Care for Neonates in Haiti's Health System – Outcomes and Lessons

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Abstract

Background

The rate of facility births in Haiti has doubled in the past two decades but this has not resulted in comparable reductions in maternal or neonatal mortality. To care for newborns requiring hospitalization in Haiti, we worked with the public health leadership in the Haitian department of the South (*Sud*) to establish a ward for compromised neonates in a large public hospital with over 3000 annual deliveries but no neonatal care capacity.

Methods

Significant investments were made in establishing basic neonatal services, train nurses, install and manage a supply chain, and strengthen infrastructure. We present outcomes for 1399 neonates admitted to the ward during the first two years of operation.

Results

Two-thirds of admissions were made from the hospital's maternity ward at birth while the remaining babies were born at home or referring facilities. Inborn neonates had better rates of hospital survival than those born elsewhere. They were also more likely to be born via cesarean section and to be admitted right at birth. Babies born elsewhere were more likely to die during their hospital stay. There were no differences between the proportion of premature or low Conclusions

birth weight babies born at the hospital or elsewhere.

Nursing care proved to be a critical part of the care delivery system. We conclude that integrated, high frequency nursing training is necessary for both maternity and neonatal nurses to support maternal and newborn care. Resources are needed to address prematurity as an important outcome, especially as it is indicative of poor prenatal care, regardless of place of birth.

Background

Haiti has struggled with multiple development setbacks over the past decades, impeding its capacity to respond effectively to the health care needs of its people [1]. A majority of Haitians are vulnerable to natural disasters such as the 2010 earthquake in Port au Prince and Hurricane Matthew which battered southern Haiti in 2016. Economic instability is a major barrier to development with rapid currency depreciation and severe cuts in capital investments and social programs marking the end of 2019 [2]. The national health budget declined four-fold between 2004 and 2016, with greater reliance on international assistance and out-of-pocket payments even though poverty is a severe barrier to accessing medical care. Maintenance of the most basic of public health functions is challenging given the current financing and governance strucutres [3]. Understandably, Haiti lags far behind other countries in achieving public health targets. For example, with an increase in facility births in low income countries, the survival

outcomes for neonates is expected to improve. In a systematic review of the effects of health facility delivery on neonatal mortality, Tura and colleagues showed that neonatal mortality was 29% lower in facility births than home births [4].

The rate of facility births in Haiti has doubled to 40% in the past two decades but this has not resulted in comparable reductions in maternal or neonatal mortality [5]. While global neonatal mortality rates have declined by 50% over the past three decades, the rate in Haiti has remained largely unchanged at 32 deaths per 1000 live births, well above the global target of 12 per 1000 by the year 2030 [6–8]. Lack of appropriate prenatal care, low quality of obstetric care, and high rates of eclampsia, obstructed labor, untreated infection, and preterm delivery are persistent factors behind the high rates of maternal and neonatal mortality in Haiti.[9, 10] In a recent analysis, we reported that 2–5% of deliveries in hospitals in southern Haiti suffered from eclampsia, which was likely an underestimation due to poor diagnostic capacity and data quality [11]. An eclampsia rate of 23% was reported in another Haitian hospital with better electronic record keeping [12].

In low-resource settings, the major clinical contributors to the death of neonates include birth asphyxia, infection, and prematurity-related complications[13]. Essential newborn care services and ability to respond to emergent situations remain important gaps in most facilities in low and middle income countries, particularly in rural areas [14, 15]. In addition to improving skilled care at birth, we need to generate evidence of the impact of providing skilled care to neonates requiring hospitalization in low-resource settings. Case management in neonatal care units can inform quality concerns for neonatal morbidity, mortality, and survival [16]. Rural hospitals in Haiti often lack the capacity to care for newborns after birth due to gaps in essential infrastructure, equipment, supplies, medicines, trained staff, and up to date protocols and guidelines [15].

Therefore, the challenges and triumphs of caring for neonates born and cared for in the facility setting in Haiti must be documented and built upon [17, 18]. To care for newborns requiring hospitalization in Haiti, we worked with the public health leadership in the Haitian department of the South (*Sud*) to establish a ward for compromised neonates in a large public hospital with over 3000 annual deliveries but no neonatal care capacity. This paper presents the neonatal outcomes that occurred within the first two years of this effort.

