Tropical Medicine and International Health doi:10.1111/j.1365-3156.2011.02931.x

VOLUME 17 NO 3 PP 272–282 MARCH 2012

Stillbirths and early neonatal mortality in rural Northern Ghana

Cyril Engmann[1], Paul Walega[2], Raymond A. Aborigo[2], Philip Adongo[3], Cheryl A. Moyer[4], Layla Lavasani[1], John Williams[2], Carl Bose[1], Fred Binka[3] and Abraham Hodgson[2]

1 *University of North Carolina, Chapel Hill, NC, USA*
2 *Navrongo Health Research Centre, Navrongo, Ghana*
3 *University of Ghana, Legon, Ghana*
4 *University of Michigan, Ann Arbor, MI, USA*

Abstract

OBJECTIVE To calculate perinatal mortality (stillbirth and early neonatal death: END) rates in the Upper East region of Ghana and characterize community-based stillbirths and END in terms of timing, cause of death, and maternal and infant risk factors.

METHODS Birth outcomes were obtained from the Navrongo Health and Demographic Surveillance System over a 7-year period.

RESULTS Twenty thousand four hundred and ninty seven pregnant women were registered in the study. The perinatal mortality rate was 39 deaths/1000 deliveries, stillbirth rate 23/1000 deliveries and END rates 16/1000 live births. Most stillbirths were 31 weeks gestation or less. Prematurity, first-time delivery and multiple gestation all significantly increased the odds of perinatal death. Approximately 70% of END occurred during the first 3 postnatal days, and the most common causes of death were birth asphyxia and injury, infections and prematurity.

CONCLUSION Stillbirths and END remain a significant problem in Navrongo. The main causes of END occur during the first 3 days and may be modifiable with simple targeted perinatal policies.

keywords stillbirth, early neonatal death, perinatal mortality, verbal autopsy, community-based, Ghana

Introduction

Six million babies are stillborn (SB) or die within the first 7 days of life (early neonatal deaths: END) each year (World Health Organization 2006; Carlo *et al.* 2010).These stillbirths and END, together termed perinatal deaths, cause the highest proportion of deaths among children 0–14 years old and result in twice as many deaths as those caused by malaria and HIV/AIDS combined (Lopez & Mathers 2006). More than 98% of these perinatal deaths occur in low- and middle-income countries, and regional estimates suggest that countries in west Africa have some of the highest perinatal mortality rates in the world (Lawn *et al.* 2005a,b; World Health Organization 2006). Compounding this, many west African countries with disproportionately high perinatal mortality rates often have weak data management and health systems, resulting in a paucity of perinatal morbidity and mortality information and a deficiency in the availability of high-quality data (McClure *et al.* 2006, 2007; Hill *et al.* 2007; Diallo *et al.* 2010).

Currently, much of the data used to estimate perinatal mortality in many west African countries are derived from complex statistical modelling techniques or from nationally representative demographic and health surveys that use cluster-level sampling of live births (Stanton *et al.* 2006). Although these surveys provide information on neonatal mortality rates, little information is gathered on stillbirths and their surrounding circumstances (Edmond *et al.* 2008a,b; Engmann *et al.* 2009a,b; Lawn *et al.* 2009). In addition, much of the primary research on perinatal deaths has been conducted in hospitals with relatively small sample sizes, thereby limiting the generalizability of their findings (Kunzel *et al.* 1996; Edmond *et al.* 2008a,b). Few accurate registries document perinatal outcomes in a community setting (Edmond *et al.* 2008a,b; Lawn *et al.* 2009). This is of particular importance because current estimates suggest that more than 70% of perinatal deaths occur at home and many may not be included in vital registrations or health facility data (Lawn *et al.* 2008; Carlo *et al.* 2010). The dearth of accurate, population-based, perinatal data poses significant challenges to developing a coherent perinatal health policy in west Africa.

In Ghana, where stillbirth rates are estimated at 24/1000 births, neonatal death rates at 30/1000 live births and maternal mortality rates at 560 deaths/100 000 (Lawn & Kerber 2006; Okiwelu *et al.* 2007; Ghana Demographic & Health Survey 2008; Zakaria *et al.* 2009; Engmann *et al.* 2010), a vital registration system has been in place for

more than 20 years in the rural Upper East region. The Navrongo Health and Demographic Surveillance System (NHDSS) records births, deaths, migrations, marriages, and pregnancies, with updates conducted by trained community key informants every 4 months. The NHDSS supplements its vital registration data using verbal autopsy (VA). VA is an indirect method of determining cause of death (COD) by collecting information from primary caregivers about the signs, symptoms and circumstances that preceded death (Fauveau 2006; Garenne & Fauveau 2006; Setel *et al.* 2007). Those descriptions are then independently reviewed by trained coders, usually physicians, to arrive at an estimated COD (Setel *et al.* 2005; Soleman *et al.* 2006; Joshi *et al.* 2009).

