Original Article

DOI: 10.7860/JCDR/2023/64515.18602

Paediatrics Section

Utility of the Modified Sick Neonatal Score to Predict the Mortality in Outborn Neonates: A Cohort Study

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ABSTRACT

Introduction: Illness severity scoring systems are essential tools for reducing mortality by identifying disease severity and providing early intervention. The application of the Modified Sick Neonatal Score (MSNS) in resource-limited settings has been studied in inborn neonates, but there is a lack of data regarding outborn neonates.

Aim: To predict mortality in outborn transported neonates by applying the MSNS score.

Materials and Methods: This cohort study was conducted from June 2020 to November 2021 in the Department of Paediatrics at Government Medical College, Nagpur, Maharashtra, India. Parameters of the MSNS scoring system (respiratory effort, heart rate, axillary temperature, capillary refilling time, random blood sugar, oxygen saturation, gestational age, and birth weight) were evaluated in all admitted outborn neonates upon admission, and outcomes (discharge or death) were noted. The score and individual parameters were correlated with the outcome. Chi-square test, Fischer's-exact test, and Mann-Whitney U test were applied to statistically analyse the data. A receiver operating curve was plotted to determine the cut-off value for the score to predict mortality.

Results: In the present study, 866 (58.2%) neonates were male, while 622 (41.8%) were female, and the mean age at admission was 43.3±58.9 hours. Nearly two-thirds of the neonates were born at term, and the mean birth weight was 2191.62±595.47 gm. A total of 91.7% of the neonates were referred by government facilities, and 82.8% of the neonates were transported by ambulance, but only one-third of the ambulance-transported neonates were accompanied by a health assistant. The mean traveling distance was 83.57±72.79 km, and the mean transport duration was 2.14±1.07 hours. The common clinical diagnosis were sepsis (42.68%), respiratory distress (19.89%), and birth asphyxia (14.78%). The neonatal mortality rate was 29.3%. The total MSNS score for neonates who survived was 11.26±2.34, compared to 8.52±2.23 for the neonates who died (p-value <0.0001). The sensitivity was 80.5%, with a specificity of 63.1% and an area under the curve of 0.79 (OR-24.72, 95% CI 0.77-0.81, p-value <0.001) when using the optimal cut-off score of ≤10.

Conclusion: The MSNS score of ≤10 has better sensitivity and specificity in predicting neonatal mortality in outborn transported neonates.

Keywords: Birth asphyxia, Disease severity scoring system, Extramural neonates, Transported neonates

INTRODUCTION

Globally, neonatal deaths contribute to around 50% of under-5 mortality [1], with India accounting for a significant proportion of global neonatal mortality and 40% of neonatal deaths occurring on the first day of life [2]. The lack of adequate neonatal care facilities in non institutional or institutional settings has resulted in higher mortality rates, necessitating the referral of neonates to higher centres [3]. Unfortunately, many neonates are transported by parents without proper pretreatment stabilisation or adequate care during transport [4-7].

The high-risk of mortality in transported neonates highlights the need for a neonatal disease severity scoring system that is simple, reliable, reproducible, and easily applicable by paramedical and medical personnel. Such a system would evaluate the well-being of neonates during transport and upon arrival at the referral centre [8,9]. While numerous scoring systems exist worldwide, they are not resource-friendly and cannot be applied in resource-limited settings due to the requirement for sophisticated equipment, investigations, and time [10-14]. Quick assessment of neonatal clinical parameters such as temperature, perfusion, and oxygenation can help anticipate the outcome of transported neonates [15]. The Sick Neonate Score (SNS) and Extended Sick Neonate Score (ESNS) have been used to predict outcomes in transported neonates but are limited by the need for blood pressure monitoring [16,17]. Therefore, the SNS has been modified by replacing blood pressure with feasible and easily recordable parameters such as birth weight and gestational age, resulting in the MSNS [18].

The MSNS has shown favourable utility with good sensitivity in predicting mortality in inborn neonates [18-20]. However, its predictability among outborn neonates remains unknown. Therefore, the present study aimed to assess the applicability of MSNS and its correlation with the outcomes of transported neonates in a resource-limited setting.

