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3.6 Million Neonatal Deaths—What Is Progressing and What Is Not?

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Each year 3.6 million infants are estimated to die in the first 4 weeks of life (neonatal period)—but the majority continue to die at home, uncounted. This article reviews progress for newborn health globally, with a focus on the countries in which most deaths occur—what data do we have to guide accelerated efforts? All regions are advancing, but the level of decrease in neonatal mortality differs by region, country, and within countries. Progress also differs by the main causes of neonatal death. Three major causes of neonatal deaths (infections, complications of preterm birth, and intrapartum-related neonatal deaths or "birth asphyxia") account for more than 80% of all neonatal deaths globally. The most rapid reductions have been made in reducing neonatal tetanus, and there has been apparent progress towards reducing neonatal infections. Limited, if any, reduction has been made in reducing global deaths from preterm birth and for intrapartum-related neonatal deaths. High-impact, feasible interventions to address these 3 causes are summarized in this article, along with estimates of potential for lives saved. A major gap is reaching mothers and babies at birth and in the early postnatal period. There are promising community-based service delivery models that have been tested mainly in research studies in Asia that are now being adapted and evaluated at scale and also being tested through a network of African implementation research trials. To meet Millennium Development Goal 4, more can and must be done to address neonatal deaths. A critical step is improving the quantity, quality and use of data to select and implement the most effective interventions and strengthen existing programs, especially at district level.
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The Millennium Development Goals (MDGs) are the most widely ratified health and development targets ever and provide a remarkable opportunity to accelerate progress for the world's poorest families. More than 190 nations have committed to reach the 8 interlinking goals that address poverty, hunger, education, and health by 2015. Multiple reports have been published and many commitments have been agreed, but is progress being made? Are fewer mothers, new-borns, and children dying? Is access to essential health care improving for the poorest?

The MDG 4 for child survival is a key factor in the recent increase in attention on neonatal deaths (deaths in the first 28 days of life; Fig. 1).[1-4] In the mid-1990s an estimated 5.6 million neonatal deaths occurred each year. In the year 2000, an estimated 4 million neonatal deaths occurred—yet this huge number of deaths still remained virtually unnoticed on global and national agendas.[5] Since 2000, there has been increasing attention to newborn deaths. Why? A recent assessment[6] suggests that rapid policy change was driven by the recognition that an increasing proportion of under-five deaths were neonatal, coupled with evidence that effective action was possible even in low resource settings.[7-9] Thus, for MDG 4 to be met, more had to be, and could be, done to address neonatal deaths.[5] Nevertheless, this assessment concludes that despite increased recognition of neonatal survival as a mainstream global health issue, the enormous burden of

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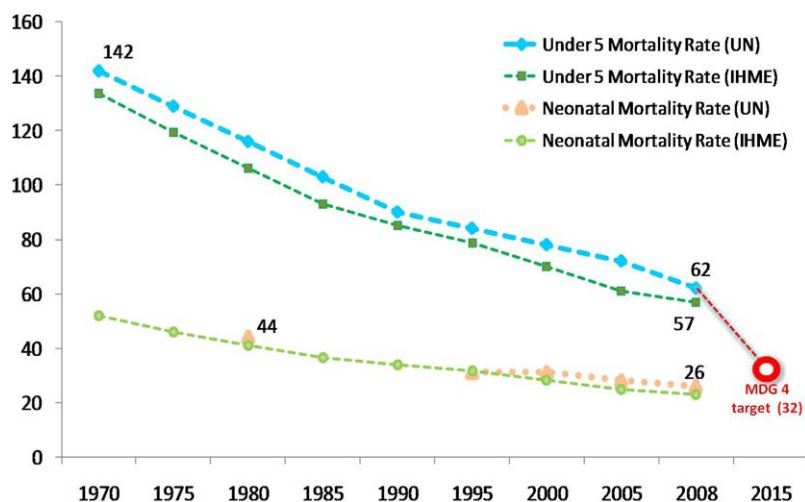
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Figure 1 Progress towards MDG 4 for child survival showing the increasing proportion of under-five deaths that occur in the neonatal period (up to 28 days of life). (Adapted from Lawn et al,[1] updated with data for 2008 from UN Child Mortality Group, updated in September 2010 for the UN MDG Summit,[2] Who/Cherg,[3] and IHME.[4]) (Color version of figure is available online.)

neonatal deaths has yet to achieve visibility and investment commensurate to the burden.[6]

In this article we review the progress in neonatal survival, highlighting links with MDG 5 for maternal survival. Progress is being made in reducing the rates and numbers of neonatal deaths in every region of the world—yet this varies dramatically between regions and even within regions, and there are marked differences in progress even for neighboring countries. Progress also differs in reducing the main causes of neonatal death. Understanding the data and improving the quality and use of local data for decision making is key to accelerating progress in the next critical few years leading up to 2015.

Progress Towards Neonatal Survival and MDG 4

MDG 4 targets a two-thirds reduction in under-five mortality between 1990 and 2015 (Fig. 1). Remarkable progress was achieved before 1990, with a halving in risk of death for children younger than 5 between 1960 and 1990. Since 1990, the global under-five mortality rate has decreased a further 28%, and the total number of under-five deaths is now fewer than 9 million.[2] However, the current rate of reduction must increase 6-fold between now and 2015 to reach MDG 4.

The global number of neonatal deaths is also decreasing.[3,4] Although neonatal, infant, and child mortality reduced fairly rapidly from 1970 to 1990, estimates from both the United Nations (UN)[3] and the Institute for Health Metrics and Evaluation (IHME)[4] suggest that progress slowed in the 1990s, and since 2000 the global annual neonatal mortality rate (NMR) has decreased more slowly than postneonatal and child mortality rates. The most recent UN estimates suggest that 3.6 million neonatal deaths occurred in the year 2008,[3] and IHME estimates also suggest 3.2 neonatal deaths for the same year.[4] Both sets of estimates agree that neonatal mortality comprises at least 41% of under-five deaths. Particularly

striking is the lack of progress during the last decade in reducing deaths during the first week of life (the early neonatal period) in low-income countries. NMRs (including early neonatal mortality) have continued to decrease rapidly in high-income countries, resulting in a widening gap in survival chances for an infant depending on where he or she is born.

Despite increasing attention to neonatal data, child-survival programs and funding continue to focus primarily on important causes of death after the first 4 weeks of life,[9] particularly on malaria and vaccine-preventable conditions,[10] whereas maternal health programs have focused primarily on the mother.[11] However, newborn deaths can be reduced by strengthening care within existing maternal and child health programs and by, including high-impact interventions to target the main causes of neonatal deaths.[12] Stillbirths are even more neglected than neonatal deaths and are not mentioned in MDG 4 or MDG 5, yet many of the 3.2 million stillbirths each year[13] are preventable with the same solutions as for maternal and newborn survival.[14]

Crucial to making progress is the improvement of neonatal death data and making better use of existing and future data in selecting and implementing the "best buys." Available information is often not used effectively to strengthen existing programs, especially at district level, or to present the case for more investment.[1]

Programmatic Data for Action

Where Do Newborns Die?
Variation Between Countries

In all regions, neonatal deaths are an important proportion of all deaths in children younger than 5 years of age, ranging from 27% to 54% of under-five deaths.[3] NMRs vary widely between regions (Table 1),[2,3,15] and more than two-thirds of the world's neonatal deaths occur in sub-Saharan Africa and South Asia.[5] The newborn health gap between rich and poor