The maintenance of a community-based vital registry supplemented with VA data makes Navrongo and the NHDSS an ideal venue for improving our understanding of stillbirth and END in rural western Africa. This study aimed to (i) identify stillbirth and END rates in the Upper East region, and (ii) characterize community-based stillbirths and END ratesin terms of timing, COD, and maternal and infant risk factors.

Methods

Study setting

Data were collected by the Navrongo Health Research Centre in the Kassena-Nankana District[1] (KND) of the Upper East region. The KND covers a land area of 1685 km^2 and has an estimated population of 150 000. The district has one major hospital that acts as a referral hospital to 5 health centres. The primary occupation is subsistence agriculture, and most parts are rural. A small central area of the district, Navrongo township, has suburban character, a population of 20 000, and is the district capital. The majority of inhabitants in the district are subsistence farmers who live in small, scattered settlements. There is little electricity, few health facilities and many transportation challenges, all of which are representative of many rural west African countries.

Cause of death determination, subjects, study design and operational definitions

Data utilized in this review originated from the NHDSS, maintained by the Navrongo Health Research Centre in the Kassena-Nankana district. These data were collected by Community key informants, who are selected members of the community, trained by the Navrongo Health Research Center to register all pregnancies, births and deaths that occur in their communities. All pregnancies are identified in the community by either the trained community key informants (CKIs) or during the 4-monthly visits by trained field workers. These pregnancies are then registered. It is during the time of registering the pregnancy that the last menstrual period is established. The pregnancy is monitored until completion, defined as having a live birth or a stillbirth, a miscarriage, an abortion or if the pregnant mother moves out of the study area. Eighty-five percent of all pregnancies are registered by week 28. Verbal autopsies (VA) are conducted on all deaths in the district. Standard INDEPTH tools, developed, reviewed and validated by numerous authors, and widely used in over 31 INDEPTH countries, were used for neonatal, postneonatal and adult deaths (Setel *et al.* 2006, 2007; Mswia *et al.* 2007; Chandramohan *et al.* 2008).

The questionnaire has both open- and closed-ended questions and includes a section for verbatim narrations of the circumstances leading to the death. The VA interviews are conducted on average 3 months after a death has occurred. The effects of recall may differ depending on the context, characteristics and demographics of the deceased (Soleman *et al.* 2006). People interviewed too early may be reluctant to talk about a death, whereas delaying the interview for too long may result in problems recalling symptoms and sequences. Some studies suggest that recall does not affect reporting an event as tragic as the loss of life and that longer recall is as reliable as short intervals (Ronsmans *et al.* 1998; Lulu & Berhane 2005). Although no standard procedures have been suitably tested or established, suggestions in the literature of the 'optimal time' between a death and an interview range from 3 months (Garenne & Fontaine 1990) to 2 years (Lulu & Berhane 2005; Byass *et al.* 2009). Trained fieldworkers, who have at least high-school education, conduct the interviews after obtaining verbal consent. Immediate caregivers who attended to the deceased prior to the death are the VA respondents. The study is rigorously supervised. Ten percent of interviews are usually reconducted for quality assurance; also, where discrepancies are detected, interviews are reconducted. Dates of birth and death are ascertained with the aid of the NHDSS database, facility records and a vital events calendar. Gestational age is determined using the mother's last menstrual period.

Three experienced physicians independently review the VA forms and assign an underlying COD. A diagnosis is established if at least 2 physicians agree on the underlying COD. Where there is disagreement among all three, the

[1]In 2008 Kassena-Nankana District was split into two districts – Kassena-Nankana East and Kassena-Nankana West districts. For the purposes of this study, the former name of the district will be used to refer to the two districts.

form is submitted to two additional physicians who discuss the available information and arrive at an underlying COD. Where there is VA information but no underlying COD can be agreed on, the case is declared undetermined. Where little or no information is available to enable an assignment of COD, the diagnosis is declared unknown. All physicians use the same locally developed COD list corresponding to the 3-digit code of *the international statistical classification of diseases and health-related problems* (*ICD-10, World Health Organization 2005*). Conditions indicated on the COD list are informed by local knowledge of common diseases in the district. The procedures and practices in the Navrongo HDSS have been essentially the same throughout the period of this investigation.

De-identified data were extracted from the NHDSS databases to reflect all registered pregnancies, births and infant deaths that occurred during the period from January 2002 – December 2008. Unique identifiers linked maternal health and demographic data to infant data, and separate databases were combined to allow for combined analysis. Table 1 highlights study operational definitions which are the same as those commonly used by the WHO (ICD 10, World Health Organization 2006; Engmann *et al.* 2009a,b). This study was reviewed and approved by the institutional ethics review committees of the Navrongo Health Research Centre, the University of North Carolina at Chapel Hill and the University of Michigan.

