Research Square

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Comparison of various neonatal transport scoring methods in predicting mortality risk for full-term out-born infants

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Research Article

Keywords: Full-term newborn infant, Out-born, Mortality, Neonatal intensive care unit, Transport scoring, Prediction

Posted Date: April 13th, 2022

DOI: https://doi.org/10.21203/rs.3.rs-1537782/v1

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Abstract

The transport of critically ill newborns makes it possible for many high-risk neonates to survive. Relatively little is known about death factors and the risk assessment of full-term newborns. We compared the effectiveness of neonatal transport scoring methods to predict the mortality risk of full-term out-born infants within the first week after transportation. A retrospective cohort study was conducted in the Neonatal Intensive Care Unit (NICU) of Beijing Children's Hospital from January 2019 to December 2020. All patients were full-term out-born neonates admitted by our transport team. Each patient was assessed by the following scores: the Transport Risk Index of Physiologic Stability (TRIPS) score; the Mortality Index for Neonatal Transportation (MINT) score; the Transport Related Mortality Score (TREMS); and the Neonatal Critical Illness Score (NCIS). Receiver operating characteristic (ROC) and decision curve analysis (DCA) in the R environment were used to test and compare the effectiveness and clinical utility of these scores in predicting the mortality risk of full-term infants within the 1st week after admission. In total, 368 full-term infants were included (368/770, 47.8% of all transported infants). Within the 1st week after admission, five infants (1.36%, 5/368) died under advanced life support and full treatment, while 24 infants (6.52%, 24/368) died soon after they were discharged against medical advice. The AUCs of the MINT, TRIPS, TREMS and NCIS in the prediction of mortality were 0.822, 0.827, 0.643 and 0.731, respectively (all $p<0.05$). However, the clinical net benefit was far superior for the MINT and TRIPS scores than for the NCIS and TREMS scores.

Conclusions: TRIPS and MINT scores might be more suitable for predicting mortality in full-term out-born neonates in the NICU within the 1st week after transportation.

What Is Known

Neonatal transport scores can assess not only the mortality risk during transportation but also the mortality risk of critically ill newborns after admission to the NICU.

The effectiveness of neonatal transport scores in predicting mortality risk is different.

What is New

Our data indicate that the diagnostic efficacy of the MINT, TRIPS and NCIS in the prediction of full-term infant mortality was high.

The TRIPS and MINT scores had better clinical utility and could be used to predict mortality within the 1st week after transportation in full-term out-born neonates.

Introduction

Neonatal mortality is an important reference indicator to reflect national health and economic status [1]. China has long been concerned about the rescue of critically ill newborns. With the liberalization of the

two or three children policies, the number of older pregnant women has increased, and maternal complications have also increased [2]. Experts recommend that pregnant women with high-risk factors should be transferred to a hospital with a neonatal intensive care units (NICUs) centre for delivery; sometimes it is inevitable that newborns are delivered in hospitals without NICUs, and many critically ill newborns require urgent transfer to other institutions [3, 4]. Thus, the transport of these newborns enables the survival of many high-risk neonates [5]. Neonatal transport to tertiary/level four NICUs occurs through a specialized neonatal emergency transport system (NETS), which is a radioactive system; this is not a simple transport process, but effective transport can occur through the continuous monitoring and treatment of neonates during the transport process [6, 7]. The transport of severely preterm infants has long been a concern, and relatively little is known about the survival, death factors and risk assessment of full-term infants [8].

Several neonatal transport scoring methods are available for full-term neonates who are transported to NICUs, including the Mortality Index for Neonatal Transportation (MINT) score, the Transport Risk Index of Physiologic Stability (TRIPS) score, the Transport Related Mortality Score (TREMS) and China's Neonatal Critical Illness Score (NCIS) [9–12]. Previous studies have shown that the AUC of the TRIPS score in the prediction of 7-day NICU mortality for infants of all gestational ages at transport was 0.83 and that of preterm infants was above 0.9, while the AUC of the MINT score was 0.8.

The aim of this study was to evaluate the performance of the above-mentioned transport scoring methods in predicting mortality in full-term neonates transported to a level four NICU and to explore the primary causes underlying the mortality rates among full-term neonates in our hospital.

Materials And Methods

This was a retrospective cohort study. The study period was from January 2019 to December 2020.

The inclusion criteria were as follows: (1) out-born infants; (2) infants with a gestational age ≥37 weeks; (3) infants admitted to the NICU by the neonatal transport team of Beijing Children's Hospital; and (4) infants with an admission age ≤ 28 days. The exclusion criteria were as follows: (1) infants with medical conflicts with the prior hospital or (2) infants with important medical information that was missing or unknown.

