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# Tropical Medicine & International Health

## Characteristics of neonatal near-miss in hospitals in Benin, Burkina Faso and Morocco in 2012-2013 --Manuscript Draft--

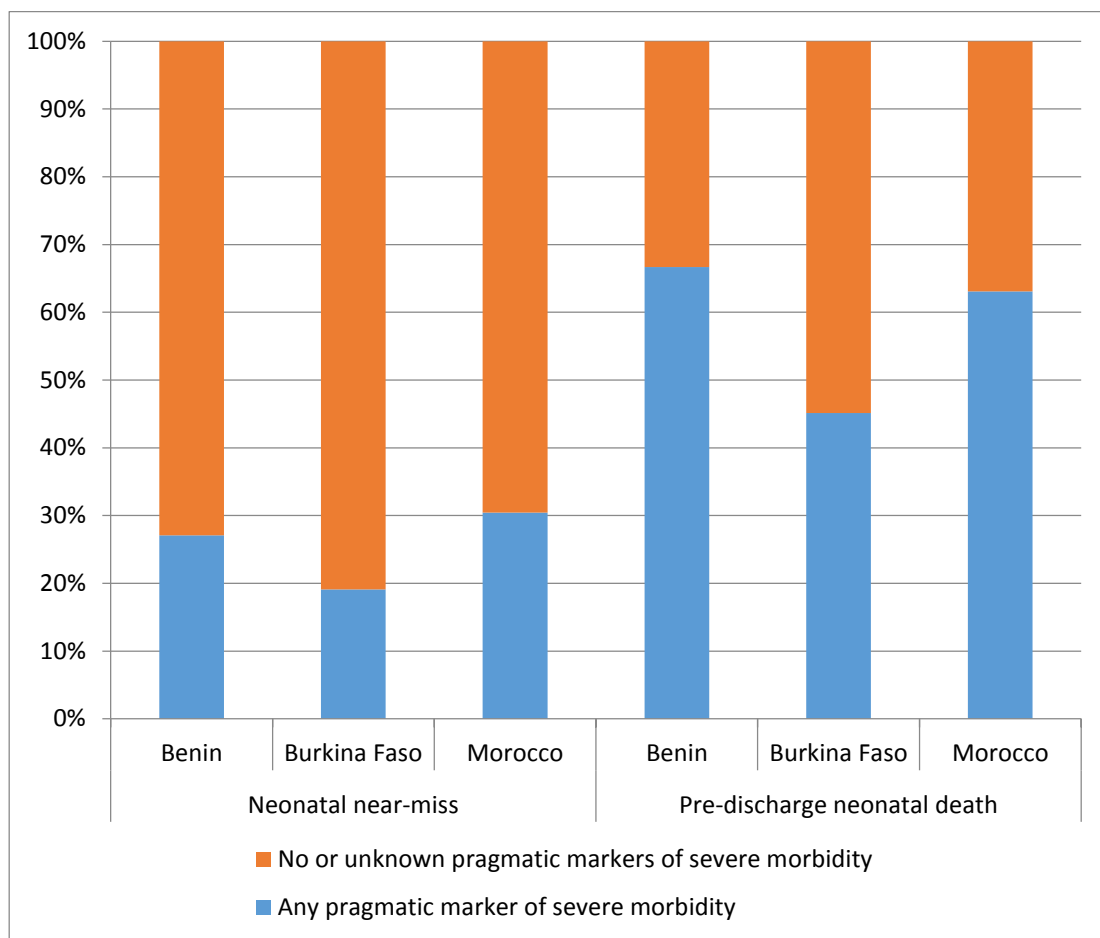
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<b>Abstract:</b>	<p><b>Objective</b> To examine the incidence of neonatal near-miss and pre-discharge neonatal deaths across various risk categories (low 5 minute Apgar score, low birth weight, low gestational age, maternal near-miss, and caesarean sections) in 17 hospitals in Benin, Burkina Faso and Morocco</p> <p><b>Methods</b> Data were collected on all maternal deaths, maternal near-miss, neonatal near-miss (based on organ-dysfunction markers), caesarean sections, stillbirths, neonatal deaths before discharge and non-cephalic presentations; and on a sample of births not falling in any of the above categories.</p> <p><b>Findings</b> The burden of stillbirth, pre-discharge neonatal death or neonatal near-miss ranged from 23 to 129 per 1000 births in Moroccan and Beninese hospitals respectively. Perinatal deaths (range 17-89 per 1000 births) were more common than neonatal near-miss (range 6-43 per 1000 live births) in all countries, and between a fifth and a third of women who had suffered a maternal near-miss lost their baby before being</p>

discharged from hospital. Pre-discharge neonatal deaths and neonatal near-miss had a similar distribution of markers of organ-dysfunction, but unlike pre-discharge neonatal deaths most neonatal near-miss (63%, 81% and 71% in Benin, Burkina Faso and Morocco respectively) occurred among babies who were not considered premature, low birth weight or with a low 5 minute Apgar score as defined by WHO's pragmatic markers of severe neonatal morbidity

#### Conclusion

Whether the quantitative measurement of neonatal near-miss adds useful insights into the quality of perinatal or newborn care in settings where facility-based intrapartum and early newborn mortality is very high is uncertain. Perhaps the greatest advantage of adding near-miss is the shift in focus from failure to success so that lessons can be learned on how to save lives even when clinical conditions are life-threatening

**Figure 1: Proportion of neonatal near-miss and pre-discharge neonatal deaths with pragmatic markers of severe morbidity (gestational age < 33 weeks, birth weight < 1750 grams or 5 minute Apgar < 7)**



