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Underlying causes of neonatal deaths in term singleton pregnancies: home births versus hospital births in the United States

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Abstract

Introduction: The objective of this study was to evaluate the underlying causes of neonatal mortality (NNM) in midwife-attended home births and compare them to hospital births attended by a midwife or a physician in the United States (US).

Methods: A retrospective cohort study of the Centers for Disease Control (CDC) linked birth/infant death data set (linked files) for 2008 through 2012 of singleton, term (≥37 weeks) births and normal newborn weights (≥2500 grams).

Results: Midwife-attended home births had the highest rate of neonatal deaths [122/95,657 neonatal mortality (NNM) 12.75/10,000; relative risk (RR): 3.6, 95% confidence interval (CI) 3–4.4], followed by hospital physician births (8695/14,447,355 NNM 6.02/10,000; RR: 1.7 95% CI 1.6–1.9) and hospital midwife births (480/1,363,199 NNM 3.52/10,000 RR: 1). Among midwife-assisted home births, underlying causes attributed to labor and delivery caused 39.3% (48/122) of neonatal deaths (RR: 13.4; 95% CI 9–19.9) followed by 29.5% due to congenital anomalies (RR: 2.5; 95% CI 1.8–3.6), and 12.3% due to infections (RR: 4.5; 95% CI 2.5–8.1).

Comment: There are significantly increased risks of neonatal deaths among midwife-attended home births associated with three underlying causes: labor and delivery issues, infections, and fetal malformations. This analysis of the causes of neonatal death in planned home birth shows that it is consistently riskier for newborns to deliver at home than at the hospital. Physicians, midwives, and other health care providers have a professional responsibility to share information about the clinical benefits and risks of clinical management.

Keywords: Congenital anomaly; home birth; hypoxic ischemic encephalopathy; infection; midwife; neonatal mortality.

Condensation: The risks of neonatal deaths among midwife-attended home births are significantly increased by underlying causes: labor and delivery issues, infections, and fetal malformations.

Introduction

Midwife-attended home births in the United States (US) are associated with an increase in adverse neonatal outcomes such as a higher incidence of neonatal mortality (NNM), Apgar score of 0 at 5 min, and neonatal seizures or serious neurologic dysfunction, [1–4] but the causes for the increase in NNM in home birth have not been reported previously. The objective of this study was to evaluate the underlying causes of NNM in midwife-attended home births and compare them to hospital births attended by a midwife or a physician in the US.

Methods

Study design and participants

We conducted a retrospective cohort study of the CDC linked birth/infant death data set (linked files) for 2008 through 2012 [5]. In this data set, information from birth certificates is linked to information from the death certificate for each infant (aged <1 year) who died in the 50 states, District of Columbia (DC), Puerto Rico, US Virgin

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Islands, or Guam. Linked birth-infant death data are not available for American Samoa and the Commonwealth of the Northern Marianas. The dataset does not contain information on maternal morbidity or deaths.

A neonatal death is defined as the death of a live-born infant between day 0 and 27 after birth and excludes stillbirths [6]. The purpose of the linkage is to use the variables documented in the birth certificate to conduct detailed analyses of infant mortality patterns. Data based on the vital statistics mortality and period linked birth/infant death data set provide information on trends in neonatal and infant mortality and on causes of neonatal and infant death [7–10]. Death certificates in the US are certified by physicians, medical examiners, or coroners [11].

Eligible patients for this study had singleton, term (≥37 weeks) births and normal newborn weights (≥2500 g) who were delivered by a physician or certified nurse-midwife (CNM) for hospital births or by a midwife (either CNM or "other" midwife) at home. We therefore excluded all preterm births, those with low birthweights (<2500 g), and those who were delivered by someone else than a midwife or physician or in a different place than the home or the hospital.

Statistical analyses were conducted for comparisons between midwife-attended home births, and midwife-attended and physician-attended deliveries in the hospital. Risk ratios (RR) and 95% confidence intervals (95% CI) were calculated for each of the three provider and location groups (midwife-attended home birth, midwife-attended hospital births, physician-attended hospital births). Certified nurse-midwife-attended hospital births served as the reference group. Statistical analyses were conducted in OpenEpi [12].

Infant mortality statistics by cause of death are compiled from entries on the medical certification portion of the death certificate that follows the World Health Organization (WHO) format, and the International Statistical Classification of Diseases (ICD) provides the basic guidance used in virtually all countries to code and classify causes of death [10, 11]. Deaths in the US are certified by physicians, medical examiners, or coroners [11]. Causes of death include all those diseases, morbid conditions or injuries that either resulted in or contributed to death and the circumstances of the accident or violence that produced any such injuries and are classified in accordance with the ICD-10 [13]. The underlying cause of death is defined by the WHO in the ICD-10 as "the disease or injury which initiated the train of events leading directly to death, or the circumstances of the accident or violence which produced the fatal injury" [7, 9].

