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Serial Modified Sick Neonatal Score as a Tool for Predicting Neonatal Mortality: An Observational Study at a Single Center

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ABSTRACT

Background and Objective: Newborn disease scoring improves outcomes but requires arterial blood gas analysis, often unavailable in limited settings. The aim of this study was to determine whether cost-effective alternatives, such as the Modified Sick Neonatal Score (MSNS), can predict neonatal mortality.

Methods: This cross-sectional study was conducted on the neonates who required admission to the neonatal intensive care unit (NICU) of a Medical College Hospital from February 2021 to September 2021. MSNS was done on admission, daily for 7 days and during the period of clinical deterioration. The mean (standard deviation (SD)) values at admission and the lowest recorded value were compared with the outcome. A receiver-operating characteristic curve (ROC) analysis was performed to determine the optimal cut-off value for predicting mortality.

Findings: The mortality rate was 4.58%. The mean (SD) MSNS at admission of deceased neonates [9.04(1.612)] was significantly lower than that of improved neonates [14.68(1.610)]. The mean (SD) lowest MSNS for deceased neonates [6.23(1.177)] was significantly lower than that for improved neonates [14.5(1.893)]. The area under the curve (AUC) for admission score was 0.958, and a score of 12 predicted mortality with a sensitivity of 91% and a specificity of 95.2%. The AUC for the lowest score was 0.995, and a score of 9 had a sensitivity of 94% and a specificity of 99% for predicting mortality.

Conclusion: Serial MSNS is a good predictor of mortality, and low scores on admission and the lowest score during hospitalization correlated well with poor outcomes.

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Introduction

The neonatal period is highly vulnerable, and globally, during the year 2020, there were around 2.4 million deaths in the neonatal period [1]. One-third of all neonatal deaths occurred during the first day of life, and 75% occurred within the first week of life [1]. The majority of the neonatal deaths were due to prematurity, birth-process-related morbidities, congenital anomalies, and sepsis [2]. Prematurity is the predominant etiology of deaths in the first week of life (62%) [3]. 25% of the total neonatal deaths worldwide occurred in India [4]. There are various factors like socio-demographic factors, literacy rates, health care seeking behavior, etc, which play a major role in the increased rates of neonatal deaths in India [5]. The neonatal deaths and illnesses are also influenced by the events that occur in the perinatal period, and also the severity of the illness in the first 60 minutes after birth [6]. Early identification of illness in neonates will help in reducing mortality, thereby minimizing complications.

There are many scoring systems to determine the degree of sickness in neonates. This is more applicable in countries where the cost of neonatal intensive care and length of stay are limiting factors. Scoring systems available for neonatal assessment include the neonatal acute physiology score, neonatal acute physiology-perinatal extension score, clinical risk index for infants, neonatal mortality prognostic index, etc., [7, 8, 9, 10]. The scoring systems are vital to assess the cardio-pulmonary status of neonates and to determine the need and type of intervention required. The scoring systems currently in use require multiple parameters, and the vast majority of them use arterial blood gas analysis as one of the parameters. To meet the needs of resource-limited countries, a simple scoring tool with few parameters that can estimate mortality is the need of the hour.

The Sick Neonatal Score (SNS) is used to assess newborns who need to be transported to other healthcare facilities and comprises 7 parameters, including respiratory effort, heart rate, blood pressure (mean), skin temperature (axillary), SpO2, capillary refill time, and blood glucose (random). The Modified Sick Neonatal Score (MSNS) comprises eight parameters, which include six parameters of the SNS. Mean blood pressure, which was included in the SNS, was removed as it requires additional gadgets to record blood pressure, which may be lacking in certain treatment units. Parameters like birth weight and gestational age were included in the MSNS as they are critical factors for neonatal outcome. Since the ABG parameters are not included, the MSNS score can be a cost-effective alternative to the other available scoring systems to accurately and easily categorize newborns by healthcare providers.

The aim of the current study was to determine whether the admission score and the lowest score of the MSNS during the first week of hospitalization can be used to predict the outcome of newborns admitted to the neonatal intensive care unit (NICU).

Methods

Study Design and Setting

This cross-sectional study was conducted on all neonates admitted to the NICU in a Medical College Hospital in Chennai, Tamil Nadu from February 2021 to September 2021.