Table 1 Neonatal and Maternal Mortality by Region

Region	Neonatal Mortality Rate per 1000 Live Births (2008)	Annual Number of Neonatal Deaths	Maternal Mortality Ratio per 100,000 Live Births (2008, Adjusted)	Annual Number of Maternal Deaths
Sub-Saharan Africa	41	1,230,000	640	194,000
Middle East and North Africa	21	209,000	167	16,600
South Asia	37	1,571,000	281	119,000
East Asia and Pacific	13	346,000	63	16,500
Latin America and Caribbean	11	117,000	78	8400
Central and Eastern Europe and the Commonwealth of Independent States	12	66,000	43	2200
High-income	4	44,000	11	1300
Middle-income	26	2,382,000	205	190,000
Low-income	37	1,149,000	528	166,000
World	26	3,575,000	260	358,000

Data sources: Neonatal mortality;[3] Maternal mortality.[15]

countries remains unacceptably high, ranging from an NMR of 1 in Japan with a gross national income (GNI) per capita of US$38,210 to an NMR of 61 in Somalia with a GNI per capita of US$140.[2] Regional variation in progress is also startling. A number of Latin American and SouthEast Asian countries have made major progress in reducing both child and neonatal mortality rates since 1990 and are on track to meet MDG 4.[2] Some low-income countries, such as Thailand and Sri Lanka, have managed to achieve NMRs less than 10 per 1000 live births.[16] In Africa, progress has been slower, but there are encouraging signs of a possible tipping point.[17] During the past few years, several African countries, including Ethiopia, Ghana, Uganda, and United Republic of Tanzania, have made rapid progress for child survival but are not yet on track. Three low-income African countries (Botswana, Eritrea, and Malawi) are on track for MDG 4.[17] All of these

countries have NMRs of approximately 30 per 1000 live births or less, which is approximately 25% less than the regional average.[18] In contrast, Nigeria, which has a relatively high GNI per capita compared with other African countries, still has a very high NMR of 49 per 1000 live births.

Nigeria is 1 of 5 countries that together account for more than 2 million newborn deaths—more than one-half the total—whereas 10 countries account for two-thirds of all deaths (Table 2).[3,15,19,20] India accounts for approximately 1 million neonatal deaths each year. These same countries also account for a high proportion of the burden of maternal deaths. Many of the 10 countries with the greatest risk of newborn death are countries that have experienced recent war or other disasters and there is limited information to guide newborn survival programming in such settings (Table 3).[3,15]

Low-income countries that have achieved major reduc-

Table 2 The 10 Countries with the Greatest Number of Neonatal Deaths, with Associated Maternal Deaths and National Plans and Situation Analysis of Relevance

Countries and Territories	Neonatal Mortality Rate per 1000 Live Births (2008)	Annual Number of Neonatal Deaths	Maternal Mortality Ratio per 100,000 Live Births (2008)	Annual Number of Maternal Deaths	National MNCH Plan	National Newborn Situation Analysis
India	37	1,004,000	233	63,000	Yes	Yes
Nigeria	49	298,000	836	50,000	Yes	Yes
Pakistan	53	284,000	259	14,000	Yes	Yes
China	11	206,000	38	6900	Yes	—
DR Congo	56	163,000	666	19,000	Yes	—
Ethiopia	39	122,000	467	14,000	Child only	—
Bangladesh	33	114,000	337	12,000	Neonatal only	Yes
Indonesia	19	80,000	237	10,000	No	—
Afghanistan	50	63,000	1391	18,000	Yes	Yes
United Republic of Tanzania	33	59,000	790	14,000	Yes	Yes
Total number (percentage of the global total)		2,393,000 (67%)		221,000 (62%)		

Data sources: Neonatal mortality,[3] Maternal mortality,[15] MNCH plan,[19] Situation analysis.[20]
Abbreviation: MNCH, maternal newborn and child health.

Table 3 The 10 Countries With the Greatest Neonatal Mortality Rates, Showing the Maternal Mortality Ratio and Numbers of Maternal Deaths

Countries and Territories	Neonatal Mortality Rate per 1000 Live Births (2008)	Annual Number of Neonatal Deaths	Maternal Mortality Ratio per 100,000 Live Births (2008)	Annual Number of Maternal Deaths
Somalia	61	24,000	1210	4800
DR Congo	56	163,000	666	19,000
Pakistan	53	284,000	259	14,000
Mali	52	28,000	825	4500
Afghanistan	50	63,000	1391	18000
Nigeria	49	298,000	836	50,000
Myanmar	48	49,000	240	2400
Central African Republic	47	7000	852	1300
Angola	47	36,000	614	4700
Guinea-Bissau	45	3000	995	1000

Data sources: Neonatal mortality,[3] Maternal mortality.[15]

tions in maternal and neonatal mortality have mostly also reached at least half of the population with skilled attendance during childbirth, although there are some notable exceptions, for example Nepal and Bangladesh.[21] Figure 2,[22] which displays the area of each country in direct proportion to the measure indicated, dramatically reveals the inverse relationship between human resources for health and mortality burden. These maps show clearly the large numbers of neonatal and maternal deaths concentrated in sub-Saharan Africa and South Asia, alongside the very low number of physicians and a dearth of midwives in these regions.[22] To rapidly accelerate progress in these countries is going to require task shifting and innovation in service delivery and technology, as well as major investment in equitably deployed, skilled human resources.

Variation Within Countries

Within countries, there is also often an unacceptably wide gap between rich and poor. Mothers and newborns in poor families are at increased risk of illness and face more challenges in accessing timely, high-quality care compared with wealthier families. An analysis of 13 African Demographic and Health Surveys (DHS) indicates that the poorest 20% of families experience, on average, 68% higher neonatal mortality than the richest 20% of families.[18] For 40 countries for which recent data are available, the largest disparity is in India, with an NMR of 26 per 1000 live births among the richest 20% compared with 56 per 1000 live births among the poorest 20%, a 2.2-fold gap.[23] If all of India experienced an NMR of 22 per 1000 live births, nearly 460,000 fewer babies would die each year.

There are also important urban–rural disparities. Infants born to families living in rural areas have poorer access to services and are at greater risk of death than babies born to families living in urban areas.[5] For instance, the doctor-to-population ratio in urban areas in India is 1.3 per 1000 population, whereas it is just 0.33 in rural areas. For 38 countries
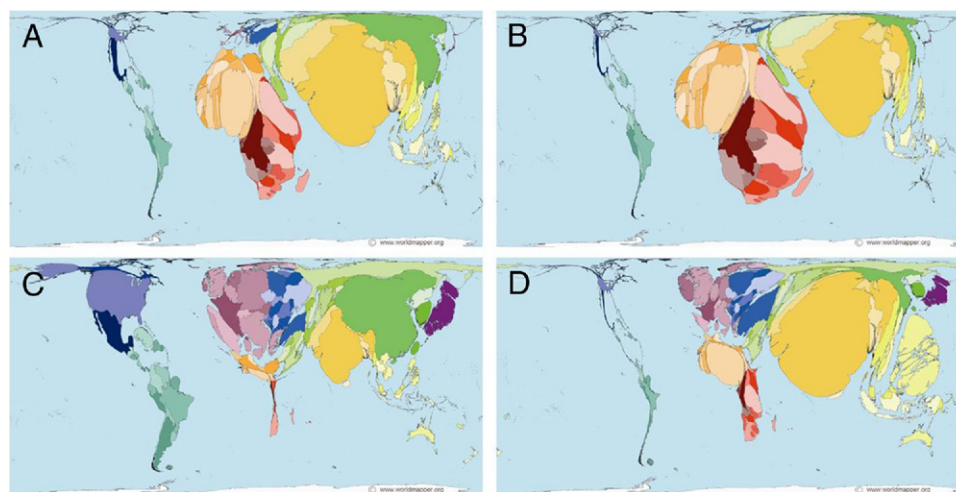

Figure 2 Global distribution of (A) early neonatal mortality, (B) maternal mortality, (C) physician workforce, and (D) midwife workforce. (Used with permission from http://www.worldmapper.org (map Numbers 260, 258, 219, and 215, respectively); ©Copyright 2006 SASI Group ([University of Sheffield] and Mark Newman [University of Michigan].[22]) (Color version of figure is available online.)

in Africa and Asia with DHS data published during the 5-years up to 2010, the NMR was, on average, 20% greater among infants born in rural areas.[23] More systematic policy and support for implementation to benefit the poorest families and those living furthest from services, with equity-based tracking, is required. Governments need to be held to account for reducing and eliminating inequities in health outcomes.