Methods

Baseline Situation

Program Setting

Hopital Immaculae Conception (HIC) is the main public referral hospital, located in *Les Cayes* and serving the departmental population of 774,976 (Fig. 2). There are 18 communes in *Sud* of which *Les Cayes* is the largest with an approximate population of 140,327 people [19]. A commune is a sub-departmental

administrative unit. The maternity ward has an annual volume of 3000–4000 deliveries [11]. At the time of our project, the maternity ward had two beds in the delivery room, staffed by a midwife or a nurse who attended deliveries and provided newborn resuscitation as needed. Obstetricians attended some of the complicated deliveries and performed caesarian sections. A warmer was available but hardly used. Normal procedures following a low-risk birth included weighing the baby and providing Vitamin K and ophthalmic tetracycline ointment. There was no oxygen in the delivery room; suction and/or resuscitation with bag valve mask was done as needed. Water and soap were available but hand sanitizer was more commonly used.

Most women arrived at the maternity ward shortly before birth after laboring at home. Accurate estimates of gestational age were generally not available. Clinical assessment and the date of last menstrual period were used to establish the gestational age to determine prematurity. Before June 2017, there were no specific staff assigned for newborn care nor adequate space, equipment, or material for case management. The pediatric unit was located next to the maternity ward and received newborns, but those in need of critical care were referred to a hospital that was more than 2 hours away.

Neonatal unit structure and function

In June 2017, a team from Dartmouth and GHESKIO, with funding from the Children' Prize and the WK Kellogg Foundation, established the first neonatal care unit at HIC. Two pediatricians were appointed to provide care on an 8-bed ward, later expanded to 13 beds due to high demand. The hospital administration hired eight nurses to staff the ward. Other support staff included a project coordinator, a data manager, a lab coordinator, three community health workers, and four cleaners. All staff were supported through project funding.

Renovation and expansion of the space as well as provision of essential equipment, medications, oxygen, and supplies were done sequentially over the course of the first two years. Although nursing and administrative staff are now integrated into the hospital's operating budget, the initial investment and technical oversight were provided by our team. However, all staff reported to supervisors within the hospital and were integrated into the hospital's human resources structure.

Staff training

The two pediatricians (MC and WJB) received three months of supervised neonatal training at Dartmouth-Hitchcock Medical Center in the United States and at the Zanmi Lasante and St. Boniface hospitals in Haiti. This included a master training in *Helping Babies Breathe* (HBB) from Dr. George Little, one of the developers of the course.[20] Neonatal training for nurses was delivered at hiring and 18 months later, with frequent on-the-job training in between from visiting Dartmouth faculty. Nursing training focused on HBB and *Essential Care for Every Baby*[21] curricula, jaundice care, shift handoff, head-to-toe exams, and intake assessments. We also reviewed nursing charts and redesigned nursing forms to ease shift handoff, acknowledge doctors' orders, reduce redundant note writing, and properly document medications.

Study Design and Analysis

Data Source and Outcome

Patients were admitted to the ward from the maternity ward at HIC or brought by families from other facility and home births in the region. In a small number of cases, referring facilities transferred the newborn by ambulance. The admitting staff included both pediatricians and nurses. A daily electronic register documenting the date of birth, date of admission, place of birth, weight at admission, prematurity status, major health issue(s), length of stay, and final outcome for all infants admitted to the ward was maintained by the pediatricians in MS Excel©. Data was reviewed quarterly by the pediatricians and Dartmouth/GHESKIO team to track progress, review mortality cases, and identify major bottlenecks. The final database for this study was a compilation of all admissions to the ward between August 2017-August 2019. The outcome of interest was neonatal death on the ward.

Diagnostic criteria

Based on the assessment of the pediatricians, primary diagnoses were established based on the International Classification of Diseases and Related Health Problems (ICD-10) maintained by WHO [22]. Due to limited laboratory and diagnostic resources, the pediatricians were unable to confirm their diagnoses with more than minimal blood work. Microbiologic definitions, other than HIV and syphilis screening tests, were not available. Prematurity was defined as gestational age less than 37 weeks which was established using The Ballard Score Maturational Assessment of Gestational Age in Newly Born Infants [23]. Low birth weight (LBW) at admission was defined as weight less than 2500 g and very low birth weight (VLBW) as less than 1500 g.