Statistical methods

Data were analysed using STATA 10.1. Descriptive analyses were conducted to describe gestational age, delivery location, maternal characteristics and infant characteristics. Factors potentially associated with perinatal mortality rates were grouped into three domains: obstetric and sociodemographic maternal characteristics; delivery location; and infant characteristics. Unadjusted and adjusted odds ratios with 95% confidence intervals were computed to assess the relationship between the outcomes (stillbirth, END and perinatal mortality) and selected variables. Reference categories were defined as those usually associated with the lowest stillbirth and END rates. All variables found to be significantly associated with perinatal deaths, stillbirths and END were then included in a Generalized Estimation Equation model, and adjusted odds ratios with 95% confidence intervals were obtained.

Results

A total of 20 497 pregnant women were registered and enrolled in the study although 955 moved out of the study area and 238 had miscarriages. There were 452 stillbirths, 18 852 live births and 293 ENDs included in the analysis (Figure 1). The perinatal mortality rate was 39 deaths per 1000 deliveries, the stillbirth rate 23 per 1000 deliveries and the END rate 16 per 1000 live births. Table 2 describes characteristics of live births, stillbirths and multiple deliveries by gestational age, birth location and socio-economic status. Seventy per cent of all deliveries were full term, and 66% occurred in the home. Most stillbirths (71%) were 31 weeks or less. More than 60% of neonates were born to mothers of socio-economic status (SES) 1–3.

Table 1 Operational definitions

The END rate is defined as death of a live born infant at or before 7 days of life per 1000 live births.
Stillbirth is defined as foetal death corresponding to approximately 28-week gestation or more with no signs of life at birth, i.e. no breathing, no heart rate and no movement per 1000 births.
Perinatal mortality rate is defined as the sum of the END and stillbirth divided by total births and expressed per 1000.
Cause-specific mortality rates are calculated by dividing the number of deaths because of a particular cause by the total number of live births in a given year, expressed per 1000 live births.
Prematurity is defined as birth before 37 completed weeks of pregnancy. Gestational age is determined using the mother's last menstrual period.
Traditional birth attendant (TBA) is defined as a person who assists other women during childbirth and initially acquired her skills by delivering babies or through apprenticeship to other TBAs.
Skilled birth attendant (SBA) is defined as a nurse, midwife or doctor who provides obstetric care.
Prenatal care is defined as at least one visit with a skilled birth attendant.
Socio-economic status is assessed using household possessions or assets where the scoring factors of each asset are used to generate a wealth index through Principal Component Analysis (Kolenikov & Angeles 2009). 128). Some of the assets used in generating the wealth index include ownership of a car, motor bike, bicycle, refrigerator, tractor, grinding mill, pressing iron, fan, phone, gas/kerosene stove, cattle, sheep, goats, donkeys, pigs, DVD player, radio cassette player etc. SES then categorized into quintiles from the spread of the household assets with quintile 1 representing the poorest quintile and quintile 5 the richest.

END, early neonatal death.

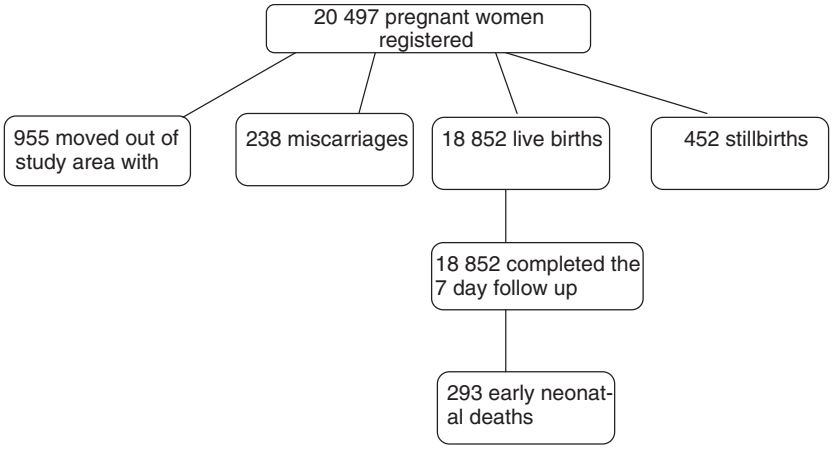

Figure 1 Study population of registered pregnant women in Navrongo HDSS from 2002 to 2008.

Table 3 describes sociodemographic, health and economic characteristics of the mother, infant characteristics and associated perinatal mortality. Nearly three quarters (73%) of mothers were 34 or younger, and 90% had either a primary level education or no formal education. Nearly 90% of mothers were living with parters or married, and 77% had one or more children. Two-thirds of women received antenatal care during their pregnancy, and approximately 97% of births were singleton deliveries. Two-thirds of the infants were full term that is >37 completed weeks of pregnancy.

In bivariate analysis, the following maternal factors conferred increased odds for perinatal death: maternal age (younger than 20 years or older than 35), primary educational status, being single, having no children or more than 3 children and lack of prenatal care. Infant characteristics that conferred increased odds of death were gestational age (prematurity) and multiple births.