More than one-half of the newborns who die in low-income countries do so at home. In Bangladesh, for example, as few as 15% of infants are born or die in a hospital. In northern Ghana, only 13% of neonatal deaths occur in hospital.[24] For the 60 million women giving birth at home each year, distance to a health facility is often a barrier.[25] Often, there are also cultural norms that conspire to keep pregnancy hidden and preclude care-seeking outside the home at the time of birth or in the postnatal period and act as a barrier to data collection.[26]

When Do Newborns Die?

The birth of an infant should be a time of celebration, yet during the entire human lifespan, the day of birth is the day of greatest risk of death. The risk of dying during the first day of life is close to 10 per 1000 live births (1%).[5] In fact, this is likely to be an underestimate of the true proportion of deaths in the first 24 hours because of lack of disclosure of very early neonatal deaths, and misclassification as stillbirths or neonatal deaths after the first day as the result of inconsistencies in recording the 24-hour period after birth. In total, more than 2 million deaths (maternal, stillbirths, and neonatal) occur every year during or shortly after childbirth (Fig. 3).[3,5,13,27-30] These deaths are closely linked to lack of adequate maternal and neonatal care at this critical time. Globally, at least an estimated 42% of maternal deaths are intrapartum-related,

defined as during birth or the first day after birth. For mothers who die of an intrapartum-related cause, it is rare for the infant to survive.[31] Maternal morbidity is also closely linked to adverse fetal and neonatal outcomes.[32] Recognition of the importance of reaching mothers and newborns in this crucial early period resulted in a UN statement in 2009 on early postnatal visits.[33] The critical focus is the first 2 days after birth.[34]

Progress for Solutions for the Main Causes of Neonatal Death

Most neonatal deaths in Africa and Asia are caused by conditions that are rarely seen in high-income countries and, when they are seen, would not usually result in death. Three major causes of neonatal deaths in high-mortality settings (infections, complications of preterm birth, intrapartum-related neonatal deaths or "birth asphyxia") account for more than 80% of all neonatal deaths globally (Fig. 4).[3] The most rapid reductions have been made in reducing neonatal tetanus and there has been apparent progress towards reducing neonatal infections. Limited, if any, reduction has been made in reducing global deaths from preterm birth and for intrapartum-related neonatal deaths (Table 4).[3,35,36] These causes and the number of global deaths each year are (with range of uncertainty in parentheses):

- Deaths caused by neonatal infection (excluding tetanus): 963,000 (uncertainty range 680,000-1,500,000)
- Deaths caused by intrapartum events: 814,000 (560,000-1,000,000)
- Deaths caused by complications of preterm birth: 1,033,000 (720,000-1,222,000)
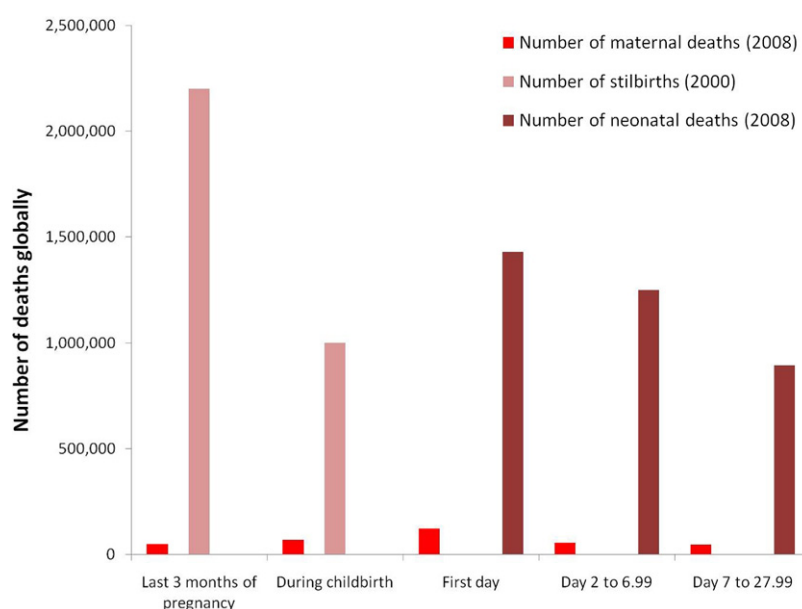

Figure 3 When do maternal deaths, stillbirths and neonatal deaths occur? (Data sources: Maternal deaths: Hogan et al, 2010.[28] Timing of maternal deaths based on Li et al.[29] Antenatal stillbirths: Stanton et al.[13] Intrapartum stillbirths: Lawn et al.[30] Neonatal deaths: Black et al.[3] Timing of neonatal deaths: Lawn et al.[5]) (Color version of figure is available online.)
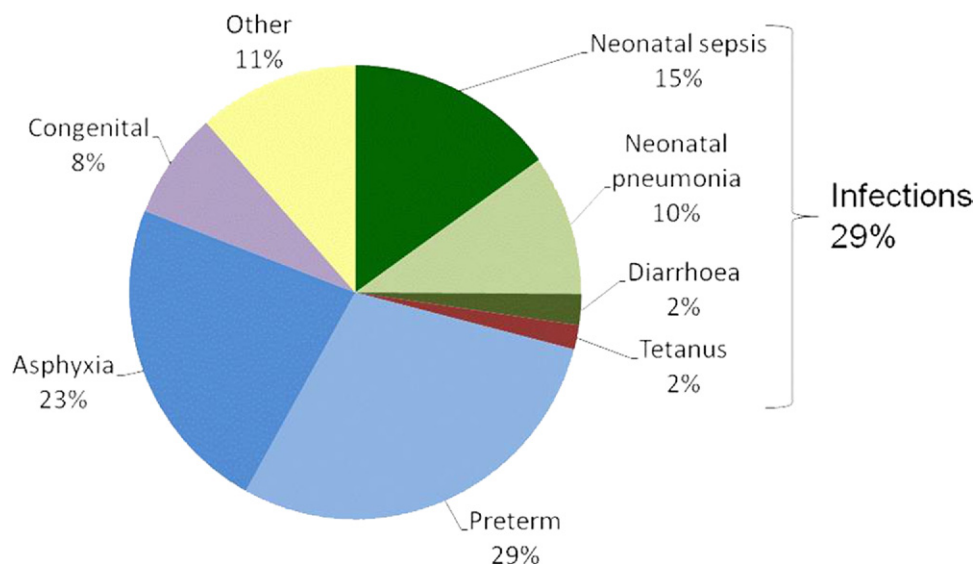
Figure 4 Causes of neonatal death for 3.6 million neonatal deaths, for 192 countries based on cause-specific mortality data and multicause modeled estimates. (Data source: Based on data from Child Health Epidemiology Reference Group and WHO in Black et al.[3]) (Color version of figure is available online.)

