviewed titles and abstracts based on the inclusion and exclusion criteria and removed any unrelated studies. Subsequently, two Authors (Sh, Kr) independently reviewed the full text of the remaining articles. To resolve any controversy, consensus was achieved in meetings.

Data extraction and synthesis

A data extraction form was developed to extract data. The two Authors (Sh, Kr) independently extracted the data, and cases of disagreement were resolved with consensus. Due to the heterogeneity of the methods and findings, the results were analyzed descriptively. It seems that in neonates with different gestational ages (GAs)/BW or in different countries, various factors are considered more important; therefore, a subgroup analysis was conducted based on different aspects, like developed and developing countries, and mortality risk factors were compared based on GA/BW as inclusion criteria. Descriptive statistics and frequency of risk factors were reported to analyze the data.

Results

Study characteristics

Out of 3,642 retrieved articles, 69 articles [1, 5, 13-79] were ultimately reviewed. **Fig. 1** presents details on the article selection process.

Fig. 2 shows that most studies were conducted in the US (8; 13%), followed by Canada and Brazil. Only 28 studies were conducted in developed nations [13, 15-18, 21, 26, 28, 30, 34-37, 42-45, 47, 53, 55, 56, 59, 61, 65, 69, 72, 78, 79] and 42 studies in developing countries [1, 5, 14, 19, 20, 22-25, 27, 29, 31-33, 38-41, 46-52, 54, 57, 58, 60, 62-64, 66-68, 70, 71, 73-77]. The average number of samples in the included studies was 6,775.8; the largest and smallest studies were conducted in the US with 72,431 live births in the years 1999 to 2009 [56] and in Turkey with 63 very low birth weight (VLBW) neonates [41]. The average data collection period was 3.52 years; the highest (18 years) was in an Australian study [79].

The inclusion and exclusion criteria are presented in **Tab. 1**. In addition to admission to NICU, GA and BW were common inclusion criteria (29 and 24 studies, respectively). The highest frequency of exclusion criteria is related to anomaly malformation (23 studies).

Results on risk factors

Risk factors were classified into three categories: maternal, neonatal, and organizational factors. Maternal factors reflect the characteristics of a pregnant mother. Neonatal factors are inherent factors and those present at birth. Organizational factors refer to the conditions of the center, hospital, or NICU where the neonate was born or transferred and the referral situations. Overall, 90 factors, 25 maternal, 59 neonatal, and six organizational factors were identified. Among the

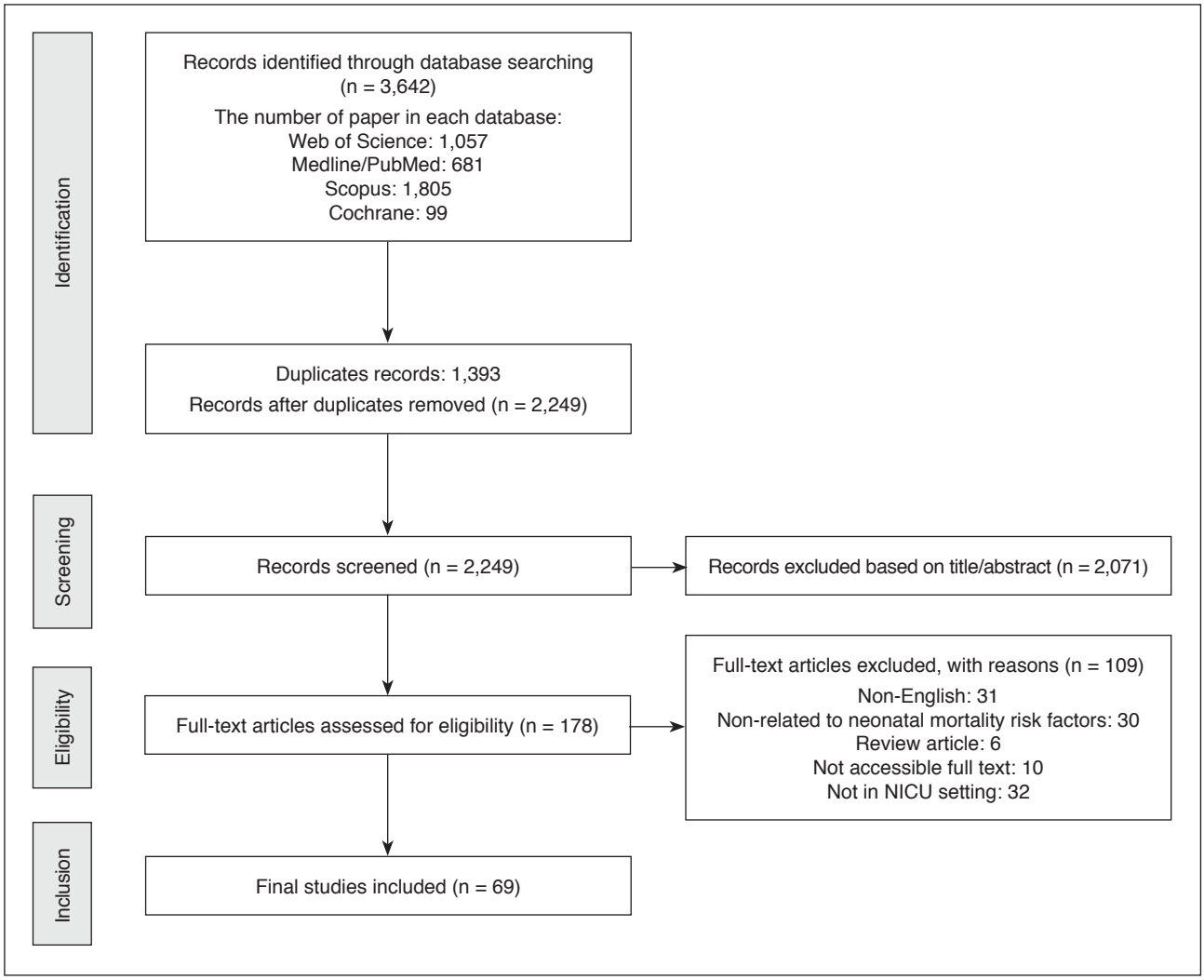

Figure 1. PRISMA flow diagram of study identification.
NICU: Neonatal Intensive Care Unit; PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-Analyses.