**Figure 2: Incidence of neonatal near-miss and perinatal deaths among caesarean deliveries**

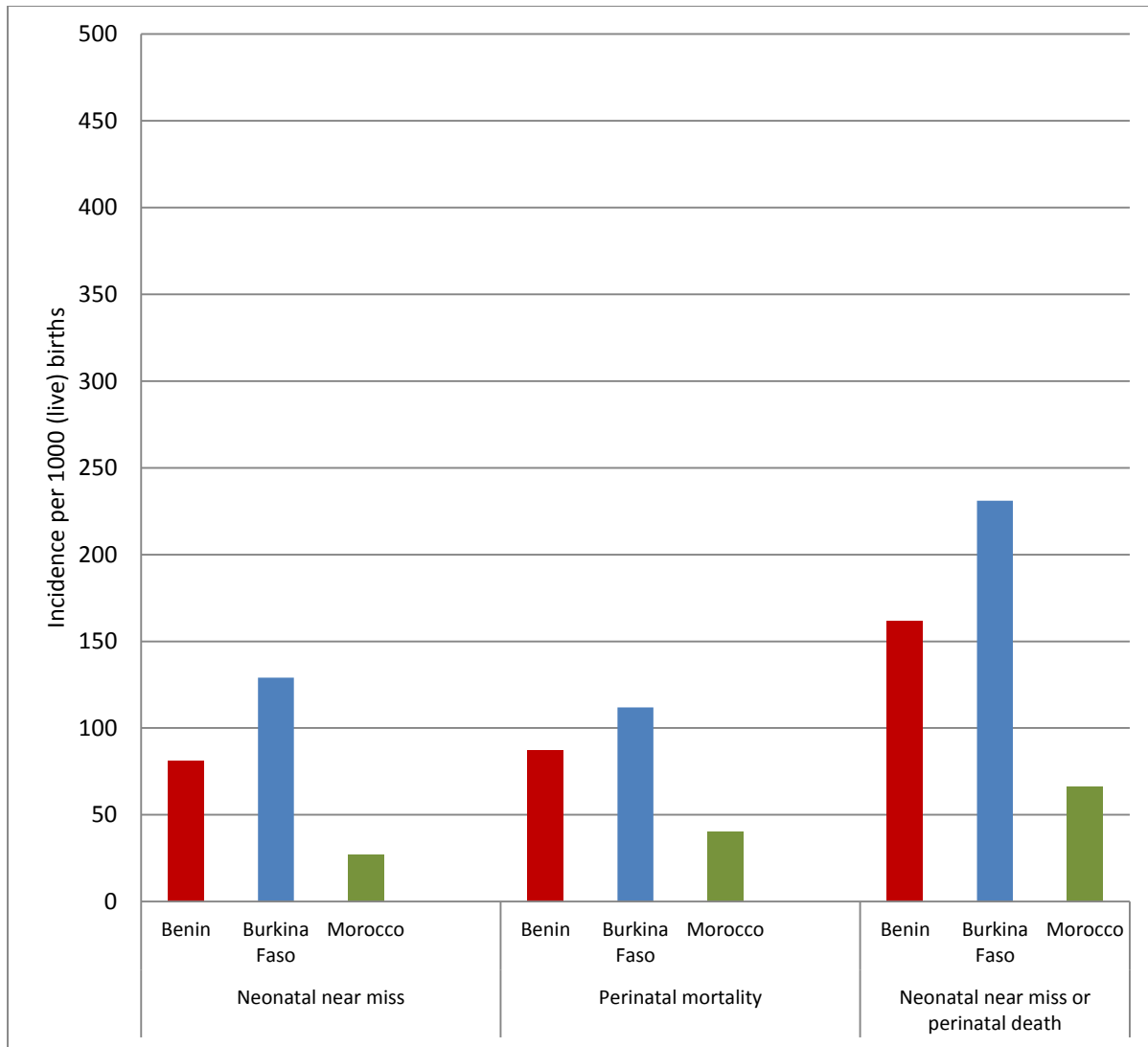


Figure 3: Incidence of neonatal near-miss and perinatal deaths among maternal near-miss cases