However, the relative proportions of these 3 causes of death vary between countries (Fig. 5) as well as within countries. For settings with very high NMR (greater than 45 neonatal deaths per 1000 live births), approximately one-half of neonatal deaths are caused by infections, including tetanus.[5,37] In low-mortality settings (NMR <15), approximately 15% of deaths are caused by infections and are more likely to take place in hygienic settings with access to antibiotics, so preventing these deaths requires more complex inputs. Hence, the populations with the highest mortality rates have great scope for reducing neonatal mortality through lower-cost and low-tech interventions.

Table 5 gives an overview of the potential solutions to the top 5 causes of newborn deaths estimated for 192 countries together with the percentage of lives that could be saved if all families received care.[3,18,38]

Table 4 Causes of Death in the Neonatal Period for 193 Countries (2000-2008)

Cause of Death	2000	2004	2008
Infection	1.04 (26)	0.94 (25)	0.89 (25)
Sepsis			0.54
Pneumonia			0.36
Diarrhea	0.11 (3)	0.07 (2)	0.07 (2)
Tetanus	0.26 (6)	0.10 (3)	0.07 (2)
Preterm	1.12 (28)	1.23 (33)	1.04 (29)
"Asphyxia"	0.91 (23)	0.91 (24)	0.83 (23)
Congenital	0.30 (7)	0.31 (8)	0.29 (8)
Other	0.26 (6)	0.19 (5)	0.39 (11)
Total	4.0 million	3.8 million	3.6 million

Values are number (percentage).
Data sources: 2000,[35] 2004,[36] 2008.[3]

Neonatal Infection (963,000 Newborn Deaths Globally)

Rapid reductions in mortality are possible, and reduce the rich-poor gap because conditions, such as neonatal tetanus almost exclusively affect the poorest families.[38] Prevention of infections is mainly dependent on maternal health packages and programs, such as antenatal care, hygienic care during childbirth and the postnatal period, and early and exclusive breastfeeding. Innovations, such as chlorhexidine cleansing of the cord are starting to move into programs.[39] Treatment of neonatal infections is possible through existing child health programs, particularly Integrated Management of Childhood Illness (IMCI) and referral care in hospitals. The scaling-up of infection case management to date has probably contributed to some reduction of deaths from infection in the late neonatal period.[24] Adding a new algorithm for care of infants in the first week of life to IMCI has provided a further opportunity to reduce neonatal and under-five mortality,[40] and as of 2010, 43 of 68 Countdown countries have updated their policy from IMCI to Integrated Management of newborn and Childhood Illness IMNCI.[19] However, data on validation of a community screening algorithm have yet to be published,[41] although the ability of community health workers to use an algorithm during household visit to identify sick newborns has been validated.[42]

Tetanus (59,000 Newborn Deaths Globally)

It is unacceptable that in the 21st century neonatal tetanus still accounts for so many preventable newborn deaths and that 2 global elimination goals have passed unmet.[43] Tetanus was not a major killer of infants in industrialized countries in modern times, even before the tetanus toxoid vaccine was developed. Investment in vaccine coverage has resulted in coverage of maternal tetanus immunization climbing to 81%
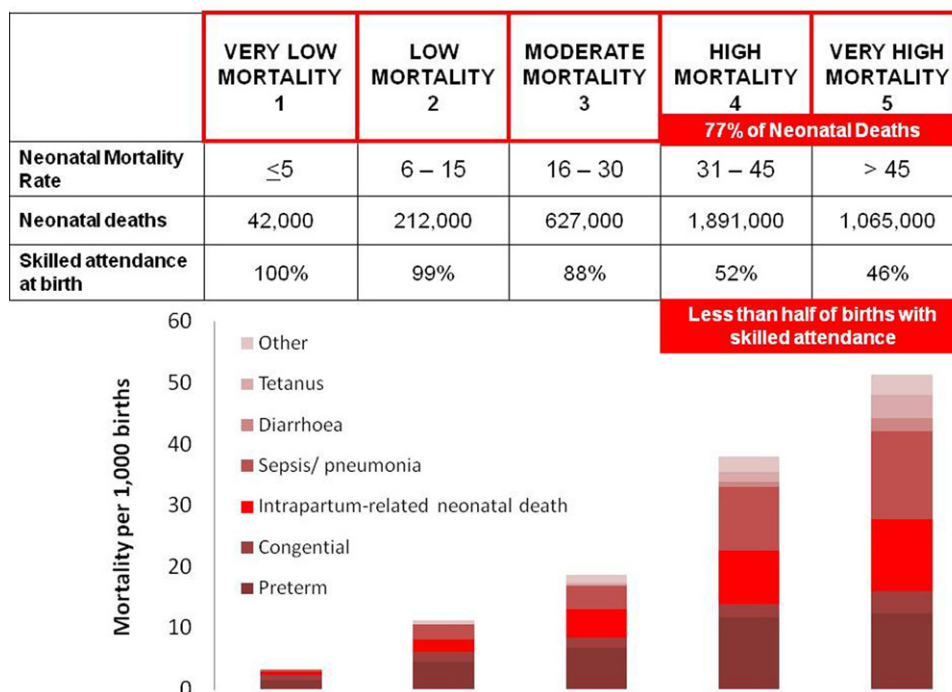
	VERY LOW MORTALITY 1	LOW MORTALITY 2	MODERATE MORTALITY 3	HIGH MORTALITY 4	VERY HIGH MORTALITY 5
				77% of Neonatal Deaths	
Neonatal Mortality Rate	≤5	6 – 15	16 – 30	31 – 45	> 45
Neonatal deaths	42,000	212,000	627,000	1,891,000	1,065,000
Skilled attendance at birth	100%	99%	88%	52%	46%
				Less than half of births with skilled attendance	

Figure 5 Variation of cause-specific neonatal mortality across 193 countries organized according to 5 levels of neonatal mortality. (Based on data from Lawn et al[27]; data sources: new analysis of 193 countries grouped by level of NMR adapted from Lawn et al[5] and updated for 2008 using neonatal mortality and revised neonatal cause-specific estimates for Black, et al[3] skilled birth attendance data from UNICEF.[2]) (Color version of figure is available online.)

of newborns globally protected at birth from tetanus.[2] Remarkable progress has been made in reducing tetanus deaths—from an estimated one million deaths in 1980 to around 59,000 in the year 2008 (Fig. 6).[3] Since 2000, 14 countries and 15 states in India have been certified as having eliminated tetanus.[44] As well as increased investment, this progress reflects increased targeting of high-risk districts and improved implementation quality, and with lessons to be learned for other programs in active, local use of data.

Intrapartum-Related Neonatal Deaths (814,000 Newborn Deaths Globally)

Infants born in the world's least-developed countries have a very high risk of intrapartum-related injury (previously loosely called "birth asphyxia"[27]) and of intrapartum stillbirth.[30,45] The most effective interventions for intrapartum-related newborn deaths involve prevention through improved antenatal care and, particularly, through skilled attendance at childbirth and emergency obstetrical care.[8,46] Once obstructed labor or hemorrhage has resulted in severe intrapartum injury, the baby may be stillborn or have a high chance (30%-50%) of dying on the first day of life.[30] Inclusion of neonatal resuscitation as a core skill for all skilled attendants is a critical missed opportunity: national service provision assessments in 6 African countries show that on average, of those births currently in a facility only 1 in 4 infants is delivered by an attendant trained in neonatal resuscitation and who has the simple equipment (bag and mask) required.[47]

The only 2 published studies from low-income settings of long-term follow-up of severely asphyxiated babies are from hospital-based cohorts in South Africa[48] and Nepal.[49] The limited follow-up data from these studies suggest that initial mortality is very high, and survivors with disability may be fewer than previously estimated, but more data are required on long-term outcomes.