Demographic data and clinical information for the current study were collected and abstracted by the investigators from the in-hospital medical records and transport records in the Hospital Information System. Transport records included patient details, vital signs, interventions by the referring hospital, diagnostic data, and interventions by the transport team. The MINT, TRIPS, TREMS and NCIS scores were calculated. All aspects of the study were approved by the Medical Ethics Committee (study numbers 2018 – 192). All study variables on neonatal outcomes and infant and maternal characteristics were in agreement with the definitions of practical neonatology in China.

Statistical analysis

Data are presented as the mean and standard deviation (SD) or median (interquartile range). We used the *t* test, Mann–Whitney *U* test or χ^2 test, according to the data properties. The receiver operating characteristic (ROC) and area under the curve (AUC) methods were used to assess the effectiveness of the four transport scoring methods in predicting the mortality risk within the 1st week after admission. Decision curve analysis (DCA) with an artificial dataset in the R environment was used to assess the clinical efficacy among these scores for decision-making. SPSS version 20.0 was used for statistical analyses. *P* values less than 0.05 were considered statistically significant.

Results

A total of 770 neonates were transferred to our NICU by the professional NET team in our hospital, and 381 were full-term neonates. We excluded 13 (3.4%) infants who met the exclusion criteria. A total of 368 full-term neonates (368/770, 47.8% of all transported infants) who met the inclusion criteria were included. Within the first 7 days after admission, five infants (1.36%, 5/368) died under advanced life support and full treatment, while 24 infants (6.52%, 24/368) died soon after they were discharged against medical advice. Most of these neonates had congenital anomalies. The total mortality rate was 7.88% (29/368) (Fig. 1). The characteristics of the study groups are presented in Table 1.

Table 1 Demographic and clinical data of the included infants

	ALL (*n* = 368)	Survivors (*n* = 339)	Nonsurvivors (*n* = 29)	*p* value
Gestational Age (weeks), mean (SD)	39.0 (1.2)	39.0 (1.3)	38.8 (1.2)	0.361
Birth weight (gram), mean (SD)	3271(562)	3295 (565)	2997 (444)	0.004
Sex (male/female), *n*	226 (142)	210 (129)	16 (13)	0.473
Delivery (V/C)	180 (188)	165 (174)	15 (14)	0.753
Hypertension during pregnancy, *n* (%)	30 (8.2)	28 (8.2)	2 (6.9)	0.692
Congenital anomaly, *n* (%)	129(35.1)	108(31.9)	21(72.4)	< 0.001
Transport age, days, mean (SD)	3.3 (5.0)	3.3 (5.0)	3.0 (4.9)	< 0.001
Duration of transport time (hours), mean (SD)	2.0 (0.7)	2.0 (0.7)	2.2 (0.8)	< 0.001
Ventilation during transport, *n* (%)	70 (19.0)	52 (14.1)	18 (62.1)	< 0.001
Length of stay in NICU, days, mean (SD)	13.3 (9.7)	14.3 (9.5)	2.2 (1.4)	< 0.001
Apgar score at 1 minute, mean (SD)	9.4 (1.5)	9.5 (1.4)	8.5 (2.5)	0.12
Apgar score at 5 minutes, mean (SD)	9.7 (0.9)	9.8 (0.8)	9.1 (1.6)	0.001
Duration of mechanical ventilation (hours), mean (SD)	38.5(95.0)	38.2(103.1)	134.9 ± 246.2	< 0.001
MINT score	4 (0–5)	3.2 (3.7)	8.5 (4.5)	< 0.001
TRIPS score	6 (0–14)	7.0 (8.9)	21.0 (10.2)	< 0.001
TREMS	0 (0–0)	0.2 (0.5)	0.7 (0.9)	0.01
NCIS, critical number (%)	186 (50.5)	159 (46.9)	27 (93.1)	< 0.001

V, vaginal; *C*, caesarean section; *SD*, standard deviation; *MINT*, Mortality Index for Neonatal Transportation; *TRIPS*, Transport Risk Index of Physiologic Stability; *TREMS*, Transport Related Mortality Score; *NCIS*, Neonatal Critical Illness Score

Mortality-related Risk Factors

Birth weight, congenital anomalies, age at transport, duration of transport time, ventilation during transport, duration of mechanical ventilation, length of stay in the NICU, and Apgar scores at 1 and 5 minutes were statistically significant ($P < 0.05$) and related to full-term neonatal mortality (Table 1).