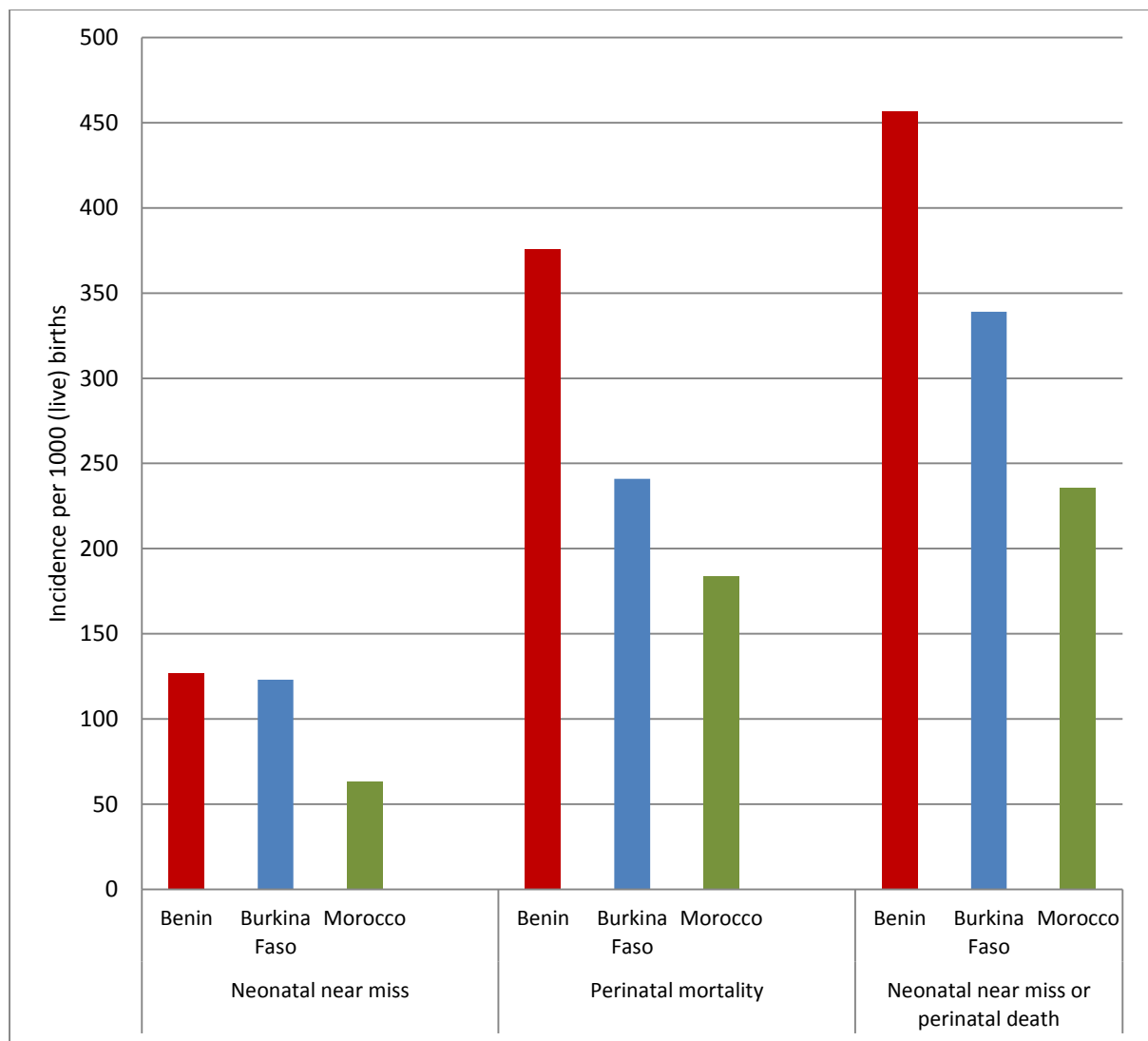
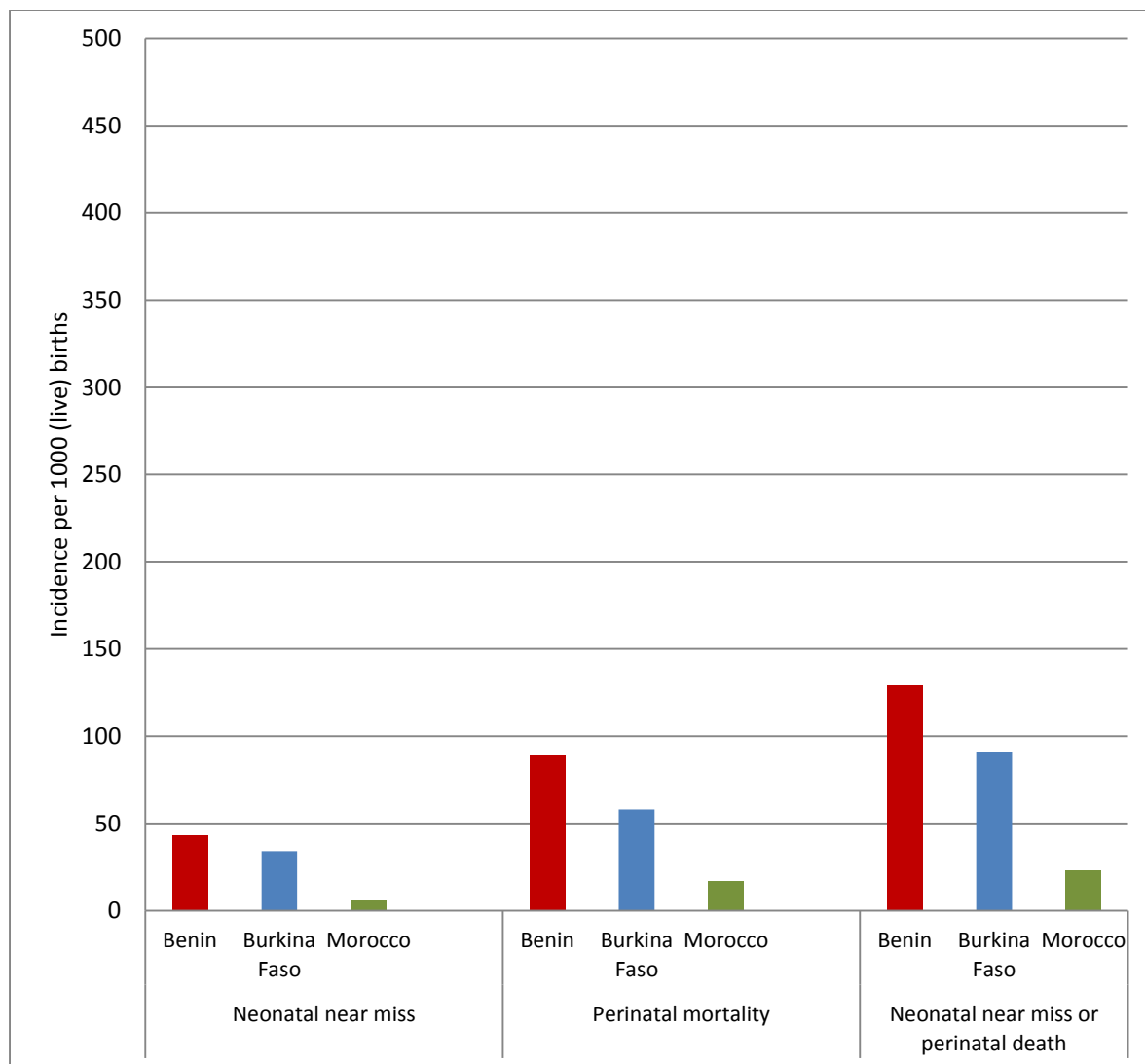


Figure 3: Incidence of neonatal near-miss and perinatal deaths among all facility-based births



**Table 1: Clinical, laboratory and management criteria to identify neonatal near-miss due to organ dysfunction**

<b>Organ system</b>	<b>South African study (Lubega and Pattinson 2010)</b>	<b>This study</b>
<b>Respiratory</b>	Need for intubation and ventilation including nasal continuous airway pressure (CPAP)	Respiratory rate >70/min*; cyanosis; absence of regular breathing pattern; any intubation
<b>Cardiac</b>	Need for adrenalin, other inotropic support or volume expansion	Cardiac arrest; cardio-pulmonary resuscitation; persistent bradycardia <80bpm; persistent tachycardia >200bpm
<b>Hypovolemia</b>	Need for blood transfusion or volume expansion	Use of vasoactive drug; volume expansion; blood transfusion
<b>Central Nervous</b>	Any convulsions or need for therapeutic anticonvulsants	Seizures; use of anticonvulsants; inability to suck
<b>Haematological</b>	Need for phototherapy or exchange blood transfusion, need for neupogen to increase white cells	Visible jaundice in first 24 hours; phototherapy in first 24 hours; any non traumatic bleeding
<b>Endocrine</b>	Need to treat hypoglycaemia (additional glucose)	-
<b>Renal</b>	Haematuria and/or oliguria, anuria	Haematuria; anuria >24 hours
<b>Immunological (congenital infection)</b>	C-reactive protein (CRP) greater than or equal to 10 or a rising CRP	Apathetic, poor tolerance of feeds
<b>Gastro-intestinal, hepatic</b>	Jaundice, nil per os for more than 24 hours	Abdominal distension & vomiting
<b>Musculo-skeletal</b>	Any fracture	Brachial plexus injury; skull fracture

