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Establishment of a neonatal nursery in a rural district hospital in Malawi: a retrospective review of neonatal outcomes in Neno District Hospital (2014—2021)

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Abstract

Background Despite efforts to improve neonatal care worldwide, neonatal mortality rates in sub-Saharan Africa remain high. Adequate space, equipment, and staff are vital to improving mortality rates through high-quality care. We evaluated the impact of a district-level neonatal special care nursery over seven years at Neno District Hospital, Malawi.

Methods We conducted a retrospective cohort study to measure the neonatal outcomes in the neonatal special care nursery before nursery establishment (study period I, 2014–2015), following the establishment of a small nursery (study period II, 2016–2018), then with a transition to a larger nursery (study period III, 2019–2021). We extracted data from the neonatal registers and employed descriptive statistics and chi-square tests to compare the overall neonatal outcomes between study periods. We performed logistic regression to isolate factors associated with neonates alive at discharge.

Results Of the 1366 neonates observed over the entire study period, the three primary admission diagnoses were birth asphyxia (30.1%), sepsis (29.0%), and prematurity (20.9%). The proportion of neonates discharged alive increased from 61.9% to 74.3% and then 87.6% in study periods I, II, and III, respectively. Neonates admitted during study periods II and III were over two and five times more likely to be discharged alive than neonates admitted during study period I in multivariate analysis controlling for sex (SPII aOR = 2.42; 95% CI: 1.43–4.08; SPIII aOR = 5.32; 95% CI: 3.13–8.98; $p < 0.001$). There was no difference in being discharged alive for neonates admitted with prematurity compared to birth asphyxia (aOR 0.87; 95% CI: 0.51-.151) but neonates admitted with sepsis were over two times more likely to be discharged alive than birth asphyxia (aOR = 2.64; 95% CI: 1.67–4.29). Neonates admitted with a birth weight of ≤ 1500 g were 69% less likely to be discharged alive than neonates admitted with a birth weight > 2500 g (aOR = 0.31, 95% CI: 0.16–0.58; $p < 0.001$).

Conclusions The establishment and systems strengthening of a neonatal nursery at Neno District Hospital resulted in a significant increase of neonates discharged alive from the neonatal special care nursery. A multidimensional

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approach to ensuring resource inputs and ongoing strengthening efforts in Malawi is critical to decreasing neonatal mortality within the special care nursery.

Keywords Neonates, Neonatal nursery, Space, Staff, Equipment, Birth asphyxia, Sepsis and prematurity

Background

Neonatal mortality is a global concern, with the highest rates in sub-Saharan Africa (SSA) [1–3]. Eighty-five percent of neonatal deaths are due to complications from prematurity, low birth weight, intrapartum-related hypoxia, and infections [4–7]. Although substantial progress has been made in reducing neonatal mortality since 1990, increased efforts to improve progress are still needed to achieve the Sustainable Development Goal (SDG) target 3.2 related to newborn and child mortality [8].

Malawi, located in southern Africa, mirrors sub-Saharan Africa's neonatal mortality. Malawi's overall neonatal mortality rate fell from 69.5 deaths per 1,000 live births in 1970 to 19.8 deaths per 1,000 live births in 2019 [9]. However, despite a 60.0% initial decline in neonatal mortality in Malawi between 1970 and 2008 (69.5 to 27.6 per 1,000 live births), there has been a slowing of the decline with only a 28.0% improvement between 2008 and 2019 (27.6 to 19.8 per 1,000 live births) [9]. The initial decrease in Malawi's neonatal mortality rate can be attributed to the collaborative efforts of multiple sectors through strengthening infrastructure, space, staff, equipment, medications, and hospital care delivery and scaling up effective interventions targeting the major causes of neonatal mortality such as improving caesarian section rates and provisions of emergency obstetric and neonatal services [10].

Despite the literature indicating that delivery in a health facility can reduce the risk of neonatal mortality by 29.0% in low- and middle-income countries [11, 12]. Related studies have demonstrated that reductions in neonatal mortality require more highly capacitated health facilities with sufficient infrastructure, health workforce, equipment, and diagnosis and care systems to provide comprehensive prevention, diagnosis, and routine, surgical, and emergency treatment to demonstrate decreased mortality [13–17]. For example, despite 90.0% of deliveries occurring in a health facility in Malawi, [11, 14] the quality of neonatal health care services in Malawi was lower than other health services at health facilities, with most women living far from high-functioning facilities, resulting in a stagnant neonatal mortality rate [17]. For example, a recent study examining facility readiness in Malawi showed that coverage of institutional deliveries was decreased by 30 percentage points (91.0% of facility deliveries but 62.0% overall facility delivery readiness) after adjusting for facility readiness [17].

Until ten years ago in Malawi, most neonatal care hospitals were only located at four urban central hospitals, which significantly limited access to care, with > 80.0% of the population living in rural areas [18]. Over the past decade, most district hospitals in Malawi have operationalized a decentralized district hospital-based neonatal nursery. Evidence suggests improved neonatal outcomes at these neonatal nurseries at the district level with improved accessibility and utilization by a larger proportion of the population [14, 19].

