Care for neonates in Haiti's health system: outcomes and lessons

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Research article

Keywords: Neonatal mortality, prematurity, hypoxia, sepsis, Haiti, newborn care, neonatal morbidity, facility-based care

Posted Date: October 19th, 2020

DOI: <https://doi.org/10.21203/rs.3.rs-81332/v1>

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Abstract

Background

The rate of facility births in Haiti has doubled over the past two decades, but without 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, training nurses, installing and managing a supply chain, and strengthening 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 after birth, while the remaining babies were born at home or at 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 immediately following birth. Babies born elsewhere were more likely to die during their hospital stay. There were no differences between the proportion of premature or low-birth-weight babies born at the hospital or elsewhere. Nursing care proved to be a critical part of the care delivery system.

Conclusions

To support maternal and newborn care, we conclude that integrated, high-frequency nursing training is necessary for both maternity and neonatal nurses. 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 developmental setbacks over the past few decades, which have impeded 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 or the devastation left by Hurricane Matthew 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 despite the fact that poverty is a severe

barrier to accessing medical care. Maintenance of even the most basic public-health functions is challenging given the current financing and governance structures in Haiti [3]. Understandably, Haiti lags far behind other countries in terms of achieving public health targets. For example, with an increase in facility births in low-income countries, the survival outcomes for neonates is generally expected to improve. For instance, 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% over the past two decades but, unexpectedly, this has not led to 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, and well above the global target of 12 per 1000 by the year 2030 [6–8]. A lack of appropriate prenatal care, the 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 neonatal death include birth asphyxia, infection, and prematurity-related complications [13]. Essential newborn care services and an 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 meeting up-to-date protocols and guidelines [15].

Therefore, the challenges and triumphs of caring for neonates born and cared for in Haitian facilities 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. 1). There are 18 communes (or sub-departmental administrative units) in *Sud*, of which *Les Cayes* is the largest, with an approximate population of 140,327 people [19]. 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 and was staffed by a midwife or a nurse who attended deliveries and provided newborn resuscitation, as needed. Obstetricians attended some of the more complicated deliveries and performed caesarian sections. A warmer was available but hardly used. Normal procedures following a low-risk birth included weighing the baby, giving vitamin K, and applying ophthalmic tetracycline ointment. There was no oxygen in the delivery room, but suction and/or resuscitation with bag valve mask was performed 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 two hours away.

Neonatal unit structure and function

In June 2017, a team from Dartmouth and GHESKIO, with funding from the Children's 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, which was 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 completed sequentially over 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. All staff, however, 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 over the interim 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 Sources and Outcomes

Patients were admitted to the neonatal care unit from the maternity ward at HIC or were born at other facilities/homes in the region and transferred to the unit by their families. In a small number of cases, newborns were transferred by ambulance from referring facilities. 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 were 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 and 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 the 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 Maturation 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 due to their exceptionally poor survival prognosis (although one 400-g infant did survive after a two-month stay at the hospital). All neonates taken home against medical advice or transferred out of the unit were excluded from the multivariate 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 at the hospital.

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 in 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 HIC 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 and August 2019 by place of birth. In all, over the 25 months, 1399 neonates who were 28 days of age or younger and weighed more than 1 kg at admission were admitted to the ward; 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 versus 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 neonates’ weights on admission and mothers’ ages 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 (4.4%) were adolescents.

The three factors that were significant by place of birth were: 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 versus 74.8% cesarean; $P < 0.001$). Of babies born outside the facility, the majority were brought in within 1–6 days of birth (45.9%), compared to those born at HIC (29.4%), where the majority were transferred the same 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	<i>P</i> -value
<i>N</i> (%)	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	<i>P</i> -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

For the neonates born at HIC but not admitted until the day after birth, the babies were initially either kept in the ward with their mother, or sent home and brought back by family members because of 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. 3). 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 then compared neonates who died on the ward to those who were discharged, while excluding those who were taken home early by their 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 by univariate analysis. Half of all deaths (85/171) occurred in babies who were born prematurely. 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 versus 13.7% of babies born at HIC; $P=0.01$). Vaginal birth (17.5% versus 9.5% cesarean; $P<0.01$) and being low or very-low birth weight at admission (56.5% versus 22.8% normal birth weight; $P<0.01$) were both risk factors for death. There was also indication that babies born to teenage mothers under 18 had higher mortality (31.8% for mothers aged <18 years versus 14.5% and 15.1% for mothers aged 18–35 years or >35 years, respectively; $P<0.01$). Other demographic characteristics, such as the neonate's sex, being a twin, or having a higher gestation birth were not correlated with mortality.