For a given death, the underlying cause is selected from the condition or conditions recorded by the certifier in the cause-of-death section of the death certificate [7, 9]. Each infant mortality in the CDC linked birth/infant data set has an associated ICD-10 code for the underlying cause of death. We chose infant deaths of a live-born infant between day 0 and 27 after birth (NNM) and grouped each into one of 4 major groups for underlying causes of deaths: labor and delivery, infections, congenital malformation, and others (all other causes). The incidence and underlying causes of neonatal deaths for each of these four groups were further examined for the three largest groups which were defined by location and provider: midwife-attended hospital birth (hospital midwife), physician-attended hospital birth (hospital physician), and midwife-attended home birth (home birth midwife). Stillbirths or maternal deaths are not part of this dataset.

Because non-identifiable data from a publicly available data set were used, our study was not considered human subjects research and did not require review by the Institutional Review Board of Weill Medical College of Cornell University.

The outcome measure was neonatal mortality (neonatal death between day 0 and 27 after birth).

Results

Patient population and characteristics

Table 1 shows the baseline population and characteristics of the study population which included 9297 neonatal deaths among 15,906,211 births (NNM 5.84/10,000 births). The midwife home birth population contained more white and married women, and older women, and fewer nulliparous women, a finding similar to our previous study [1]. Hospital midwife and physician groups were fairly similar demographically, although the physicians' hospital deliveries included women who were older and were less likely to deliver after 41 weeks.

Neonatal deaths

Table 2 shows the neonatal mortality rate (per 10,000) by patient characteristics, provider, and location. Overall, the midwife-attended home births had the highest rate of neonatal deaths (122/95,657 NNM 12.75/10,000;

Table 1: Baseline characteristics of the study population.

	Hospital midwife (n=1,363,199)	Hospital MD (n=14,447,355)	Home midwife (n=95,657)
Unmarried, n (%)	587,688 (43.1)	5,721,977 (39.6)	8685 (9.1)
White non-Hispanic, n (%)	728,918 (53.5)	7,779,467 (53.8)	84,759 (88.6)
Para=0, n (%)	540,582 (39.7)	5,896,748 (40.8)	22,773 (23.8)
41+ weeks, n (%)	297,534 (20.5)	2,252,777 (15.6)	27,825 (29.1)
Mother's age ≥35 years – n (%)	146,339 (10.7)	2,087,544 (14.4)	20,807 (21.8)

Table 2: Neonatal mortality rate (per 10,000) by patient characteristics, provider, and location (2008–2012).

NNM per 10,000 (n/total)	Certified nurse midwife-attended hospital births (n=1,363,199)	Physician-attended hospital births (n=14,447,355)	Midwife-attended home births (n=95,657)	Physician-attended hospital births RR [95% CI]	Midwife-attended home births RR [95% CI]
Neonatal mortality per 10,000 (n/total)	3.52 (480)	6.02 (8,695)	12.75 (122)	1.71 [1.6–1.9]	3.62 [3–4.4]
Marriage status					
Married	3.02 (234/775,511)	5.18 (4519/8,725,378)	12.99 (113/86,972)	1.71 [1.5–2]	4.31 [3.4–5.4]
Unmarried	4.19 (246/587,688)	7.3 (4176/5721977)	10.36 (9/8,685)	1.74 [1.5–2]	2.48 [1.3–4.8]
Race					
White non-Hispanic	3.57 (260/728,918)	5.99 (4,663/7,779,467)	13.21 (112/84,759)	1.68 [1.5–1.9]	3.71 [3–4.6]
Others	3.47 (220/634,281)	6.05 (4,032/6,667,888)	9.18 (10/10,898)	1.74 [1.5–2]	2.65 [1.4–5]
Parity					
Para=0	3.7 (200/540,582)	6.06 (3,574/5,896,748)	19.76 (45/22,773)	1.64 [1.4–1.9]	5.34 [3.9–7.4]
Para>0	3.4 (280/822,617)	5.99 (5,121/8,550,607)	10.56 (77/72,884)	1.76 [1.6–2]	3.1 [2.4–4]
Weeks' gestation					
≥37 to <41 weeks	3.49 (378/1,083,665)	6.14 (7,487/12,194,578)	11.35 (77/67,832)	1.76 [1.6–1.9]	3.25 [2.6–4.2]
≥41 weeks	3.65 (102/279,534)	5.36 (1,208/2,252,777)	16.17 (45/27,825)	1.47 [1.2–1.8]	4.43 [3.1–6.3]
Mother's age					
Mother's age <35 years	3.53 (429/1,216,860)	6.09 (7,527/12,359,811)	12.29 (92/74,850)	1.73 [1.6–1.9]	3.49 [2.8–4.4]
Mother's age ≥35 years	3.49 (51/146,339)	5.6 (1168/2,087,544)	14.42 (30/20,807)	1.61 [1.2–2.1]	4.1 [2.6–6.5]

Reference: Certified nurse midwife attended hospital births=1.

RR: 3.6 (95% CI 3–4.4), followed by hospital physician births (8,695/14,447,355 NNM 6.02/10,000; RR: 1.7 95% CI 1.6–1.9) and hospital midwife births (480/1,363,199 NNM 3.52/10,000 RR: 1).

The NNM rate for nulliparous women among midwife-assisted home births was significantly higher than for midwife-assisted hospital births: 19.97/10,000 versus 3.7/10,000 births; (RR=5.34; 95% CI 3.9–7.4). The NNM among postterm pregnancies (≥41 weeks) in midwife-assisted home births was significantly higher than in midwife-assisted hospital births (16.17 versus 3.65/10,000 births; RR 4.43 95% CI 3.1–6.3).