Study Population and Sample Size

All neonates who met the criteria for admission to the NICU were considered participants for the study. The most common indications for admission to the NICU were asphyxia, sepsis, jaundice, low birth weight, prematurity, respiratory distress syndrome, seizures, metabolic problems, congenital anomalies, birth injuries, meconium aspiration syndrome, etc. Newborns discharged at the parents' request before completion of treatment were not included. The sample size was calculated based on a previous study of 700 [11]. The newborn mortality rate was 18 % with a sensitivity of 80 %, a precision of 3 % and within a confidence interval of 95%.

The study was commenced after obtaining approval from the Institutional Ethics Committee. Parents were informed about the purpose and importance of the study and their consent was obtained. Basic demographic information, such as name, age, gender, gestational age, birth weight, mode of delivery, maternal risk factors, and diagnosis, was documented.

Neonatal Assessment Using MSNS

The MSNS was used to assess the condition of the neonate (Table 1).

Each of the parameters of the MSNS was scored from 0 to 2. A score of 0 indicated an unfavorable clinical condition and a score of 2 indicated a favorable clinical condition for the parameter assessed. The maximum possible score was set at 16. For the assessment, the respiratory effort was noted after the respiratory rate had been counted for 60 seconds. The heart rate was counted and recorded for 60 seconds. The baby's skin temperature was measured with a digital thermometer in the armpit. Capillary refill time was checked by applying pressure to the sternum and the time to refill was noted. Capillary blood glucose was measured with a glucometer by drawing blood from the heel. Oxygen saturation in room air was measured with a pulse oximeter. Gestational age was calculated from the last menstruation and the New Ballard Score. The weight of the newborn was measured using a digital baby scale.

Follow-up and Outcome Assessment

The neonate's condition was assessed and evaluated using the MSNS on admission and daily for the following 7 days, as well as at each clinical deterioration. The lowest score recorded during this period was used for the statistical analysis. The neonate's score at the end of the 7 days after admission was recorded and neonates were reviewed until discharge and the outcome at the end of hospitalization was noted. If the neonates were discharged before the end of the seven days, a telephone follow-up was conducted on day 7.

Statistical Analysis

The data was entered using Microsoft Excel and analyzed using SPSS 22. Mean, standard deviation (SD) and frequency were calculated. For analytical statistics, the ROC curve was used to predict mortality together with the optimal cut-off value, sensitivity, specificity, positive predictive value and negative predictive value. The ROC curve was used to estimate the area under the curve (AUC) with confidence intervals.

Table 1 Modified sick neonatal score

Parameter	Score 0	Score 1	Score 2
Respiratory effort	Apnoea or grunting	Tachypnea >60/m with or without retractions	Normal 40 to 60
Heart rate	Bradycardia <100 or asystole	Tachycardia(>160)	Normal (100-160)
Axillary temperature(C)	<36	36 -36.5	36.5 -37.5
Capillary filling time (s)	>5	3-5	<3
Random blood sugar(mg/dl)	<40	40-60	>60
SpO2(in room air)	<85%	85-92%	>92%
Gestational age(weeks)	<32	32-36 + 6 days	>37
Birth weight (kg)	<1.5	1.5 to 2.49	>2.5

Results

The present study was conducted on 700 neonates, including 379 (54.1%) male neonates. Totally, 456 (65.14%) neonates had normal birth weight (2.5-4 kg), 4 (0.57%) newborns had extremely low birth weight (<1 kg), 28 (4%) neonates had very low birth weight (1-1.5 kg), 198 (28.28%) had low birth weight (<2.5kg) and only 4 (0.57%) neonates weighed >4 kg.

In addition, 348 (49.71%) neonates were delivered by normal vaginal delivery, 43 (6.14%) by assisted vaginal delivery (forceps or vacuum) and 309 (44.14%) neonates were delivered by lower segment cesarean section. Of the neonates, 509 (72.71%) were born at term. Among the preterm neonates, 9 (1.28%) were extremely preterm (<28 weeks of gestation), 28 (4%) were very preterm (28-31 weeks 6 days) and 154 (22%) were moderate to late preterm (32 to 36 weeks 6 days). 663 (94.71%) were delivered in our hospital, while 37(5.3%) neonates were delivered and referred outside.

The neonates were admitted with the diagnosis of jaundice (17.57%), low birth weight (19.28%), perinatal complication in infants of diabetic mothers (18.28%), perinatal asphyxia (8.71%), transient tachypnea of the newborn (5.85%), sepsis (8.57%), respiratory distress syndrome (5.85%) and intrauterine growth retardation (2.57%). The other diagnoses that warranted admission were birth injury, congenital anomalies, pneumothorax and meconium aspiration syndrome (Table 2).