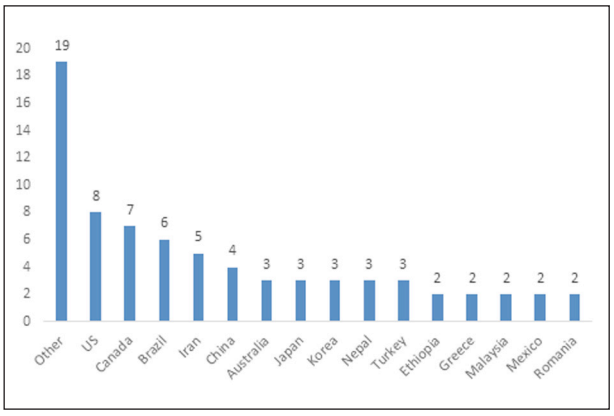

Figure 2. Distribution of papers by country.

maternal factors, delivery mode (n = 6) was the most cited factor. Among the neonatal factors, BW (n = 35), GA (n = 31), and Apgar score (n = 18) are the most cited factors. Congenital anomaly, sepsis, and respiratory distress syndrome (RDS) were other important risk factors for neonatal death. Among the organizational factors, the hospital/NICU level was the most cited factor (**Tab. 2**).

In comparing developed and developing nations, it was found that the most cited risk factors in developed countries were BW (n = 14, 50%), GA/prematurity (n = 12, 42.8%), gender (n = 9, 32.1%), and delivery mode (n = 7, 25%) and in developing countries were BW (n = 24, 57.1%), Apgar score (n = 17, 40.7%), GA (n = 16, 38%), RDS (n = 10, 23.8%), and sepsis (n = 10, 23.8%). The comparison further indicated that some factors are not the same in developed and developing countries; for example, in developing countries, factors such as RDS, asphyxia, intubation, and congenital heart disease (CHD) were considered risk factors, which were not seen in the risk factors found in developed countries. Furthermore, factors such as multiple pregnancies, intrauterine growth restriction (IUGR), and infection were among the risk factors

Table 1. Distribution of papers based on inclusion and exclusion criteria.

Inclusion criteria		
Variables	**References**	**Frequency (%)**
GA	[14, 15, 18, 22, 23, 28, 30, 33, 35-38, 42-45, 48-51, 54, 55, 61, 62, 64-66, 73, 79]	29 (42)
BW	[14, 15, 21, 23, 28, 32-34, 38, 40, 41, 44, 46, 47, 50, 51, 53, 56-59, 69, 71, 78]	24 (34.7)
Live born	[14, 24, 39, 42, 46, 50, 51, 54, 57, 61, 62, 70, 72, 79]	14 (20.3)
Inborn	[5, 14, 15, 30, 62, 72, 76, 79]	8 (11.6)
NICU stay/admit in the first 24 h	[5, 13, 22, 30, 61, 63]	6 (8.7)
Singleton/multiple gestation	[5, 21, 37, 45, 51]	5 (7.2)
Death within 24 h/at delivery room	[13, 30, 46]	3 (4.3)
Transfer to another NICU	[13, 30]	2 (2.9)
Data availability	[33]	1 (1.4)
Others [a]	[5, 17, 34, 45, 63]	5 (7.2)
Exclusion criteria		
Variables	**References**	**Frequency (%)**
Anomaly malformation (lethal anomaly, chromosomal abnormality, genetic syndrome, congenital anomaly, Down's syndrome)	[21, 22, 28, 32-36, 38, 40, 42, 43, 45, 49, 51, 56, 57, 62, 69, 71-73, 78]	23 (33.3)
Inadequate data	[19, 25, 29, 37, 41, 43-46, 56, 68-70, 74, 78, 79]	16 (23.1)
Outborn	[5, 14, 15, 30, 62, 72, 76, 79]	8 (11.6)
BW	[14, 37, 40, 41, 45, 56, 70, 78]	8 (11.6)
Transfer to/from other institutions	[5, 24, 50, 57, 67]	5 (7.2)
Voluntary discharge/parents didn't give consent	[5, 23, 63, 77]	4 (5.8)
GA	[30, 57, 70, 78]	4 (5.8)
Death in the delivery room	[50, 58, 72]	3 (4.3)
Admission after 24 h of life	[22, 63]	2 (2.9)
Death in the first 12 h	[38, 40]	2 (2.9)
Death in the first 24 h	[31]	1 (1.4)
Death after 28 day	[68]	1 (1.4)
Death to discharge	[64]	1 (1.4)
Death within 7 days of life	[71]	1 (1.4)
Death before admission	[26]	1 (1.4)
Others [b]	[16, 31, 51, 54]	4 (5.8)

[a] Hospital with > 100 beds by obstetric and pediatrics services, congenital anomaly, ethnic (white), visible external malformation, obtained parental consent; [b] admission for convalescent or step-down care, transient thrombocytopenia, antepartum or intrapartum stillbirth in the reference population, multiple births.
BW: birth weight; GA: gestational age; NICU: Neonatal Intensive Care Unit.

for neonatal death emphasized only in developed countries.

The studies were classified into three groups based on the inclusion criteria. In the first and second groups, GA and BW < 1,500 g were considered as an inclusion criterion, respectively, and the third group included studies performed on all neonates without GA/prematurity and BW as their inclusion criteria. Among the first group of studies, five important risk factors in neonatal death were GA (prematurity), BW (SGA, z-score < 1), Apgar score, congenital anomaly, heart disease, and gender. In the second group, these factors included BW, Apgar score, GA, gender, and delivery mode. However, in the third group of studies, GA, congenital anomaly, sepsis, Apgar score, and RDS were the five most cited risk factors. In other words, in both premature neonates and neonates with BW < 1,500 g, BW and GA are the most cited factors, but in studies performed on all neonates without any inclusion criterion, congenital anomaly, sepsis, RDS, and asphyxia are also considered important.

Table 2. Neonatal mortality risk factors in NICUs (continues on the next page).