Diagnostic Efficacy In The Prediction Of Full-term Neonatal Mortality

The TRIPS, MINT, NICS and TREMS had AUCs of 0.827, 0.822, 0.731 and 0.643, respectively, in predicting mortality for full-term neonates in the first week after birth and were statistically significant (all $p < 0.05$, Fig. 2). A TRIPS score of ≥ 13.5 had a sensitivity of 86.2% and a specificity of 77.6%, while a MINT score of ≥ 5.5 had a sensitivity of 72.4% and a specificity of 80.2%. A TREMS of ≥ 0.5 had a sensitivity of 44.8% and a specificity of 81.7%. Although the sensitivity was higher for the NCIS score (93.1%) than for the other scores, the specificity (53.1%) was lower.

MINT, Mortality Index for Neonatal Transportation; *TRIPS*, Transport Risk Index of Physiologic Stability; *TREMS*, Transport Related Mortality Score; *NCIS*, Neonatal Critical Illness Score

The Clinical Utility Of The Four Transport Scores

To further explore the predictive effectiveness and value of different scoring systems, we used decision curve analysis (DCA) to compare the effectiveness of the four scoring systems as predictive models. The results of the decision curve analysis showed that the potential risk based on the overintervention threshold (X-axis) and the prediction model (Y-axis, the difference between the true positive rate and the false positive rate) showed the net benefit for the infants. We concluded that the MINT score and TRIPS score were more suitable in clinical decision-making for predicting full-term neonatal death (Fig. 3).

MINT, Mortality Index for Neonatal Transportation; *TRIPS*, Transport Risk Index of Physiologic Stability; *TREMS*, Transport Related Mortality Score; *NCIS*, Neonatal Critical Illness Score

Discussion

Establishing a professional NETS and transferring high-risk neonates to a tertiary/level four NICU through a professional transport team for continued treatment is essential for reducing neonatal mortality. This study with full-term neonates transferred by the neonatal transport team of Beijing Children's Hospital demonstrates mortality, mortality-related risk factors, and the prediction of mortality within the 1st week after admission. The full-term infant mortality rate within the 1st week was 1.36% (5/368), similar to some US and European developed countries [8, 13, 14]. Twenty-four infants (6.52%, 24/368) died soon after they were discharged against medical advice, and the total full-term neonatal mortality rate was 7.88%, far below that of the NICUs of sub-Saharan African and South Asian countries (16.6%-23%) [15, 16]. This study provides evidence that the TRIPS, MINT and NCIS scores can all be used to assess the

severity of transported full-term neonates and to predict full-term neonatal mortality in the first week after admission. Clinical decision-making can be based on the first two scores.

Previous studies [9–11, 17] showed a correlation between birth weight and mortality, consistent with previous studies. Our data demonstrated that birth weight and age at transport were correlated with 7-day mortality ($P < 0.005$). The Apgar scores at 1 and 5 minutes and the duration of transport time were also significant ($P < 0.05$). Cnattingius [18] studied the Apgar scores of 113300 premature babies born in Sweden over 24 years. The result was that the lower the Apgar score was, the higher the relative risk of neonatal death at all gestational ages. Bouchut [19] showed significant exposure of a sick neonate to both stationary and impulsive dynamic physical stressors during transport, especially in ground transport; the farther the transfer distance, the more delayed the time for a newborn to receive better treatment.

We found that congenital anomalies were related to mortality, which was similar to the study by Broughton [11]. In his study, which consisted of 2504 neonates, the presence of congenital abnormalities was significantly associated with death. Among the full-term neonates we studied, malformations accounted for a certain proportion (35.1%, 129/368), and 108 (83.7%, 108/129) infants survived due to surgery or other treatments. The two most common anomalies were congenital heart malformations (33.3%) and alimentary malformations (20.8%). Beijing Children's Hospital is a specialty hospital for neonatal surgery and is at the leading level in China. A green channel for postpartum treatment has been opened for congenital malformations found before birth. Therefore, children with deformities may be transferred to our centre to evaluate whether there is an opportunity for surgery, but due to family decisions, the economy, the prognosis and other reasons, the abandonment rate of these babies is also higher.

In our study, MINT, TRIPS and NCIS scores were generally considered good models for predicting full-term neonatal mortality, and the TREMS showed some discrimination but not very well. Previous studies [9, 11, 20–21] showed that the AUC of the TRIPS and MINT in the prediction of neonatal mortality ranged from 0.80 to 0.99, consistent with our results (0.827 and 0.822, respectively). Sutcuoglu [10] showed that the AUC was 0.84 for the TREMS; however, in our research, it was only 0.643, and there were similar situations in other studies (AUCs from 0.655–0.712) [17, 22]. We considered that this variation might result from the differences in the characteristics and number of included babies.