In multivariate analysis, mothers without other children had a nearly twofold increase in the odds of perinatal death, and multiple gestation was associated with a fivefold increased odds of perinatal death. Prematurity nearly tripled the odds of perinatal death in the most premature infants (<32 weeks).

Table 4 describes sociodemographic, health and economic characteristics of the mother, infant characteristics and associated stillbirth. A total of 452 stillbirths occurred out of 19 304 total deliveries. In the multivariate analysis, mothers who were 35 years or older, and mothers without prior children had a 45% and 32% higher odds of stillbirth (respectively) than mothers aged 20–34 years. Gestational age was significantly correlated with stillbirth, with the highest odds occurring in the youngest infants (<32 weeks).

Table 5 describes characteristics of the mother, perinatal/neonatal care and associated END. The early neonatal mortality rate was 16 deaths per 1000 live births. Nearly 75% of END occurred to mothers 34 years and under. The early neonatal mortality rates were markedly different if infants were multiples (61/1000) compared with singletons (14/1000 live births), and also if infants were 31 weeks or less (37/1000 live births *vs.* 12/1000 live births if the infants were term). In multivariate analysis, there was a more than fivefold increase in the odds of END if infants were multiples, a threefold increase in the odds if they were <32 weeks and nearly double the odds of END if the mother did not have any children.

Figure 2 shows the early neonatal mortality rates by day of life. Over 40% of END occurred on the first day of life, 20% on the second day and 10% on the third day; thus, nearly 70% of all ENDs occurred during the first three postnatal days. There was a flattening of the cumulative proportion of END curve after the third day. The cumulative assignment for causes of END during the first 3 days was highest for birth asphyxia and birth trauma and lowest for infections (Figure 3). Figure 4 is a pie chart of the most common underlying COD. Infections, birth asphyxia and birth trauma, and prematurity were responsible for over 75% of all ENDs.

Discussion

The overall stillbirth rate of 23 per 1000 deliveries and the END rate of 16 deaths per 1000 live births are more than fourfold higher rate than is reported for high-income countries (Stanton *et al.*2006; World Health Organization 2006). Our END rates are similar to those reported from the 2008 Ghana DHS. Based on an unweighted sample of <500 infants, the Ghana DHS reported a neonatal death

Table 2 Characteristics of deliveries from 2002 to 2008 in Kassena-Nankana Districts of Northern Ghana (n = 19304)

	Gestation age (%)			Birth location (%)			Socio-economic status (%)					
Categories	<32 weeks	32–36 weeks	>36 weeks	Home/other	Clinic/Hospital	Missing	Poor	Less poor	Average	Next rich	Rich	Missing
Deliveries*	2091 (10.8)	4308 (22.3)	12905 (66.9)	12357 (64.0)	6495 (33.7)	452 (2.3)	4373 (22.6)	3754 (19.4)	3666 (19.0)	3565 (18.5)	1943 (10.1)	2003 (10.4)
Stillbirth†	323 (71.4)	74 (16.4)	55 (12.2)	–	–	–	113 (25.0)	82 (18.1)	93 (20.6)	73 (16.2)	29 (6.4)	62 (13.7)
Live births‡	1768 (9.4)	4234 (22.4)	12850 (68.2)	6495 (34.5)	12357 (65.5)	0	4260 (22.6)	3672 (19.5)	3573 (19.0)	3492 (18.5)	1914 (10.1)	1941 (10.3)
Multiple births§	66 (10.9)	168 (27.8)	371 (61.3)	357 (59.0)	248 (41.0)	0	137 (22.6)	147 (24.3)	99 (16.4)	106 (17.5)	78 (12.9)	38 (6.3)

*Total n: deliveries = 19304.
†Total n: stillbirths = 452.
‡Total n: live births = 18852.
§Total n: of live births, which were multiple deliveries = 605.

rate (deaths during the first 28 days after birth) of 17/1000 live births from the Upper East region of Ghana. Although no model mortality patterns were developed in that study, numerous authors have concluded from other studies that between 60% and 70% of all neonatal deaths occur during the first week of life, thus making it plausible that END rates from the Upper East region be considered between 11 and 13/1000 live births (Lawn *et al.* 2005a,b. World Health Organization 2006). Baiden *et al.* (2006b) reported a halving in END from 26 per 1000 live births to 13 per 1000 live births, when they examined data from the NHDSS collected between 1995 and 2002. They attributed this decline to multiple community-based health research activities over the years, each accompanied by numerous health education campaigns, which collectively resulted in improved access to basic health services, high levels of antenatal attendance, use of impregnated bed nets and antitetanus coverage for pregnant women (Baiden *et al.* 2006b). Although infant and neonatal mortality rates in the Upper East are among the lowest of the 10 regions of the country, our results suggest that the decline in END appears to have levelled off in the Kassena-Nankana district over the past 9 years.