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

	Discharged	Died	Total	<i>P</i> -value
<i>N</i> (%)	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	<i>P</i> -value
Unknown	22 (71.0)	9 (29.0)	31 (100.0)	< 0.001

Regression models also showed a 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 full-term babies (OR = 2.31; $P = 0.001$). As expected, babies who were very-low birth weight (VLBW) and low birth weight (LBW) had higher odds of death when compared to normal-weight babies (NBW); VLBW babies were five times as likely to die ($P < 0.001$) and LBW babies were almost twice as likely to pass away before discharge ($P = 0.035$). Babies admitted 1–6 days after birth (OR = 0.47; $P = 0.001$) or even a week after birth (OR = 0.44; $P = 0.024$) had less than half the odds of dying compared to 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<0.001
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 a neonatal ward, recording daily admissions and tracking outcomes over the course of hospitalization. During 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's resources, 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 immediately after birth. Babies born elsewhere were more likely to come in at least one day after birth. Having availability to perform cesarean sections was also a factor; babies born vaginally had poorer survival, indicating an unmet need for surgical intervention. Over the course of 25 months, one in four neonates was taken home by their families before discharge. Three community health workers attempted to follow-up with these families, but were not able to make contact due to missing or incorrect contact information. Having a social worker and establishing a fund to assist families with food and lodging costs could have alleviated some of the financial stress that likely drove these families' decisions to depart the hospital early.

The proportion of preterm babies and those born with 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 a lack of imaging and laboratory facilities. Hypoxia and infection represented a majority of the diagnoses made. Of note: perinatal hypoxia results from an insufficiency in the baby's oxygen supply during the intrapartum and postpartum periods. A "hypoxia" diagnosis was given to babies that had "no cry at birth," meconium aspiration, surfactant deficiency, fetal distress, and/or 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 HIC, indicating that the sickest babies were also those who were transferred right at birth, as opposed to babies born elsewhere who likely died before being brought in, thus contributing to potential selection bias in our sample. We did not record the 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 gestational age (31%) versus those that were 32–26-weeks gestational age [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 day-to-day ward operations, which showed us that, over the period of the study, there was considerable variability in the delivery of neonatal care. 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 also 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.

Another unexpected challenge was the lack of communication between the maternity and neonatal wards. Despite our 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 the maternity ward 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 to remedy. Communication between doctors and nurses was also stifled, and it was unclear to what extent nurses had the power to affect working conditions. Infrastructure was poor across the hospital, due to a piecemeal, project-by-project approach to building capacity that had left a 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 thus needs to account for the overall working conditions of the host institution.

There are a few notable strengths to this work. We critically examined hospital neonatal mortality in Haiti and discuss implications for future programming. We were able to collect data on relevant indicators, since the service was newly established in the hospital and we were able to create 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 on retrospective chart reviews. We were also able to identify and highlight ongoing data-quality issues for staff by performing periodic reviews of the service-delivery outcomes for the ward and field visits by the Dartmouth team. We benefitted from the tireless effort of the pediatricians to document each and every data point, and to alert us of any discrepancies with due notice. While we could not do anything about data that were missing all-together, we did trust that the data we collected were of the highest quality.

This study 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, i.e., including the 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 set 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 ultimately 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 were not able to 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 do not believe that neonatal mortality programs should run independent of maternal programs, 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, at the very least; (2) Coordinating communication between the maternity and neonatal wards is critical during complicated deliveries, transfer, and the postpartum period; (3) Neonatology should be co-located with obstetrics, rather than pediatrics, and be staffed 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) In the absence of a physician, algorithms are needed to support nurses as they manage admission and monitor vital signs and/or suspected infections; and (5) Specialized care is needed for premature neonates.

Abbreviations

HIC Hopital Immaculae Conception

ICD International Classification of Diseases and Related Health Problems

LBW Low Birthweight

NBW Normal Birthweight

VLBW Very-Low Birthweight

Declarations

Ethics approval and consent to participate

Approval for the collection of these 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 a minimal-risk study was secured and informed consent was not required from study subjects, since the data were extracted from patient charts after discharge or death. We paid careful attention to maintaining and preserving 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.

Funding

Funding for this project was provided by the W.K. Kellogg Foundation and The Children's Prize. The funders did not participate in the design of the study; collection, analysis, and interpretation of data; or in writing the manuscript. The funders did receive annual reports on the progress of the project.

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. All authors have read and approved the manuscript.