Exclusion Criteria

A flow chart shows the derivation of the sample and reasons for exclusion (Fig. 2). Very small neonates weighing less than 1 kg (n = 12) and those who were more than 28 days of age (n = 11) were excluded from the dataset. We excluded very small neonates from the analysis due to their exceptionally poor survival prognosis although one infant weighing 400 g at birth did survive after a 2-month stay at the hospital. All neonates taken home against medical advice or transferred out were excluded from the multivariable analysis. Parents' reasons for leaving early were numerous: having other children to care for at home; timing with major festivals; lack/cost of room and board for families; and political unrest and insecurity. We suspected that some parents also wanted the child to receive traditional medicine at home or were not confident that the baby could recover.

Analyses

Univariate analyses were completed to obtain crude measurements without adjustment using chi-squared t-tests. Neonates who were born at HIC were compared to those who were born elsewhere (at home or another facility) to identify any community referral patterns (Table 1). Next, we looked at univariate relationships between those who died and those who were discharged, excluding neonates whose

parents took them home early against medical advice, to identify significant factors contributing to mortality on the ward (Table 2). Multivariate analysis was performed on the same dataset.

Patient and Public Involvement

As this study was based on retrospective data review, patients were not involved in choosing the methods and agreeing to plans for dissemination of the study results to participants and linked communities.

Results

Neonatal characteristics

Half of the patients admitted to the neonatal ward at HIC came from *Les Cayes*, the commune in which the hospital is located (Fig. 1). The next biggest sending commune was *Torbeck* (10%), which has a birthing center with ambulance availability. The remaining cases came from the rest of *Sud* and communes in departments sharing a border with *Sud*. We did not ascertain why some of the neonates came from other departments but it is possible they had family relations near HIC.

Table 1 presents the characteristics of all neonates admitted to the ward between August 2017–August 2019 by place of birth. In all, 1399 neonates who were 28 days of age or younger and weighed more than 1 kg at admission were admitted to the ward over the 25 months; 66% were “inborn” meaning born at HIC (922/1399) and the rest were “outborn” meaning born at home or another facility. There were few differences in the recorded baseline characteristics of patients by place of birth. The proportions of boy and girl neonates were similar for those born at HIC and elsewhere. Preterm birth complicated one fifth of all admissions regardless of place of birth. Less than 1 in 10 babies were from multiple gestation pregnancies. Differences in the neonate’s weight on admission and mother’s age were also insignificant by place of birth. Close to one third of neonates were low or very low birth weight regardless of place of birth. A majority of mothers were between 18 and 34 years of age and 62 were adolescents.

What was significant by place of birth was survival status, the mode of delivery, and age at admission. Mortality was higher among outborn babies (14.5% mortality among babies arriving from outside of the hospital setting versus 11.1% among babies born in the HIC, $p < 0.001$). The mode of delivery was vaginal for most births, but more so for outborn babies which included home births (91.4% vaginal vs. 74.8% cesarean; $p < .0001$). If they were born outside, the majority were brought in within 1–6 days after birth (45.9%) compared to those born at HIC (29.4) where the majority were transferred at day of birth (62.7%). A majority of the admissions were made in the first week of life. A higher proportion of births at HIC were through cesarean section (25%) compared to those born elsewhere (9%).