Risk factors	References	Frequency (%)
Maternal factors		
Preterm delivery/placental disorder/abruption/PROM/antepartum hemorrhage/IUGR	-	10 (14.49)
Antepartum hemorrhage	[36, 40, 42]	3 (4.34)
Placental disorder/abruption	[21, 40, 44]	3 (4.34)
Preterm delivery	[21, 74]	2 (2.89)
IUGR	[42]	1 (1.44)
PROM	[42]	1 (1.44)
Delivery mode	[15, 21, 40, 47, 59, 72]	6 (8.69)
Obstetric complications	-	5 (7.24)
Obstetric complications	[66]	1 (1.44)
Incompetent cervix	[21]	1 (1.44)
Pregnancy-induced hypertension	[36]	1 (1.44)
Maternal infection/choriamnionitis	[42]	1 (1.44)
Maternal pre-eclampsia	[40]	1 (1.44)
Absence of antenatal steroids/corticosteroid	-	5 (7.24)
Absence of antenatal corticosteroid	[24, 43, 72]	3 (4.34)
Absence of antenatal steroids	[14, 50]	2 (2.89)
Absence of antenatal/prenatal care	[21, 32, 68, 76]	4 (5.79)
Ethnicity/race	-	4 (5.79)
Ethnicity	[13, 75]	2 (2.89)
Foreign mother	[57]	1 (1.44)
Geographic regions	[46]	1 (1.44)
Surfactant use	[40, 43, 50, 77]	4 (5.79)
No prenatal maternal transfer	[17]	1 (1.44)
Non-use of a pain scale	[50]	1 (1.44)
Instrumental delivery	[67]	1 (1.44)
Polyhydramnios	[21]	1 (1.44)
Maternal age	[73]	1 (1.44)
Ultrasonography requirement	[77]	1 (1.44)
Stillbirth	[29]	1 (1.44)
Neonatal factors		
Respiratory factor	-	45 (65.21)
RDS	[1, 19, 21, 25, 27, 38, 40, 48, 60, 63, 70, 74, 76]	13 (18.84)
Perinatal asphyxia	[1, 20, 27, 39, 47, 63, 67, 70, 74]	9 (13.04)
Pulmonary hemorrhage	[1, 27, 40, 47]	4 (5.79)
Pulmonary malformation with hemorrhage	[47, 52]	2 (2.89)
Persistent pulmonary hypertension/PFC	[1, 47]	2 (2.89)
Pneumonia	[25, 63]	2 (2.89)
CLD	[26, 27, 40]	3 (4.34)
Respiratory problems	[42]	1 (1.44)
Respiratory failure related to congenital myotonic dystrophy	[27]	1 (1.44)
NCPAP	[40]	1 (1.44)
Air leak syndrome	[1, 25, 27, 47, 52, 70]	6 (8.69)
TTN	[70]	1 (1.44)
BW (modeled in multiple way including SGA, z-score)	[5, 13, 14, 17, 21, 23, 24, 28, 29, 31-33, 35-47, 50, 57-59, 62, 63, 66, 73-76]	35 (50.72)

Table 2. Neonatal mortality risk factors in NICUs (continues from the previous page and on the next page).

Risk factors	References	Frequency (%)
Neonatal factors		
GA/prematurity (prematurity with SGA, prematurity [GA] with RDS, prermaturity with grade 3/4 IVH, late-preterm)	[13-15, 17, 18, 20, 22, 23, 28, 30, 33, 36, 38, 39, 42-45, 50, 52, 54, 58-60, 64, 70, 73, 76]	31 (44.92)
Apgar score	[5, 14, 23, 24, 28, 29, 32, 33, 36, 38-40, 50, 55, 57, 60, 62, 74-76]	18 (26.08)
Infection	-	17 (24.63)
Sepsis/blood culture positive sepsis	[13, 19, 22, 25, 27, 31, 33, 48, 63, 67, 68, 70, 73]	13 (18.84)
Septic shock	[1, 25]	2 (2.89)
Infections	[42]	1 (1.44)
Positive CRP	[60]	1 (1.44)
Congenital abnormality	-	16 (23.18)
Congenital anomalies	[1, 14, 16, 20, 24, 39, 44, 63, 70, 74, 76]	11 (15.94)
CHD	[26-28, 48, 64]	5 (7.24)
Blood factor	-	13 (18.84)
Platelet transfusion	[5, 31]	2 (2.89)
DIC	[1, 25]	2 (2.89)
Blood Gases	[5]	1 (1.44)
P(A-a) O_2	[5]	1 (1.44)
PaO_2/FiO_2	[5]	1 (1.44)
Lactate	[5]	1 (1.44)
Base excess	[38]	1 (1.44)
RBC transfusion	[71]	1 (1.44)
Serum glucose	[5]	1 (1.44)
Hematological abnormality	[40]	1 (1.44)
Thrombocytopenia	[31]	1 (1.44)
Gender	[17, 21, 30, 36, 43, 45, 47, 50, 57, 59, 69, 75]	12 (17.39)
Gastrointestinal disorder	-	12 (17.39)
NEC	[19, 22, 25, 44, 47, 70]	6 (8.69)
Gastrointestinal diseases	[26, 40, 42, 77]	4 (5.79)
Intestinal malformations (severe defects of the abdominal wall)	[47]	1 (1.44)
Tracheoesophageal fistula	[19]	1 (1.44)
Oxygen treatment	-	10 (14.49)
Mechanical ventilation	[29, 40, 43, 52, 66, 77]	6 (8.69)
Intubation	[14, 24, 40]	3 (4.34)
Oxygen treatment	[39]	1 (1.44)
Brain damage	-	9 (13.04)
IVH	[1, 19, 25, 27, 42, 51, 63]	7 (10.14)
Hypoxic ischemic encephalopathy	[19]	1 (1.44)
Brain hemorrhage	[44]	1 (1.44)
Singleton or multiple births	[17, 44, 50, 57, 61]	5 (7.24)
Kidney disorder	-	3 (4.34)
AKI	[53]	1 (1.44)
Acute renal failure with hyperkalemia	[27, 78]	2 (2.89)
Body temperature	-	3 (4.34)
Hypothermia	[14, 49, 79]	3 (4.34)
Neonatal seizure	[25, 40]	2 (2.89)

Table 2. Neonatal mortality risk factors in NICUs (continues from the previous page).

Risk factors	References	Frequency (%)
Neonatal factors		
Surgical intervention	[77]	1 (1.44)
Administration inotropes	[65]	1 (1.44)
Resuscitation	[57]	1 (1.44)
Brusing at birth	[15]	1 (1.44)
Nosocomial infection	[1]	1 (1.44)
IEM	[1]	1 (1.44)
Multiple organ failure	[47]	1 (1.44)
Meconium aspiration	[70]	1 (1.44)
Hemodynamic instability	[38]	1 (1.44)
Management factors		
Hospital level/NICU level/type of hospital	[15, 21, 23, 34, 46, 56]	6 (8.69)
Outborn status	[13, 42, 43, 57]	4 (5.79)
Hospital volume of VLBW	[17, 21, 46]	3 (4.34)
Admission from another NICU/transfer	[16, 44, 74]	3 (4.34)

AKI: acute kidney injury; BW: birth weight; CHD: congenital heart disease; CLD: chronic lung disease; CRP: C-reactive protein; DIC: disseminated intravascular coagulation; IEM: inborn errors of metabolism; IUGR: intrauterine growth restriction; IVH: intraventricular hemorrhage; NCPAP: nasal continuous positive airway pressure; NEC: necrotizing enterocolitis; NICU: Neonatal Intensive Care Unit; PFC: persistent fetal circulation; PROM: premature rupture of membranes; RDS: respiratory distress syndrome; TTN: transient tachypnea of the newborn; VLBW: very low birth weight.