Our findings demonstrated that the TRIPS and MINT scores had good sensitivity and specificity for predicting neonatal deaths in a NICU. Previous studies have shown a range of cut-off scores for predicting mortality in the NICU. We found a MINT score of ≥ 5.5 and a TRIPS score of ≥ 13.5, with a higher sensitivity and specificity for predicting full-term neonatal mortality. Broughton [11] showed that the cut-off point for the MINT score was 20; when the MINT score was greater than 20, 80% of hospitalized newborns died, and a TRIPS score of 20 points was an important cut-off value for early disease evaluation [9, 23]. Qiu [17] showed that the cut-off point for preterm neonatal mortality was 10 for the MINT score and 19 for the TRIPS score. The differences within these studies might be due to the

study gestational age being different. The TRIPS and MINT scores were developed abroad, which may differ from our actual situation and need further verification in China.

The DCA assessed the utility of models for decision-making and showed that the net benefits of the MINT and TRIPS scores were larger than the range of benefits for the NCIS and TREMS scores. Our data indicated that TRIPS and MINT scores might be more suitable for predicting mortality within the 1st week after transportation in full-term out-born neonates in NICUs in China.

This observational study has several limitations. This was a single-centre study, and more data need to be collected. Another limitation in our study is that based on the risks of a transfer, the transfer team will sometimes relax the intubation indications and have some experience with targeted medical intervention to reduce the incidence of transport complications. The TRIPS score and TREMS score will also be affected by medical interventions. All of these were some of the potential sources of bias in this study.

Conclusion

The AUCs and DCA indicated that the TRIPS and MINT scores were superior to other transport scores, such as the NICS and TREMS scores. This study supports the hypothesis that the TRIPS and MINT scores might be more suitable for predicting mortality within the 1st week after transportation in full-term out-born neonates in the NICU.

Abbreviations

AUC, Area under the curve; DCA, Decision curve analysis; MINT, Mortality Index for Neonatal Transportation; NCIS, Neonatal Critical Illness Score; NETs, neonatal emergency transport system; NICU, Neonatal Intensive Care Unit; ROC, Receiver Operating Characteristic; TREMS, Transport Related Mortality Score; TRIPS, Transport Risk Index of Physiologic Stability

Declarations

Authors' contributions WWQ designed the research study, collected the

data, contributed to the data interpretation, and wrote the manuscript.

YHS and YJQ contributed to the study design and data interpretation, and reviewed the final version of the manuscript. XZ and JJZ and DW and WWH contributed to the data collection and interpretation and reviewed the final

version of the manuscript. MJ and WJG contributed to the study design

and data interpretation and reviewed the final version of the manuscript.

MYH designed the research study, contributed to the data interpretation,

and reviewed the final version of the manuscript. All authors reviewed the manuscript.

Ethics Approval Approval by the Medical Ethics Committee of Beijing Children's Hospital, Beijing, China (IRB:2018-192).

Conflict of interest The authors declare that they have no conflict of interest. Investigator led research grant from the Special Fund of the Pediatric Medical Coordinated Development Center of Beijing Hospitals Authority (XTCX201816).