MATERIALS AND METHODS

This cohort study was conducted in the Department of Paediatrics at the Government Medical College and Hospital Nagpur, Maharashtra, India, which is one of the largest tertiary care teaching Government referral Institutes. The study spanned a period of one and a half years, from June 2020 to November 2021. The study protocol was approved by the Institutional Ethics Committee (No. 2041/EC/Pharmac/GMC/NGP, dated 04/05/2020), and informed consent was obtained from parents or legal guardians.

Inclusion criteria: All outborn neonates, regardless of severity, who were admitted through either the outpatient or emergency department and treated in a separate neonatal cabinet in the general paediatric ward with facilities such as central oxygen pipes, phototherapy units, warmers, and bubble Continuous Positive Airway Pressure (CPAP) machines, were included in the study.

Exclusion criteria: Neonates with fatal congenital malformations, neonates with acute surgical emergencies, as well as neonates whose parents did not give consent to participate or left the hospital against medical advice, were excluded.

Sample size calculation: The sample size calculation was based on the sensitivity of the MSNS score, which was determined to be 80% [18]. With an absolute precision of 3% and a confidence interval of 99%, the minimum required sample size was calculated using the following formula:

$N=Z^2_{1-\alpha}\ p(1-p)/d^2$

Where:

N=Sample size

α=Level of significance

Z1-α=Corresponding normal standard variant

P=Sensitivity (%)

d=Absolute precision

Based on the calculation, the minimum sample size required was 1269. A total of 1770 neonates were admitted to the general paediatric ward during the study duration, out of which 282 neonates were excluded based on the exclusion criteria. Therefore, a total of 1488 neonates were included in the final analysis.

Study Procedure

Demographic, maternal, and neonatal data, along with other clinical details, were collected upon admission. This information was obtained from either the mother or caregiver using a especially designed structured data sheet for the present study. Haematological, biochemical, and radiological investigations were performed. A preparatory educational session was conducted for all second and third-year Junior Residents, as well as all Senior Residents, to standardise and improve the quality of observations, ensure uniformity in neonate screening, and application of MSNS parameters. Each session lasted for two hours and was conducted twice a week for eight weeks.

The MSNS parameters (respiratory effort, heart rate, axillary temperature, capillary refilling time, random blood sugar, oxygen saturation at room air, gestational age, and birth weight) were recorded by on-duty residents at the time of admission or within an hour [Table/Fig-1] [18]. Each parameter was assigned a score of 0, 1, or 2. The total score ranged from 0 to 16. Under the supervision of senior residents, the findings of the parameters were recorded, and scores were assigned by the on-duty residents.

Parameters	Score 0	Score 1	Score 2
Respiratory effort (rate/min)	Apnoea or grunt	Tachypnoea (RR >60/min with or without retraction	Normal (RR 40-60/min)
Heart rate (beats/min)	Bradycardia or asystole	Tachycardia (>160/min	Normal (100-160/min)
Axillary temperature (ºC)	<36	36-36.5	36.5-37.5)
Capillary refill time (Seconds)	>5	3-5	<3
Random blood sugar (mg/dL)	<40	40-60	>60
Oxygen saturation (in room air) (%)	<85	85-92	>92
Gestational age (in weeks)	<32	32 to 36+6/7 days	37 and above
Birth Weight (kg)	<1.5	1.5-2.49	2.5 or above

[Table/Fig-1]: Parameters of Modified Sick Neonatal Score (MSNS) [18].
(RR: Respiratory rate)

Axillary temperature of neonates was recorded using a digital thermometer for two minutes, and the lowest reading was recorded. Oxygen saturation was measured twice using a pulse oximeter at room air, and the mean value was considered. Capillary refilling time was assessed using a stopwatch while gentle pressure was applied until the skin blanched at the sternum. The time at which the skin returned to normal colour was noted. If a repeat recording was needed, a gap of 30 seconds was given before the next attempt. A glucometer with its strip was used for blood sugar measurement. The modified New Ballard Score was applied to assess gestational age, which was confirmed with maternal documents containing the last menstrual period or ultrasonography [21]. A digital weighing machine was used to measure the weight at admission, which was considered as the birth weight with a negligible error of 10 g. A multipara monitor was used to record heart rate over one minute, and respiratory efforts and rate were estimated clinically.

All cases were managed according to the standard treatment protocol of the hospital, and outcomes were noted at discharge or death.