Table 1 Baseline characteristics of 1399 neonatal inpatients at Hopital Immaculae

Conception, Les Cayes by place of birth (2017–2019)

	Outborn	Inborn	Total	P-value
n (%)	477 (34.1)	922 (65.9)	1399 (100.0)	
Sex				
Male	288 (60.4)	521 (56.5)	809 (57.8)	
Female	189 (39.6)	401 (43.5)	590 (42.2)	0.16
Age at admission				
Day of birth	128 (26.8)	578 (62.7)	706 (50.5)	
1–6 days after birth	219 (45.9)	271 (29.4)	490 (35.0)	
7–28 days after birth	130 (27.3)	73 (7.9)	203 (14.5)	< 0.001
Timing of birth				
Term	386 (80.9)	741 (80.4)	1127 (80.6)	
Preterm	91 (19.1)	181 (19.6)	272 (19.4)	0.80
Outcome				
Died	69 (14.5)	102 (11.1)	171 (12.2)	
Discharged	274 (57.4)	643 (69.7)	917 (65.5)	
Left against Dr's orders	123 (25.8)	168 (18.2)	291 (20.8)	
Transferred	11 (2.3)	9 (1.0)	20 (1.4)	< 0.001
Multiple gestations				
Singleton	435 (91.2)	851 (92.3)	1286 (91.9)	
Twin or more	42 (8.8)	71 (7.7)	113 (8.1)	0.47
Birthweight categories				
1.0-1.4 kg	35 (7.3)	52 (5.6)	87 (6.2)	
1.5–2.4 kg	145 (30.4)	258 (28.0)	403 (28.8)	
2.5 + kg	297 (62.3)	612 (66.4)	909 (65.0)	0.23
Type of Delivery				
Vaginal	436 (91.4)	690 (74.8)	1126 (80.5)	
Cesarean	41 (8.6)	232 (25.2)	273 (19.5)	< 0.001
Age of mother				
<18 years	17 (3.6)	45 (4.9)	62 (4.4)	

	Outborn	Inborn	Total	P-value
18–35 years	368 (77.1)	737 (79.9)	1105 (79.0)	
>35 years	76 (15.9)	112 (12.1)	188 (13.4)	
Unknown	16 (3.4)	28 (3.0)	44 (3.1)	0.17

Neonates born at HIC but admitted the day after birth were either kept on the ward with the mother initially, or sent home and brought back by family members due to illness. Therefore, triage at birth to identify high risk babies was not well established. Although we do not show the data, home births were more likely to be admitted later than births from other facilities. We did not document whether births from other facilities were referred at birth or first taken home and later brought to the hospital by family members.

Clinical characteristics

Diagnostic capacity was limited by the lack of confirmatory testing and information on maternal risk factors. The most common health issues experienced by the neonates included suspected infection, hypoxia, and prematurity; neonates often suffered from more than one complication. (Fig. 4). Overall, 41% of neonates were suspected of having an infection which was treated empirically; 6% also shared a diagnosis of hypoxia in addition to the suspected infection. One in three neonates suffered hypoxia, with 14% also having complications from prematurity. The combined prematurity rate was 15% of all admissions (including hypoxia). Other health issues included: congenital malformations, obstetrical complications, jaundice, infections such as tetanus and meningitis, other pulmonary complications, seizures, cardiac conditions, and inappropriate feeding at home. Encephalitis was clinically diagnosed in 6% of cases.

Neonatal mortality

We compared neonates who died on the ward to those who were discharged, excluding those who were taken home early by parents (Table 2). Preterm birth, admission on day of birth, place of birth, mode of delivery, and weight at admission were significant risk factors for ward mortality in the univariate analysis. Half of all deaths (85/171) occurred in babies who were born preterm. Death was also more likely for babies born at home or at other facilities compared to those born at HIC (20.1% of babies born outside vs. 13.7% of babies born at HIC; $p = .01$). Vaginal birth (17.5% vs. 9.5% cesarean; $p < .01$) and being low or very low birth weight at admission (56.5% vs 22.8% normal birth weight; $p < .01$) were both risk factors for death. There was also indication that babies born to teenage mothers under 18 had higher mortality (31.8% vs. 14.5% 18–35 & 15.1% >35; $p < .01$). Other demographic characteristics such as the neonate's sex or being a twin or higher gestation birth were not correlated with mortality.