The factors included in five common neonatal death scoring systems were compared with those found in the reviewed studies (**Tab. 3**), and some of the factors mentioned in this study are common among the scoring systems. For example, BW is also included in CRIB, CRIB-II, SNAPPE, and SNAPPE-II. GA is also considered in CRIB, SNAPPE, and SNAPPE-II. However, RDS, sepsis, delivery mode, and hospital/NICU levels were found to be important risk factors in the current study, but they are not considered in any of these scoring systems. Additionally, factors such as apnea, blood urea nitrogen, calcium, creatinine, urine output, direct bilirubin, etc., which are included in SNAP, SNAPPE, SNAP-II, and SNAPPE-II, were not confirmed as important factors in the current study (**Tab. 3**).

Discussion

Summary of results and comparison with other studies

In this study, 69 articles about neonatal mortality risk factors in NICUs were identified. In addition to BW and GA, other factors such as low Apgar score, sepsis, RDS, gender (male), congenital anomaly, asphyxia, IVH, necrotizing enterocolitis (NEC), ventilator need, antepartum hemorrhage, delivery mode, and hospital/NICU level were the most cited factors in neonatal death, respectively.

The studies reviewed herein were heterogeneous in terms of population; 29 studies were conducted on premature neonates (< 37 weeks) and 28 studies on neonates with BW < 1,500 g. Factors such as GA, BW, Apgar score, congenital anomaly, and heart diseases were common neonatal mortality risk factors among all three groups of studies. However, gender was not mentioned as an important factor in studies with GA or BW restrictions, but it was important in studies without these inclusion criteria. Furthermore, the hospital level was considered a neonatal mortality risk factor in LBW and premature neonates only.

This review found that congenital anomaly and outborn status were considered as exclusion criteria in some studies, while these two factors were considered important in neonatal death. In other words, management of the conditions of neonates with a congenital anomaly or those born in a hospital and referred to a NICU for more specialized care is also important to decreasing neonatal deaths.

In 2011, a study was conducted on predictive models for the death of premature neonates and indicated that BW, GA, being average size for GA, gender (female), non-white ethnicity, use of

Table 3. Comparison of neonatal mortality risk factors in scoring systems and those in the current study (continues on the next page).

Risk factors	Current article	CRIB	CRIB-II	SNAP	SNAPPE	SNAP-II	SNAPPE-II
Absence of antenatal corticosteroid	✔						
Absence of antenatal steroids	✔						
Absence of antenatal/prenatal care	✔						
Absolute neutrophil count				✔	✔		
Acute renal failure with hyperkalemia	✔						
Administration inotropes	✔						
Admission from another NICU/transfer	✔						
Air leak syndrome	✔						
AKI	✔						
Antepartum hemorrhage	✔						
Apgar score	✔				✔		✔
Apnea				✔	✔		
Base excess	✔	✔	✔				
Blood gases	✔						
Blood urea nitrogen				✔	✔		
Brain hemorrhage	✔						
Brusing at birth	✔						
BW (modeled in multiple way including SGA, z-score)	✔	✔	✔		✔		✔
Calcium (ionized)				✔	✔		
Calcium (total)				✔	✔		
CHD	✔						
CLD	✔						
Congenital anomalies	✔	✔					
Creatinine, urine output				✔	✔		
Delivery mode	✔						
DIC	✔						
Direct bilirubin				✔	✔		
Ethnicity/race	✔						
First temperature at NICU < 35.0°C	✔		✔	✔	✔	✔	✔
Foreign mother	✔						
GA/prematurity (prematurity with SGA, prematurity [GA] with RDS, prematurity with grade 3/4 IVH, late-preterm)	✔	✔			✔		✔
Gastrointestinal diseases	✔						
Gender	✔		✔				
Geographic regions	✔						
Heart rate				✔	✔		
Hematological abnormality	✔						
Hemodynamic instability	✔						
Hospital level/NICU level/type of hospital	✔						
Hospital volume of VLBW	✔						
Hypothermia	✔						
Hypoxic ischemic encephalopathy	✔						
IEM	✔						
Immature total ratio				✔	✔		
Incompetent cervix	✔						

Table 3. Comparison of neonatal mortality risk factors in scoring systems and those in the current study (continues from the previous page and on the next page).

Risk factors	Current article	CRIB	CRIB-II	SNAP	SNAPPE	SNAP-II	SNAPPE-II
Indirect bilirubin				✔	✔		
Infections	✔						
Instrumental delivery	✔						
Intestinal malformations (severe defects of the abdominal wall)	✔						
Intubation	✔						
IUGR	✔						
IVH	✔						
Lactate	✔						
Maternal age	✔						
Maternal infection/choriamnionitis	✔						
Maternal pre-eclampsia	✔						
Mechanical ventilation	✔						
Meconium aspiration	✔						
Min/max appropriate FiO_2 in the first 12 h		✔					
Multiple organ failure	✔						
NCPAP	✔						
NEC	✔						
Neonatal seizure	✔			✔	✔	✔	✔
No prenatal maternal transfer	✔						
Non-use of a pain scale	✔						
Nosocomial infection	✔						
Obstetric complications	✔						
Outborn status	✔						
Oxygen treatment	✔						
Oxygenation index				✔	✔		
$P(A\text{-}a)O_2$	✔						
Packed cell volume				✔	✔		
PaO_2/FiO_2	✔						
PCO_2				✔	✔		
Perinatal asphyxia	✔						
Persistent pulmonary hypertension/PFC	✔						
Placental disorder/abruption	✔						
Platelet transfusion	✔						
Pneumonia	✔						
Pneumothorax	✔						
Polyhydramnios	✔						
Positive CRP	✔						
Potassium				✔	✔		
Pregnancy-induced hypertension	✔			✔	✔	✔	✔
Preterm delivery	✔						
PROM	✔						
Pulmonary hemorrhage	✔						
Pulmonary malformation with hemorrhage	✔						
RBC transfusion	✔						
RDS	✔						

Table 3. Comparison of neonatal mortality risk factors in scoring systems and those in the current study (continues from the previous page).