Characteristics of patients delivering in the hospital such as parity and postdates had no significant discernible effect on the risk of neonatal deaths.

Underlying causes of neonatal death

There were 583 different ICD-10 diagnoses identified as underlying causes of neonatal deaths among the 9297 total neonatal deaths. Of these 583 diagnoses, 25 were due to labor and delivery issues, 78 to infections, 217 to congenital malformations, and 263 were others. Table 3 and Figure 1 show the distribution of causes of underlying neonatal deaths by categories of provider and birth location. The major underlying cause of NNM for the study population were congenital anomalies (50.2%; n=4666), followed by others (27.9%; n=2594), labor and delivery issues (13.2%; n=1225), and infections (8.7%; n=812).

Among midwife-assisted home births, underlying causes attributed to labor and delivery caused 39.3% (48/122)

Table 3: Rate per 10,000 births and relative risk of underlying causes of neonatal deaths (day 0–27 post partum) by care provider and location.

Underlying causes of NNM	Hospital midwife (n=1,363,199) Per/10,000 (n)	Hospital MD (n=14,447,355) Per 10,000 (n)	Home birth midwife (n=95,657) Per/10,000 (n)	Home birth midwife vs. hospital midwife RR [95% CI]	Home birth midwife vs. hospital MD RR [95% CI]	Hospital MD vs. hospital midwife RR [95% CI]
Labor and delivery	0.37 (51)	0.78 (1,126)	5.02 (48)	13.4 [9–19.9]	6.4 [4.8–8.6]	2.1 [1.6–2.8]
Infection	0.34 (47)	0.52 (750)	1.57 (15)	4.5 [2.5–8.1]	3 [1.8–5.0]	1.5 [1.1–2.0]
Congenital anomalies	1.5 (205)	3.06 (4,425)	3.76 (36)	2.5 [1.8–3.6]	1.2 [0.9–1.7]	2 [1.8–2.3]
Others	1.3 (177)	1.66 (2,394)	2.4 (23)	1.9 [1.2–2.9]	1.5 [1–2.2]	1.3 [1.1–1.5]
Total	3.52 (480)	6.02 (8,695)	12.75 (122)	3 [3–4.4]	2.2 [1.7–2.5]	1.7 [1.6–1.9]

Reference: Hospital midwives RR=1.

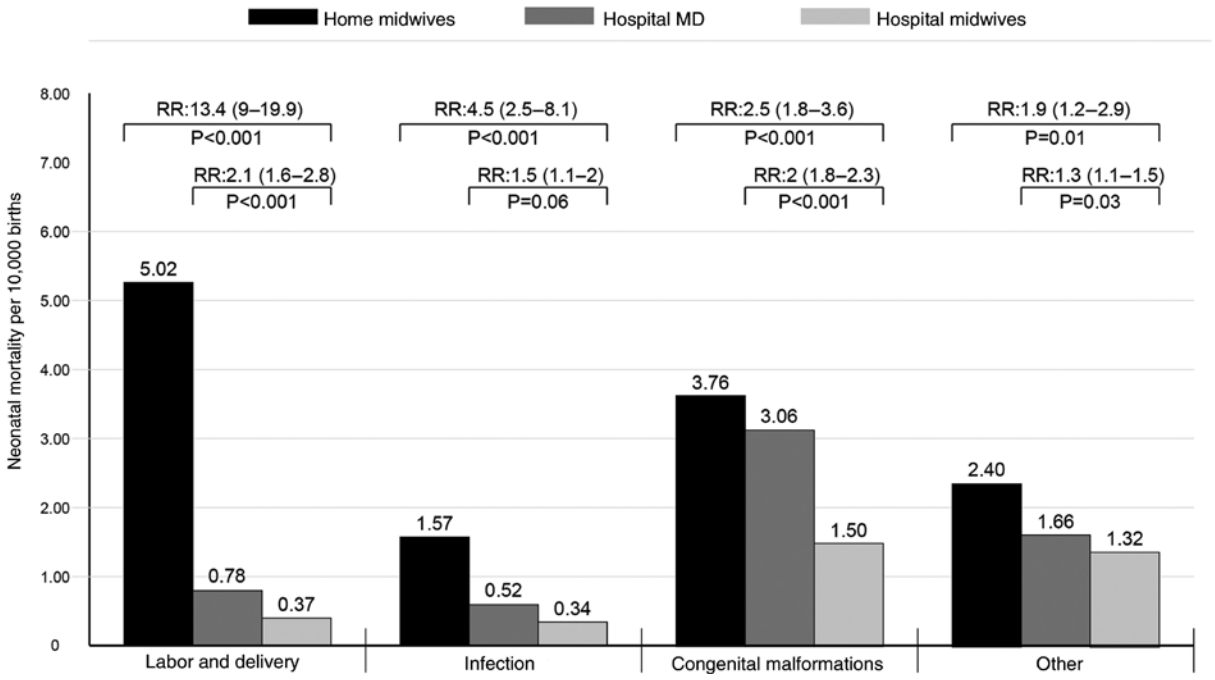

Figure 1: Relative risk of neonatal deaths by underlying causes and birth attendants.

of neonatal deaths (RR: 13.4; 95% CI 9–19.9) followed by 29.5% due to congenital anomalies (RR: 2.5; 95% CI 1.8–3.6), and 12.3% due to infections (RR: 4.5; 95% CI 2.5–8.1).