There is a paucity of detailed or regional data on stillbirth rates in Ghana. Baiden *et al.* (2006b) were unable to provide stillbirth estimates from the NHDSS because such data had not been collected throughout the period in which they conducted their analysis. The Ghana DHS reported an overall national stillbirth rate of 13 per 1000 pregnancies using a sample size of 2949 reported pregnancies, nearly 10 times smaller than our sample size (Ghana Demographic and Health Survey 2008). By contrast, in a study from the Central Region of Ghana utilizing a comparable sample size to ours, Edmond *et al.* (2008a,b) reported a stillbirth rate of 35/1000. Rates of neonatal, infant and under-5 mortality in the Central Region are among the highest in Ghana, which may explain the discrepancy between Edmond's estimates and ours.

Prematurity, multiple births and being pregnant without any other children conferred the highest odds of perinatal death in our study. Similar observations have been made from multiple studies conducted in rural western and Central Africa, and south-east Asia (Edmond *et al.* 2008a,b; Engmann *et al.* 2009a; Jehan *et al.* 2009; Diallo *et al.* 2010). Compared with the youngest gestational age categories, stillbirths and ENDs had strikingly dissimilar proportions. The odds of a stillbirth were increased 42-fold and END nearly tripled if the foetus had a gestational age shorter than 32 weeks. For a foetus of 32- to 36-week gestation, the odds of a stillbirth or END were considerably lower (4.1 and 1.3 respectively), suggesting

Table 3 Characteristics by mother, perinatal care, neonates and associated perinatal mortality

Categories	Total deliveries N = 19304 n (%)	Total perinatal deaths (perinatal mortality rate)	Odds ratio (95% CI)	GEE model Odds ratio (95% CI)
Maternal characteristics				
Maternal age				
<20	1921 (9.9)	108 (56.2)	1.42 (1.20–1.68)	
20–34	12216 (63.3)	419 (34.3)	1	NS
35+	5167 (26.8)	218 (42.2)	1.29 (1.06–1.56)	
Educational status				
No formal education	8539 (44.2)	324 (37.9)	1.37 (0.97–1.92)	
Primary/JSS	9249 (47.9)	372 (40.2)	1.45 (1.03–2.04)	
Secondary/Tertiary	1355 (7.0)	38 (28.0)	1	
Missing	161 (0.8)	11 (68.3)	2.54 (1.27–5.08)	
Presence of partner				
Single	2208 (11.4)	106 (48.0)	1.30 (1.05–1.60)	NS
Married/cohabitating	17096 (88.6)	639 (37.4)	1	
Number of children				
0	4361 (22.6)	234 (53.7)	1.78 (1.49–2.12)	1.85 (1.35–2.53)
1–3	9767 (50.6)	302 (30.9)	1	1
>3	5176 (26.8)	209 (40.4)	1.32 (1.10–1.58)	0.94 (0.65–1.36)
Perinatal care				
No perinatal care	5523 (28.6)	238 (43.1)	1.18 (1.0–1.38)	NS
One visit or more	12210 (63.3)	450 (36.9)	1	
Missing	1571 (8.1)	57 (36.3)		
Delivery location				
Home/other	12357 (64.0)	182 (14.7)	0.86 (0.68–1.09)	
Clinic/hospital	6495 (33.6)	111 (17.1)	1	
Missing	452 (2.3)	452 (100)		
Infant characteristics				
Sex				
Male	9583 (49.6)	166 (17.3)	1.23 (0.98–1.55)	
Female	9273 (48.0)	131 (14.1)	1	
Missing	448 (2.3)	448 (100)		
Gestation age				
<32 weeks	2091 (10.8)	389 (186.0)	13.8 (11.54–16.38)	2.84 (2.12–3.81)
32–36 weeks	4308 (22.3)	145 (33.7)	2.1 (1.69–2.60)	1.29 (0.97–1.71)
>36 weeks	12905 (66.9)	211 (16.4)	1	1
Multiple				
Yes	605 (3.1)	37 (61.2)	4.51 (3.16–6.42)	5.24 (3.62–7.57)
No	18249 (94.5)	260 (14.2)	1	
Missing	450 (2.3)	448 (99.6)		
Socio-economic status				
Poor	4373 (22.6)	182 (41.6)	1.07 (0.86–1.35)	
Next poor	3754 (19.4)	140 (37.3)	0.96 (0.76–1.22)	
Average	3666 (19.0)	142 (38.7)	1	
Next rich	3565 (18.5)	112 (31.4)	0.80 (0.63–1.04)	
Rich	1943 (10.1)	63 (32.4)	0.83 (0.61–1.12)	
Missing	2003 (10.4)	106 (52.9)	1.39 (1.07–1.79)	

NS, not significant; GEE, generalized estimated model.

that among such infants, survival in rural, remote areas is possible with targeted intervention packages such as maternal tetanus, immunization, clean cord practices, exclusive breast feeding, skin-to-skin kangaroo care and recognition and early treatment of infection (Bhutta *et al.* 2005; Darmstadt *et al.* 2005; Haws *et al.* 2007). Interestingly, lower SES did not confer increased odds for perinatal death. This may in part be explained by the community health and family planning project established in the Navrongo region which assigns nurses to community