Like most districts in Malawi, Neno District Hospital (NDH) did not have a formal neonatal nursery until 2016. Critical neonates were either referred to an urban tertiary hospital over two hours away or kept within the delivery rooms for care [20]. The reported neonatal mortality rate was 12.6 deaths per 1000 live births in 2015 [21–23]. However, there was a concern for poor recognition of diagnoses, identification, and reporting of complications, lack of treatment, and inadequate reporting of neonatal deaths compared to observed practice and outcomes. Before the establishment of the neonatal nursery, small or sick neonates were kept in the delivery room or with their mothers in the high-risk postpartum area of maternity. There was no specific diagnostic and treatment equipment except for resuscitation and warmers in the delivery rooms and no training for staff or guidelines for care.

In January 2016, a small level two neonatal nursery, or special care nursery per Moxon et al. [24], was inaugurated at NDH with the support of the nongovernmental organization (NGOs) Partners in Health (PIH) to strengthen health service delivery and neonatal outcomes [25]. The initial nursery was created in a small room near the delivery rooms with neonatal equipment and medications, technical assistance, and capacity building for maternity staff responsible for neonatal care and developing referral protocols, diagnosis, and treatment guidelines. With increasing demand for admissions and the acknowledgment of needed dedicated staff for the nursery, the neonatal special care nursery was shifted to a larger space with dedicated clinicians and nursing staff in January 2019. The neonatal special care nursery at NDH admitted neonates delivered at NDH and those referred from other primary health facilities and the community hospital within the district. Since 2016, Partners In Health and the Newborn Essential Solutions and Technologies (NEST 360) [25] have supported the nursery with newborn essential equipment such as overhead heaters, phototherapy machines, pulse oximeters, oxygen concentrators, Pumani bCPAP machines, suction machines, oxygen splitters, digital weighing scales, syringe pumps, and hemacues for hemoglobin testing. Partners In Health initially supported training and hands-on mentorship support on the opening of the special care nursery in 2016 and then from 2020 through a partnership with the University of California San Francisco (UCSF) Global Action in Nursing (GAIN) project implemented through Partners In Health and the Ministry of Health [26].

Since the neonatal nursery establishment at NDH over seven years with comprehensive resource inputs as described, there has yet to be a longitudinal evaluation of neonatal outcomes for the entire period. An initial impact evaluation of the NDH special care nursery in 2017 examined neonatal admissions and outcomes from January to July 2016 in the 146 admissions recorded with high rates of sepsis and birth asphyxia. Examination of nursery admissions showed neonatal mortality at 11.7/1000 live births from January-June 2015 and 14.4/1000 live births from July-December 2015 before the establishment of the special care nursery. With the initiation of the small nursery, there were 11.7/1000 live births from January to July 2016. However, due to the short evaluation period, neonatal mortality was similar to the prenursery baseline, and no further review was done for the neonatal nursery at NDH. Other studies have been completed in Malawi examining the effect of neonatal special care nurseries at the district level, but none over more than eighteen months [12]. In this study, we retrospectively assessed the impact of neonatal special care nursery establishment and subsequent strengthening on neonatal outcomes over seven years from 2014 to 2021 at the Neno District Hospital.

Methods

Study design and setting

This retrospective cohort review of sick neonates treated in the neonatal special care nursery at NDH between 2014 and 2021. The study period was split into three periods (I, II, and III) to compare outcomes. Study period I was 24 months before the formal establishment of a special care neonatal nursery when sick neonates were kept in the delivery rooms or postnatal care (1 Jan 2014 to 31 Dec 2015). Study period II was from establishing the small neonatal special care nursery in January 2016 in a small room within the maternity unit for 36 months (1 Jan 2016 to 31 Dec 2018) until moving to the larger nursery in 2019. This neonatal nursery space allowed for up to 8–10 neonates or kangaroo mother care (KMC) and had two radiant warmers, two oxygen sources, two continuous pressure airway pressure (CPAP) machines and two phototherapy machines. In addition to maternity ward medications, dedicated vitamin K and cefotaxime medications were stocked for the special care nursery.

Additionally, education and capacity building for three nurses and one clinician who staffed the nursery with the maternity ward was supported with continued mentorship. Study period III was from the transition to a larger neonatal special care nursery in January 2019 for 36 months (1 Jan 2019 to 31 Dec 2021) with dedicated staff and larger space within the postnatal ward. One room was for the neonatal special care nursery with 10 neonatal beds, and one contained 6 KMC beds with the same dedicated equipment with a perfuser pump and additional oxygen sources. In the larger space, a dedicated trained staff of five nurses and one clinician were assigned to the neonatal special care nursery and KMC unit without other responsibilities within the maternity unit. The admission criteria for the nursery were established with the opening of the nursery in 2016 and stayed the same through the end of the study period.

Neno district is located in the southwestern part of Malawi, with a population estimate of 156,029 as of 2024 [18]. The district has fifteen health facilities, of which nine primary health facilities (health centers), one community hospital, and one district hospital (NDH) offer regular maternal and infant health services, with a combined number of deliveries of 5207 in 2021 [18]. However, only the NDH provides neonatal special care services within the district. Neno district is in a mountainous rural area with a poor road network, often resulting in delayed access to health services and > 70.0% living in poverty on less than two dollars a day [18].