Table 2 Risk factors for ward mortality among 1088 neonatal inpatients at Hopital

Immaculae Conception, Les Cayes (2017–2019)

	Discharged	Died	Total	P-value
n (%)	917 (84.3)	171 (15.7)	1088 (100.0)	
Sex				
Male	521 (83.6)	102 (16.4)	623 (100.0)	
Female	396 (85.2)	69 (14.8)	465 (100.0)	0.49
Age at admission				
Day of birth	435 (78.5)	119 (21.5)	554 (100.0)	
1–6 days after birth	336 (90.6)	35 (9.4)	371 (100.0)	
7–28 days after birth	146 (89.6)	17 (10.4)	163 (100.0)	< 0.001
Timing of birth				
Term	783 (90.1)	86 (9.9)	869 (100.0)	
Preterm	134 (61.2)	85 (38.8)	219 (100.0)	< .001
Place of birth				
Outborn	274 (79.9)	69 (20.1)	343 (100.0)	
Inborn	643 (86.3)	102 (13.7)	745 (100.0)	0.001
Multiple gestation				
Singleton	841 (84.7)	152 (15.3)	993 (100.0)	
Twin or more	76 (80.0)	19 (20.0)	95 (100.0)	0.23
Birthweight				
1.0–1.4 kg	30 (43.5)	39 (56.5)	69 (100.0)	
1.5–2.4 kg	244 (77.2)	72 (22.8)	316 (100.0)	
2.5 + kg	643 (91.5)	60 (8.5)	703 (100.0)	< 0.001
Type of delivery				
Vaginal	712 (82.4)	152 (17.6)	864 (100.0)	
Cesarean	205 (91.5)	19 (8.5)	224 (100.0)	< 0.001
Age of mother				
<18 years	30 (68.2)	14 (31.8)	44 (100.0)	
18–35 years	741 (85.5)	126 (14.5)	867 (100.0)	
>35 years	124 (84.9)	22 (15.1)	146 (100.0)	

	Discharged	Died	Total	P-value
Unknown	22 (71.0)	9 (29.0)	31 (100.0)	< 0.001

Regression models also showed higher risk of dying on the ward for neonates who were preterm (Table 3). After adjusting for birthweight, preterm neonates had over double the odds of dying as term babies (OR = 2.31; p = .001). As expected, babies who were very low birth weight (VLBW) and low birth weight (LBW) had higher odds of death on the ward when compared to normal weight babies (NBW); VLBW babies were five times as likely to die (p < .001) and LBW babies were almost twice as likely to pass away before discharge (p = .035). Babies admitted 1–6 days after birth (OR = 0.47; p = .001) or even a week after birth (Or = 0.44; p = .024) had less than half the odds of dying that babies admitted on the day of birth. Odds of dying were 1.68 times higher for babies referred to the hospital than those born at HIC (p = 0.015). Those born through cesarean section had a survival advantage (OR = 0.47; p = 0.014). Mothers who were less than 18 years of age had higher odds of losing their neonate – as were mothers whose age was not established, possibly indicating young age or a correlated risk factor.

Table 3
Odds of death on the ward compared to discharge by risk categories

Died	Odds Ratio	(95% confidence interval)	P-value
Timing of delivery			
Term	*reference*		
Preterm	2.31	(1.36–3.93)	0.001
Birthweight			
VLBW 1.0–1.4 kg	5.03	(2.39–10.6)	p < .001
LBW 1.5–2.4 kg	1.81	(1.12–2.95)	0.035
NBW 2.5 kg +	*reference*		
Age at admission			
Day of birth	*reference*		
1–6 days	0.47	(0.30–0.75)	0.001
7 days or more	0.44	(0.24–0.81)	0.024
Place of birth			
Inborn	*reference*		
Outborn	1.68	(1.26–2.87)	0.015
Type of delivery			
Vaginal			
Cesarean	0.47	(0.27–0.82)	0.014
Age of mother			
< 18 years	2.81	(1.35–5.86)	0.006
18–34 years	*reference*		
> 35 years	1.26	(0.74–2.13)	0.41
Unknown	2.65	(1.08–6.50)	0.033