Table 4 Characteristics by mother, perinatal care, neonates, and associated stillbirth

Categories	Total deliveries $N = 19304$ n (%)	Total number of stillbirths (stillbirth rate)	Odds ratio (95% CI)	GEE model Odds ratio (95% CI)
Maternal characteristics				
Maternal age				
<20	1921 (9.9)	58 (30.2)	1.49 (1.12–1.99)	0.86 (0.61–1.21)
20–34	12216 (63.3)	250 (20.5)	1	1
35+	5167 (26.8)	144 (27.9)	1.37 (1.11–1.69)	1.45 (1.08–1.94)
Educational status				
No formal education	8539 (44.2)	202 (23.7)	1.47 (0.94–2.29)	
Primary/JSS	9249 (47.9)	220 (23.8)	1.48 (0.95–2.30)	
Secondary/Tertiary	1355 (7.0)	22 (16.2)	1	
Missing	161 (0.8)	8 (49.7)	3.17 (1.39–7.24)	
Presence of partner				
Single	2208 (11.4)	60 (27.2)	1.19 (0.90–1.57)	
Married/cohabitating	17096 (88.6)	392 (22.9)	1	
Number of children				
0	4361 (22.6)	134 (30.7)	1.66 (1.32–2.08)	1.32 (1.0–1.73)
1–3	9767 (50.6)	183 (18.7)	1	1
>3	5176 (26.8)	135 (26.1)	1.40 (1.12–1.76)	0.99 (0.74–1.33)
Perinatal care				
No perinatal care	5523 (31.2)	151 (27.3)	1.24 (1.01–1.51)	NS
One visit or more	12210 (68.8)	271 (22.2)	1	
Missing	1571	30 (19.1)	0.86 (0.59–1.26)	
Gestation age				
<32 weeks	2091 (10.8)	323 (154.5)	42.7 (31.93–57.05)	42.7 (31.8–57.2)
32–36 weeks	4308 (22.3)	74 (17.2)	4.08 (2.88–5.80)	4.06 (2.86–5.77)
>36 weeks	12905 (66.9)	55 (4.3)	1	1
Socio-economic status				
Poor	4373 (22.6)	113 (25.8)	1.02 (0.77–1.35)	
Next poor	3754 (19.4)	82 (21.8)	0.86 (0.64–1.16)	
Average	3666 (19.0)	93 (25.4)	1	
Next rich	3565 (18.5)	73 (20.5)	0.80 (0.59–1.10)	
Rich	1943 (10.1)	29 (14.9)	0.58 (0.38–0.89)	
Missing	2003 (10.4)	62 (31.0)	1.23 (0.89–1.70)	

NS, not significant; GEE, generalized estimated model.

locations where they provide basic curative and preventive care (Phillips *et al.* 2006).

Our study documented that over 40% of all ENDs occurred during the first postnatal day of life and over 70% by third day of life. This is consistent with estimates by Lawn *et al.* in a sample of over 10 000 neonatal deaths from 47 DHS data sets, in which 25–45% occurred the same day the child was born (Lawn *et al.* 2005a,b). Similar observations have been reported from single-site studies in rural India by Baqui *et al.* (2006) and in Ghana by Edmond *et al.* (2008a,b). The risk of END during the first 3 days of life was highest for birth asphyxia and birth injury and lowest for infections, strengthening the case for improved and continuous training of community health workers and increased facility-based delivery.

Three conditions were responsible for three quarters of END in our study. Birth asphyxia and birth injuries were responsible for 28% of END, prematurity for 26% and infections for 20%. By contrast, Edmond reported that birth asphyxia was responsible for 42% of END, while prematurity and infections were each responsible for 24% of END. Similarly, Ngoc reported that 42% of END was prematurity related, 23% because of to asphyxia and birth trauma and 13% congenital abnormalities. Interestingly, infections were only attributed to 1.4% of END (Edmond *et al.* 2008a,b; Ngoc *et al.* 2006). Differentiating sepsis and prematurity poses a major challenge even in developed countries, and the diversity of these findings highlights the inherent difficulties in interpreting VA data and comparing COD among studies. Although the data describing causes of END in rural areas are limited, our findings are also

Table 5 Characteristics by mother, perinatal care, neonates and associated early neonatal deaths