ACKNOWLEDGEMENTS

Clinical staff in the maternity and pediatric wards at HIC were extremely helpful during implementation and included Dr. Jean Yves Domercant (Medical Director); Dr. Lucien Gerard (Chief of Maternity); Dr. Edna Roberte (Chief of Pediatrics); Ms. Lucie Lafortune (Chief of Maternity Nursing); and Ms. Hyppolite (Chief of Pediatric Nursing). Our operational team in Haiti also provided significant operational assistance including Dr. Eli Francois (GHESKIO); Ms. Marie Shella Goda (GHESKIO); and Mr. Judner Mondelus (HIC). Finally, would like to acknowledge the families who trusted us with their infants despite considerable challenges. Dr. Jean Pape and Ms. Penny Wright also provided valuable guidance as needed.

References

1. Labrador R. Haiti's Troubled Path to Development. Counc Foreign Relat [Internet]. [cited 2020 Apr 21]; Available from: <https://www.cfr.org/background/haitis-troubled-path-development>.
2. Cavagnero E, Cros M, Dunworth A, Sjoblom M. Better Spending. Better Care: A Look at Haiti's Health Financing [Internet]. Washington, D.C: World Bank; 2017 Jun. Report No.: 11682. Available from: <http://documents1.worldbank.org/curated/en/393291498246075986/pdf/116682-WP-v1-wb-Haiti-english-PUBLIC-summary.pdf>.
3. Lowrance DW, Tappero JW, Poncelet JL, Etienne C, Frieden TR, Delsoins D. Public Health Progress in Haiti. *Am J Trop Med Hyg*. 2017;97:1–3.
4. Tura G, Fantahun M, Worku A. The effect of health facility delivery on neonatal mortality: systematic review and meta-analysis. *BMC Pregnancy Childbirth*. 2013;13:18.
5. ICF. The DHS Program STATcompiler. Funded by USAID. <http://www.statcompiler.com>. 2015.
6. Hug L, Alexander M, You D, Alkema L. National, regional, and global levels and trends in neonatal mortality between 1990 and 2017, with scenario-based projections to 2030: a systematic analysis. *Lancet Glob Health*. 2019;7:e710–20.
7. Institut Haïtien de l'Enfance (IHE). ICF. Enquête Mortalité, Morbidité et Utilisation des Services (EMMUS -VI 2016–2017). Pétiön -Ville, Haïti, et Rockville. Maryland: IHE et ICF; 2018.
8. United Nations. Goal 3: Sustainable Development Knowledge Platform [Internet]. [cited 2020 Feb 10]. Available from: <https://sustainabledevelopment.un.org/sdg3>.
9. Jacobs LD, Judd TM, Bhutta ZA. Addressing the Child and Maternal Mortality Crisis in Haiti through a Central Referral Hospital Providing Countrywide Care. *Perm J*. 2016;20:59–70.
10. Bridwell M, Handzel E, Hynes M, Jean-Louis R, Fitter D, Hogue C, et al. Hypertensive disorders in pregnancy and maternal and neonatal outcomes in Haiti: the importance of surveillance and data collection. *BMC Pregnancy Childbirth BioMed Central*. 2019;19:1–11.
11. Dev A, O'Hern K, Domercant JY, Lucien G, Lucie L, Grand-Pierre R, et al. A retrospective review of facility-level obstetric complications and stillbirths in southern Haiti, 2013–2016. *Rev Panam Salud Pública*. 2019;43:1.