Preterm Birth Complications (1,033,000 Newborn Deaths Globally)

Preterm birth complications are a direct cause for approximately 29% of neonatal deaths globally. Most preterm infants are born between 33 and 37 weeks of gestation.[50] They should survive with careful attention to feeding, warmth and early treatment of problems, including breathing problems, infections and jaundice. Babies born before 33 weeks' gestation or with birth weight under 1500 g are more likely to need advanced care, especially for breathing problems and feeding. If possible, these babies should receive care in a referral hospital. Kangaroo mother care (KMC) involves caring for small, particularly preterm, infants by having them strapped skin-to-skin to the mother's front. A meta-analysis of 3 randomized trials suggests a 51% reduction in mortality for newborns <2000 g.[51] KMC is simple and effective, empowers mothers, and is feasible in most facilities in low-income settings in which care for small infants is provided. Additional home visits for extra care at home with skin-to-skin care and additional support for breastfeeding has great potential.[52,53] The use of antenatal corticosteroids is a missed

Table 5 Interventions and Estimated Potential Lives Saved With Essential Maternal, Newborn, and Childcare Interventions According to the Most Common Causes of Newborn Death

Cause of Death	Estimated Deaths Globally	Timing of Deaths	Prevention Solutions	Treatment Solutions	Potential Lives Saved	Feasibility
Neonatal infections (sepsis, meningitis, pneumonia and diarrhea)	963,000	Sepsis and meningitis: first week Pneumonia and diarrhea: increases towards end of first mo	• Treating maternal infections • Clean childbirth practices and hygienic care, especially cord care • Breastfeeding	• Case management as an outpatient, inpatient care with full case management but coverage is very low owing to physical and cultural barriers to access in the first mo of life • In countries with integrated management of childhood illness, adding neonatal illness case management is an important opportunity • Enabling policies for what to give and where and by whom, eg, "gold standard" regimen (7-10 days injectable antibiotics, usually in hospital) may block community-based treatment	47%-82%	• Highly feasible through routine increased skilled attendance, postnatal care, integrated management of childhood illness and improved hospital care of sick newborns
Intrapartum-related deaths ("birth asphyxia")	814,000	First day of life	• Antenatal care, especially to identify/manage hypertension in pregnancy and pre-eclampsia • Skilled attendance, including use of partograph • Emergency obstetrical care for complications (eg, obstructed labor, hemorrhage)	• Resuscitation • Care of babies with neonatal encephalopathy • Lack of capacity and staff with necessary skills for resuscitation, even in countries where more births are in health facilities • Lack of supplies, eg, bag and mask	39%-71%	• Feasible with more commitment to scaling up skilled attendance during childbirth and emergency obstetrical care and adequate referral and transport
Complications of preterm birth	1,033,000	First week for many (in the absence of intensive care) but continuing increased risk, especially from infections	• Treating maternal infections • Iron/folic acid supplements • Preventing malaria in pregnancy • Antenatal steroids	• Resuscitation at birth • Improved breastfeeding practices • Kangaroo mother care • Early identification and treatment of complications, especially infections	37%-71%	• Prevention feasible through antenatal care, especially with malaria prevention in endemic areas • Treatment feasible through existing facility care, especially kangaroo mother care and extra support for feeding • Improved coverage and quality of postnatal care
Tetanus	59,000	Peaks during days 4-9 of life	• Tetanus toxoid immunization during pregnancy • Clean childbirth practices and cord hygiene	• Antibiotics • Antitetanus globulin • Supportive care	—	• Highly feasible through routine antenatal care and immunization outreach campaigns
Congenital abnormalities	272,000	First week of life for severe abnormalities	• Preconceptional folic acid to prevent neural tube defects • Preventing unwanted pregnancy for older women	• Supportive care, depending on type and severity	—	• Curative care may be complex • Reducing unwanted pregnancy for older women would reduce incidence of Down syndrome • Preconceptional folic acid may be cost-effective in low-resource settings, especially through food fortification

Adapted from Lawn and Kerber[18] with permission; data sources: neonatal cause of death estimates for 2008,[3] neonatal lives saved for Africa and South Asia from Darmstadt et al.[38]
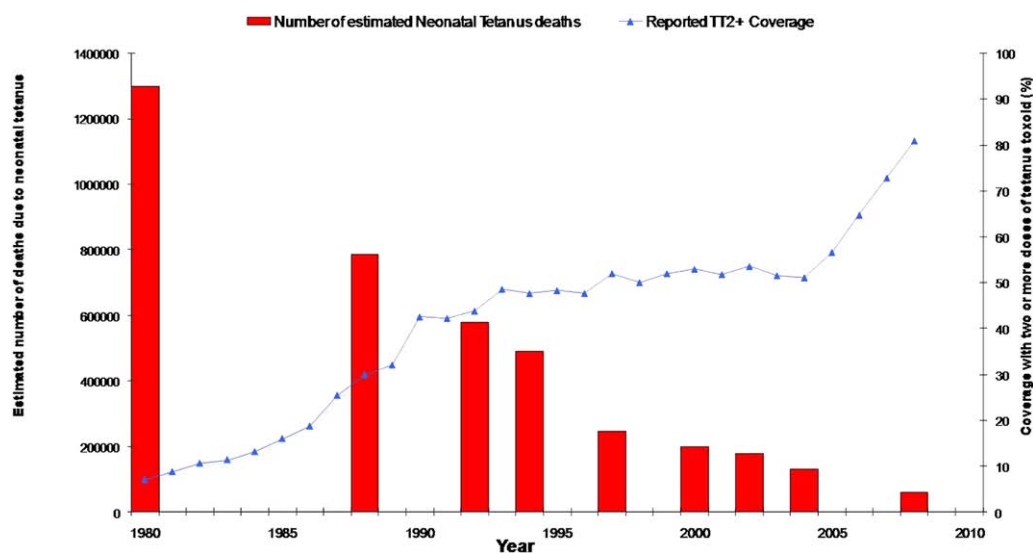
Figure 6 Progress in reducing global deaths from neonatal tetanus and the associated increase in coverage of maternal tetanus toxoid immunization (1980-2008). (Source: updated from Blencowe et al.[44]) (Color version of figure is available online.)

opportunity with potential to reduce neonatal deaths by up to one-half a million per year.[51]

Preterm birth acts a risk factor for mortality as well as a direct cause of death. According to the International Classification of Disease, the direct cause of death is only attributed to preterm birth if the death results from complications specific to preterm birth or is in a severely preterm baby. For example, if a moderately preterm baby has an infection and dies, the death is most appropriately attributed to infection and preterm birth is acting as a risk factor. Thus, many infants recorded as dying from infection are also preterm.