Risk factors	Current article	CRIB	CRIB-II	SNAP	SNAPPE	SNAP-II	SNAPPE-II
Respiratory failure related to congenital myotonic dystrophy	✔						
Respiratory problems	✔						
Respiratory rate				✔	✔		
Resuscitation	✔						
Sepsis/blood culture positive sepsis	✔						
Septic shock	✔						
Serum bicarbonate				✔	✔		
Serum glucose	✔			✔	✔		
Serum pH				✔	✔	✔	✔
Singleton or multiple birth	✔						
Sodium				✔	✔		
Stillbirth	✔						
Stool guaiac				✔	✔		
Surfactant use	✔						
Surgical intervention	✔						
Thrombocytopenia	✔						
Tracheoesophageal fistula	✔						
TTN	✔						
Ultrasonography requirement	✔						
Urine output						✔	✔

AKI: acute kidney injury; BW: birth weight; CHD: congenital heart disease; CLD: chronic lung disease; CRP: C-reactive protein; DIC: disseminated intravascular coagulation; GA: gestational age; IEM: inborn errors of metabolism; IUGR: intrauterine growth restriction; IVH: intraventricular hemorrhage; NCPAP: nasal continuous positive airway pressure; NEC: necrotizing enterocolitis; NICU: Neonatal Intensive Care Unit; PFC: persistent fetal circulation; PROM: premature rupture of membranes; RBC: red blood cells; RDS: respiratory distress syndrome; SGA: small for gestational age; TTN: transient tachypnea of the newborn; VLBW: very low birth weight.

antenatal steroid, Apgar score > 5, normal body temperature at admission, and stable respiratory condition were the most important factors in predicting survival [9]. In a 2014 study on estimating the distribution of death causes of neonates and children aged between 1-59 months in 2000-2013, with the aim of projecting the priorities of the coming years after 2015, preterm birth complication and intrapartum-related complication such as birth asphyxia were introduced as the most common reasons for neonatal death [80], which supports the current findings.

Since 1993, various scoring systems have been introduced, each of which has its own characteristics. However, having a high number of variables and being time-consuming are considered to be their major disadvantages. Additionally, since different treatments depend on the healthcare centers' policies, the use of this type of model and comparing the results with other centers is not possible [8]. As mentioned, some of the factors described in this study are common among other scoring systems; however, factors such as RDS, sepsis, delivery mode, and hospital/NICU level have not been considered in any of the common scoring systems. Conversely, there are factors (blood factors such as serum pH, calcium, bilirubin, urine output) that have been included in SNAP, SNAPPE, SNAP-II and SNAPPE-II [6] but were not found in the current study. For each scoring system, the conditions for developing the model and determining the neonatal death risk factors to be included are different; therefore, some scoring systems focus mainly on laboratory factors [6], and no scoring systems consider organizational factors, while it was found in this review that organizational factors can also have an impact on neonatal survival or death rates.

Implication

The main audience of this review will be physicians and neonatologists in NICUs. In

addition, researchers who are willing to develop predictive models for neonatal mortality may also use the results of this study to develop models for neonatal death prediction. It should be noted that the risk factors for neonatal death in NICUs differ from those for premature neonates, those for infants with BW < 1,500 g, and those for normal neonates, which highlights the need to develop different systems based on the target group.

Strengths and weaknesses

This study's principal strengths are the systematic search strategy and the examination of all keywords in this field. Another advantage is that this review includes all effective parameters mentioned as major factors for increasing mortality or survival reduction in even just one article. Other systematic studies [9] have reported only factors that are repeated in at least 10 articles.

The inclusion of studies on neonates admitted to NICUs is one of the issues that may result in the loss of related studies conducted to identify mortality risk factors in other infants. In addition, the removal of studies that have examined factors in perinatal death may be considered another limitation of this study, because, according to the definition [11], the 7-day interval overlaps between perinatal and neonatal death, which may lead to the loss of important effective parameters. In addition, this study compared only the known scoring systems, including CRIB, CRIB-II, SNAP, SNAP-II, SNAPPE, and SNAPPE-II; the others may be considered for future studies. Considering only English papers and publication period (2007-2018) are further limitations of this study. Furthermore, the frequency of neonatal risk factors should not be considered as the importance of each factor.

Future work

To develop proper models for the prediction of neonatal death, models must be designed based on relevant risk factors identified for each GA or BW group. Therefore, it may be necessary to re-assess and/or re-design existing predictive models such as CRIB, SNAP, etc., based on advances in medical science, because in most cases these models were introduced before the usage of surfactant and prenatal steroids and may not consider mortality risk factors based on current medical literature. Moreover, these models may need to be updated to include organizational factors because of the importance of outborn status, referrals and transfers, and hospital/NICU levels in neonatal deaths.

Considering the views of neonatologists as experts in this area to determine the neonatal mortality risk factors and the use of agreed-upon factors for developing scoring or predictive models seem to be useful. Studying physicians' opinions about existing scoring systems, determining their views on reasons for using or not using these systems, and considering these reasons in updating or developing new and more usable scoring or predictive models can be considered by future researchers.

All of the included studies and predictive models for neonatal death are based on routine statistical methods and regression analysis. It is suggested that artificial intelligence-based methods (such as case-based reasoning and fuzzy logic) and machine learning algorithms (such as artificial neural networks) be used to develop such models and systems, especially in the form of decision support systems to help physicians and neonatologists determine the conditions of at-risk neonates.

Conclusion

This review study identified and classified neonatal mortality risk factors in NICUs into three categories. Among the maternal factors, delivery mode, non-use of steroid or corticosteroid; among neonatal factors, BW, GA, and Apgar score; and among organizational factors, hospital/NICU level and outborn status have been introduced as the most prevalent risk factors for neonatal death in NICUs. Furthermore, factors including BW, GA/prematurity, gender, and delivery mode are more common risk factors in developed countries; however, BW, Apgar score, GA, RDS, and sepsis are the most important neonatal mortality risk factors in developing countries.

Acknowledgements

The present study was part of a Ph.D. dissertation supported by Iran University of Medical Sciences (grant No: 9321481001; research ethics committee: IR.IUMS.REC 1396.9321481001).

Declaration of interest

The Authors have no conflicts of interest to declare.