STATISTICAL ANALYSIS

The collected data was cleaned and entered into a Microsoft excel spreadsheet. It was then coded and analysed using the statistical software STATA version 14.0. The results were recorded as mean with standard deviation, median with interquartile ranges, and percentages in the appropriate tables. The Chi-square test was employed to determine the significance of a trend in mortality for ordinal categories, while Fisher's-exact test was used for data with a small frequency. The Receiver Operating Characteristics (ROC) curve was generated using MSNS to predict mortality. Sensitivity and specificity values were calculated for the cut-off value. To compare the scores between survival and non survival neonates for each individual parameter, the Mann-Whitney U test was utilised. A p-value of <0.05 was considered statistically significant.

RESULTS

A total of 1488 outborn neonates were recruited for the study, with a male to female ratio of 1.4:1. The mean age at admission was 43.3±58.9 hours. The majority of neonates, 938 (63.04%), were born at term, with a mean gestational age of 36.57±2.75 weeks. Out of the total, 777 (52.22%) neonates had a birth weight less than 2500 gm, with a mean birth weight of 2191.62±595.47 gm [Table/Fig-2].

Characteristics	Frequency (n=1488, %)
Age at admission (Hours) (median IQR)	**24 (24-48)**
Gestational age (mean±SD) (in weeks)	**36.57±2.75**
Preterm	545 (36.63)
Term	938 (63.04)
Post-term	5 (0.33)
Weight on admission (gm) (mean±SD)	2191.62±595.47
≥2500 gms	711 (47.78)
1500-2499 gms	553 (37.16)
1000-1499 gms	177 (11.90)
<1000 gms	47 (3.16)
Respiratory rate/minute (mean±SD)	**69.57±11.15**
Heart rate/min (mean±SD)	**169.56±12.72**
Temperature (°C) (mean±SD)	**36.44±0.63**
Oxygen saturation at room air (%) (mean±SD)	**90.81±5.17**
Capillary refill time (Second) (mean±SD)	**3.95±1.47**
Random blood sugar (mg%) (mean±SD)	**88.16±26.97**
Total MSNS score (mean±SD)	**10.45±2.62**
Duration of hospital stay (mean±SD) (days)	**7.63±5.07**
Gender	
Male	866 (58.20)
Female	622 (41.80)
Mode of delivery	
Vaginal	1239 (83.27)
Caesarean	221 (14.85)
Assisted	28 (1.88)

Parity	
Primipara	1034 (69.49)
Multipara	454 (30.51)
Antenatal care status (>3 visits)	1418 (95.30)
Antenatal care status (<3 visits)	70 (4.70)
Residence	
Rural	924 (62.10)
Urban	564 (37.90)
Maternal age (years) (mean±SD)	**23.85±2.92**

[Table/Fig-2]: Baseline characteristics of study participants.
(IQR: Interquartile range; SD: Standard deviation)

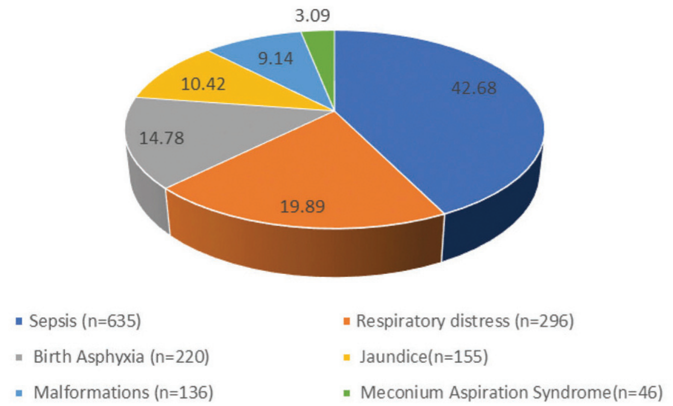
Although the majority of neonates (82.8%) were transported by ambulance, only one-third (25.08%) of these neonates were accompanied by a health assistant. Most of the neonates (91.73%) were referred by government facilities, with a mean travel distance of 83.57±72.79 km and a mean transport duration of 2.14±1.07 hours [Table/Fig-3].