Study population and sample size

The target population for this study was sick newborns receiving care in the neonatal special care nursery at NDH. Our analysis included all 1366 neonates documented in the NDH sick neonatal register, which serves as the admission register to the neonatal special care nursery, between 1 January 2014 and 31 December 2021. The sick neonatal registers capture core variables of neonates (columns) include: identification (date, neonate's name, mother's name or other precise identifiers, sex, age), assessment of vital signs (weight, temperature, respiratory rate, oxygen saturation, heart rate), classification of diagnosis (prematurity, low birthweight, jaundice, sepsis, birth asphyxia), treatment, referral and outcome (e.g., discharged, referral, or died). The sick neonate registers recorded neonates delivered at NDH or those referred from outside facilities within Neno District (i.e., all primary health facilities and Lisungwi Community Hospital).

A power analysis for a one-tailed exact Fisher exact test indicated that the minimum sample size in each group to yield a statistical power of at least 0.80 with an alpha of 0.05 was 249. When calculating the power for given sample sizes from the retrospective review, the power achieved between study periods I and II was 0.56, between study periods I and III was 0.59, and between study periods II and III was 0.99.

Data collection

We extracted data for all neonates captured in the sick neonatal register during the study period into a standardized Excel worksheet. We trained nonclinical research assistants for two days, focusing on specific clinical terms used in the neonatal units, how to read neonatal records, and abstract data from the registers. After data entry, we conducted data cleansing by fixing incorrect, missing, incomplete, or duplicates from the data set to ensure reliability and integrity in the data source. Furthermore, to ensure data quality and integrity, we conducted data validation and verification by double-checking and entering the extracted data and comparing it with the registers to ensure no errors were made during data extraction and entries. The independent variables extracted included the date of birth, admission date, place of birth [NDH, in-transit, another facility, home/traditional birth attendant (TBA)], age in days, sex, mode of delivery [spontaneous vertex delivery (SVD), vacuum extraction (VE), cesarean section (CS), breech, other]. We also included human immunodeficiency virus (HIV) exposure, gestational age in weeks, birth weight in grams, admission diagnosis [birth asphyxia, sepsis, prematurity, and other diagnoses, including respiratory distress syndrome (RDS), pneumonia, and congenital disorders], and duration of stay in days. The dependent variable was neonatal outcomes categorized by i) discharged alive, ii) referral to a higher-level tertiary facility, iii) absconded, or iv) death.

Data analysis

We imported data from Microsoft Excel to R Software Version 4.2.2 and utilized RStudio to clean and analyze the data. We used descriptive statistics such as counts and percentages for all categorical variables and medians and interquartile ranges (IQRs) to describe the background characteristics of the subjects in the study. We used a chi-square/Fisher's exact test to analyze relationships between categorical variables such as outcomes, admission diagnosis, and study period. We fitted a logistic regression model to determine factors that significantly affected survival in the three study periods using a binary (alive/dead) outcome. In the final multivariate model, we reported global test p-values for the significance of the relationship between the covariate and the outcome. Starting from a nominal level of 5%, we divided by the number of tests (i.e., 12) to account for multiple testing, producing a level of 0.417% (i.e., 5%/12) for statistical significance.

Results

Demographics and clinical characteristics of neonates admitted to neno district hospital

We analyzed records from 1366 neonates admitted to Neno District Hospital (NDH) neonatal special care nursery during the entire study period. In all admissions to the special care nursery, 52.0% (n = 712) were female, and of 1356 neonates with birth weights recorded, the average weight was 2700 g. Nearly two-thirds (64.0%, n = 878) of 1366 neonates with complete gestational age records were reported to be full-term. The highest number of admissions (60.8%, n = 830) occurred during study period III, with the largest jump in admissions from study periods I to II. Initially in study period I, 71.4% of the infants identified as sick were born in NDH. This increased to 82.5% in study period II and then decreased to 74.9% in study period III. The proportion of maternal HIV status positive at delivery dropped by more than sixfold from study period I to study period III. Of the 1289 neonates with the duration of stay in the hospital recorded, the median stay was six days (IQR: 4.0–8.0) (Table 1).

Admission diagnosis over the study periods

The top three primary admission diagnoses in the Neno District Hospital neonatal special care nursery were birth asphyxia (30.11%, n=411), sepsis (29.0%, n=396), and prematurity (21.0%, n = 286), (Table 2). Other diagnoses included congenital abnormalities, including congenital heart disease, neonatal pneumonia, respiratory distress syndrome, and meconium aspiration syndrome. The admission diagnosis proportions for birth asphyxia, sepsis, prematurity, and other diagnoses over the three study periods under review are shown in Fig. 1.