Small Infants—Big Risk Of Death

Globally, an average of 14% of babies are born with low birthweight (LBW)—a weight at birth of less than 2500 g.[2] LBW may be caused by preterm birth or growth restriction of full-term babies, or a combination of the two. Preterm infants have a risk of neonatal death that is around 13 times greater than full-term infants[54] and at least one-half of neonatal deaths are in preterm babies. Babies who are both preterm and growth-restricted have an even greater risk of death.[54] LBW infants in Africa are at greater risk of being born preterm—the regional estimate for preterm birth is around 12%, which is almost double the frequency of preterm birth in European countries and probably related to infections, particularly sexually transmitted infections, malaria and HIV/AIDS.[55] This differs markedly from the situation in South Asia, where the LBW rate is almost twice that in Africa but most LBW babies are term infants who are small for gestational age. Indeed, coinfection during pregnancy with HIV and malaria is more than "double trouble": the 2 infections act synergistically, with serious consequences for maternal and newborn health, especially increasing the LBW rate.

To date, strategies to prevent LBW and preterm birth have

not resulted in significant progress and remain a critical discovery research gap for both high and low income countries.[56] However, identifying small infants and providing extra support for feeding, warmth, and care, particularly KMC has great potential to reduce neonatal deaths in the short term.[50]

Gender and Neonatal Death

In societies in which care is equal for boys and girls, baby girls have a lower mortality rate than baby boys: the ratio of neonatal mortality for boys to girls is usually at least 1.2. Typically there are about 10% more baby boys born than girls, although this ratio has been distorted further in countries with gender-specific termination of pregnancy.[57] Analysis of DHS data for African countries does not suggest any loss of the natural survival advantage for girl babies.[5] However, several studies from South Asia have reported reduced care-seeking for baby girls and even female infanticide, and after the neonatal period there are more data on the existence of practices that have a significant detrimental effect on the survival of girls.[58]

Progress for Coverage of Care

Evidence-based strategies to save the lives of women and children include a wide range of interventions, which are usually provided through integrated service delivery packages along the timeline of the continuum of care, notably[59]:

- reproductive health services to provide contraceptive services;
- antenatal care for pregnant women;
- skilled attendance and emergency obstetrical care during birth; and

- postnatal care services, including both preventive and curative interventions.

Global-tracking mechanisms tend to collect information on the contact point but not always on the provision of effective care, although there is more information available on the numbers of contacts and the content of these contacts for antenatal care than for intrapartum care or, especially, for postnatal care.

Nevertheless, time series data on these contact points provide valuable information. Contraceptive use, although one of the most cost-effective interventions for maternal, newborn and child health, appears to be stagnating, possibly related to lack of global prioritization and funding. The median use of a modern contraceptive for 68 priority Countdown countries is currently only 31%, and nearly one-quarter of women express an unmet need for family planning.[60]

Antenatal care is one of the success stories in low-income settings, with high coverage and relatively equitable reach to poor and marginalized populations. Data on trends in service coverage have limitations, but it is clear that antenatal care has increased in all regions and the current global average for at least 1 visit is 78%. Indeed, in sub-Saharan Africa, 71% of women now have at least 1 visit, although fewer have 4 or more visits (44%).[2] However, the content of care does not always include the most effective interventions, nor is the service delivered with high quality. Given the high potential to save lives and the low cost and apparent feasibility in low-resource settings, the current low coverage of key interventions, such as identification and management of pregnancy induced hypertension represents a major missed opportunity.

Overall contact for women in low-income countries is much higher for antenatal care than for skilled care at birth, with only 38% of women in the 50 least developed countries having a skilled attendant present during childbirth.[2] Except for eastern and southern Africa, all developing regions have increased their coverage of skilled delivery attendance during the past decade, with particularly marked increases in the Middle East and North Africa. However, regional and country averages hide large inequities in care, especially for skilled attendance.[17] For example, although 6% of women in Ethiopia overall have a skilled attendant at birth, 25% of the wealthiest families do in contrast with only 1% of the poorest families. Similarly, rural mothers have much lower access to skilled birth attendance and Cesarean section than mothers in urban areas.[60] The gap in coverage of skilled birth attendance is widest in sub-Saharan Africa and South Asia, where baseline coverage is lowest globally and progress to reaching universal skilled attendance is slow. The rate of increase of skilled birth attendance in these regions is less than 0.5% per year and, at current rates, by 2015 a skilled birth attendant will only reach 1 in 2 women in sub-Saharan Africa and South Asia.[17] This is a priority gap requiring substantial work to define potentially scalable approaches to reaching universal skilled birth attendance in varying contexts.

Postnatal care is also a critical yet neglected gap in low- and middle-income countries and with coverage even lower than that for skilled birth attendance. Early and effective contact with mothers and babies is critical, ideally within 24 or at most 48 hours of birth (instead of the more common visit 6 weeks after birth). Recent data from Bangladesh show that a visit in the first 2 days of life is associated with significantly fewer neonatal deaths compared with those who did not receive a postnatal visit, or received a first visit after 48 hours.[34] In the 68 priority Countdown countries, a median of 38% of mothers received postnatal care within 48 hours of birth.[60] For infants and mothers facing complications, such as neonatal sepsis or postpartum hemorrhage, a delay of even a few hours in receiving appropriate care can be fatal or result in long-term injuries or disability. This is also the crucial time for establishing healthy practices: evidence shows that effective breastfeeding support and counseling for mothers in the first days after birth increases rates of exclusive breastfeeding.[61] Other key behaviors during the neonatal period, such as hygienic cord care and keeping the baby warm, can make the difference between life and death, particularly for babies who are born preterm.[62] In addition, evidence shows that active case-finding through routine home visits has a major effect on increasing treatment for neonatal sepsis and reducing mortality.[63,64] However, in many countries the 6-week postnatal visit is the mother and baby's first interaction with the formal health system after birth.[65,66] There is increasing consensus on the need for a clearly defined package of postnatal practices and suitable delivery strategies in varying settings.[33]

The indicator measuring postnatal care for the global Countdown to 2015 for maternal, newborn and child health now focuses on care provided within 2 days of birth.[19] Large-scale surveys are changing to measure this indicator consistently in more countries and communities.

Priority Gaps for Action and Research

Addressing Program Gaps and Delays

Delays in receiving appropriate care can be important for many conditions, but delays of even a few hours in addressing an obstetrical emergency around the time of birth or the onset of sepsis in a neonate can be significant. The "classic" 3 delays were first described in relation to delay for women with obstetrical emergencies.[67] These 3 delays are:

1. **Delay in recognition of the problem and the decision to seek care**. Physical distance and financial and cultural barriers to seeking care are compounded when there is a delay in recognizing illness and taking the decision to seek care, especially in rural settings.[68] Such a delay, even if short, can be fatal because neonatal illness generally presents less obviously and progresses more quickly than in older infants.[69]
2. **Delay to reach a health facility**. This covers the time it takes to reach a first-level facility—often using public transport on bad roads—as well as the time to reach a higher level health facility if referred. In a study in Uganda, fewer than 10% of newborns referred from the first-level facility actually sought care.[70]

3. **Delay in receiving quality care at the facility**. There is often a gap in time between arrival at a facility and receipt of timely and effective emergency care. One recent analysis found that addressing missed opportunities in health facilities by ensuring that births already taking place in a health facility receive the necessary obstetrical and neonatal interventions could reduce maternal and newborn deaths by one-quarter without substantial additional cost.[71] Many such interventions are feasible with improvements in competency-based training for health workers and logistics management to address key gaps, such as resuscitation equipment.

Strategies to reduce these 3 delays by linking mothers and babies effectively to skilled obstetrical and newborn care are essential.[72] Functional transport schemes and other linkages are especially important for the 60 million women who deliver at home each year.[25]

Addressing Data Gaps and Increasing Use of Local Data

Improved health information systems, providing timely data on quality of care and on maternal and newborn outcomes, are essential to track progress effectively and to guide program implementation (Box 1).