References

1. Mirfazeli A, Sedehi M, Golalipour MJ. Neonatal and prenatal causes of death in Gorgan-North of Iran. Med J Islam Repub Iran. 2014;28:266-71.
2. United Nations Children's Fund, World Bank Group, World Health Organization, United Nations Population Division. Levels and trends in child mortality (Report 2018). United Nations Children's Fund: New York, 2018.
3. Wardlaw T, You D, Hug L, Amouzou A, Newby H. UNICEF Report: enormous progress in child survival but greater focus on newborns urgently needed. Reprod Health. 2014;11(82):1-4.
4. Mah-Mungyeh E, Chiabi A, Tchokoteu FL, Nguefack S, Bogne JB, Siyou H, Fru FS, Enoh J, Mbonda E, Tchokoteu PF. Neonatal mortality in a referral hospital in Cameroon over a seven year period: trends, associated factors and causes. Afr Health Sci. 2014;14(4):985-92.
5. Márquez-González H, Jiménez-Báez MV, Muñoz-Ramírez CM, Yáñez-Gutiérrez L, Huelgas-Plaza AC, Almeida-Gutiérrez E, Villa-Romero AR. Development and validation of the Neonatal Mortality Score-9 Mexico to predict mortality in critically ill neonates. Arch Argent Pediatr. 2015;113(3):213-20.
6. Dorling J, Field D, Manktelow B. Neonatal disease severity scoring systems. Arch Dis Child Fetal Neonatal Ed. 2005;90(1):F11-6.
7. Gagliardi L, Cavazza A, Brunelli A, Battaglioli M, Merazzi D, Tandoi F, Cella D, Perotti G, Pelti M, Stucchi I. Assessing mortality risk in very low birthweight infants: a comparison of CRIB, CRIB-II, and SNAPPE-II. Arch Dis Child Fetal Neonatal Ed. 2004;89(5):F419-22.
8. Pollack MM, Koch MA, Bartel DA, Rapoport I, Dhanireddy R, El-Mohandes AA, Harkavy K, Subramanian KS. A comparison of neonatal mortality risk prediction models in very low birth weight infants. Pediatrics. 2000;105(5):1051-7.
9. Medlock S, Ravelli AC, Tamminga P, Mol BW, Abu-Hanna A. Prediction of mortality in very premature infants: a systematic review of prediction models. PLoS One. 2011;6(9):1-9.
10. Moher D, Liberati A, Tetzlaff J, Altman DG. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. Ann Intern Med. 2009;151(4):264-9.
11. MacDorman MF, Gregory EC. Fetal and perinatal mortality: United States, 2013. Natl Vital Stat Rep. 2015;64(8):1-24.
12. Barfield WD. Standard Terminology for Fetal, Infant, and Perinatal Deaths. Pediatrics. 2016;137(5):e1-5.
13. Claydon JE, Mitton C, Sankaran K, Lee SK. Ethnic differences in risk factors for neonatal mortality and morbidity in the neonatal intensive care unit. J Perinatol. 2007;27(7):448-52.
14. Sritipsukho S, Suarod T, Sritipsukho P. Survival and outcome of very low birth weight infants born in a university hospital with level II NICU. J Med Assoc Thai. 2007;90(7):1323-9.
15. Arad I, Braunstein R, Bar-Oz B. Neonatal outcome of inborn and outborn extremely low birth weight infants: Relevance of perinatal factors. Isr Med Assoc J. 2008;10(6):457-61.
16. Berry MA, Shah PS, Brouillette RT, Hellmann J. Predictors of mortality and length of stay for neonates admitted to children's hospital neonatal intensive care units. J Perinatol. 2008;28(4):297-302.
17. Itabashi K, Horiuchi T, Kusuda S, Kabe K, Itani Y, Nakamura T, Fujimura M, Matsuo M. Mortality Rates for Extremely Low Birth Weight Infants Born in Japan in 2005. Pediatrics. 2009;123(2):445-50.
18. Kitsommart R, Janes M, Mahajan V, Rahman A, Seidlitz W, Wilson J, Paes B. Outcomes of late-preterm infants: A retrospective, single-center, Canadian study. Clin Pediatr (Phila). 2009;48(8):844-50.
19. Poudel P, Budhathoki S, Shrivastava MK. Maternal risk factors and morbidity pattern of very low birth weight infants: A NICU based study at Eastern Nepal. J Nepal Paediatr Soc. 2009;29(2):59-66.
20. Abushhaiwia AME, Ziyani MMN, Dekna M. Mortality in the special care baby unit of the main children's hospital in Tripoli, Libyan Arab Jamahiriya. East Mediterr Health J. 2010;16(11):1137-42.
21. Chung JH, Phibbs CS, Boscardin WJ, Kominski GF, Ortega AN, Needleman J. The effect of neonatal intensive care level and hospital volume on mortality of very low birth weight infants. Med Care. 2010;48(7):635-44.
22. Kalyoncu O, Aygun C, Cetinoglu E, Kucukoduk S. Neonatal morbidity and mortality of late-preterm babies. J Matern Fetal Neonatal Med. 2010;23(7):607-12.
23. Navaei F, Aliabady B, Moghtaderi J, Moghtaderi M, Kelishadi R. Early outcome of preterm infants with birth weight of 1500 g or less and gestational age of 30 weeks or less in Isfahan city, Iran. World J Pediatr. 2010;6(3):228-32.
24. Risso Sde P, Nascimento LF. Risk factors for neonatal death in neonatal intensive care unit according to survival analysis. Rev Bras Ter Intensiva. 2010;22(1):19-26.
25. Shrestha S, Dangol SS, Shrestha M, Shrestha RP. Outcome of preterm babies and associated risk factors in a hospital. J Nepal Med Assoc. 2010;50(180):286-90.
26. Simpson CDA, Ye XY, Hellmann J, Tomlinson C. Trends in cause-specific mortality at a Canadian outborn NICU. Pediatrics. 2010;126(6):e1538-44.
27. Choi YY, Song ES, Kim YH, Song TB. Analysis of high-risk infant births and their mortality: ten years' data from chonnam national university hospital. Chonnam Med J. 2011;47(1): 31-8.
28. Jakuskiene R, Vollmer B, Saferis V, Daugeliene D. Neonatal outcomes of very preterm infants admitted to a tertiary center in Lithuania between the years 2003 and 2005. Eur J Pediatr Surg. 2011;170(10):1293-303.
29. Lanfranchi LMMM, Viola GR, Nascimento LFC. The use of Cox regression to estimate the risk factors of neonatal death in a private NICU. Rev Paul Pediatr. 2011;29(2):224-30.
30. Binet ME, Bujold E, Lefebvre F, Tremblay Y, Piedboeuf B; Canadian Neonatal Network™. Role of Gender in Morbidity

and Mortality of Extremely Premature Neonates. Am J Perinatol. 2012;29(3):159-65.