\* In Morocco this was defined as Respiratory rate >100/min



**Table 2: Maternal and neonatal birth outcomes in 17 hospitals in Benin, Burkina Faso and Morocco**

	<b>Benin March-September 2012</b>	<b>Burkina Faso May-November 2012</b>	<b>Morocco February 2012- January 2013</b>	<b>All</b>
<b>Maternal near-miss#</b>	370	224	267	861
<b>Caesarean sections#</b>	1,509	676	1,961	4,146
<b>Stillbirths#</b>	308	151	271	730
<b>Pre-discharge neonatal deaths#</b>	99	82	65	246
<b>Neonatal near-miss#</b>	181	131	115	427
<b>Non-cephalic presentation#</b>	410	183	557	1,150
<b>Sample of births without severe complications#</b>	655	285	3,296	4,236
<b>Total births*</b>	4,550	4,003	19,304	27,857

# Data on complications were obtained from the data in our study, singleton births only \*Data on total births were obtained from routine hospital statistics, singleton and multiple births

**Table 3: Neonatal near-miss and pre-discharge neonatal deaths by organ dysfunction criteria in 17 hospitals in Benin, Burkina Faso & Morocco**

Criteria		Neonatal near-miss			Pre-discharge neonatal deaths		
		Benin	Burkina Faso	Morocco	Benin	Burkina Faso	Morocco
Respiratory	Respiratory rate >70/min	11 (6.1%)	10 (7.6%)	25 (21.7%)	2 (2.0%)	3 (3.7%)	6 (9.2%)
	Cyanosis	76 (42.0%)	45 (34.4%)	68 (59.1%)	32 (32.3%)	10 (12.2%)	17 (26.2%)
	Absence of regular breathing pattern	49 (27.1%)	35 (26.7%)	48 (41.7%)	26 (26.3%)	17 (20.7%)	17 (26.2%)
	Any intubation	0	2 (1.5%)	6 (5.2%)	1 (1.0%)	0	1 (1.5%)
Cardiovascular	Cardiac arrest	1 (0.6%)	4 (3.1%)	1 (0.9%)	38 (38.4%)	0	6 (9.2%)
	Cardio-pulmonary resuscitation	41 (22.7%)	36 (27.5%)	9 (7.8%)	13 (13.1%)	12 (14.6%)	3 (4.6%)
	Persistent bradycardia <80bpm	10 (5.5%)	5 (3.8%)	11 (9.6%)	2 (2.0%)	4 (4.9%)	2 (3.1%)
	Persistent tachycardia >200bpm	2 (1.1%)	0	4 (3.5%)	0	0	0
Hypovolemia	Use of vasoactive drug	0	1 (0.8%)	7 (6.1%)	0	1 (1.2%)	0
	Volume expansion	0	1 (0.8%)	10 (8.7%)	0	0	1 (1.5%)
	Blood transfusion	10 (5.5%)	0	3 (2.6%)	0	1 (1.2%)	0
Central nervous	Seizures	17 (9.4%)	12 (9.2%)	32 (27.8%)	11 (11.1%)	5 (6.1%)	9 (13.8%)
	Use of anticonvulsants	17 (9.4%)	28 (21.4%)	23 (20.0%)	9 (9.1%)	3 (3.7%)	4 (6.2%)
	Inability to suck	12 (6.6%)	26 (19.8%)	2 (1.7%)	5 (5.1%)	7 (8.5%)	2 (3.1%)
Haematological	Visible jaundice in first 24 hours	27 (14.9%)	3 (2.3%)	19 (16.5%)	2 (2.0%)	2 (2.4%)	0
	Phototherapy in first 24 hours	12 (6.6%)	2 (1.5%)	7 (6.1%)	1 (1.0%)	0	0
	Any active non traumatic bleeding	2 (1.1%)	2 (1.5%)	0	0	0	0
Renal	Haematuria	0	0	0	0	0	0
	Anuria >24 hours	1 (0.6%)	2 (1.5%)	0	0	1 (1.2%)	0
Infection	Apathetic, poor tolerance of feeds	8 (4.4%)	0	0	3 (3.0%)	0	0
Gastro-intestinal	Abdominal distension & vomiting	2 (1.1%)	2 (1.5%)	11 (9.6%)	0	0	0
Musculoskeletal	Brachial plexus injury	0	1 (0.8%)	0	0	0	0
	Skull fracture	0	0	1 (0.9%)	0	0	0
<b>At least one of the above criteria</b>		<b>181 (100%)</b>	<b>131 (100%)</b>	<b>115 (100%)</b>	<b>63 (63.6%)</b>	<b>34 (41.5%)</b>	<b>29 (44.6%)</b>
<b>All neonatal near miss or deaths</b>		<b>181 (100%)</b>	<b>131 (100%)</b>	<b>115 (100%)</b>	<b>99 (100%)</b>	<b>82 (100%)</b>	<b>65 (100%)</b>

Table 4: Association between gestational age, birth weight, Apgar score and neonatal near miss/pre-discharge neonatal death among live births in 17 hospitals in Benin, Burkina Faso and Morocco [\[can you please change the](#)