Over the entire study period, the proportions of premature infants were 15.5, 25.0, and 19.3 for study periods I, II, and III, respectively, which shows, on average, an increasing trend (Table 2). However, birth asphyxia decreased from being the leading cause of admission in study period I at 46.0% to only 23.6% of admissions in study period III. Sepsis and other diagnoses increased the most from study period II to study period III by 12.2% and 8.8%, respectively. By study period III, sepsis was the leading cause of admission (34.0%), followed by birth asphyxia (23.6%), other diagnoses (23.4%), and finally, prematurity (19.3%) (Fig. 1, Table 2). The changes in birth asphyxia, sepsis and other diagnoses

Table 1 Demographic and clinical characteristics of neonates admitted to the Neno District Hospital neonatal special care nursery

Characteristic	Study period I (2014–2015) (*n* = 84)	Study period II (2016–2018) (*n* = 452)	Study period III (2019–2021) (*n* = 830)	Entire Study Period (*n* = 1366)
Gender				
Male	35 (42.0%)	185 (41.0%)	434 (52.0%)	654 (48.0%)
Female	49 (58.0%)	267 (59.0%)	396 (48.0%)	712 (52.0%)
Gestation Age Category				
Preterm (< 37 weeks)	26 (31.0%)	170 (38.0%)	281 (34.0%)	477 (35.0%)
Term (≥ 37–41 weeks)	51 (61.0%)	278 (62.0%)	549 (66.0%)	878 (64.0%)
Post-date(≥ 42 weeks)	7 (8.3%)	4 (0.9%)	0 (0.0%)	11 (0.8%)
Mother's HIV status at delivery				
Positive	20 (24.0%)	56 (12.0%)	31 (3.7%)	107 (7.8%)
Negative	58 (69.0%)	371 (82.0%)	739 (89.0%)	1168 (86.0%)
Unknown	6 (7.1%)	24 (5.3%)	60 (7.2%)	90 (6.6%)
Missing	0	1	0	1
Place of Delivery				
Inborn at Neno District Hospital	60 (71.4%)	373 (82.5%)	622 (74.9%)	1055 (77.2%)
Out born with referral from primary health centres and one community hospital[1]	24 (28.6%)	79 (17.5%)	208 (25.1%)	311 (22.8%)
Duration of Stay				
Median duration of Stay in days[2] (Median, IQR)	5.0 (2.8- 7.2)	7.0 (5.0- 9.0)[3]	6.0 (4.0–8.0)[4]	6.0 (4.0–8.0)[5]
Birth weight				
Birth Weight (grams)	2700 (2075- 3000)	2609 (1800- 3100)	2794 (2100–3100)[6]	2700 (2000- 3100)[7]

[1] Primary health centres and community hospital are all within Neno District

[2] Includes all admissions (discharge alive, death, absconded/referral)

[2] 3 missing values

[3] 74 missing values

[4] 77 missing values

[5] 10 missing values

[6] 10 missing values

Table 2 Comparison of neonatal admission diagnoses in the Neno District Hospital neonatal special care nursery over study periods I, II, and III

Admission diagnosis	Total (*N* = 1366)	Period I (*n* = 84)	Period II (*n* = 452)	Period III (*n* = 830)	*p* value[1]
Birth Asphyxia	411 (30.1%)	39 (46.4%)	176 (38.9%)	196 (23.6%)	$p < 0.001$*
Sepsis	396 (29.0%)	19 (22.6%)	97 (21.5%)	280 (33.7%)	$p < 0.001$*
Prematurity	286 (20.9%)	13 (15.5%)	113 (25.0%)	160 (19.3%)	$p = 0.025$
Other Diagnosis	273 (20.0%)	13 (15.5%)	66 (14.6%)	194 (23.4%)	$p < 0.001$*

[1] Results of Chi-squared test comparing proportion with diagnosis in study periods I, II, and III

* Statistically significant at level of 0.00417

over the three study periods were significant (all p<0.001) but there was no significant change for the diagnosis of prematurity (p=0.025).

Neonatal outcomes over the study periods

During the entire study period, the majority of neonates admitted to the Neno District Hospital neonatal special

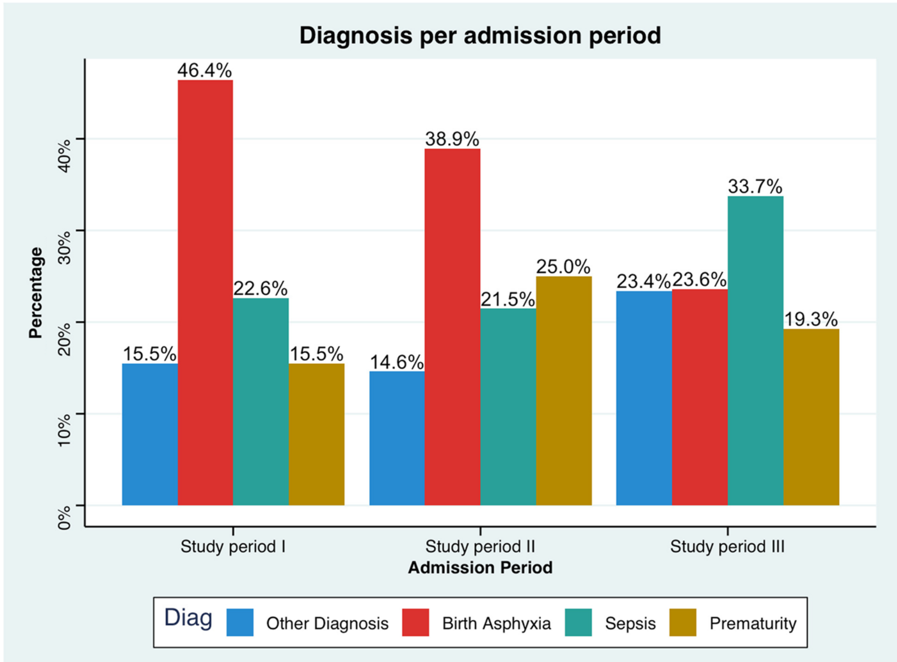

Fig. 1 Primary diagnoses of neonates in the Neno District Hospital neonatal special care nursery over study periods I, II, and III