31. Bolat F, Kilic SC, Oflaz MB, Gulhan E, Kaya A, Guven AS, Aygunes U, Icagasioglu D, Gultekin A. The prevalence and outcomes of thrombocytopenia in a neonatal intensive care unit: a three-year report. Pediatr Hematol Oncol. 2012;29(8):710-20.
32. Carneiro JA, Vieira MM, Reis TC, Caldeira AP. Risk factors for mortality of very low birth weight newborns at a neonatal intensive care unit. Rev Paul Pediatr. 2012;30(3):369-76.
33. Freitas BA, Sant'ana LF, Longo GZ, Siqueira-Batista R, Priore SE, Franceschini SDCC. Epidemiological characteristics and deaths of premature infants in a referral hospital for high-risk pregnancies. Rev Bras Ter Intensiva. 2012;24(4):386-92.
34. Garrido MM, Allison KC, Bergeron MJ, Dowd B. Hospital religious affiliation and outcomes for high-risk infants. Med Care Res Rev. 2012;69(3):316-38.
35. Giapros V, Drougia A, Krallis N, Theocharis P, Andronikou S. Morbidity and mortality patterns in small-for-gestational age infants born preterm. J Matern Fetal Neonatal Med. 2012;25(2):153-7.
36. Kent AL, Wright IMR, Abdel-Latif ME, New SWAC. Mortality and Adverse Neurologic Outcomes Are Greater in Preterm Male Infants. Pediatrics. 2012;129(1):124-31.
37. Qiu X, Lodha A, Shah PS, Sankaran K, Seshia MMK, Yee W, Jefferies A, Lee SK. Neonatal outcomes of small for gestational age preterm infants in Canada. Am J Perinatol. 2012;29(2): 87-93.
38. Terzic S, Heljic S. Assessing mortality risk in very low birth weight infants. Med Arh. 2012;66(2):76-9.
39. Worku B, Kassie A, Mekasha A, Tilahun B, Worku A. Predictors of early neonatal mortality at a neonatal intensive care unit of a specialized referral teaching hospital in Ethiopia. Ethiop J Health Dev. 2012;26(3):200-7.
40. Afjeh SA, Sabzehei MK, Fallahi M, Esmaili F. Outcome of very low birth weight infants over 3 years report from an Iranian center. Iran J Pediatr. 2013;23(5):579-87.
41. Atalay D, Salihoglu O, Can E, Beskardes A, Hatipoglu S. Short-term outcomes of very low birth weight infants born at a tertiary care hospital, istanbul, Turkey. Iran J Pediatr. 2013;23(2): 205-11.
42. Corchia C, Ferrante P, Da Fre M, Di Lallo D, Gagliardi L, Carnielli V, Miniaci S, Piga S, Macagno F, Cuttini M. Cause-specific mortality of very preterm infants and antenatal events. J Pediatr. 2013;162(6):1125-32.e4.
43. Ge WJ, Mirea L, Yang JM, Bassil KL, Lee SK, Shah PS, Canadian Neonatal N. Prediction of Neonatal Outcomes in Extremely Preterm Neonates. Pediatrics. 2013;132(4):E876-85.
44. Lutomski J, Dempsey E, Molloy E. An epidemiological study of factors associated with preterm infant in-hospital mortality. Ir Med J. 2013;106(1):9-12.
45. Manktelow BN, Seaton SE, Field DJ, Draper ES. Population-based estimates of in-unit survival for very preterm infants. Pediatrics. 2013;131(2):e425-32.
46. Shim JW, Kim MJ, Kim EK, Park HK, Song ES, Lee SM, Lee JH, Jin HS, Kim ES, Chang YS. The impact of neonatal care resources on regional variation in neonatal mortality among very low birthweight infants in Korea. Paediatr Perinat Epidemiol. 2013;27(2):216-25.
47. Wariki WM, Mori R, Boo NY, Cheah IG, Fujimura M, Lee J, Wong KY. Risk factors associated with outcomes of very low birthweight infants in four Asian countries. J Paediatr Child Health. 2013;49(1):E23-7.
48. Zamudio RP, Terrones CRL, Barboza AR. Morbidity and mortality in premature newborns in the Irapuato General Hospital. Bol Med Hosp Infant Mex. 2013;70(4):299-303.
49. de Almeida MFB, Guinsburg R, Sancho GA, Rosa IRM, Lamy ZC, Martinez FE, da Silva R, Ferrari LSL, Rugolo L, Abdallah VOS, Silveira RD; Brazilian Network on Neonatal Research. Hypothermia and Early Neonatal Mortality in Preterm Infants. J Pediatr. 2014;164(2):271-5.
50. de Castro ECM, Leite AJM, de Almeida MFB, Guinsburg R. Perinatal factors associated with early neonatal deaths in very low birth weight preterm infants in Northeast Brazil. BMC Pediatr. 2014;14(312):1-8.
51. Suciu LM, Puscasiu L, Szabo B, Cucerea M, Ognean ML, Oprea I, Bell EF. Mortality and morbidity of very preterm infants in Romania: how are we doing? Pediatr Int. 2014;56(2): 200-6.
52. Zhou WQ, Mei YB, Zhang XY, Li QP, Kong XY, Feng ZC. Neonatal outcomes of very preterm infants from a neonatal intensive care center. World J Pediatr. 2014;10(1):53-8.
53. Arcinue R, Kantak A, Elkhwad M. Acute kidney injury in ELBW infants (< 750 grams) and its associated risk factors. J Neonatal Perinatal Med. 2015;8(4):349-57.
54. Ashish KC, Wrammert J, Nelin V, Ewald U, Clark R, Malqvist M. Level of mortality risk for babies born preterm or with a small weight for gestation in a tertiary hospital of Nepal. BMC Public Health. 2015;15:1-9.
55. Bartman T, Bapat R, Martin EM, Shepherd EG, Nelin LD, Reber KM. Apgar Score at 5 Minutes Is Associated with Mortality in Extremely Preterm Infants even after Transfer to an All Referral NICU. Am J Perinatol. 2015;32(13):1268-72.
56. Jensen EA, Lorch SA. Effects of a Birth Hospital's Neonatal Intensive Care Unit Level and Annual Volume of Very Low-Birth-Weight Infant Deliveries on Morbidity and Mortality. JAMA Pediatr. 2015;169(8):1-9.
57. Lim JW, Chung SH, Kang DR, Kim CR. Risk Factors for Cause-specific Mortality of Very-Low-Birth-Weight Infants in the Korean Neonatal Network. J Korean Med Sci. 2015;30(Suppl 1):S35-44.
58. Lin HJ, Du LZ, Ma XL, Shi LP, Pan JH, Tong XM, Li QP, Zhou JG, Yi B, Liu L, Chen YB, Wei QF, Wu HQ, Li M, Liu CQ, Gao XR, Xia SW, Li WB, Yan CY, He L, Liang K, Zhou XY, Han SP, Lyu Q, Qiu YP, Li W, Chen DM, Lu HR, Liu XH, Liu H, Lin ZL, Liu L, Zhu JJ, Xiong H, Yue SJ, Zhuang SQ. Mortality and Morbidity of Extremely Low Birth Weight Infants in the

Mainland of China: A Multi-center Study. Chin Med J (Engl). 2015;128(20):2743-50.