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Figures

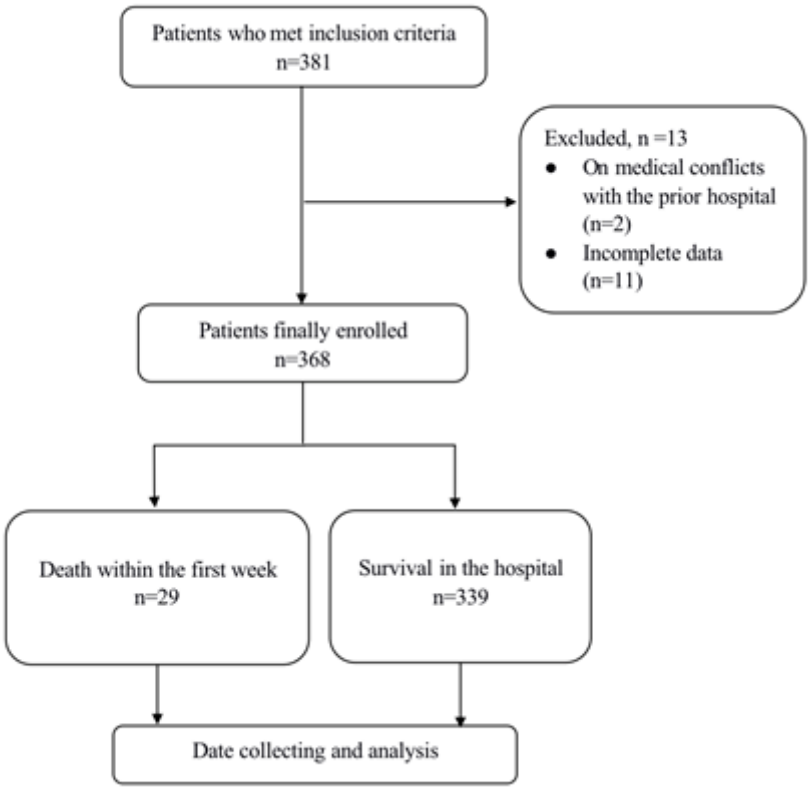

Figure 1

Flow chart of enrollment

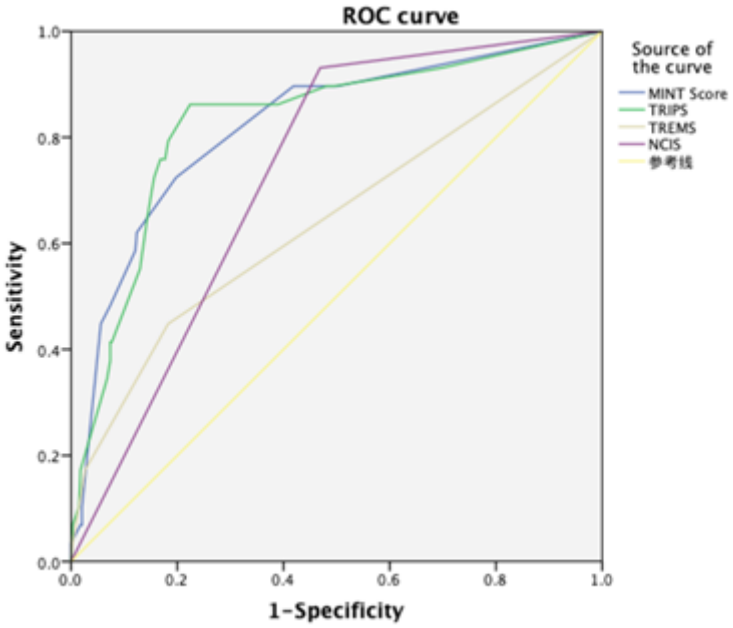

Figure 2

The receiver operating characteristic (ROC) curves of transport scoring systems to predict full-term neonatal 7-day mortality in the NICU. MINT score, area under curves (AUC) is 0.822 [95% confidence interval (CI): 0.737–0.907], TRIPS score, AUC is 0.827 [95% CI: 0.743–0.912], the NICS, AUC is 0.731 [95% CI: 0.655–0.807], the TREMS, AUC is 0.643 [95% CI: 0.525–0.760], the best performance of the scores was the TRIPS score.

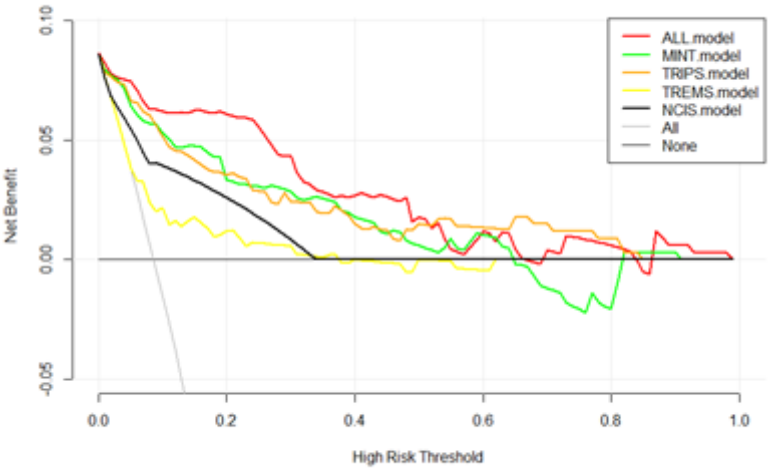

Figure 3

Decision curve analysis (DCA) to assess the clinical utility among four transport scores in predicting the mortality risk of full-term neonates within the 1st week after admission. The net benefit curves for the

four prediction scores are shown. X-axis indicates the threshold probability for full-term mortality in the first week and Y-axis indicates the net benefit. The preferred score is the TRIPS and MINT model, the net benefit of which was larger over the range of NCIS and TREMS.