Discussion

We had the unique opportunity to describe neonatal survival status for newborns receiving care at a large public health hospital in southern Haiti. We collected data over the first two years of operation of the neonatal ward, recording daily admissions and tracking outcomes over the course of hospitalization. In this period, we contributed to improvements in health service delivery through training, improvements to

infrastructure, provision of essential equipment and medications, and improvements in operational systems. While working within the limited capacity of the facility conditions we found, we were able to care for more than 1400 babies. Hospital survival was better among neonates born at the hospital than those born elsewhere, indicating a survival advantage for referral right at birth. Babies born elsewhere were more likely to come in at least one day after birth. Availability of cesarean sections was a factor; babies born vaginally had poorer survival indicating an unmet need for surgical intervention. Over the course of the 25 months, one in four neonates was taken home by their families before discharge. Three community health workers attempted to follow-up of neonates after discharge but this proved to be challenging due to missing or incorrect addresses and phone numbers. Having a social worker and establishing a fund to assist families with food and lodging costs could have alleviated some of the financial stress.

The proportion of preterm babies and those born low or very low birth weight were similar for inborn and outborn infants. Similar comparisons have been made in other settings [24]. This suggests that prenatal care plays a significant role in birth outcomes, regardless of place of birth. Diagnoses were mostly clinical due to lack of imaging and laboratory availability. Hypoxia and infection represented a great part of the diagnostic criteria. Perinatal hypoxia results from an insufficiency in the baby's oxygen supply during the intrapartum and postpartum period. The diagnosis was made for babies with 'no cry at birth', meconium aspiration, surfactant deficiency, fetal distress, and secondary hypoxic injury such as hypoxic ischemic encephalopathy. We found that hypoxia was often complicated by other health issues such as infection or prematurity. In the sickest babies, manual resuscitation was often maintained by the pediatricians, which compromised their capacity to attend to other clinical duties. Pediatricians were also not available at night.

Survival was higher among neonates born at HIC, likely due to the risks associated with home births or births at facilities without cesarean or other emergency obstetric capacity. Lower level facilities in Haiti have been found to be poorly equipped to provide obstetric care even if they do provide labor and delivery services.[25] We also found that the risk of dying was highest among babies admitted at birth from – indicating that the sickest babies were also those who were transferred right at birth from HIC as opposed to babies born elsewhere who likely died before being brought in, contributing to potential selection bias in our sample. We did not record length of stay in hours and it is possible that babies admitted from HIC were merely alive for a few hours before succumbing to their illnesses. While the standard practice is to separate community transfers or outborn babies from inborn babies due to risk of infection, we did not have the capacity to do so and there was likely transmission of infection from outborn to inborn neonates [26].

Deaths were highest among preterm neonates and those of low or very low birth weights. Half of premature neonates died, as has been noted in similar settings [27]. Among premature neonates in Burundi in 2011–2012, inpatient mortality was higher among those less than 32 weeks gestation (31%) than those among 32 – 26 weeks gestation [28]. Other published estimates of premature mortality are approximately 50% among neonates born at 34 weeks of gestation, and 70% among neonates born at <

32 weeks of gestation in low-income countries [29, 30]. Weight categories provided a more nuanced representation of vulnerability as preterm birth was not disaggregated by gestational age.

Beyond clinical outcomes, the most important lessons were learned during daily ward operations which showed us that over the period of the study, there was considerable variability in the delivery of neonatal care on the ward. This was driven in large part by the availability of antibiotics, laboratory testing, oxygen, and electricity. However, political instability, holidays, nursing schedules, and seasonal conditions contributed to the unpredictability of ward conditions. Hot summer temperatures in a crowded ward were dangerous for infection control and hurricane season rains often flooded the ward. Power outages were common at night and parents often slept on the floor of the ward by the neonatal beds. During renovations, the beds were moved to different parts of the pediatric ward which affected the time it took to walk the babies over from the maternity ward. Over time, we were able to improve many of these conditions by renovating the neonatal space, providing better quality furniture and equipment as well as air conditioning, and a steady supply of antibiotics and oxygen. However, conditions remained precarious due to the lack of adequate financial support from the health authorities that could be dedicated to ward operations.