Among hospital births the main underlying cause of neonatal deaths was attributable to congenital malformations: 51% for physicians (4425/8695) and 43% for hospital midwives (205/480) while labor and delivery issues as underlying causes of NNM constituted 10.6% of hospital midwife births and 12.9% of MD births.

Table 4 shows the individual ICD-10 underlying causes of labor and delivery associated neonatal deaths by location and providers. The most frequent individual causes of neonatal deaths associated with labor and delivery issues at home births was a combination of brain-damaging conditions including hypoxic ischemic encephalopathy, birth asphyxia, intrauterine hypoxia, and others: 2.3/10,000 births versus 0.21/10,000 in hospital midwife deliveries; RR: 3.55 (95% CI 1.95–6.46) which constituted 18% of all homebirth-associated deaths as compared to 8.6% of neonatal deaths among physician and 5.5% among all midwife-assisted hospital births.

Comment

Our study shows that the significantly increased risks of neonatal deaths among midwife-attended home births are associated with three underlying causes: labor and delivery issues, infections, and fetal malformations. Each of these underlying causes was significantly increased when compared to midwife-attended hospital births.

The hospital NNM in our study is similar to the NNM reported for 2010 in the US by Matthews and MacDorman [7]. This study's significantly elevated term NNM of 12.75/10,000 births for home births confirms the increased neonatal mortality risks reported among midwife-attended home births by other US home birth studies: Cheyney et al. [14] reported a NNM of 12.3/10,000 from 2004 to 2009 and Grunebaum et al. [1] reported a term NNM for home births of 12.6/10,000 from 2006 to 2009. Other studies on homebirth outcomes such as studies from the Netherlands, Ontario and British Columbia, where homebirths are well integrated in the health system, found no increased risk of adverse perinatal outcomes for planned home births among low-risk women [15–18]. However, these conclusions apply to regions where home births are well integrated into the maternity care system, and are therefore not generalizable to current practice in the US [19].

The increased risk of neonatal deaths caused by labor and delivery issues in midwife-attended home births is striking when compared not only to midwife-attended hospital birth but also physician-attended hospital births. The most frequent individual causes of neonatal deaths associated with labor and delivery issues at home births was a combination of brain damage conditions. Hospital settings

Table 4: ICD-10 cause of labor and delivery-associated neonatal deaths by location and provider.[a]

ICD-10 Code	Hospital midwife NNM=480	Hospital physician NNM=8,695	Home midwife NNM=122	RR home midwife vs. hospital midwife OR [95% CI]
P91.6 (Hypoxic ischemic encephalopathy of newborn); G93.1 (Anoxic brain damage, not elsewhere classified); P21.9 (Birth asphyxia, unspecified); P20.9 (Intrauterine hypoxia, unspecified); P21.0 (Severe birth asphyxia); P91.0 (Neonatal cerebral ischaemia); P11.2 (Unspecified brain damage due to birth injury); P10.1 (Cerebral hemorrhage due to birth injury); P11.1 (Other specified brain damage due to birth injury)	5.8% (28)	8.6% (747)	18% (22)	3.55 [1.95–6.46]
P24.0 (Neonatal aspiration of meconium); P24.1 (Neonatal aspiration of amniotic fluid and mucus)	3.1% (15)	1.2% (108)	4.9% (6)	1.60 [0.61–4.22]
P02.5 (Newborn affected by other compression of umbilical cord); P02.4 (Newborn affected by prolapsed cord); P50.1 (Fetal blood loss from ruptured cord);	0	0.4% (39)	4.9% (6)	Infinite
P03.1 (Newborn affected by other malpresentation, malposition and disproportion during labour and delivery); P03.0 (Newborn affected by breech delivery and extraction)	0.2% (1)	0.1% (9)	6.6% (8)	33.61 [4.16–271.46]
P02.7 (Newborn affected by chorioamnionitis)	0.4% (2)	0.3% (30)	3.3% (4)	8.10 [1.47–44.76]
P03.5 (Newborn affected by precipitate delivery); P15.0 (Birth injury to liver); P03.8 (Newborn affected by other specified complications of labour and delivery); P03.9 (Newborn affected by complication of labour and delivery, unspecified); P15.9 (Birth injury, unspecified); P15.9 (Birth injury, unspecified); P15.8 (Other specified birth injuries); P80.9 (Hypothermia of newborn, unspecified); P02.1 (Newborn affected by other forms of placental separation and hemorrhage);	1% (5)	2.2% (193)	1.6% (2)	1.58 [0.3–8.26]

[a]% as a percent of all neonatal deaths for the group.

usually include safety features and life-saving interventions [20]. Very few of these are available in a home birth setting.