59. Rozanska A, Wojkowska-Mach J, Adamski P, Borszewska-Kornacka M, Gulczynska E, Nowiczewski M, Helwich E, Kordek A, Pawlik D, Bulanda M. Infections and risk-adjusted length of stay and hospital mortality in Polish Neonatology Intensive Care Units. Int J Infect Dis. 2015;35:87-92.
60. Sivasubramaniam P, Quinn CE, Blevins M, Al Hajajra A, Khuri-Bulos N, Faouri S, Halasa N. Neonatal outcomes of infants admitted to a large government hospital in Amman, Jordan. Glob J Health Sci. 2015;7(4):217-34.
61. Yeo KT, Lee QY, Quek WS, Wang YA, Bolisetty S, Lui K. Trends in morbidity and mortality of extremely preterm multiple gestation newborns. Pediatrics. 2015;136(2):263-71.
62. Kong XY, Xu FD, Wu R, Wu H, Ju R, Zhao XL, Tong XM, Lv HY, Ding YJ, Liu F, Xu P, Liu WP, Cheng HB, Chen TQ, Zeng SJ, Jia WZ, Li ZK, Qiu HX, Wang J, Feng ZC. Neonatal mortality and morbidity among infants between 24 to 31 complete weeks: a multicenter survey in China from 2013 to 2014. BMC Pediatr. 2016;16(174):1-8.
63. Malik S, Gohiya P, Khan IA. Morbidity profile and mortality of neonates admitted in Neonatal Intensive Care Unit of a Central India Teaching Institute: A prospective observational study. J Clin Neonatol. 2016;5(3):168-73.
64. Ognean ML, Boanta O, Kovacs S, Zgarcea C, Dumitra R, Olariu E, Andreicut D. Persistent Ductus Arteriosus in Critically Ill Preterm Infants. J Crit Care Med. 2016;2(4):175-84.
65. Pergialiotis V, Daskalakis G, Baroutis G, Stamouli K, Antsaklis A, Loutradis D, Papantoniou N. Identification of factors of neonatal mortality among preterm births: A tertiary center experience. Archives of Perinatal Medicine. 2016;22(1):23-7.
66. Cupen K, Barran A, Singh V, Dialsingh I. Risk Factors Associated with Preterm Neonatal Mortality: A Case Study Using Data from Mt. Hope Women's Hospital in Trinidad and Tobago. Children (Basel). 2017;4(12):1-10.
67. Demisse AG, Alemu F, Gizaw MA, Tigabu Z. Patterns of admission and factors associated with neonatal mortality among neonates admitted to the neonatal intensive care unit of University of Gondar Hospital, Northwest Ethiopia. Pediatric Health Med Ther. 2017;8:57-64.
68. Dey SK, Afroze S, Islam T, Jahan I, Hassan Shabuj MK, Begum S, Chisti MJ, Mannan MA, Shahidullah M. Death audit in the neonatal ICU of a tertiary care hospital in Bangladesh: a retrospective chart review. J Matern Fetal Neonatal Med. 2019;32(5):776-80.
69. Ito M, Tamura M, Namba F; Neonatal Research Network of Japan. Role of sex in morbidity and mortality of very premature neonates. Pediatr Int. 2017;59(8):898-905.
70. Umran RMR, Al-Jammali A. Neonatal outcomes in a level II regional neonatal intensive care unit. Pediatr Int. 2017;59(5): 557-63.
71. Wang YC, Chan OW, Chiang MC, Yang PH, Chu SM, Hsu JF, Fu RH, Lien R. Red Blood Cell Transfusion and Clinical Outcomes in Extremely Low Birth Weight Preterm Infants. Pediatr Neonatol. 2017;58(3):216-22.
72. Diguisto C, L'Helias LF, Morgan AS, Ancel P-Y, Kayem G, Kaminski M, Perrotin F, Khoshnood B, Goffinet F. Neonatal Outcomes in Extremely Preterm Newborns Admitted to Intensive Care after No Active Antenatal Management: A Population-Based Cohort Study. J Pediatr. 2018;203: 150-5.
73. Gargari SS, Kashanian M, Zendedel H, Nayeri F, Shariat M, Haghollahi F. Survival and Risk Factors of Extremely Preterm Babies (< 28 weeks) in the Three Iranian Hospitals. Acta Med Iran. 2018;56(3):181-8.
74. Owusu BA, Lim A, Makaje N, Wobil P, SameAe A. Neonatal mortality at the neonatal unit: the situation at a teaching hospital in Ghana. Afr Health Sci. 2018;18(2):369-72.
75. Pinstrup Joergensen AS, Bjerregaard-Andersen M, Biering-Sørensen S, Byberg S, Camala L, Martins C, Rodrigues A, Aaby P, Stabell Benn C. Admission and mortality at the main neonatal intensive care unit in Guinea-Bissau. Trans R Soc Trop Med Hyg. 2018;112(7):335-41.
76. Reyes JCL, Ramírez ROP, Ramos LL, Ruiz LMG, Vázquez EAB, Patiño VR. Neonatal mortality and associated factors in newborn infants admitted to a Neonatal Care Unit. Arch Argent Pediatr. 2018;116(1):42-8.
77. Sabzehei MK, Basiri B, Shokouhi M, Eghbalian F, Eslamian MH. Causes and Risk Factors Associated to Neonatal Mortality in Neonatal Intensive Care Unit (NICU) in Besat Hospital Hamadan-Iran in 2015 to 2016. Int J Pediatr. 2018;6(9): 8185-94.
78. Srinivasan N, Schwartz A, John E, Price R, Amin S. Acute kidney injury impairs postnatal renal adaptation and increases morbidity and mortality in very low-birth-weight infants. Am J Perinatol. 2018;35(01):039-47.
79. Tay VY, Bolisetty S, Bajuk B, Lui K, Smyth J; the New South Wales and the Australian Capital Territory Neonatal Intensive Care Units' Data Collection. Admission temperature and hospital outcomes in extremely preterm infants. J Paediatr Child Health. 2018;55(2):216-23.
80. Liu L, Oza S, Hogan D, Perin J, Rudan I, Lawn JE, Cousens S, Mathers C, Black RE. Global, regional, and national causes of child mortality in 2000–13, with projections to inform post-2015 priorities: an updated systematic analysis. Lancet. 2015;385(9966):430-40.