Characteristics	All cases (n=1488, %)	Discharged (n=1052, %)	Died (n=436, %)	p-value
Referring hospital				
Private hospital	123 (8.27)	94 (8.94)	29 (6.65)	0.14
Primary health centre	333 (22.38)	242 (23.00)	91 (20.87)	0.36
Rural hospital	508 (34.14)	359 (34.13)	149 (34.17)	0.98
District hospital	524 (35.21)	357 (33.93)	167 (38.31)	0.1
Travelling distance (km) Mean±SD)	83.57±72.79	77.93±70.11	97.18±77.29	<0.0001
0-50	601 (40.39)	542 (51.52)	59 (13.53)	<0.0001
51-100	430 (28.90)	274 (26.05)	156 (35.78)	0.0001
101-150	280 (18.82)	173 (16.44)	107 (24.54)	0.0002
151-200	108 (7.26)	22 (2.09)	86 (19.73)	<0.0001
>200	69 (4.63)	41 (3.90)	28 (6.42)	0.03
Transport duration (mean±SD)	2.14±1.07	2.04±1.03	3.04±0.93	<0.0001
<1 hour	528 (35.48)	404 (38.4)	124 (28.44)	0.0002
1-2 hours	449 (30.18)	334 (31.75)	115 (26.38)	0.03
2-3 hours	279 (18.75)	177 (16.83)	102 (23.39)	0.003
>3 hours	232 (15.59)	137 (13.02)	95 (21.79)	<0.0001
Mode of transport				
Ambulance without Health Assistant	923 (62.03)	643 (61.12)	280 (64.22)	0.2
Ambulance with Health Assistant	309 (20.77)	221 (21.01)	88 (20.18)	0.72
Private car	59 (3.97)	52 (4.94)	7 (1.61)	0.002
Autorickshaw	50 (3.36)	43 (4.09)	7 (1.61)	0.01
Motor-bike	6 (0.4)	5 (0.48)	1 (0.22)	0.49
Public transport	141 (9.47)	88 (8.36)	53 (12.16)	0.02

[Table/Fig-3]: Transport characteristics of study participants.
(Km: Kilometre; SD: Standard deviation)

The most common clinical diagnosis among the study participants was sepsis in 635 (42.68%) neonates, followed by respiratory distress in 296 (19.89%) neonates. Birth asphyxia was diagnosed in 220 (14.78%) neonates, while malformations were noted in 136 (9.14%) participants [Table/Fig-4]. The duration of hospital stay for neonates who died was significantly shorter (5.06±4.37 days) compared to neonates who survived (8.69±4.96 days) (p-value <0.0001).

Neonates who were discharged had a higher frequency of better scores (Score 1 and 2) across all parameters, and the difference was statistically significant. The mean total MSNS score for neonates who were alive was 11.26±2.34, compared to 8.52±2.23 for neonates who died, which was statistically significant (p-value <0.0001) [Table/Fig-5].



[Table/Fig-4]: Clinical diagnosis of participants.

Parameters	Score	Frequency (n)	Discharged (n, %)	Died (n, %)	p-value
Respiratory effort	0	48	10 (20.83)	38 (79.17)	<0.0001
	1	1288	905 (70.26)	383 (29.74)	
	2	152	137 (90.13)	15 (9.87)	
Heart rate	0	20	3 (15)	17 (85)	<0.0001
	1	1299	904 (69.59)	395 (30.41)	
	2	169	145 (85.80)	24 (41.20)	
Axillary temperature	0	204	74 (36.27)	130 (63.73)	<0.0001
	1	830	559 (66.35)	271 (32.65)	
	2	454	419 (92.29)	35 (7.71)	
Capillary refilling time	0	220	59 (26.82)	161 (73.18)	<0.0001
	1	801	564 (70.41)	237 (29.59)	
	2	467	429 (91.86)	38 (8.14)	
Random blood sugar	0	40	15 (37.50)	25 (62.50)	<0.0001
	1	184	129 (70.11)	55 (29.89)	
	2	1264	908 (71.84)	356 (28.16)	
Oxygen saturation (in room air)	0	99	40 (40.40)	59 (59.60)	<0.0001
	1	918	570 (62.09)	348 (37.91)	
	2	471	442 (93.84)	29 (6.16)	
Gestational age	0	98	28 (28.57)	70 (71.43)	<0.0001
	1	445	290 (65.17)	155 (34.83)	
	2	945	734 (77.67)	211 (22.33)	
Birth weight	0	229	97 (42.36)	132 (57.62)	<0.0001
	1	559	410 (73.35)	149 (26.65)	
	2	700	545 (77.86)	155 (22.14)	
Total score (mean±SD)			11.26±2.34	8.52±2.23	<0.0001