Though planned cesarean delivery for breech presentation at term is safer, [21] vaginal deliveries of breech presentations are frequent in home births [22]. Attempting a safe breech vaginal delivery requires ultrasound, electronic fetal monitoring, and immediate access cesarean delivery or specified maneuvers and analgesia, [23–25] all of which are unavailable at home births. A recent review of planned midwife-assisted home births, even though voluntary, showed an increased early neonatal mortality among breech presentations of 45.7/10,000 and a late neonatal mortality of 4.59/10,000 births or an increase of 1169% and 1430%, respectively over vertex presentations [14].

An estimated 10%–30% of pregnant women are colonized with group B streptococcus (GBS) and GBS infection of the newborn can be fatal in 5% of babies who carry it [26]. Routine antibiotic prophylaxis of GBS positive carriers has substantially decreased the incidence of newborn GBS disease, [26] and the CDC recommends intravenous antibiotic treatment in labor of patients with GBS carriage [27]. Prompt diagnosis of chorioamnionitis and timely treatment with broad-spectrum antibiotics can help avert the significant short-term and long-term consequences that may result [28]. Patients at home births do not usually have intravenous access and thus have no effective intravenous antibiotic treatment, thus placing newborns at increased risks of infection and subsequent neonatal morbidity and mortality.

Induction of labor can reduce the time to delivery and the rates of perinatal infections [29], and has been reported to decrease the incidence of chorioamnionitis without increasing cesarean delivery rates [30]. In cases of premature rupture of membranes (PROM), induction of labor in term pregnancies has been recommended [31]. The increase of infection related neonatal deaths among home births may

be partly explained by the absence of safe induction of labor at home and delays in transfer to the hospital, potentially leading to prolonged rupture of fetal membranes and an increase of neonatal infection and morbidity and mortality risks. The evidence presented in our paper is not compatible with the claim that planned home birth has a lower risk of perinatal infection than hospital birth.

Postnatal intervention and neonatal expert management immediately following delivery may be required to improve outcome in a neonate with a significant anomaly such as a cardiac lesion, diaphragmatic hernia, or gastroschisis [32, 33]. These are unavailable at home births. The increase in congenital malformations in this study as a cause of neonatal mortality among home births may be due to a mother who may consciously decide to deliver at home when the diagnosis of a significant anomaly such as a significant chromosomal syndrome or anencephaly was made prior to labor and delivery and there is certainty that the child will die shortly after birth. Or, it may be a reflection of antepartum unawareness of a congenital malformation.

Risk selection among attended home births

There are multiple increased risks at midwife-attended home births such as postdates, breech presentations, and trial of labor after cesarean which may explain the increase of underlying causes of neonatal mortality in this study [22]. Nulliparity is a risk factor for neonatal encephalopathy [34] and our study's findings of increased NNM among nulliparous women confirm other reports of increased poor neonatal outcomes among women in planned home births with their first pregnancy [35] leading Buekens [36] to recommend that nulliparous women should be discouraged from having home births. According to the Birthplace in England study [35] after a strict selection process women planning birth in a midwifery unit and multiparous women planning birth at home experience fewer interventions than those planning birth in an obstetric unit with no impact on perinatal outcomes although nulliparous women who planned home births also have fewer interventions but have poorer perinatal outcomes.

The American College of Obstetricians and Gynecologists (ACOG) and the American Academy of Pediatrics (AAP) consider a gestational age over 41 weeks, breech presentation and prior cesarean deliveries contraindications to attempted home births, and recommend that only American Midwifery Certification Board (AMCB) certified midwives attend home births [19, 37]. Guidelines for midwives performing planned home births in other countries such as Australia, New Zealand, Canada, the Netherlands, and England specifically exclude risk patients from their home-birth eligibility requirement [35, 38, 39]. A review of perinatal deaths identified inappropriate risk inclusions at home births and inadequate fetal surveillance during labor as a contributing cause in perinatal deaths [40]. In the US, at least 30% of midwife-attended home births are not low risk according to ACOG/AAP recommendations [22]. There has been an increase in the number of women with prior cesarean section delivering at home by midwives, [41] notwithstanding the fact that women with planned VBAC at home have significantly increased neonatal morbidity and mortality risks [42]. In addition, about 2/3 of all midwife-attended home births in the US are attended by midwives who are not certified by the American Midwifery Certification Board (AMCB) [22].

There are presently no national or state midwifery risk guidelines for homebirths, and, according to Cook who queried US midwives, there was less support for national home birth guidelines among midwives, and their primary concern was that an adoption of national guidelines could compromise provider autonomy [43]. At the present time, the only national US homebirth risk guidelines have been established by two physician organizations, ACOG and AAP [19, 37].

The neonatal mortality rate for hospital births attended by physicians when compared to midwife-attended home births was over 50% lower (6.02 vs. 12.75/10,000) while hospital births attended by midwives had a nearly 40% lower neonatal mortality rate when compared to physician attended hospital births (3.52 vs. 6.02/10,000). The difference of neonatal mortality between midwife and physician-attended hospital births is likely due to higher patient acuity and increased risks of physician-attended hospital births. Transfers of high-risk women from midwives to physicians would further add to the acuity. Nonetheless, the superior outcomes in midwife deliveries in the hospital combined with a decrease in interventions [35] supports the essential value of midwives in low-risk women in hospitals.