		N live births#	per 1000 live births* (N)			
			Neonatal Near-miss	p-value**	Predischarge Neonatal Death	p-value**
<b>BENIN</b>						
Gestational age at birth (weeks)	< 33	41	45 (3)	0.5110518	149 (10)	<0.0001
	33- 36	219	57 (21)		44 (16)	
	37-41	1,982	41 (148)		19 (68)	
	>41	64	52 (5)		31 (3)	
	Unknown	38	53 (4)		26 (2)	
Birth weight (g)	< 1750	25	55 (2)	0.59756368	301 (11)	<0.0001
	1750 - 2499	275	51 (24)		44 (21)	
	2500-4000	1,978	42 (152)		18 (64)	
	>4000	34	20 (1)		0 (0)	
	Unknown	32	38 (2)		57 (3)	
Apgar score at 5 minutes	<7	158	269 (48)	<0.0001	331 (59)	<0.0001
	>=7	2,172	33 (132)		9 (37)	
	Unknown	14	51 (1)		152 (3)	
Any pragmatic marker of severe morbidity	Yes	198	196 (49)	<0.0001	264 (66)	<0.0001
	No or unknown	2,146	33 (132)		8 (33)	
<b>BURKINA FASO</b>						
Gestational age at birth (weeks)	< 33	1	-	-	-	-
	33- 36	5	-		-	
	37-41	23	-		-	
	>41	2	-		-	
	Unknown	1,062	-		-	
Birth weight (g)	< 1750	29	7 (1)	0.1315773	44 (6)	0.30825591
	1750 - 2499	121	54 (21)		36 (14)	
	2500-4000	904	33 (105)		19 (62)	
	>4000	22	28 (2)		0 (0)	
	Unknown	17	43 (2)		0 (0)	
Apgar score at 5 minutes	<7	100	152 (24)	<0.0001	202 (32)	<0.0001
	>=7	979	29 (106)		13 (47)	
	Unknown	14	30 (1)		90 (3)	
Any pragmatic marker of severe morbidity	Yes	124	87 (25)	0.0001	128 (37)	<0.0001
	No or unknown	969	30 (106)		13 (45)	
<b>MOROCCO</b>						
Gestational age at birth (weeks)	< 33	40	93 (6)	<0.0001	218 (14)	<0.0001
	33- 36	82	60 (10)		42 (7)	
	37-41	4,308	5 (67)		2 (34)	
	>41	140	18 (6)		0 (0)	
	Unknown	1,077	6 (26)		3 (10)	
Birth weight (g)	< 1750	39	101 (8)	<0.0001	151 (12)	<0.0001
	1750 - 2499	159	50 (21)		33 (14)	
	2500-4000	4,637	4 (71)		2 (35)	
	>4000	731	6 (13)		2 (3)	
	Unknown	81	10 (2)		5 (1)	
Apgar score at 5 minutes	<7	107	131 (29)	<0.0001	154 (34)	<0.0001
	>=7	5,484	5 (84)		2 (28)	
	Unknown	56	17 (2)		25 (3)	
Any pragmatic marker of severe morbidity	Yes	153	110 (35)	<0.0001	128 (41)	<0.0001
	No or unknown	5,494	4 (80)		1 (2442)	

\* Sampling weights applied; \*\*Proportions are compared using the chi square test; # Number of live births for each exposure are obtained from the data in our study, singleton births only.

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**Table 5: Neonatal near-miss and mortality among caesarean sections, maternal near-miss and all births in 17 hospitals in Benin, Burkina Faso and Morocco**

		Benin	Burkina Faso	Morocco
<b>CAESAREAN SECTIONS</b>				
Neonatal near-miss per 1000 live births (N)[95% CI]		81 (113) [35, 176]	129 (80) [85, 193]	27 (51) [12, 61]
Mortality rate	Stillbirths per 1000 births (N)[95% CI]	49 (74) [22, 107]	72 (49) [46, 113]	30 (58) [22, 39]
	Pre-discharge neonatal deaths per 1000 live births (N)[95% CI]	40 (58) [13, 122]	43 (27) [16, 112]	11 (20) [4, 30]
	Perinatal deaths per 1000 births (N)[95% CI]	87 (132) [34, 206]	112 (76) [64, 190]	40 (78) [27, 59]
Neonatal near-miss or perinatal death per 1000 births (N)[95% CI]		162 (245) [72, 325]	231 (156) [147, 344]	66 (129) [40, 108]
Ratio neonatal near miss : perinatal death		1 : 1.2	1 : 0.9	1 : 1.5
<b>MATERNAL NEAR MISS</b>				
Neonatal near-miss per 1000 live births (N)[95% CI]		127 (30) [66, 230]	123 (22) [81, 183]	63 (14) [13, 254]
Mortality rate	Stillbirths per 1000 births (N)[95% CI]	338 (125) [210, 495]	179 (40) [95, 312]	161 (43) [82, 291]
	Pre-discharge neonatal deaths per 1000 live births (N)[95% CI]	57 (14) [21, 145]	76 (14) [24, 214]	27 (6) [5, 142]
	Perinatal deaths per 1000 births (N)[95% CI]	376 (139) [255, 514]	241 (54) [125, 414]	184 (49) [90, 339]
Neonatal near-miss or perinatal death per 1000 births (N)[95% CI]		457 (169) [356, 561]	339 (76) [202, 511]	236 (63) [95, 476]
Ratio neonatal near miss : perinatal death		1 : 4.6	1 : 2.4	1 : 3.5
<b>ALL BIRTHS IN FACILITIES*</b>				
Neonatal near-miss per 1000 live births (N)[95% CI]		43 (181) [24, 77]	34 (131) [26, 45]	6 (115) [3, 12]
Mortality	Stillbirths per 1000 births (N)[95% CI]	68 (308) [51, 90]	38 (151) [31, 46]	14 (271) [10, 21]
	Pre-discharge neonatal deaths per 1000 live births (N)[95% CI]	23 (99) [12, 43]	21 (82) [13, 35]	3 (65) [2, 8]
	Perinatal deaths per 1000 births (N)[95% CI]	89 (407) [69, 115]	58 (233) [52, 65]	17 (336) [12, 26]
Neonatal near-miss or perinatal death per 1000 births (N)[95% CI]		129 (588) [100, 165]	91 (364) [78, 106]	23 (451) [16, 35]
Ratio neonatal near miss : perinatal death		1 : 2.2	1 : 1.8	1 : 2.9

\* [Sampling weights applied](#)

[All 95% CIs allow for clustering by hospital](#)

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## **Characteristics of neonatal near-miss in hospitals in Benin, Burkina Faso and Morocco in 2012-2013**

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## **Abstract**

### **Objective**

To explore the usefulness of neonatal near-miss in low and middle income countries by examining the incidence of neonatal near-miss and pre-discharge neonatal deaths across various obstetric risk categories in 17 hospitals in Benin, Burkina Faso and Morocco

### **Methods**

Data were collected on all maternal deaths, maternal near-miss, neonatal near-miss (based on organ-dysfunction markers), caesarean sections, stillbirths, neonatal deaths before discharge and non-cephalic presentations; and on a sample of births not falling in any of the above categories.