Of the maternal risk factors, 153 (21.85%) had diabetes mellitus, 77 (11%) had gestational hypertension, 125 (17.85%) mothers had premature rupture of membranes, 36 (5.14%) had oligohydramnios, 14 (2%) had anemia, 15 (2.14%) were HbsAg +ve and 34(4.85%) were COVID positive and one mother was HIV positive.

At the end of 7 days, 665 (95%) newborns had improved, 26 (3.7%) neonates had expired, 5 (0.71%) neonates had worsened and no change in status was noted in 4 (0.57%) infants. At the end of hospitalization, it was observed that out of 700 neonates, 668 neonates were discharged (95.4%) and 32 newborns died (4.6%).

The mean (SD) MSNS score at admission was 14.41 (1.997). The lowest MSNS score on admission was 6 and the highest score was 16. The mean lowest MSNS (SD) score was 14.13 (2.525). The minimum score was 5 and the maximum score was 16.

The mean (SD) MSNS admission score and the mean (SD) MSNS low score for newborns who died after 7 days were lower than the corresponding values for newborns who fared better (Table 3).

The mean (SD) length of stay of neonates in the NICU was 135 (128.911) hours. For neonates, the mean (SD) age at admission was 12.52 (27.307) hours, while the mean (SD) age at neonatal admission was 45.92 (39.036) hours.

Receiver operating characteristic analysis showed that the AUC for the admission score was 0.958 [CI (0.910-1), p=0.001] and a score of 12 predicted mortality with a sensitivity of 91% and a specificity of 95.2%. The false-positive value was 0.048; the positive predictive value (PPV) and the negative predictive value (NPV) were given as 100%. The specificity of 95.2% indicates that this cut-off score of 12 can correctly predict mortality in 95% of neonates (Table 4) (figure 1).

The ROC analysis was done to determine the cut-off of the lowest score for predicting mortality. It yielded an AUC of 0.995 [(CI 0.991-0.999) p=0.002] and a score of 9 had a sensitivity of 94% and a specificity of 99%, the false positive rate was 0.013, PPV and NPV were reported as 100%. This illustrates that the score of 9 can correctly predict mortality in 99% of neonates (Table 4) (figure 2).

Table 2. Basic demographic details of the study population

Factor		Expired N (%)	Discharged N (%)
Gender	Male	12(37.5)	367(59.94)
	female	20(62.5)	301(45.059)
Birth weight	<1 kg	11(34.4)	3(0.449)
	1 to 1.5kg	11(34.4)	17(2.544)
	1.5 to 2.5kg	5(15.6)	193(28.892)
	2.5 to 4 kg	5(15.6)	451(67.514)
	>4kg	0(0)	4(0.598)
Gestational age	39 to 42 weeks	1(3.125)	203(30.389)
	37 to 39 weeks	4(12.5)	301(45.059)
	32 to 37 weeks	6(18.75)	148(22.155)
	28 to 32 weeks	13(40.62)	15(2.245)
	<28 weeks	8(25)	1(0.149)
Inborn/Outborn	inborn	31(96.87)	632(94.61)
	outborn	1(3.125)	36(5.389)
Diagnosis	Asphyxia	6(18.75)	55(8.233)
	Respiratory distress syndrome	22(68.75)	19(2.844)
	Low birth weight	1(3.125)	122(18.263)
	Congenital heart disease	1(3.125)	10(1.497)
	Prematurity	1(3.125)	7(1.047)
	Meconium aspiration syndrome	1(3.125)	2(0.299)
	Sepsis	0	60(8.982)
	Neonatal jaundice	0	135(20.209)
	Transient tachypnea of newborn	0	41(6.137)
	Others	0	217(32.485)

Table 3. Modified sick neonatal score and outcome (MSNS)

Outcome	MSNS score	Improved	Expired	P value	Worsened	Status quo	P-value
At the end of seven days	Admission score mean(SD)	14.68±1.610	9.04±1.612	<0.0001	10.60±3.362	10.25±2.363	0.8658
	Lowest score mean(SD)	14.52±1.860	6.23±1.177	<0.0001	6.60±1.342	9.25±2.062	0.0519
Final outcome at the end of hospital stay	Admission score mean(SD)	14.66±1.640	9.31±1.975	<0.0001	-	-	-
	Lowest score mean(SD)	14.50±1.893	6.38±1.264	<0.0001	-	-	-