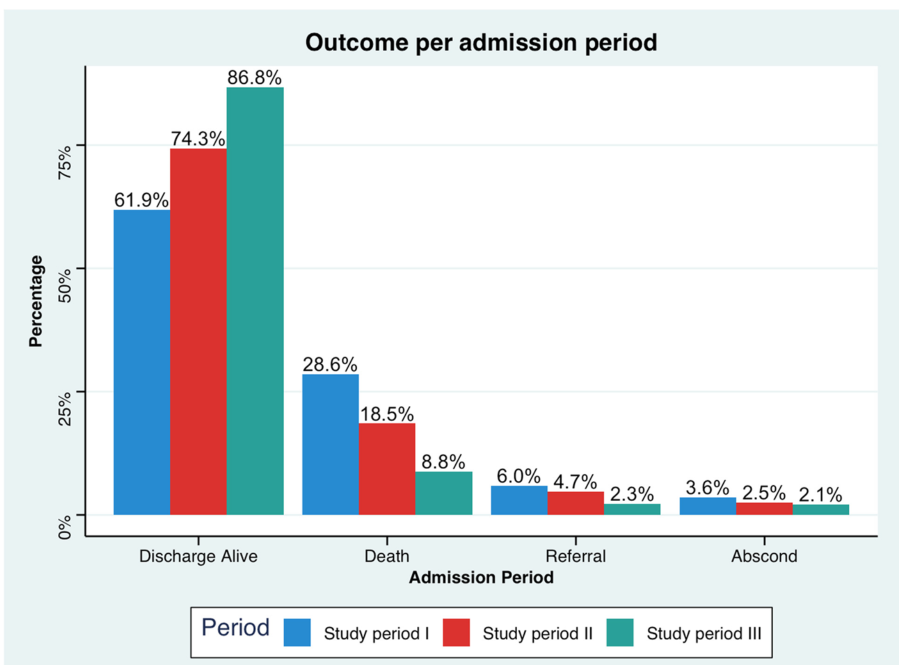

Fig. 2 Neonatal outcomes of neonates admitted to the neonatal special care nursery at Neno District Hospital per study periods I, II, III

care nursery were discharged alive (82.0%, n = 1115), and the second highest outcome proportion was death (13.0%, n = 173). Referral out (3.4%, n = 37) and absconding from (2.3%, n = 31) the neonatal nursery was the lowest proportion of outcomes during the entire study period (Fig. 2, Table 3).

Table 3 Comparison of neonatal outcomes in the Neno District Hospital neonatal special care nursery over study periods I, II, and III

Outcome	Total ($N=1366$)	Period I ($n=84$)	Period II ($n=452$)	Period III ($n=830$)	*p* value[1]
Discharge Alive	1,115 (81.6%)	52 (61.9%)	336 (74.3%)	727 (87.6%)	$p<0.001$*
Abscond or referred*	78 (5.7%)	8 (9.5%)	33 (7.3%)	37 (4.5%)	$p=0.033$
Death	173 (12.7%)	24 (28.6%)	83 (18.4%)	66 (8.0%)	$p<0.001$*

[1] Results of Chi-squared test comparing proportion with outcome in study periods I, II, and III

* Statistically significant at level of 0.00417

The proportion of neonates discharged alive increased from 61.9% in study period I to 74.3% in study period II and further increased to 87.6% in study period III. Conversely, the proportion of neonates who died during the overall study period decreased by 19.5%. Overall, there were low proportions of neonates who absconded and those who were referred to a higher level of care over the study entire study period. Both outcomes decreased over the entire study period—neonates referred for a higher level of care to other facilities by 3.7%, and neonates absconding decreased by 1.5% (Fig. 2). Combining the outcomes of referral and absconding into one outcome due to low numbers of patients, there was no significant difference between all study periods ($p=0.033$) (Table 3).

Survival rates

A bivariate logistic regression demonstrated a significant relationship between discharged alive (yes/no) and the gestational age, admission period, admission diagnosis, and birth weight. Neonates admitted to the neonatal special care nursery during study period II and III were almost two and four times more likely to be discharged alive than neonates admitted during study period I (SPII OR = 1.78; 95% CI: 1.09–2.89; $p=0.020$; SPIII OR = 4.34; 95% CI: 2.65–7.04; $p<0.001$). There was no significant difference in sex for neonates being discharged alive. Neonates admitted with prematurity as a primary diagnosis were less likely to be discharged alive compared to birth asphyxia (OR = 0.50; 95% CI: 0.35–0.71 $p<0.001$). However, neonates with sepsis were three times more likely to be discharged compared to birth asphyxia (OR = 3.03; 95% CI: 1.94–4.86 $p<0.001$). Regarding birthweight, neonates admitted with a birth weight of $\leq$ 1500 g were 75.0% less likely to be discharged alive than neonates admitted with a birth weight > 2500 g (OR = 0.25, 95% CI: 0.17–0.36; $p<0.001$) (Table 4).