Patient safety at home birth versus hospital birth

Patient safety measures in hospitals can improve obstetric outcomes [44–46] and can decrease cesarean delivery rates [47]. The home birth location, without advanced equipment or breadth of well-trained obstetric or neonatal personnel, the majority of whom are not certified by the AMCB, remote locations and delays in transportation, as well as inadequate essential clinical services, conceivably leads to sub-optimal patient safety and preventable

adverse outcomes such as increased neonatal and delivery related perinatal deaths and low Apgar scores [1–4].

Hospital physicians manage both low-risk and high-risk pregnancies. It is therefore striking that risks of neonatal mortality and causes of neonatal deaths in physician-attended hospital births were markedly lower when compared to midwife-attended home births.

Strength and limitations

The strength of this study is that the CDC birth and death certificate data are nationally comprehensive. No comparable database exists. This dataset is being used regularly to report on infant, neonatal and postneonatal mortality statistics [7, 48, 49]. The data elements used in this study have been shown to be accurate and reliable [50–52].

Prospective randomized studies might be more precise in informing us about detailed outcomes between home and hospital births as an intention-to-treat design. However, given documented increased risks of perinatal morbidity and mortality in planned home births, [14] evidence-based equipoise, an essential requirement for a prospective randomized study, does not exist [53]. Moreover, the only prospective trial including 37,735 normal infants with a gestational age ≥37 weeks within a Dutch region, though it compares unequal groups, similarly found that the overall perinatal death rate was significantly higher for nulliparous when compared to multiparous women (RR: 1.65, 95% CI: 1.11–2.45) [54].

There are several limitations of our study. The actual number of patients with increased neonatal deaths in home births is possibly underestimated because the neonatal deaths in the linked CDC database only capture those who deliver at home, not those transferred from an attempted home birth to the hospital prior to birth. These transfers have been estimated in a British study to be about 20% of all births, and even higher (44%) in nulliparous patients, [55] and have likely an increase in adverse outcome [56]. Another limitation is the use of an administrative database which was originally not intended for research. The small number of individual ICD-10 diagnostics codes for infection and congenital malformations in the home birth setting did not permit a meaningful sub-analysis of the individual diagnoses within these groups. One limitation is that we compared midwife-attended home births with hospital births attended by midwives and physicians. If at all, this comparison would have an impact on hospital births as it would include more risk patients. Our study only included neonatal deaths, as the CDC linked file does not have information on morbidity of surviving neonates. The CDC linked database only includes birth certificate data on live born infants and does not have information on stillbirths as these do not have birth certificates. Finally, a planned home birth may have been a conscious choice by some women in case of previously diagnosed lethal fetal malformations with a hopeless prognosis and the desire to be in a more personal environment.

Conclusion

The significantly increased risks of neonatal deaths among midwife-attended home births are associated with three underlying causes: labor and delivery issues, infections, and fetal malformations. Each of these underlying causes was significantly increased when compared to midwife-attended hospital births. This analysis of the causes of neonatal death in planned home birth shows that it is consistently riskier for newborns to deliver at home than at the hospital. As part of the informed consent process physicians, midwives, and other health care providers have a professional responsibility to share information about the clinical benefits and risks of clinical management [57, 58] The increased risks of neonatal deaths at home births should therefore be disclosed to all women who are contemplating planned home births.

References

[1] Grünebaum A, McCullough LB, Sapra KJ, Brent RL4, Levene MI5, Arabin B, et al. Early and total neonatal mortality in relation to birth setting in the United States, 2006–2009. Am J Obstet Gynecol. 2014;211:390.e1–7.
[2] Cheng YW, Snowden JM, King TL, Caughey AB. Selected perinatal outcomes associated with planned home births in the United States. Am J Obstet Gynecol. 2013;209:325.e1–8.
[3] Wax JR, Lucas FL, Lamont M, Cartin A, Blackstone, J. Maternal and newborn outcomes in planned home birth vs planned hospital births: a metaanalysis. Am J Obstet Gynecol. 2010;203:243.e1–8.
[4] Grünebaum A, McCullough LB, Sapra KJ, Brent RL, Levene MI, Arabin B, et al. Apgar score of zero at five minutes and neonatal seizures or serious neurologic dysfunction in relation to birth setting. Am J Obstet Gynecol. 2013;209:323. e1–6.
[5] National Center for Health Statistics. Vital Statistics Data Available Online: Birth Data Files. Available at: http://www.cdc.gov/nchs/data_access/VitalStatsOnline.htm (last accessed April 15, 2015).
[6] http://www.cdc.gov/reproductivehealth/maternalinfanthealth/infantmortality.htm (last accessed 5/2/2015).
[7] Matthews TJ, MacDorman MF. Infant mortality statistics from the 2010 period linked birth/infant death data set. Natl Vital Stat Rep. 2013;62:1–26.