Table 4. ROC curve for Modified Sick Neonatal Score (MSNS) on admission and lowest MSNS

Score	AUC*	SE**	95% CI of AUC		Sensitivity %	Specificity %	PPV # %	NPV ## %	P-value
			Lower	Upper					
MSNS admission	0.958	0.022	0.910	1	91	95.2	100	100	P<0.001
MSNS lowest	0.995	0.002	0.991	0.999	94	99	100	100	P<0.002

* Area under the curve
** Standard Error
# Positive predictive value
Negative predictive value

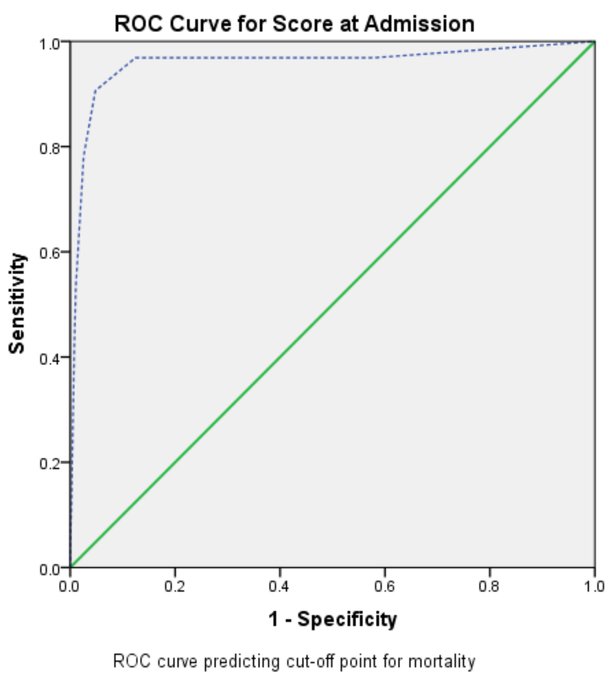

Figure 1. ROC curve for MSNS on admission

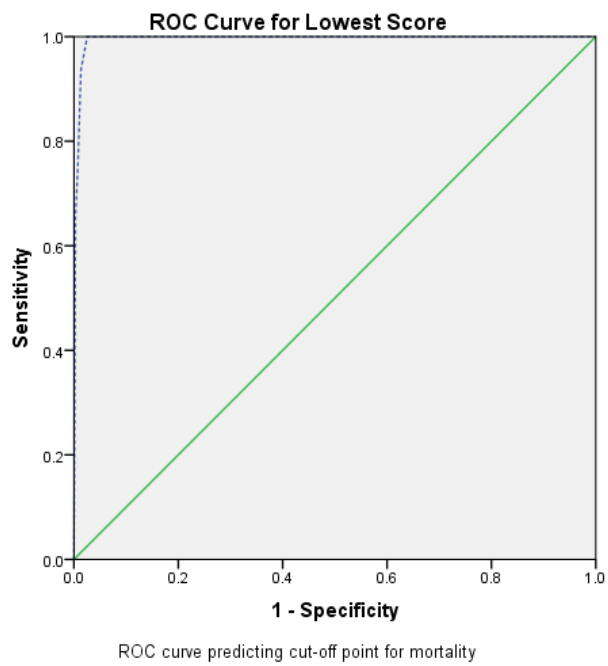

Figure 2. ROC curve for lowest MSNS

Discussion

In the current study, the MSNS was applied serially and its correlation with the outcome of admitted newborns was examined.

It was observed that both the admission score and the lowest score recorded during hospitalization were lower in neonates who died than in those who improved with treatment. The score of 12 recorded at admission and the lowest score of 9 recorded during hospitalization had higher specificity than sensitivity and had excellent PPV and NPV for the outcome.

Neonates whose condition was static had a lower mean (SD) MSNS admission score than those whose condition was deteriorating, but this was not statistically significant. However, the mean (SD) MSNS lowest score for neonates whose condition deteriorated was lower than that of neonates whose clinical condition did not change. When the outcome at the end of hospital stay was compared with the mean (SD) MSNS admission score and the mean (SD) MSNS lowest score, we observed that neonates whose condition improved had correspondingly higher scores than neonates who expired and this was statistically significant.