After adjusting for the sex of the neonates in a multivariate logistic regression, the discharge of a live neonate was associated with admission diagnosis, study period, and birth weight. Compared to birth asphyxia, the odds of being discharged alive for a diagnosis of sepsis increased almost three-fold (aOR = 2.64; 95% CI: 1.67–4.29 $p<0.001$), whereas there was no significant difference for being discharged alive for prematurity and other diagnosis. Neonates admitted during study periods II and III had twofold and fivefold higher odds of being discharged alive than neonates admitted during study period I, respectively (SPII aOR = 2.42; 95% CI: 1.43–4.08; SPIII aOR = 5.32; 95% CI: 3.13–8.98; $p<0.001$). Neonates admitted with a birth weight of $\leq$ 1500 g were 69.0% less likely to be discharged alive than neonates with a birth weight of > 2500 g after adjusting for the sex of the neonates (aOR = 0.31, 95% CI: 0.16–0.58; $p<0.001$) (Table 4).

Discussion

This study is the first to investigate the impact of a decentralized neonatal nursery at the Neno District Hospital on longitudinal neonatal outcomes in a rural, hard-to-reach setting in Malawi. The results demonstrate that the development of the neonatal nursery led to significant improvement over the study period in neonates being discharged alive, aligning with increased resources, including space, assigned neonatal staffing with dedicated training and mentorship, and appropriately available equipment, medications, and supplies.

The critical inputs for the intervention were increased resources, comprising space, well-trained neonatal staff, and appropriate materials. These resource inputs are essential for providing small and sick neonatal care. Several studies in similar contexts within sub-Saharan Africa have shown that neonatal care provision in rural resource-limited settings remains a challenge [18, 25–28] due to barriers. Some of these barriers relate to the individual provider and the health system. These include inadequate knowledge and training, rigid division of roles and responsibilities, poor leadership, lack of effective communication, human resource constraints, insufficient equipment and clinical guidelines, poor documentation and infrastructure, and economic insecurity of the patients [8, 25, 27]. Despite these observations from the literature, our findings suggest that improvements in neonatal survival are possible with adequate inputs, training support, and heightened awareness and communication, as in the neonatal nursery in the Neno District Hospital [29–31]. In this study, admissions to the nursery at Neno District Hospital increased almost fivefold as the

Table 4 Parameter estimates from univariate and multiple logistic regression models for the neonates discharged alive from Neno District Hospital neonatal special care nursery

	Bivariate			Multivariate		
Characteristic	**OR**	**95% CI**	***p*-value[1]**	**Adjusted OR**	**95% CI**	***p*-value[2]**
Gender						0.12
Male	—	—		—	—	
Female	0.80	0.61—1.06	0.120	0.90	0.67—1.20	
Gestation Age						< 0.001*
Term ≥ 37–41 weeks	—	—		—	—	
Preterm < 37 weeks	0.52	0.39—0.68	< 0.001	1.04	0.65—1.67	
Post-date ≥ 42 weeks	1.74	0.33—32.0	0.60	5.41	0.96 – 1.02	
Admission period						< 0.001*
Study period I	—	—		—	—	
Study period II	1.78	1.09—2.89	0.020	2.42	1.43—4.08	
Study period III	4.34	2.65—7.04	< 0.001	5.32	3.13—8.98	
Admission Diagnosis						< 0.001*
Birth Asphyxia	—	—		—	—	
Sepsis	3.03	1.94—4.86	< 0.001	2.64	1.67—4.29	
Prematurity	0.50	0.35—0.71	< 0.001	0.87	0.51—1.51	
Other Diagnosis	0.89	0.61—1.32	0.600	0.72	0.48—1.08	
Birth weight category						< 0.001*
> 2500 g	—	—		—	—	
1500–2500 g	0.78	0.56—1.10	0.200	0.92	0.58—1.46	
< 1500 g	0.25	0.17—0.36	< 0.001	0.31	0.16—0.58	

OR Odds Ratio, *CI* Confidence Interval

[1] *p*-value from bivariate logistic regression

[2] Global *p*-value

[*] Statistically significant at level of 0.00417

neonatal nursery was developed and enlarged with dedicated staff. A possible reason for the increase in admissions was the recognition of small and sick newborns and expanded capacity to accommodate previously unmet neonatal care needs. This presence of unmet need/burden of disease exceeding capacity was suggested by HMIS data reporting the annual number of newborns with low birth weight in Neno District, which ranged from 305 to 465 during the study period [32]. Moreover, with increased numbers of neonates referred from the surrounding facilities, there was increased recognition and referrals of small or sick neonates. Increased admissions and the three primary diagnoses (birth asphyxia, sepsis, and prematurity were > 95% of all admissions) of this cohort were comparable to recent studies in district-level neonatal care units in sub-Saharan Africa [26, 32, 33]. These trends suggest that critical resource inputs are required for improved neonatal quality of care and mortality within the neonatal nursery, as described in this study.