Pregnancy Outcome Data

High coverage with vital registration systems is increasing with 72 countries now having achieved over 80% completeness of death registration—almost a doubling since 2000. However, these countries include fewer than 5% of all neonatal deaths and the patterns of mortality observed in these countries cannot be generalized to typical low- and middle-income country settings. Neonatal deaths that occur in the first hours after birth or in small babies are less likely than other neonatal deaths to be reported through death certificates.

Most global mortality data for children and neonates are derived from 5-yearly household surveys.[73] These surveys remain a very uncertain way to count stillbirths and moving from birth to pregnancy histories is theoretically advantageous but under researched.[74] Verbal autopsies (interviews done with family members after the death) are the only option for obtaining cause-of-death data for the majority of neonatal deaths and stillbirths where vital registration systems are still weak. Although there have been advances in case definitions and algorithms for use with verbal autopsy data, there is little consistency across studies, particularly for hierarchical attribution if the infant died with signs suggestive of several possible causes of death.[75,76] Misclassification of neonatal deaths and stillbirths remains a challenge.

Improving pregnancy outcomes for the mother, fetus and neonate will require a shift to identifying and recording pregnancies and the key outcomes, not just live births and ideally tracking and being accountable for each pregnancy through birth and the neonatal period.[77]

Coverage Data

Although some progress has been made on package definition and delivery strategies for postnatal care, key gaps around implementation and monitoring remain. The little information available on the timing of the first visit after birth and cadre of provider comes from mothers' responses in household surveys, such as DHS or from research settings. Additional survey modules would provide important information on the content and quality of postnatal visits that are taking place, including the number of visits, extra visits for small or sick infants, mothers who know newborn danger signs, breastfeeding, family planning, thermal care and hygienic practices.

Use of Local Data for Decision Making

Data that are available may not be optimally used. Although efforts have been made at the global level to improve availability, tracking and quality of relevant indicators for newborn health, particularly through the Countdown to 2015 for Maternal, newborn and Child Health,[19] there is limited use of local data to inform policies and programs. This has prevented advocacy, program prioritization, and rational budget allocation. Countries, such as United Republic of Tanzania have used innovative tools to link burden of disease to district level budgeting, and Nigeria has begun to use state-level profiles that emphasize the vast differences between states in potential strategies for addressing newborn survival (Fig. 7).[78] The Lives Saved Tool (LiST) is purpose-built software that has also been used to facilitate program decisions based on mortality effects determined by modeling the estimated impact of scaling up coverage of specific health interventions.[79]

Addressing Research Gaps

There are immediate opportunities to add to or strengthen high-impact neonatal interventions within current maternal and child health programs and to monitor and evaluate the effectiveness of such implementation. Thus, Although new technology or improvements to existing technologies may provide some improvement (for example, by identifying fetal distress or preventing preterm labor), key priority questions also include "who, where and how" regarding task shifting, supervision and management at scale to reach high coverage of evidence-based interventions.[73] This requires implementation research—a better understanding of how to deliver effective care and reach the poorest families with high-impact interventions. To date, much of the evidence for community-based newborn care has come from Asia. A new network of studies in 8 African countries is examining nationally adapted packages and potentially scalable cadres of workers.[80] Analyses of lives saved using software, such as LiST, costs and feasibility at scale will help guide policies and programs to improve maternal and newborn care in varying settings.

Conclusions

Together, maternal, newborn and child deaths remain a massive burden but more low-income countries are making good

Box 1 Improving the Data for Decision-Making for Programs at the Time of Birth and for Stillbirth and Neonatal Outcomes

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Improved measurement of outcome data for stillbirths and neonatal deaths

Intrapartum stillbirths
- Improved measurement of the numbers/rates of stillbirths, especially in settings where most births occur at home and/or where stillbirths are a taboo subject
- Consistent definitions and classification systems to allow comparability of causes of death measurement across low- and high-income settings
- Tools to assess the causes of stillbirths, and to better distinguish intrapartum stillbirths from antepartum stillbirths and from intrapartum-related neonatal deaths (for example, through verbal autopsy)
- Linking to data collection mechanisms (for example, vital registration, household surveys, demographic surveillance systems)

Intrapartum-related neonatal deaths
- Improved measurement of intrapartum-related outcomes (mortality and morbidity)
- Consistent definitions and classification systems to allow comparability of measurement of intrapartum-related neonatal outcomes across low- and high-income settings
- Verbal autopsy tools and hierarchical methods to distinguish intrapartum-related neonatal deaths from other causes of very early death, such as early-onset sepsis and preterm birth
- combined marker of intrapartum-related stillbirths and neonatal deaths, and/or intrapartum-related maternal deaths
- Validation of a composite indicator of quality of intrapartum care; for example, intrapartum stillbirths plus first-day (or predischarge if earlier) neonatal deaths more than 2000 g as a surrogate for intrapartum-related neonatal deaths, consider addition of intrapartum-related maternal deaths
- Classification systems to cross-tabulate stillbirth and neonatal outcomes with maternal deaths, complications and risk factors

Impairment and disability
- Feasible case definitions for neonatal encephalopathy in low-income and community settings (for example, surrogate marker proposed is seizures in first 24 hours in neonate with birth weight above 2500 g)
- Screening methods (for example, application of surveillance or screening tool followed by definitive testing of screen positives) for identification of infants at high risk of disability or impairment and who may benefit from early intervention
- Feasible, sustainable instruments to measure disability that are validated at population level to ensure that improved newborn survival (from intrapartum-related or other conditions, such as preterm birth or infection) is not contributing to an increase in disability rates

Improvement in measurement of service coverage data for care at birth

Obstetrical care coverage indicators (refinement, consensus and consistent reporting)
- Attendance at birth
  - Skilled birth attendance coverage, monitoring of skills, competence, and procedures performed by skilled attendants
  - Place of delivery, and other birth attendants
  - Cross tabulation by rural/urban and by socio-economic status
- Emergency obstetrical care services
  - Access, use, and met need for emergency obstetrical care services, better determination of baseline marker of "need" in different settings
  - Consistent definitions of maternal indications, complications and life-saving interventions
  - Cesarean deliveries as percentage of all births: specify those for maternal–fetal indications
- Indicators to track referral systems for obstetrical and newborn care from community to facility and between facilities

Neonatal care coverage (refinement, consensus, and consistent reporting)
- Indicators of newborn care at birth—proportion of facilities with capacity for neonatal resuscitation (training and equipment), proportion of staff competent in neonatal resuscitation, neonates receiving resuscitation, validation of data collected through facility assessments or through retrospective surveys
- Routine postnatal care—timing, frequency, cadres and content of postnatal care visit in facility and at home, validation of data collected through retrospective surveys
- Emergency newborn care—proportion of facilities with capacity for continuing care for neonatal encephalopathy (neonatal intensive care, assisted ventilation, nutrition support and fluid management)

Adapted from Lawn et al.[27]

progress towards MDG 4 and, with strategic investments, including more attention to neonatal deaths, MDG 4 is achievable for many countries.[17,19] Although some uncertainty remains about the figures, it is clear that there are huge numbers of maternal (358,000) and neonatal (3.6 million) deaths, also closely linked with stillbirths (3.2 million). Often, however, maternal health advocates do not include neo-

natal outcomes, or vice versa, and stillbirths are not included in the MDG framework and frequently left out of policy dialogue and program planning. If outcomes are consistently measured and reported, attention and action are likely to increase.