[Table/Fig-5]: Distribution of parameters of MSNS among study participants.
(MSNS: Modified Sick Neonatal Score; SD: Standard deviation; Chi-square test, Fisher-exact test)

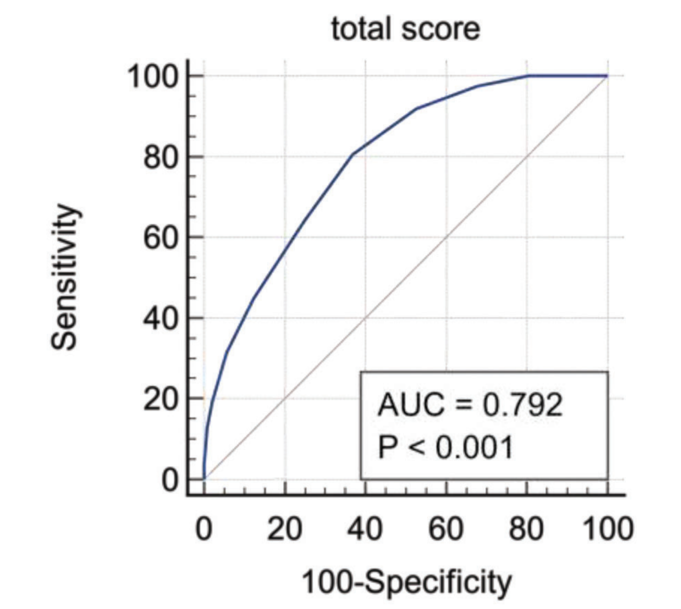
The difference in scores for parameters such as respiratory effort, heart rate, axillary temperature, capillary refilling time, oxygen saturation, gestational age, and birth weight were statistically highly significant among neonates who were discharged compared to neonates who died [Table/Fig-6].

MSNS parameters	Outcome	Median (IQR)	Mann-Whitney test Z value	p-value
Respiratory effort	Discharged	1 (1-2)	8.34	<0.0001
	Died	1 (1-1)		
Heart rate	Discharged	1 (1-2)	5.99	<0.0001
	Died	1 (1-2)		
Axillary temperature	Discharged	1 (1-2)	14.74	<0.0001
	Died	1 (0-2)		
Capillary refilling time	Discharged	1 (1-2)	16.48	<0.0001
	Died	1 (0-2)		

Random blood sugar	Discharged	2 (2-2)	2.55	0.01
	Died	2 (2-2)		
Oxygen saturation (in room air)	Discharged	1 (1-2)	14.06	<0.0001
	Died	1 (1-2)		
Gestational age	Discharged	2 (1-2)	8.92	<0.0001
	Died	1 (1-2)		
Birth weight	Discharged	2 (1-2)	8.26	<0.0001
	Died	1 (0-2)		

[Table/Fig-6]: Median (IQR) for parameters among discharged and expired.
((MSNS: Modified Sick Neonatal Score; IQR: Interquartile range)

The ROC curve, drawn with the MSNS score as the test variable to predict mortality, is shown in [Table/Fig-7]. The area under the curve was 0.79 (OR-24.72, 95% CI 0.77-0.81, p-value <0.001). The maximum cut-off value for the prediction of mortality was 10, which predicted almost 80% mortality for the optimum cut-off score of ≤10, with a sensitivity of 80.5% and specificity of 63.1%.



[Table/Fig-7]: Receiver Operating Characteristic (ROC) curve with total MSNS score <10 to predict mortality.

DISCUSSION

Quick recognition and early interventions of acute life-threatening events are crucial in reducing neonatal mortality on their first day of life and achieving sustainable developmental goals. However, the applicability of various illness severity scoring systems in resource-limited settings is challenging due to their limitations.