Over the seven years of this study, there was a significant increase in the number of neonates discharged alive for all diagnoses. In multivariate analysis adjusting for the sex of the neonate, neonates admitted during study period III were fivefold more likely to be discharged alive than neonates admitted during study period I ($p < 0.001$). These findings mirror recent studies in similar low-income contexts with improvements in available space for caring for sick neonates (i.e., isolation and KMC units), increased numbers of trained staff dedicated to the nursery, and appropriate equipment with backup of solar electricity for resuscitation, respiratory support, and temperature control [34, 35]. Strengthening existing in-service training programs, such as longitudinal mentorship, is crucial to addressing the high staff turnover due to rotations and attrition, ultimately improving patient outcomes [24, 36, 37]. In our observations of resources in study period III, there was specific nursing staff allocation to the neonatal special care unit with a clinical officer assigned each day of the week. These allocations also required the neonatal special care nursery to be reported on at morning handovers with improved communication and more staff recognition of available resource inputs and guidelines. Our study, supported by others, suggests strengthening neonatal care units can reduce NMR [29, 37].

In the examination of specific diagnostic outcomes in Neno District Hospital, the proportion of infants with birth asphyxia decreased by 22.8%, with about a 10.0% increase in the diagnosis of sepsis with a relatively stable proportion of prematurity. All changes in diagnosis except for prematurity were statistically significant over the study period ($p < 0.001$). We utilized birth asphyxia as the comparator in a multivariate analysis with a lower chance of being discharged alive compared to sepsis (aOR 2.64) but a higher chance of being discharged alive compared to prematurity (aOR 0.87) and other diagnoses (aOR 0.72). As shown in other studies, birth asphyxia prevention and outcomes are dependent on staff training and mentorship, appropriate equipment, and quality improvement programs in appropriate resuscitation, perinatal monitoring, and neonatal care [24, 32, 36, 37]. Our results demonstrate improvement; however, future training and guidelines for peripartum and postnatal management, plus quality improvement, need strengthening. There is a need to enhance collaboration with antenatal and perinatal maternal care to prevent and further decrease birth asphyxia mortality and morbidity.

The proportion of neonates with sepsis discharged alive was almost three-fold compared to neonates with birth asphyxia, with a rising rate of diagnosis over the study periods. This adjustment was likely due to earlier recognition and clinical diagnosis with adequate treatment and establishment of the neonatal special care nursery. Recent studies in similar contexts with neonatal nurseries have suggested that multidisciplinary approaches such as antibiotic stewardship, hygiene, and protocols for feeding are necessary further to reduce the burden of sepsis in preterm infants, which can be extrapolated to full-term infant sepsis prevention [2, 25, 29, 38]. Future interventions at Neno District Hospital should include improved blood, urine, and cerebrospinal fluid culture diagnostics, early empiric antibiotic treatment when sepsis is clinically suspected, and enhanced patient observation [3, 4, 38, 39].

Our study had an overall preterm birth rate of 20.9%, without significant change in the total study period, ranging from 15.5% in study period I to 25.0% in study period II and decreasing again to 19.3% in study period III. Our observed prematurity rates are within the range of recent reports from sub-Saharan Africa, ranging from 7.9 to 29.7%, which is higher than higher-income countries driven by infectious diseases such as HIV and malaria, nutritional factors such as anemia and malnutrition and social factors such as domestic violence [39–43]. As demonstrated in other studies, the non-significant increase between study periods I to II and III is likely due to a rise in recognition and diagnosis of preterm infants with care within the neonatal special care nursery [10, 20, 44]. Preterm neonates were 50.0% less likely to be discharged alive compared to neonates with birth asphyxia in bivariate analysis ($p < 0.001$), but this dropped to 13.0% and was not significant in the multivariate analysis when controlled by sex. This, in part, suggests that despite increasing recognition of prematurity, there are additional upstream preventative interventions to decrease prematurity rates as indicated above, along with further strengthening of care for preterm infants such as early oxygen, and continuous positive airway pressure, thermoregulation, and nutrition that is required to continue to improve outcomes [45].

One limitation at the Neno District Hospital is the lack of first-trimester antenatal ultrasound dating, resulting in the need for postnatal determination of neonates who are preterm versus low birth weight, which is common in Malawi and similar settings. If postnatal dating of neonates is not completed, especially within 24 h of admission, using birth weight or maternal and or health care worker reports of the number of months pregnant to determine gestational age can lead to an overestimation of preterm deliveries [44–48]. Further capacity for early antenatal dating and mentorship on effective early postnatal dating and recognition of LBW versus preterm birth is required to quantify preterm birth accurately. This limitation is demonstrated in our study, where the bivariate analysis of gestational age showed a significant decrease in mortality of 48.0% in preterm infants (< 37 weeks gestation) compared to term neonates ($p < 0.001$) but no significant difference in the multivariate analysis. However, in the examination of birth weight, there was a significant drop in survival by 69.0% in neonates less than or equal to 1500 g in birth weight compared to those > 2500 g, further supporting the preterm survival proportions by admission diagnosis.