Categories	Live born births N = 18852 *n* (%)	Total number of early neonatal deaths (early neonatal mortality rate)	Odds ratio (95% CI)	GEE model Odds ratio (95% CI)
Maternal characteristics				
Maternal age				
<20	1863 (9.9)	50 (26.8)	1.93 (1.40–2.65)	
20–34	11966 (63.5)	169 (14.1)	1	NS
35+	5023 (26.6)	74 (14.7)	1.04 (0.79–1.37)	
Educational status				
No formal education	8337 (44.2)	122 (14.6)	1.22 (0.72–2.07)	
Primary/JSS	9029 (47.9)	152 (16.8)	1.41 (0.84–2.37)	
Secondary/Tertiary	1333 (7.1)	16 (12.0)	1	
Missing	153 (0.8)	3 (19.6)	1.65 (0.47–5.72)	
Presence of partner				
Single	2148 (11.4)	46 (21.4)	1.46 (1.06–2.00)	NS
Married/cohabitating	16704 (88.6)	247 (14.8)	1	
Number of children				
0	4227 (22.4)	100 (23.7)	1.93 (1.47–2.52)	1.75 (1.28–2.40)
1–3	9584 (50.8)	119 (12.4)	1	1
>3	5041 (26.8)	74 (14.7)	1.18 (0.88–1.59)	0.96 (0.67–1.39)
Perinatal care				
No perinatal care	5372 (28.5)	87 (16.2)	1.08 (0.84–1.40)	
One visit or more	11939 (63.3)	179 (15.0)	1	
Missing	1541 (8.2)	27 (17.5)		
Delivery location				
Home/other	12357 (65.5)	182 (14.7)	0.86 (0.68–1.09)	
Clinic/hospital	6495 (34.5)	111 (17.1)	1	
Infant characteristics				
Sex				
Male	9582 (50.8)	165 (17.2)	1.25 (0.99–1.58)	NS
Female	9270 (49.2)	128 (13.8)	1	
Gestation age				
<32 weeks	1768 (9.4)	66 (37.3)	3.16 (2.35–4.22)	2.84 (2.11–3.81)
32–36 weeks	4234 (22.5)	71 (16.8)	1.39 (1.05–1.84)	1.28 (0.96–1.70)
>36 weeks	12850 (68.1)	156 (12.1)	1	1
Multiple				
Yes	605 (3.2)	37 (61.2)	4.58 (3.21–6.53)	5.22 (3.61–7.54)
No	18245 (96.8)	256 (14.0)	1	1
Missing	2	0 (0)		
Socioeconomic status				
Poor	4260 (22.6)	69 (16.2)	1.18 (0.82–1.71)	
Next poor	3672 (19.5)	58 (15.8)	1.15 (0.79–1.69)	
Average	3573 (18.9)	49 (13.7)	1	
Next rich	3492 (18.5)	39 (11.2)	0.81 (0.53–1.24)	
Rich	1914 (10.2)	34 (17.8)	1.30 (0.84–2.02)	
Missing	1941 (10.3)	44 (22.7)	1.67 (1.11–2.52)	

NS, not significant; GEE, generalized estimated mode.

consistent with other community-based studies published since 1990 from other low-income countries which suggest that infections may be responsible for 20–42% of END, birth asphyxia for 26% and prematurity up to 25% (Lawn *et al.* 2005a,b; World Health Organization 2006; Thaver & Zaidi 2009) These figures underscore the potential benefit of strategies that serve to increase access to skilled birth attendants who are prepared to identify and manage birth asphyxia and injuries, ensure prompt referral and access to quality emergency obstetric and neonatal services, treat maternal infections and utilize hygienic procedures and equipment.

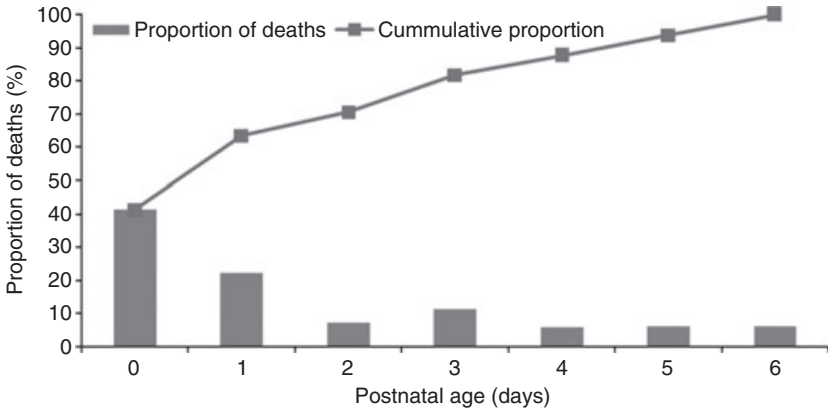

Figure 2 Timing of Early Neonatal Deaths in Navrongo HDSS from 2002 to 2008.

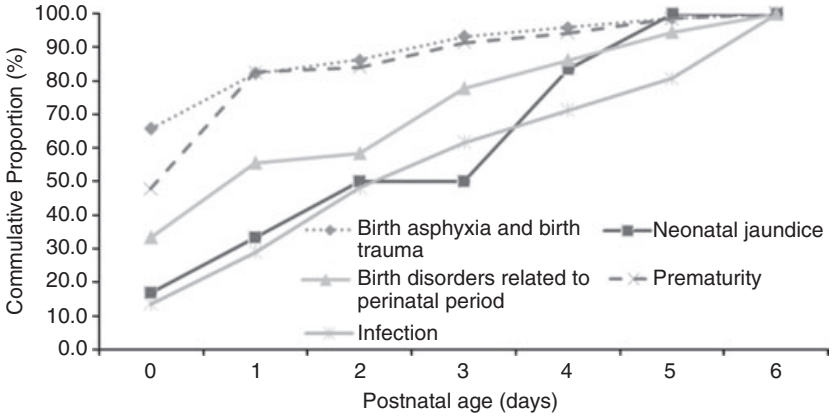

Figure 3 Timing of Early Neonatal Deaths by Cause Determined by Verbal Autopsy: 2002–2008.