Out of the total 1488 outborn transported neonates enrolled in the present, male neonates were predominant, which may be due to biological factors and preferential care for male neonates. Approximately 70% of the neonates were born to primiparous mothers who received adequate antenatal care, and most of them were delivered vaginally. About 63% of the transferred neonates were born at term, and 55.2% had low birth weight. The most prevalent clinical diagnosis in the present was sepsis, followed by respiratory distress. Similar findings have been reported by other researchers, highlighting the predominance of vaginal deliveries among mothers who had atleast three antenatal visits, the majority of transported neonates being of low birth weight and term gestation, and the common occurrence of sepsis and respiratory distress [7,22,23].

The mortality rate in the present was 29.3%, which is comparable to the findings of previous studies done by Singh J (30.1 %) and Malpani P et al., (28.4%) while higher mortality is recorded by Shah BH et al., (38%) and lower by Agrawal J et al., (18%) in outborn neonates [22,24-26]. There is some variation in mortality rates reported by different researchers, indicating the need for further investigation.

As the present study hospital is the largest referral centre in the geographic area, a significant number of neonates (91.7%) enrolled in the present were referred by government healthcare facilities. This is likely influenced by programs such as Janani-Shishu Suraksha Karyakram and health insurance schemes for low-income earners. Although the majority of neonates (82.8%) were transported by ambulance, only one-third (25.08%) were accompanied by a health assistant. These findings are consistent with previous studies that reported a high percentage of neonates being referred by government healthcare set-ups and transported by neonatal ambulances [6,23].

In resource-limited settings, the use of illness severity scoring systems is challenging due to their limitations. However, in the present, the MSNS was applied to 1488 transported neonates. It was observed that neonates who survived had a significantly higher MSNS score (11.26±2.34) compared to those who died (8.52±2.23) (p-value <0.0001). Lower scores for each parameter were also significantly associated with poor outcomes and mortality. Similar observations have been made in previous studies when MSNS was applied to inborn neonates [18-20].

Different studies have reported varying sensitivity, specificity, and area under the curve values for MSNS in predicting mortality in neonates [18-20]. In the present study, the authors observed a sensitivity of 80.5%, a specificity of 63.1%, and an area under the curve of 0.79 (OR-24.72, 95% CI 0.77-0.81, p-value <0.001) when the optimum cut-off score was ≤10. This indicates that MSNS is equally useful in predicting mortality in outborn transported neonates.

Other scoring systems commonly used for referral neonates include the Score for Neonatal Severity (SNS) and the Expanded Score for Neonatal Severity (ESNS). While these scoring systems have shown promising results, they require sophisticated equipment. In contrast, MSNS is a simple, reproducible, and easily applicable scoring system in resource-limited settings. However, it is important to note that no single mathematical formula can completely depict the complex clinical process in neonates.

Limitation(s)

The major limitation of the present was that it was conducted in a single centre, which may limit the generalisability of the findings. Additionally, the study only applied the scoring system at admission, without taking into consideration maternal/obstetric complications, perinatal events, and transport factors that could potentially influence neonatal outcomes.

CONCLUSION(S)

The majority of outborn neonates in the present were transported by ambulance from government facility-based centres. Approximately two-thirds of the neonates were born at term, but the majority of them had low birth weight. Sepsis was the most common clinical diagnosis. The MSNS score showed a sensitivity of 80.5% and a specificity of 63.1% in predicting mortality in outborn transported neonates. These results are consistent with the findings in inborn neonates. Further research is needed with larger participant samples and consideration of maternal variables and transportation factors.

Acknowledgement

The authors would like to express their sincere gratitude to the parents of the study participants.

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PLAGIARISM CHECKING METHODS: [Jain H et al.]
- Plagiarism X-checker: Apr 11, 2023
- Manual Googling: May 26, 2023
- iThenticate Software: Jul 29, 2023 (20%)

ETYMOLOGY: Author Origin

EMENDATIONS: 7

AUTHOR DECLARATION:
- Financial or Other Competing Interests: None
- Was Ethics Committee Approval obtained for this study? Yes
- Was informed consent obtained from the subjects involved in the study? Yes
- For any images presented appropriate consent has been obtained from the subjects. NA

Date of Submission: **Apr 06, 2023**
Date of Peer Review: **May 17, 2023**
Date of Acceptance: **Aug 02, 2023**
Date of Publishing: **Oct 01, 2023**