### **Findings**

The burden of stillbirth, pre-discharge neonatal death or neonatal near-miss ranged from 23 to 129 per 1000 births in Moroccan and Beninese hospitals respectively. Perinatal deaths (range 17-89 per 1000 births) were more common than neonatal near-miss (range 6-43 per 1000 live births), and between a fifth and a third of women who had suffered a maternal near-miss lost their baby. Pre-discharge neonatal deaths and neonatal near-miss had a similar distribution of markers of organ-dysfunction, but unlike pre-discharge neonatal deaths most neonatal near-miss (63%, 81% and 71% in Benin, Burkina Faso and Morocco respectively) occurred among babies who were not considered premature, low birth weight or with a low 5 minute Apgar score as defined by WHO's pragmatic markers of severe neonatal morbidity

### **Conclusion**

Whether the measurement of neonatal near-miss adds useful insights into the quality of perinatal or newborn care in settings where facility-based intrapartum and early newborn mortality is very high is uncertain. Perhaps the greatest advantage of adding near-miss is the shift in focus from failure to success so that lessons can be learned on how to save lives even when clinical conditions are life-threatening

## Introduction

The concept of maternal near-miss, - a woman who nearly died but survived - has taken firm hold in maternal health. Most maternal near-miss survive as a result of care received in hospital, and their investigation can therefore give useful insights into the quality of facility-based obstetric care<sup>1</sup>. The incidence of maternal near-miss may also reflect delays in accessing emergency obstetric care, particularly when those who reach the hospital in a critical state are separated from those who develop a near-miss in hospital<sup>2,3</sup>. Recently, this concept has been expanded to neonates, though experience is limited, particularly in low and middle income countries<sup>4</sup>. The feasibility of applying the near-miss concept to neonates and the usefulness of neonatal near-miss in the assessment of the quality of obstetric or perinatal care in such settings are still to be explored.

Efforts to capture the severity of neonatal morbidity using standard criteria are not new, and neonatal scoring systems have been widely used for a range of purposes. In high income countries efforts have mostly focused on the need to explain variation in mortality and other outcomes between neonatal intensive care units<sup>5-7</sup>. Neonatal scoring systems have also been used to predict an individual's prognosis in order to guide interventions, including end of life decisions<sup>6,7</sup>. Severity indices are generally based on a combination of gestational age or birth weight thresholds with clinical markers, but there is no consensus on the most optimal set of markers.

The use of the term neonatal near-miss is more recent, though investigations of near-miss in infants, particularly in relation to sudden infant death syndrome, have been used for more than 40 years<sup>8-12</sup>. The last five years have seen a renewed interest in neonatal near-miss in low and middle income countries, partly stimulated by work in South Africa. Analogous to the concept of maternal near-miss, South African investigators have developed indicators of neonatal organ-dysfunction using a standard set of clinical, laboratory and management criteria<sup>12-14</sup>. Knowledge of the magnitude and clinical causes of neonatal near-miss are thought to help identify deficiencies in perinatal care, particularly in settings where neonatal deaths have become less common<sup>12</sup>. By comparing the incidence of near-miss in various risk groups, for example whether the baby was born premature, at low birth weight or HIV infected, remedial action might be better targeted and the quality of care improved<sup>13,14</sup>.

More recently, the WHO has developed a set of standard markers of neonatal near-miss in order to facilitate assessments of the quality of perinatal care<sup>15-17</sup>. Defined as "an infant who nearly died but survived a severe complication that occurred during pregnancy, birth, or within 7 days of extra-uterine life", neonatal near-miss are identified based on so-called "pragmatic" and "management" markers of severe neonatal morbidity. Pragmatic markers include a 5 minute Apgar score less than 7, a birth weight less than 1750 grams, or a gestational age less than 33 weeks; and management markers refer to life-saving interventions such as the use of therapeutic intravenous antibiotics or the need for intubation or phototherapy<sup>16</sup>. Based on an assessment of the accuracy in predicting neonatal death, the authors suggest that newborns having a combination of pragmatic and management markers and surviving the first week of life should be considered a neonatal near-miss. Experience with the use of this indicator is limited however, and how or whether it informs the quality of perinatal care is not known.

In this paper we aim to further explore the use of the concept of neonatal near-miss in 17 hospitals in two low income and one middle income country (Benin, Burkina Faso and Morocco). Consistent with the definition of maternal near-miss, we define a neonatal near-

miss as a neonate who almost died but survived before discharge from hospital, using organ-dysfunction criteria. We examine the association between neonatal near-miss and pre-discharge neonatal death and low 5 minute Apgar score, low birth weight and low gestational age; and we examine variation in the incidence of neonatal near-miss, stillbirths, pre-discharge neonatal deaths and perinatal deaths among births associated with a maternal near-miss, births by caesarean section, and all births.

### Methods

This study took place in 17 hospitals in Benin, Burkina Faso and Morocco in 2012-2013 as part of a broader evaluation effort of the quality of emergency and routine care in referral facilities<sup>18</sup>. In Benin the study was conducted in 5 hospitals (1 public teaching, 2 public district and 2 confessional hospitals). In Burkina Faso data were collected in 6 public hospitals (2 regional and 4 district hospitals) and in Morocco the study took place in 8 public hospitals (2 teaching, 2 regional and 4 district hospitals). In Morocco, data in teaching and regional hospitals were only collected for women originating from any of the 4 districts in which the hospitals were located.

In each hospital doctors, nurses and midwives involved in patient care were trained to complete a structured form for each birth fulfilling the study criteria. The number of health professionals involved in data collection varied by hospital and country: between 3 and 17 per hospital in Benin, between 1 and 3 in Burkina Faso and between 2 and 6 in Morocco. Data collection took place from March to September 2012 in Benin, from May to November 2012 in Burkina Faso, and from February 2012 to January 2013 in Morocco.

Data were collected prospectively on all maternal deaths, maternal near-miss, neonatal near-miss, caesarean sections, stillbirths, neonatal deaths before discharge and non-cephalic presentations (including breech, transverse lie, front, and face); and on a sample of births not falling in any of the above categories. Data were obtained from the delivery ward and, where relevant, from neonatal wards for babies admitted to neonatal or pediatric units (6 of the 17 hospitals had specialised neonatal units). Data included obstetric history, mode of delivery, maternal and neonatal complications, gestational age, birth weight, birth outcome, and Apgar score. We also collected information on the total number of births in each hospital in the same period from routine records, but detailed individual characteristics were only collected for the groups identified above.