12. Raghuraman N, March MI, Hacker MR, Modest AM, Wenger J, Narcisse R, et al. Adverse maternal and fetal outcomes and deaths related to preeclampsia and eclampsia in Haiti. *Pregnancy Hypertens.* 2014;4:279–86.
13. Goldenberg RL, McClure EM, Saleem S. Improving pregnancy outcomes in low- and middle-income countries. *Reprod Health* [Internet]. 2018 [cited 2019 Sep 18];15. Available from: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6019988/>.
14. Montagu D, Sudhinaraset M, Diamond-Smith N, Campbell O, Gabrysch S, Freedman L, et al. Where women go to deliver: understanding the changing landscape of childbirth in Africa and Asia. *Health Policy Plan.* 2017;32:1146–52.
15. Winter R, Yourkavitch J, Wang W, Mallick L. Assessment of health facility capacity to provide newborn care in Bangladesh, Haiti, Malawi, Senegal, and Tanzania. *J Glob Health* [Internet]. [cited 2019 Apr 25];7. Available from: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5804038/>.
16. Goyet S, Broch-Alvarez V, Becker C. Quality improvement in maternal and newborn healthcare: lessons from programmes supported by the German development organisation in Africa and Asia. *BMJ Glob Health* [Internet]. 2019 [cited 2019 Nov 26];4. Available from: <https://gh.bmj.com/content/4/5/e001562>.
17. Gabrysch S, Nesbitt RC, Schoeps A, Hurt L, Soremekun S, Edmond K, et al. Does facility birth reduce maternal and perinatal mortality in Brong Ahafo, Ghana? A secondary analysis using data on 119 244 pregnancies from two cluster-randomised controlled trials. *Lancet Glob Health.* 2019;7:e1074–87.
18. Lohela TJ, Nesbitt RC, Pekkanen J, Gabrysch S. Comparing socioeconomic inequalities between early neonatal mortality and facility delivery: Cross-sectional data from 72 low- and middle-income countries. *Sci Rep.* 2019;9:1–11.
19. Facebook Connectivity Lab, Center for International Earth Science Information Network - CIESIN - Columbia University. High Resolution Settlement Layer (HRSL). Source imagery for HRSL [Internet]. DigitalGlobe; 2016 [cited 2020 Apr 16]. Available from: <https://data.humdata.org/dataset/haiti-high-resolution-population-density-maps-demographic-estimates>.
20. Breathe HB, Edition S. A Model for Strengthening Educational Programs to Increase Global Newborn Survival | Global Health: Science and Practice [Internet]. [cited 2020 Feb 10]. Available from: <https://www.ghspjournal.org/content/6/3/538.short>.
21. American Academy of Pediatrics. Essential Care for Every Baby.
22. WHO. ICD-10 online versions [Internet]. WHO. World Health Organization; [cited 2020 Apr 16]. Available from: <http://www.who.int/classifications/icd/icdonlineversions/en/>.
23. Burstein R, Henry NJ, Collison ML, Marczak LB, Sligar A, Watson S, et al. Mapping 123 million neonatal, infant and child deaths between 2000 and 2017. *Nature.* 2019;574:353–8.
24. Zonneveld R, Holband N, Bertolini A, Bardi F, Lissone NPA, Dijk PH, et al. Improved referral and survival of newborns after scaling up of intensive care in Suriname. *BMC Pediatr.* 2017;17:189.

25. Wang W, Winner M, Burgert-Brucker CR. Limited Service Availability, Readiness, and Use of Facility-Based Delivery Care in Haiti: A Study Linking Health Facility Data and Population Data. *Glob Health Sci Pract*. 2017;5:244–60.
26. Segal. The bacterial profile of neonatal sepsis and antibiotic use in the tertiary care NICU of Kosovo. *J Pediatr Neonatal Care* [Internet]. MedCrave Publishing; 2018 [cited 2020 Apr 21];Volume 8. Available from: <https://medcraveonline.com/JPNC/JPNC-08-00319.pdf>.
27. Hedstrom A, Ryman T, Otai C, Nyonyintono J, McAdams RM, Lester D, et al. Demographics, clinical characteristics and neonatal outcomes in a rural Ugandan NICU. *BMC Pregnancy Childbirth* [Internet]. 2014 [cited 2020 Mar 11];14. Available from: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4174605/>.
28. Ndelema B, Van den Bergh R, Manzi M, van den Boogaard W, Kosgei RJ, Zuniga I, et al. Low-tech, high impact: care for premature neonates in a district hospital in Burundi. A way forward to decrease neonatal mortality. *BMC Res Notes*. 2016;9:28.
29. Blencowe H, Cousens S, Chou D, Oestergaard M, Say L, Moller A-B, et al. Born Too Soon: The global epidemiology of 15 million preterm births. *Reprod Health*. 2013;10:2.
30. Lawn JE, Gravett MG, Nunes TM, Rubens CE, Stanton C, GAPPS Review Group. Global report on preterm birth and stillbirth (1 of 7): definitions, description of the burden and opportunities to improve data. *BMC Pregnancy Childbirth*. 2010;10(Suppl 1):1.

Figures

Figure 1

Location of Hopital Immaculae Conception, its sending communes, and population density in surrounding areas [19] The map shows the population density (by sub-commune) and the percentage of neonates coming from each of the communes in the region. The highest proportion (51%) of neonates were admitted from the area in the immediate vicinity of HIC. The remaining neonates were spread out across the Sud region, some coming from neighboring departments of Nippes and Grand Anse.

Figure 2

Sample calculation

Figure 3

Major health issues experience by neonates