Another unexpected challenge was the lack of communication between the maternity and neonatal wards. Despite out best efforts to establish a referral system where critical maternal information about labor and delivery would be communicated to the neonatal team, securing any clinical information from maternity proved nearly impossible. We believe this was reflective of a broader lack of communication across the hospital and reflected entrenched hierarchies and systems that will require a significant cultural shift. Communication between doctors and nurses was also stifled and it was unclear what power nurses wielded in ensuring better working conditions. Infrastructure was poor across the hospital and a piecemeal, project by project approach to building capacity had left no long-term mark on the hospital's operations. Programs that were better funded, such as HIV/AIDS prevention and treatment, were better staffed, equipped, and efficient. Any effort to establish a higher-level care delivery program needs to account for the overall working conditions of the host institution.

Our work had some strengths. We critically examine hospital neonatal mortality in Haiti and discuss implications for future programming. We were able to collect data on relevant indicators as the service was new to the hospital and we created new medical charts with clearly identified data fields. This made it easier for the clinical team to collect relevant data in real time rather than rely solely on extensive chart reviews at a later date. We were also able to discuss ongoing data quality issues through periodic reviews of the service delivery outcomes for the ward, usually during field visits by the Dartmouth team. We benefitted from the tireless effort of the pediatricians to document each and every data point and alert us of any discrepancies with sufficient notice. While we could not do anything about data that were missing all together, we did trust that the data we collected were of high quality.

We also had a number of limitations. Although improvements in infrastructure and service delivery capacity have been associated with improved neonatal survival in other settings, we could not

meaningfully analyze the impact of improvements in our ward's infrastructure and quality improvement efforts, including provision of free medications, as these improvements were made on an ongoing basis and often during unstable political conditions [24]. Additionally, there were too many changes in nurse staffing, electrical supply, and other service delivery parameters by the hospital that were beyond our control and that led to fluctuations in care. There was considerable unpredictability in the hospital's supply chain which also led us to secure treatment through the private-sector. With less control of supply chain management, we could not standardize the treatment to established protocols. We also did not capture maternal risk factors including intrapartum complications despite our best efforts to work in tandem with the maternity team. For similar reasons, we did not collect maternal socioeconomic status or neonatal Apgar scores. We believe that with additional maternal health information, we would have been able to better understand neonatal prognosis at admission. Transfer of knowledge has to be an essential part of all neonatal mortality reduction efforts – we don't believe that neonatal mortality programs should run independent of mothers, whatever the cost.

Conclusion

The potential to improve the quality of care in dedicated inpatient neonatal units in low and middle-income countries is great. There are many missed opportunities to provide effective interventions to mothers and babies, particularly those who seek facility-based care. In the short term, intrapartum-related neonatal deaths can be substantially reduced by improving the quality of services for all childbirths that occur in health facilities. An integrated nursing approach to reducing maternal and neonatal mortality is essential, especially for families who choose to deliver at a facility. In conclusion we offer the following recommendations: 1) a neonatal resuscitation program by itself cannot reduce neonatal deaths due to perinatal asphyxia. Resuscitation trainings should be delivered to both neonatal and maternity nursing staff, combined with a regular supply of clean bag masks and oxygen in the very least; 2) Coordinating communication between the maternity and neonatal wards is critical during complicated deliveries, transfer, and postpartum; 3) Neonatology should be co-located with obstetrics rather than pediatrics with nurses who care for both mothers and babies, and understand the etiology of poor outcomes for neonates due to poor quality intrapartum care; 4) Algorithms are needed for nurses to manage admission, vital signs, and suspected infection in the absence of a physician; and 5) Specialized care is needed for premature neonates.

Declarations

ETHICS

Approval for the analysis of the data was obtained from The Haitian Committee for Protection of Human Subjects at GHESKIO and from the Institutional Review Board of Dartmouth-Hitchcock Medical Center (Study number 02000017). An exemption for minimal study risk was secured and informed consent was not required from study subjects as the data were extracted from patient charts after discharge or death. We paid careful attention to maintain and preserve anonymity of the subjects in any presentation of data.

The results were made available for review by all the participating partners before submission for publication.

CONSENT FOR PUBLICATION

Not applicable.

AVAILABILITY OF DATA

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

COMPETING INTERESTS

Not applicable.

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AUTHORS' CONTRIBUTIONS

AD analyzed the data, wrote the first draft of the paper, and completed all editing after review. MC, WJB, EL, and KS reviewed the paper several times and provided comments. AW was instrumental in assessing the capacity of the maternity ward. PJ and PW served as project advisors and were the primary people in charge of overall project governance. They also reviewed the paper and provided comments.