In the present study, it was found that neonates who died had significantly lower MSNS scores both at the time of admission and during hospitalization (p<0.0001). This is consistent with a study by K.P. Mansoor et al. in which the mean (SD) MSNS score on admission was lower in neonates who died. The MSNS score was 8.22(2.96) in the deceased and 13.4(2.14) in the discharged [11].

Other studies were consistent with our observations that MSNS scores were lower in neonates who died than in neonates who were discharged. In the study by Shivaramakrishnababji [12], the mean (SD) of total MSNS was lower in the deceased neonates than in the discharged neonates (p<0.0001) and in another study by Padar C., it was 7.94 (1.89) in the deceased group and 14.46 (1.84) in the discharged group (p<0.001) [13].

There are several studies that have been performed using the SNS that have also made similar observations. An earlier study by Rathod D., examining the utility of SNS at admission to predict mortality, found a lower score of 6 in expired neonates compared to 10 in all neonates [14]. Other studies have represented a significant difference between the average SNS of newborns who fared better and those who died (11.35 vs. 8.02) [15] and (13.2 vs 8.4) [16].

In most studies, the severity score was applied only once at the time of admission, whereas in the present study, it was applied serially for the first seven days of admission and also at times of deterioration, indicating that both the lowest MSNS and admission score can reliably predict mortality. Since the scoring was performed serially for 7 days, the dynamic changes in the clinical condition of the admitted neonates and also the possibility of deterioration due to nosocomial infections could be detected and the correlation with the outcome could be investigated.

In the present study, the ROC yielded an AUC of 0.958 at a cut-off score of 12 for MSNS on admission, with a sensitivity of 91% and a specificity of 95.2%. The lowest MSNS score had a sensitivity of 94% and a specificity of 99% when a cut-off score of 9 was used to predict mortality, and the AUC was 0.995. Several studies have been conducted to validate the SNS and using ROC, different cut-off scores have yielded different predictive abilities. For the MSNS, an AUC of 0.913 (95% CI: 0.879–0.946) was observed using a cut-off score of ≤10 to predict outcome [11]. Using a similar cut-off for MSNS, Shivaramakrishnababji found an AUC of 0.811 (95%CI: 0.788-0.835) [12]. A higher AUC of 0.98 was observed by Padar C. at a cut-off value of 10 using MSNS [13].

Rathod D. in his study suggested lower sensitivity and specificity at an SNS cut-off of ≤ 8 [14], while a SNS of 9 showed a higher sensitivity of 82.75% and specificity of 86.49% in Agrawal J's study [15] With a higher MSNS cut-off ≤ 12, Pandey A observed a sensitivity of 86.1 % and a specificity of 78.3 % . He also observed that the time to reach hospital was a crucial factor that influenced the mortality with non-survivors having a significantly longer median time than survivors (5.1 vs 3.4, p<0.001) [16].

In the present study, the overall mortality in the study population was 4.6%. In two separate studies conducted in South India, neonatal mortality was 11.25% and 6.9% respectively [12, 13]. Other studies have observed a higher mortality rate of 18-20% [14, 15]. The lower mortality rate in our study population compared to the previous studies was probably due to differences in the severity of illness of admitted neonates.

Limitations and Recommendations

The present study had a few limitations. Many of the neonates admitted were in a stable physiologic condition, as the study included intramural neonates admitted in level II care. The number of extramural neonates examined was small. In the future, larger multicenter studies with larger sample sizes will certainly determine the prognostic accuracy of the MSNS if extramural neonates with severe conditions warranting level III care are included in the study in larger numbers.

The current study recommends that the MSNS can be used by healthcare professionals to assess the newborn and decide on referral to higher centers. It can also be used for prognostication; hence, counseling of concerned parents if the neonate's condition warrants admission during the neonatal period.

Conclusion

The MSNS is a useful tool for assessing neonates admitted to healthcare facilities and for estimating treatment outcomes. The lower the score, the worse the prognosis. The MSNS admission score of 12 and the lowest MSNS score of 9 can significantly predict mortality. The score can help identify newborns with a low score who need to be referred to a higher center for appropriate intervention. Given the discrepancy between admission profiles and resource availability in developing countries, the MSNS is a good tool to bridge this gap.

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Ethical Considerations

This study was commenced after obtaining approval from the Institutional Ethics Committee (protocol ID 440/2021, meeting held on 4/2/2021).

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Conflict of interest

There is no conflict of interest.

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