[8] Tolson GC, Barnes JM, Gay GA, Kowaleski JL. The 1989 revision of the U.S. standard certificates and reports. National Center for Health Statistics. Vital Health Stat 4. 1991:1–34. http://www.cdc.gov/nchs/data/dvs/std-dcrt.pdf.
[9] Murphy SL, Xu J, Kochanek KD. Deaths: final data for 2010. National vital statistics reports; vol 61 no 4. Hyattsville, MD: National Center for Health Statistics, 2013.
[10] Documentation for the mortality public use data set, 1999 Last accessed April 5, 2015: http://www.cdc.gov/nchs/data/dvs/mort99doc.pdf.
[11] U.S. Standard Certificate of Death: http://www.cdc.gov/nchs/data/dvs/death11-03final-acc.pdf accessed May 5, 2015.
[12] Dean AG, Sullivan KM, Soe MM. OpenEpi: open source epidemiologic statistics for public health, version 2.3.1. Updated June 23, 2011. Available at: www.OpenEpi.com. Last accessed May 1, 2015.
[13] World Health Organization. International statistical classification of diseases and related health problems, tenth revision. Geneva. 1992.
[14] Cheyney M, Bovbjerg M, Everson C, Gordon W, Hannibal D, Vedam S. Outcomes of care for 16,924 planned home births in the United States: the midwives alliance of North America Statistics Project, 2004 to 2009. J Midwifery Womens Health. 2014;59:11–27.
[15] de Jonge A, Geerts CC, van der Goes BY, Mol BW, Buitendijk SE, Nijhuis JG. Perinatal mortality and morbidity up to 28 days after birth among 743 070 low-risk planned home and hospital births: a cohort study based on three merged national perinatal databases. Br J Obstet Gynaecol. 2015;122:720–8.
[16] Anderson RE, Murphy PA. Outcomes of 11,788 planned home births attended by certified nurse-midwives. A retrospective descriptive study. J Nurse Midwifery. 1995;40:483–92.
[17] Murphy PA, Fullerton J. Outcomes of intended home births in nurse-midwifery practice: a prospective descriptive study. Obstet Gynecol. 1998;92:461–70.
[18] Johnson KC, Daviss BA. Outcomes of planned home births with certified professional midwives: large prospective study in North America. Br Med J. 2005;330:1416.
[19] Committee opinion no. 669: planned home birth. Obstet Gynecol. 2016;128:e26–31.
[20] American College of Obstetricians and Gynecologists Committee on Patient Safety and Quality Improvement. Committee opinion no. 590: preparing for clinical emergencies in obstetrics and gynecology. Obstet Gynecol. 2014;123:722–5.
[21] Joseph KS, Pressey T, Lyons J, Bartholomew S, Liu S, Muraca G, et al. Once more unto the breech: planned vaginal delivery compared with planned cesarean delivery. Obstet Gynecol. 2015;125:1162–7.
[22] Grünebaum A, McCullough LB, Brent RL, Arabin B, Levene MI, Chervenak FA. Perinatal risks of planned home births in the United States. Am J Obstet Gynecol. 2015;212:350.e1–6.
[23] ACOG Committee Opinion No. 340. Mode of term singleton breech delivery. (ACOG Committee on Obstetric Practice) Obstet Gynecol. 2006;108:235–7.
[24] Hannah ME, Hannah WJ, Hewson SA, Hodnett ED, Saigal S, Willan AR. Planned cesarean section versus planned vaginal birth for breech presentation at term: a randomized multicenter trial; term breech trial collaborative group. Lancet. 2000;356:1375–83.
[25] Azria E, Le Meaux JP, Khoshnood B, Alexander S, Subtil D, Goffinet F; PREMODA Study Group. Factors associated with adverse perinatal outcomes for term breech fetuses with planned vaginal delivery. Am J Obstet Gynecol. 2012;207:285.e1–9.
[26] Schrag SJ, Zywicki S, Farley MM, Reingold AL, Harrison LH, Lefkowitz LB, et al. Group B streptococcal disease in the era of intrapartum antibiotic prophylaxis. N Engl J Med. 2000;342:15–20.
[27] Verani JR, McGee L, Schrag SJ; Prevention of perinatal group B streptococcal disease – revised guidelines from CDC, 2010. MMWR Recomm Rep. 2010;59:1–36.
[28] Johnson CT, Farzin A, Burd I. Current management and long-term outcomes following chorioamnionitis. Obstet Gynecol Clin North Am. 2014;41:649–69.
[29] Dare MR, Middleton P, Crowther CA, Flenady VJ, Varatharaju B. Planned early birth versus expectant management (waiting) for prelabour rupture of membranes at term (37 weeks or more). Cochrane Database Syst Rev. 2006;1:CD005302.
[30] López-Zeno JA, Peaceman AM, Adashek JA, Socol ML, A controlled trial of a program for the active management of labor. N Engl J Med. 1992;326:450–4.
[31] ACOG Practice Bulletin No. 139: Premature rupture of membranes. American College of Obstetricians and Gynecologists. Obstet Gynecol. 2013;122:918–30.
[32] Johnson BA, Ades A. Delivery room and early postnatal management of neonates who have prenatally diagnosed congenital heart disease. Clin Perinatol. 2005;32:921–46, ix.
[33] Werlein A, Goebert P, Maier RF. Planning delivery in cases of congenital malformations from the neonatologist's point of view]. Z Geburtshilfe Neonatol. 2014;218:27–33.
[34] Spain JE, Tuuli MG, Macones GA, Roehl KA, Odibo AO, Cahill AG. Risk factors for serious morbidity in term nonanomalous neonates. Am J Obstet Gynecol. 2015;212:799.e1–7.
[35] Birthplace in England Collaborative Group, Brocklehurst P, Hardy P, Hollowell J, Linsell L, Macfarlane A, et al. Perinatal and maternal outcomes by planned place of birth for healthy women with low risk pregnancies: the birthplace in England national prospective cohort study. Br Med J. 2011;343:d7400.
[36] Buekens P, Keirse MJ. In the literature: home birth: safe enough, but not for the first baby. Birth. 2012;39:165–7.
[37] American Academy of Pediatrics: Policy Statement Planned Home birth. Pediatrics. 2013:131:1016–20.
[38] Commissie Verloskunde van het CVZ. Verloskundig Vademecum 2003. Diemen, the Netherlands: College voor Zorgverzekeringen, 2003.
[39] Janssen PA, Saxell L, Page LA, Klein MC, Liston RM, Lee SK. Outcomes of planned home birth with registered midwife versus planned hospital birth with midwife or physician. [published erratum appears in] Can Med Assoc J. 2009;181:377–83.
[40] Kennare RM, Keirse MJ, Tucker GR, Chan AC. Planned home and hospital births in South Australia, 1991–2006: differences in outcomes. Med J Aust. 2010;192:76–80.
[41] Macdorman MF, Declercq E, Mathews TJ, Stotland N. Trends and characteristics of home vaginal birth after cesarean delivery in the United States and selected States. Obstet Gynecol. 2012;119:737–44.
[42] Cox KJ, Bovbjerg ML, Cheyney M, Leeman LM. Planned home VBAC in the United States, 2004–2009: outcomes, maternity care practices, and implications for shared decision making. Birth. 2015;42:299–308.