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Figures

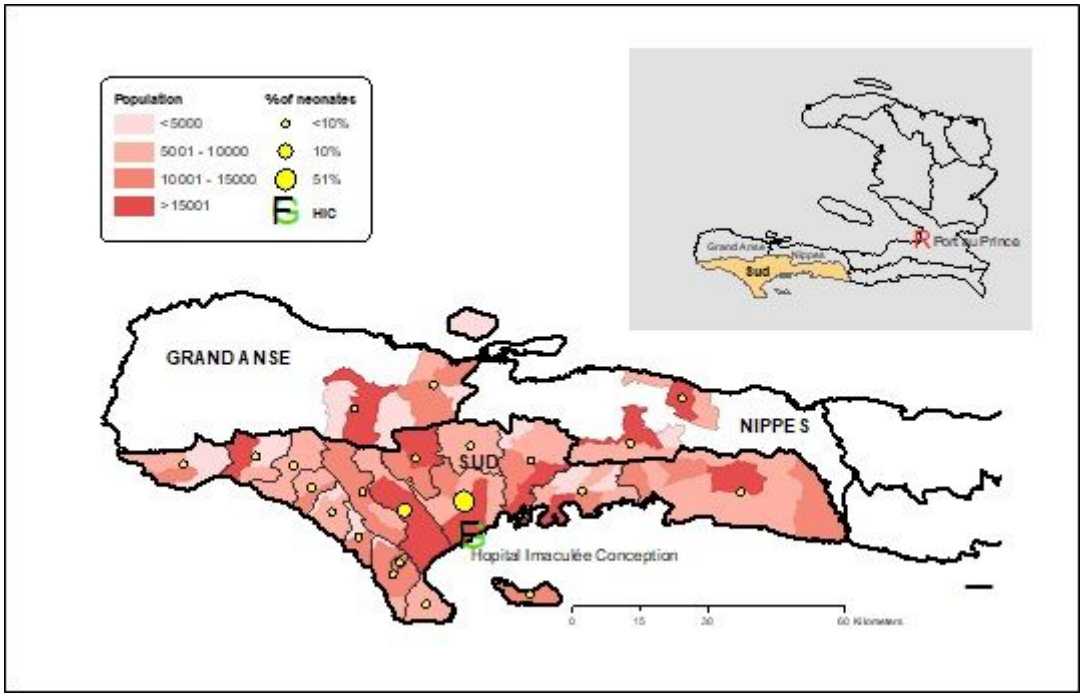

Figure 1

Location of HIC and Sending Communes and Population Distribution [19]

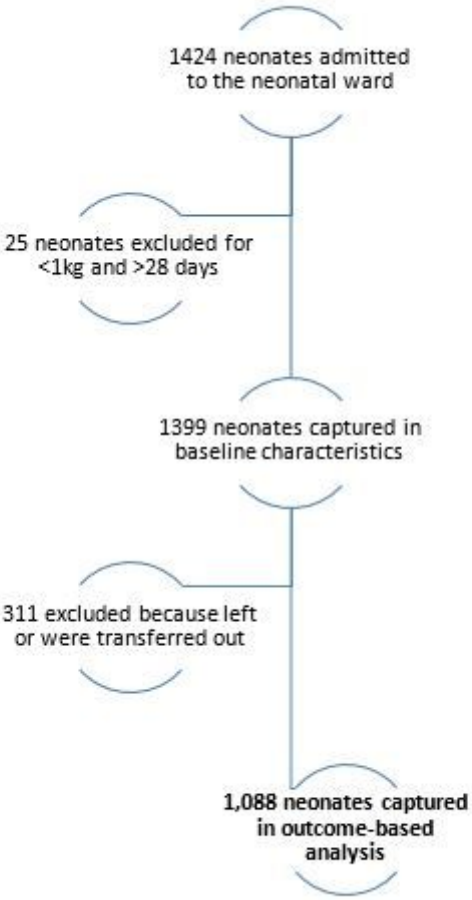

Figure 2

Sample Calculation