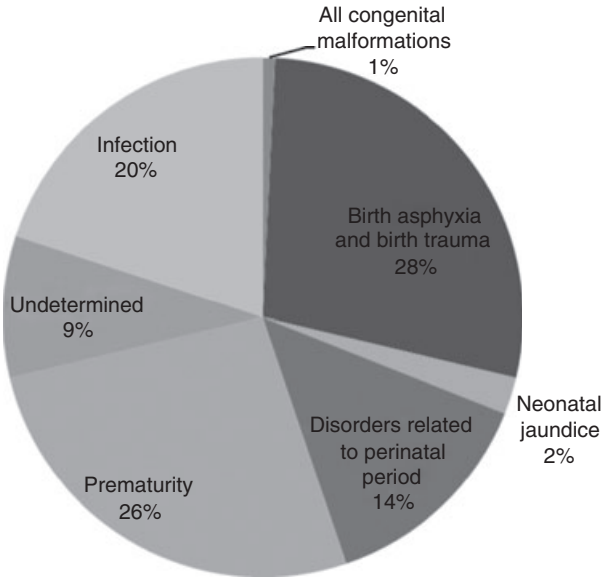

Figure 4 Causes of Early Neonatal Death in Navrongo HDSS from 2002 to 2008.

There are a number of limitations to this study. First, there was a lack of birthweight data for these perinatal deaths. We do not think this significantly affects the results. Frequently, birth weight is used as a proxy for gestational age, and both demonstrate similar interactions with perinatal deaths (McClure *et al.* 2007; Engmann *et al.* 2009a,b; Jehan *et al.* 2009). Second, as with any epidemiologic study, cause and effect cannot be discerned from the data, nonetheless the increased odds of death associated with factors such as prematurity, multiple gestation and having no other children, begin to elucidate potential modifiable factors that are contributing to perinatal deaths in rural west Africa. There are challenges to distinguishing stillbirth from late abortions, especially based on maternal reports. Because abortion is illegal in Ghana (Baiden *et al.* 2006a,b), it is possible some women may not disclose an abortion or may deliberately misclassify it as a stillbirth. However, the information collected from mothers is de-identified, mothers know that the focus of the 4-monthly interviews is for research purposes, and there has been no precedent for invoking criminal proceedings based on

maternal reports; thus, it is unlikely mothers will deliberately misclassify a late abortion as a stillbirth. Additionally, late abortions cases are reported to be very low in Ghana (Ahiadeke 2001). Another potential limitation is that this study was designed to provide population data and lacks a direct comparison group. Finally, as with many VA studies, there was no validation component through the use of medical diagnostic aids such as laboratory, radiologic, microbiologic or postmortem studies, as these were often not available. The use of the last menstrual cycle, widely used in environments where there is no technology, may introduce recall bias to this study. However, VA has been investigated previously in validation studies, and the results have been favourable (Setel *et al.* 2005; Soleman *et al.* 2006; Edmond *et al.* 2008a,b; Lawn *et al.* 2008; Fottrell & Byass 2010).In that regard, two percent of deaths were attributed to jaundice although because of the multiplicity of causes of jaundice coders were unable to determine specifically what caused the cases of jaundice. It is conceivable that not all pregnancies were initially captured; however, given the 4-monthly enumerations and the familiarity of field workers who live in the same communities as the study subjects, we think this is unlikely to have occurred and view the capture and follow-up of these subjects as strength of the study. Other strengths of this study are the large sample size, rigorous study oversight and data validation, the conduct of a study in a region familiar with research and interviews, and the use of experienced study personnel.

In conclusion, stillbirths and END remain a significant problem in Navrongo. END particularly appears to have reached a plateau, while stillbirth rates remain unacceptably high. This study highlights birth asphyxia and birth injuries, prematurity and infection as the major causes of death and notes also that three quarters of END occur in the first 3 days of life. Further research is needed to understand the influence of cultural and sociologic practices during pregnancy, childbirth and childhood, and how best to develop a targeted perinatal policy that encourages deliveries in health facilities.

Funding

Funding was provided by grants and in-kind contributions from the Navrongo Health Research Center and the Universities of North Carolina and Michigan.

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Corresponding Author Cyril Engmann, Division of Neonatal-Perinatal Medicine, Department of Pediatrics, University of North Carolina School of Medicine, CB#7596, 4th Floor, UNC Hospitals, UNC-Chapel Hill, Chapel Hill, NC 27599-7596, USA. E-mail: cengmann@med.unc.edu