Maternal near-miss was defined based on the organ-dysfunction criteria suggested by WHO<sup>1,19</sup> and/or on clinical criteria of severity<sup>20</sup>. For the clinical criteria, categories of maternal near-miss were: severe anaemia (haemoglobin < 4g/dl ; or haemoglobin  $\geq$ 4 g/dl and < 7g/dl and palor of the skin or mucosa) ; uterine rupture or Bandl's ring ; severe haemorrhage (with shock, cardiac arrest, blood transfusion or laparotomy) ; severe infection (temperature > 38 °C or < 36.5 °C with shock, jaundice or cardiac arrest ; or a diagnosis of septicemia) ; severe pre-eclampsia (diastolic blood pressure  $\geq$ 110 mm Hg with hyper reflectivity, severe headache, blurred vision, oliguria, jaundice, abdominal pain or pulmonary edema) and eclampsia (diastolic blood pressure  $\geq$ 90 mm Hg with convulsions or coma).

We defined neonatal near-miss based on organ-dysfunction markers proposed in South Africa<sup>13,14</sup> (Table 1). These criteria were modified after review by obstetricians and pediatricians in each of the countries. The main issues for consideration in adapting criteria were availability of information and ease of use. For example, C-reactive protein was not



measured in any of the hospitals, and congenital infection was diagnosed on the basis of apathy and poor tolerance of feeds. The definition of neonatal near-miss was the same in all three countries, except for the respiratory rate for respiratory dysfunction which had to exceed 70 per minute in Benin and Burkina Faso compared to >100 per minute in Morocco. Newborns identified with an organ-dysfunction at any time during hospitalization were recorded as neonatal near-miss.

We restricted the analysis to singleton births. We first examine the frequency of organ-dysfunction criteria in neonatal near-miss and pre-discharge neonatal deaths. We then report the association between gestational age at birth, birth weight and 5 minute Apgar score and neonatal near-miss and pre-discharge neonatal death among all live births for which such detailed information was available (i.e. all maternal near-miss, caesarean sections, non-cephalic presentations and the sample without any such complications). Because information on birthweight, Apgar and gestational age was only available for the data collected in our study (sample of uncomplicated deliveries and all complicated deliveries), we calculated the sampling fraction of uncomplicated deliveries from the total/routine statistics and applied a weight to allow for this. Third, we examine the incidence of neonatal near-miss, stillbirths, pre-discharge neonatal deaths, perinatal deaths and combined near-miss/perinatal deaths, and the ratio of perinatal death to neonatal near-miss in three groups: babies born to women who experienced a maternal near-miss, those born by caesarean section and among all births occurring in the hospital over the study period. All analyses were stratified by country. Proportions are compared using the chi square test and all 95% confidence intervals allow for clustering by hospital.

## Results

The characteristics of the sample are described in Table 2. The hospitals contributed 27,857 singleton births to the analysis, including 861 maternal near-miss, 4,146 caesarean sections, 730 stillbirths, 246 pre-discharge neonatal deaths and 427 neonatal near-miss. The causes of maternal near-miss included eclampsia or pre-eclampsia (34%), uterine rupture or pre-rupture (32%), severe anemia (27%), hemorrhage (21%), and infection (2%) (data not shown).

The distribution of markers of organ dysfunction in neonatal near-miss and pre-discharge neonatal deaths is shown in Table 3. Most neonatal near-miss had one (50%) or two (30%) criteria of organ dysfunction recorded. Among pre-discharge neonatal deaths 43% had no criteria recorded, 21% had one criterion and a further 16% had two criteria. Respiratory dysfunction, designated by cyanosis and absence of a regular breathing pattern, was the most common criterion of neonatal near-miss in all three countries. Cardio-pulmonary resuscitation was frequent in Benin and Burkina Faso, and seizures and/or use of anticonvulsants were common criteria in all three countries. Criteria for renal, immunological, gastro-intestinal or musculoskeletal dysfunction were rarely identified. The frequency of organ-dysfunction in pre-discharge neonatal deaths was similar to that in neonatal near-miss.

The association between gestational age, birth weight, Apgar score and neonatal near-miss/pre-discharge neonatal death is shown in Table 4. Gestational age was missing for a large proportion of births in Burkina Faso (97%) and we therefore did not examine associations with gestational age in that sample. ~~As expected, †~~The risk of pre-discharge neonatal death ~~differed~~ ~~was higher among babies born at early~~by gestational age, ~~at low~~birth

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weight ~~and or with a low~~ Apgar score in all countries ( $p < 0.0001$ ). The association between pragmatic markers and neonatal near-miss was much weaker, and only Apgar score  $< 7$  was consistently associated with a greater risk of neonatal near-miss. Most neonatal near-miss had a birth weight of more than 1750 g (range 93.0-99.2%) or an Apgar score of 7 or more (range 73.3-81.5%). Overall, the proportion of neonatal near-miss who had any of the pragmatic markers of severe neonatal morbidity was relatively small (27.1%, 19.1% and 30.4% in Benin, Burkina Faso and Morocco respectively); and much smaller than among pre-discharge neonatal deaths (66.7%, 45.1% and 63.1% in Benin, Burkina Faso and Morocco respectively)(Figure 1).

Table 5 and Figures 2-4 show the incidence of neonatal near-miss, stillbirths, pre-discharge neonatal deaths and perinatal deaths among babies born by caesarean, babies born to women who suffered a maternal near-miss, and among all births registered in the hospitals. The number of perinatal deaths was greater than the number of neonatal near-miss in all countries and among almost all subgroups of women. The incidence of neonatal near-miss among all births ranged from 6 per 1000 live births in Morocco to 43 per 1000 live births in Benin but 17 and 89 per 1000 births resulted in a perinatal death (ratio near-miss to perinatal death 1:1.9 and 1:2.5 respectively). The incidence of neonatal near-miss was high among caesarean births (range 49 - 136 per 1000 live births) and among those whose mother had suffered a maternal near-miss (range 96 - 128 per 1000 live births). Overall, the incidence of perinatal death or neonatal near-miss was very high (129, 91 and 23 per 1000 births in Benin, Burkina Faso and Morocco respectively).