In a review of the changing resource inputs and system over the study period, there were critical inputs of dedicated staff, space, equipment, and medications. For example, with the establishment of the neonatal special care nursery in 2016, radiant warmers, CPAP machines, and phototherapy machines were provided. Similarly, with the transition to a larger dedicated space for the nursery in study period III, staffing was finally dedicated to the neonatal special care nursery. These vital inputs have been critical to improving the care and outcomes of the neonates over the study period. For example, in study period I, there was frequent stock-outs of neonatal supplies and medications, poor staffing levels, and limited neonatal care, which has been reported in other neonatal nursery studies [27, 28, 47].

Furthermore, even though study period III only had minor additional equipment, there was increased dedicated staff who received specialized training in neonatal care, followed by longitudinal mentorship with improved communication and recognition of the neonatal care nursery within the hospital. Other studies have shown staffing shortages were frequently mentioned as barriers to implementing neonatal care [8, 18, 25, 26], demonstrating this need. Therefore, additional staff may have improved the monitoring of neonates in the ward with recognition of small and sick neonates, but further studies focused on quality of care are required. This study, supported by other studies in similar settings, suggests improved care and outcomes for neonates born at a secondary district hospital with decentralized capacity building [8, 24, 26, 36, 48]. Further quality improvement work and research are required to identify specific interventions and diagnostics that most effectively and efficiently improve outcomes in the care of sick neonates at district-level care.

Limitations

Our study has several limitations in design and data collection. First, the study has data from a neonatal special care nursery from only one district hospital in a rural setting. Therefore, our results may not broadly demonstrate the challenges and facilitators in improving neonatal outcomes in diverse settings. However, other studies in similar settings confirm our findings, suggesting the replicability and validity of the results [25, 28, 40, 42].

Second, this review data was taken from the sick neonatal registers and not from all deliveries at NDH; the study sample was constrained to neonates admitted to the nursery. This likely introduced selection bias and potential confounders as it is possible the patient selection to the nursery changed over the total study period. However, the admission criteria for the neonatal nursery did not change during the study period with control of patient-level variables. Therefore, within the scope of the study, we cannot comment on the overall mortality for NDH but have demonstrated care and outcomes improved over the total study period for neonates admitted to the NDH neonatal nursery.

Third, the study had a small sample size during study period I, resulting from incomplete or incorrect neonatal registers from which the data for this study was taken. In a recent study in a similar setting, Kapito et al. [49] found poor record keeping, underreporting of maternal and neonatal complications, and discrepancies between data recorded in the monthly maternal register and client charts in the first quarter of 2018 that correlate with our findings. This limits the power calculations and statistical analysis when comparing neonates born during study period I. The sample size is adequate for study periods II and III for power 0.99.

Lastly, a potential limitation is there may have been unrecorded neonatal deaths occurring before admission in the nursery from outside facilities. These deaths occurred while in transit to a health facility, during home deliveries, and fresh stillbirths. Despite these limitations, the registers provide the most comprehensive data repository among all forms of routinely collected data in Malawi.

Conclusions

Our findings show that to improve the recognition and treatment of neonatal conditions to improve neonatal mortality within the neonatal special care nursery, district secondary hospitals must have neonatal care space, capacity, resources, and well-defined care systems in a multidimensional and comprehensive approach. Despite significant improvements in neonatal outcomes over seven years for neonates admitted to the special care nursery at Neno District Hospital, there is a need for enhanced quality improvement efforts to improve the prevention, recognition, and treatment of birth asphyxia and prematurity, along with an increased diagnostic capacity to identify and adequately treat serious bacterial infections.

Abbreviations

bCPAP	Bubble continuous positive airway pressure
C	Confidence interval
CO	Clinical officer
CS	Cesarean section
DHIS	District Health Information System
GAIN	Global Action in Nursing
HDU	High dependency unit
HIV	Human immunodeficiency virus
IQR	Interquartile range
KMC	Kangaroo mother care
LBW	Low birth weight
MOH	Ministry of Health
N	Sample size
NBW	Normal birth weight
NDH	Neno District Hospital
NCU	Neonatal care unit
NEST	Newborn Essential Solutions and Technologies
NMR	Neonatal mortality rate
°C	Degrees centigrade
OR	Odds ratio
P	*p*-Value
PIH/APZU	Partners In Health/Abwenzi Pa Za Umoyo
RDS	Respiratory distress syndrome
SDG	Sustainable Development Goal
SVD	Spontaneous vertex delivery
TBA	Traditional birth attendant
UCSF	University of California San Francisco
VE	Vacuum extraction
WHO	World Health Organization

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Authors' contributions
MGM, EC, MBA, and BM designed the study. MGM, MBA, and PS contributed to data collection and statistical analysis. MGM, MBA, LN, LN, MK, EN, FM, IM, PS, AB, KB, BM, CK, and EC prepared the first draft of the manuscript. All authors contributed to the critical interpretation of the results and development of the manuscript, and approved the final version.

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Data availability
Deidentified data are available at Zenodo. The manuscript and its supporting information files include all other relevant data.

Declarations

Ethics approval and consent to participate
The National Health Sciences Research Committee (NHSRC) of Malawi approved protocol # 20/10/1216. The primary (MGM) investigator deidentified the data before analysis and password-protected it.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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