[43] Cook E, Avery M, Frisvold M. Formulating evidence-based guidelines for certified nurse-midwives and certified midwives attending home births. J Midwifery Womens Health. 2014;59:153–9.
[44] Grunebaum A, Chervenak F, Skupski D. Effect of a comprehensive obstetric patient safety program on compensation payments and sentinel events. Am J Obstet Gynecol. 2011;204:97–105.
[45] Weiner E, Bar J, Fainstein N, Ben-Haroush A, Sadan O, Golan A, et al. The effect of a program to shorten the decision-to-delivery interval for emergent cesarean section on maternal and neonatal outcome. Am J Obstet Gynecol. 2014;210:224.e1–6.
[46] Kirschbaum KA, Rask JP, Brennan M, Phelan S, Fortner SA. Improved climate, culture, and communication through multidisciplinary training and instruction. Am J Obstet Gynecol. 2012;207:200.e1–7.
[47] Grunebaum A, Dudenhausen J, Chervenak FA, Skupski D. Reduction of cesarean delivery rates after implementation of a comprehensive patient safety program. J Perinat Med. 2013;41:51–5.
[48] Matthews TJ, MacDorman MF. Infant mortality statistics from the 2008 period linked birth/infant death data set. Natl Vital Stat Rep. 2012;60:1–27.
[49] Matthews TJ, MacDorman MF. Infant Mortality statistics from the 2009 period linked birth/infant death data set. Natl Vital Stat Rep. 2013;61:1–27.
[50] DiGiuseppe DL, Aron DC, Ranbom L, Harper DL, Rosenthal GE. Reliability of birth certificate data: a multi-hospital comparison to medical records information. Mat Child Health J. 2002;6:169–79.
[51] Zollinger TW, Przybylski MJ, Gamache RE. Reliability of Indiana birth certificate data compared to medical records. Ann Epidemiol. 2006;16:1–10.
[52] Northam S, Knapp TR. The reliability and validity of birth certificates. J Obstet Gynecol Neonatal Nurs. 2006;35:3–12.
[53] Brody BA, McCullough LB, Sharp RR. Consensus and controversy in clinical research ethics. J Am Med Assoc. 2005;294:1411–4.
[54] Evers AC, Brouwers HA, Hukkelhoven CW, Nikkels PG, Boon J, van Egmond-Linden A, et al. Perinatal mortality and severe morbidity in low and high risk term pregnancies in the Netherlands: prospective cohort study. Br Med J. 2010;341:c5639.
[55] Rowe RE, Townend J, Brocklehurst P, Knight M, Macfarlane A, McCourt C, et al. Duration and urgency of transfer in births planned at home and in freestanding midwifery units in England: secondary analysis of the birthplace national prospective cohort study. BMC Pregnancy Childbirth. 2013;13:224.
[56] Bix E, Kumle M, Kjærgaard H, Øian P, Lindren HE. Transfer to hospital in planned home births: a systematic review. BMC Pregnancy Childbirth. 2014;14:179.
[57] Chervenak FA, McCullough LB, Brent RL, Levene MI, Arabin B. Planned home birth: the professional responsibility response. Am J Obstet Gynecol. 2013;208:31–8.
[58] Chervenak FA, McCullough LB, Grünebaum A, Arabin B, Levene MI, Brent RL. Planned home birth in the United States and professionalism: a critical assessment. J Clin Ethics. 2013;24:184–91.

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