### Discussion

The burden of neonatal ill health as measured in terms of stillbirth, pre-discharge neonatal death or neonatal near-miss was very high in the hospitals studied, ranging from 23 to 129 per 1000 births in Morocco and Benin respectively. Perinatal deaths were more common than neonatal near-miss in all countries, and among women who had suffered a maternal near-miss between a fifth and a third lost their baby before being discharged from hospital. Pre-discharge neonatal deaths and neonatal near-miss had a similar distribution of markers of organ-dysfunction, but unlike pre-discharge neonatal deaths most neonatal near-miss occurred among babies who were not considered premature, low birth weight or with a low 5 minute Apgar score as defined by WHO's pragmatic markers of severe neonatal morbidity<sup>16</sup>.

The incidence of neonatal near-miss of 34 and 43 per 1000 live births in Benin and Burkina Faso was higher than that reported in Morocco but similar to that reported in other low and middle income countries. The WHO multi-country surveys reported an incidence of management-based neonatal near-miss of between 35<sup>17</sup> and 60<sup>16</sup> per 1000 live births depending on the survey population; in the sub-group of countries with a low human development index the incidence of neonatal near-miss was 35 per 1000 live births<sup>17</sup>. In South African hospitals the incidence of neonatal near-miss was 23<sup>13</sup> and 24 per 1000 live births<sup>14</sup>. Caution is required in making any comparisons since study populations (including the type of hospital and the prevalence of HIV) and case definitions varied considerably. WHO's markers of severity were based on interventions rather than clinical criteria, and the use of therapeutic intravenous antibiotics – present in three quarters of cases - was by far the most common criterion<sup>16</sup>. Clinicians in South Africa and in our study did not consider intravenous antibiotics to be a marker of neonatal near-miss, and respiratory dysfunction was the most common cause.

Perinatal mortality was very high in the hospitals studied, and the number of perinatal deaths exceeded the number of neonatal near-miss. This contrasts with the findings from studies in South Africa and elsewhere where the number of neonatal near-miss far exceeded the number of perinatal deaths<sup>13,14</sup>. Although this may point to poor quality of perinatal care in hospitals, perinatal mortality is not a good indicator of the quality of intrapartum or newborn care since stillbirths occurring before labour are not preventable at that time. The number of stillbirths was much higher than the number of pre-discharge neonatal deaths in our study, and many women may have arrived too late for the hospital to be able to save the baby. In a review of indicators to monitor emergency obstetric care WHO restricts its indicator of the quality of intrapartum and newborn care to very early neonatal (within the first 24 hours) or intrapartum deaths (fresh stillbirths) because such deaths can be averted by the availability and use of good-quality obstetric care and neonatal resuscitation<sup>21</sup>. Interestingly, newborns under 2.5 kg are to be excluded from the numerator and the denominator, as “low birthweight infants have a high fatality rate in most circumstances”.

Since our intention was to capture the quality of intrapartum and early newborn care we restricted our criteria of near-miss to conditions marking an organ-dysfunction that could either be prevented or required special care during labour or in the early postpartum. We did not include pragmatic markers of severity because prematurity and low birth weight are not preventable at the time of labour, and because useful insights can be gained by comparing the incidence of neonatal near-miss across the various categories of gestational age, birth weight and Apgar scores. Most neonatal near-miss occurred in babies without extreme values of gestational age, birth weight or Apgar score, and the incidence of neonatal near-miss was very high, for example, in babies born with a normal birth weight of 2500-4000 grams or more (79, 126 and 21 per 1000 live births in Benin, Burkina Faso and Morocco respectively). This may be partly related to the fact that the mother had a complication – as reflected in the high incidence of neonatal near-miss among babies born by caesarean section or whose mother had a maternal near-miss -, but further investigation may also highlight important aspects of intrapartum and newborn care that could have prevented the near-miss from occurring. A mere quantitative analysis is unlikely to reveal the nature of deficiencies in care, and an in-depth audit will be required to further elucidate the quality of care received<sup>22</sup>.

Our study had some limitations. First we selected hospitals purposively within districts offering a range of contexts in terms of poverty and accessibility and our findings are not necessarily representative of all births taking place in health facilities in the three countries. Second, gestational age was missing for a large number of births. However, gestational age and birth weight are highly correlated and many low birth weight babies will have been born premature. Third, we only collected data on gestational age, birth weight and Apgar score in a sub-sample of births that was highly skewed towards severe maternal and neonatal complications, and the incidence of neonatal near-miss and pre-discharge neonatal death across these categories may have been biased. However, this should not have affected the proportion of neonatal near-miss or pre-discharge deaths with or without pragmatic markers of severity. Fourth, our organ-dysfunction criteria were pragmatic and may have overly relied on subjective clinical impressions, particularly when clinical signs such as absence of regular breathing patterns are used. Unfortunately, we did not note the time of occurrence of the organ-dysfunction signs and symptoms, in particular whether the babies deteriorated before or after receiving treatment.

Many authors have reported poor quality of perinatal care and care for children with severe illnesses in low and middle income country hospitals<sup>23-26</sup>. Yet measuring the quality of

perinatal and newborn care using reliable and valid outcome measures remains a challenge, even in high income countries<sup>27</sup>. Whether the quantitative measurement of neonatal near-miss adds useful insights into the quality of perinatal or newborn care in settings where facility-based intrapartum and early newborn mortality is very high is uncertain. As with maternal near-miss, perhaps the greatest advantage of adding near-miss is the shift in focus from failure to success so that lessons can be learned on how to save lives even when clinical conditions are life-threatening<sup>22</sup>. Such lessons will not be learned from quantitative indicators alone however, and individual case audits will be needed to understand the circumstances that led to success<sup>22</sup>.

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Characteristics of neonatal near-miss in hospitals in Benin, Burkina Faso and Morocco in 2012-2013; Tropical Medicine & International Health

Dear Dr van Asten

Thank you very much for your email dated December 31, 2015. We agree with your comment that the ChiSquare does not allow any inference regarding the direction of effect and we have edited the sentence as you suggested: "The risk of pre-discharge neonatal death differed by gestational age, by birth weight and by Apgar score in all countries ( $p < 0.0001$ )."

Yours sincerely,

Professor Carine Ronsmans  
London School of Hygiene and Tropical Medicine