The data for action for neonatal survival highlight many commonalities with maternal survival and indeed mothers
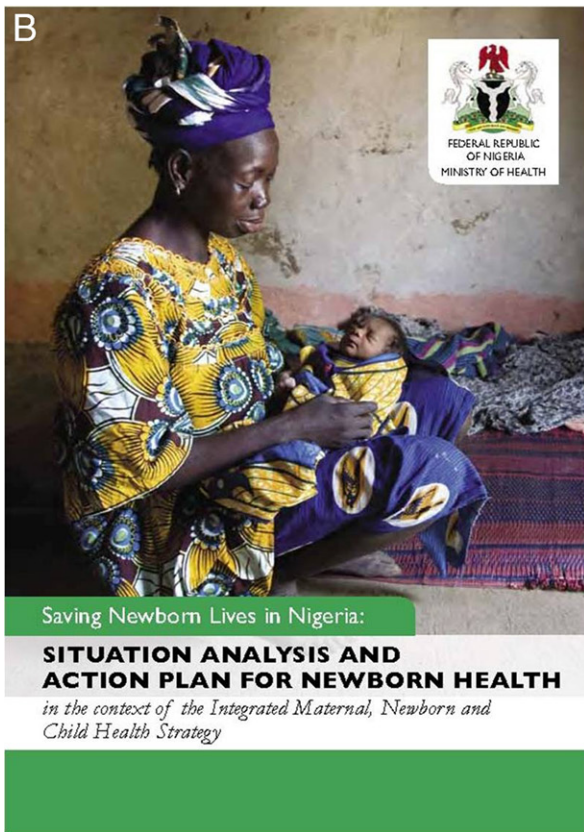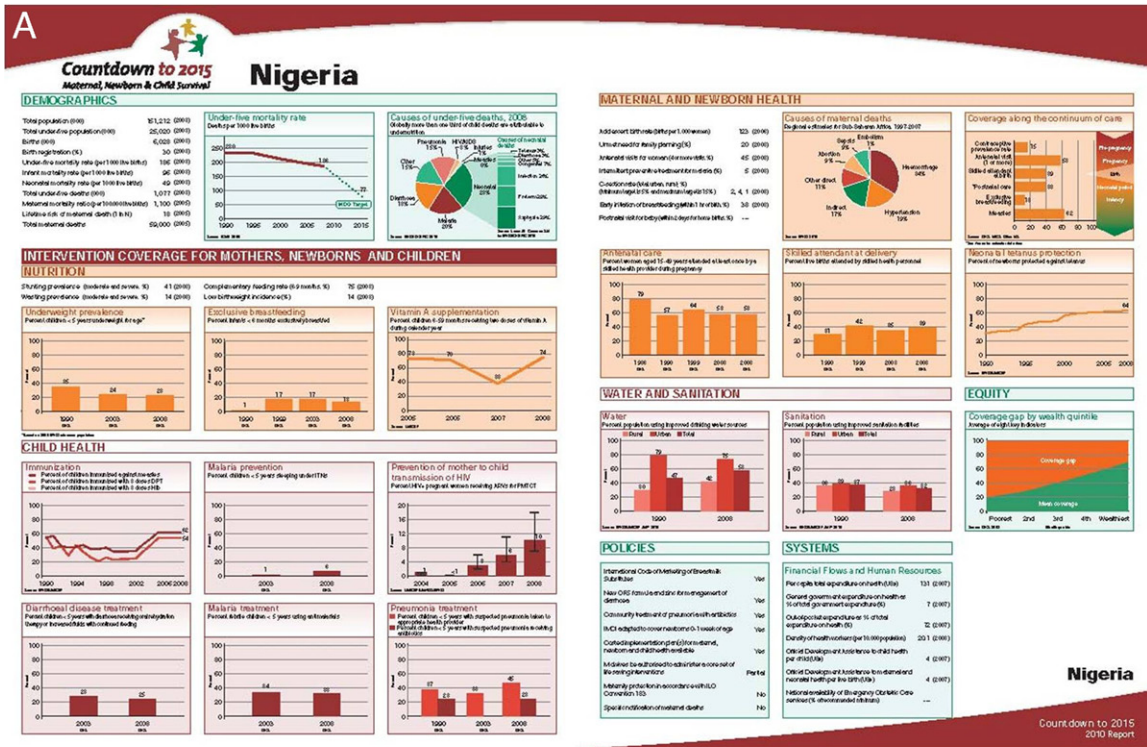
Figure 7 Examples of data profiles to promote the use of data in programmatic decision making and accountability. (A) Countdown to 2015—national-level 2 page profile for Nigeria.[19] (B) State-level 1 page profile for Gombe state in Nigeria.[78] (Color version of figure is available online.)

and their babies are intimately linked. Previous false dichotomies in advocacy and programs for maternal, newborn and child survival have not been helpful in accelerating progress. An integrated call for action for mothers, newborns, and stillbirths would be more likely to increase global visibility and national action. Health professionals and policy makers need to link numbers for mothers, newborns and stillbirths together, and to work together to implement the highest impact solutions that save the lives of women, infants, and children.[12] Given the high proportion of maternal (at least 42%), neonatal (23%), and stillbirths (31%) that are directly related to care at birth (Fig. 3),[32] the data support the urgent need to invest in care at birth and in the early postnatal period. Reaching 60 million home births must be a priority.[25]

The political priority and investment for a given global health issue is not always directly correlated to the size of the problem but is determined by other factors, such as consensus regarding practical solutions and the actors involved.[81] There are also many common themes in the solutions for mothers and babies, particularly related to health systems issues, notably the need for rapid scale-up of skilled human resources to provide care at birth, increasing the availability of emergency obstetrical care, solutions to address the gap for early postnatal care, and case management of ill newborns or mothers.

Given the short timeline until the target date of the MDGs in 2015 and the fact there is not one-a one-size-fits-all solution, it is critical that implementation priorities be set using data at national or subnational level, particularly at district level. Where possible, consideration should be given to using evidence-based mortality effect estimation tools to guide implementation priorities, based on local cause of death data, effect of interventions and local coverage of interventions, as demonstrated through LiST.[82,83] Existing interventions addressing the most common causes of death could save hundreds of thousands of lives each year.

Although existing data are often underused for action, there are nevertheless major data gaps. A shift in focus to measurement of pregnancies and pregnancy outcomes for mother, fetus and baby would benefit public health planning. Reliable stillbirth data are particularly lacking and stillbirth outcomes should be consistently reported in programs and studies. There are also important gaps for coverage of care data, especially at the time of birth, and postnatal care and for the highest impact interventions (eg, KMC, antenatal steroids and neonatal resuscitation). The data on quality of care is even more limited (Box 1).

For research investments in the short to medium-term, the most effect on lives saved would come from a greater focus on implementation research—the "how-to" questions—but still with as rigorous design as possible to better inform policy priorities regarding cost and effect of various strategies to implement known interventions. Prevention of preterm birth is a critical discovery research question[50] but remains a higher risk and longer-term investment as several decades of investment in high income countries have not yet proved fruitful.[73,84]

Investment in maternal and neonatal survival is increasing.[10] Even given the limitations in the current data, the priorities are clear especially for more investment immediately around the time of birth. The use of data to prioritize programmatic action has the potential to result in major changes for maternal and newborn survival in many countries and for the world's poorest families before 2015—the question is are we using the data and will we act?

Acknowledgments

References

1. Lawn JE, Kerber K, Enweronu-Laryea C, et al: Newborn survival in low resource settings—are we delivering? Br J Obstet Gynaecol 116:49-59, 2009 (suppl 1)
2. UNICEF: State of the World's Children 2010. New York, United Nations Children's Fund, 2009
3. Black RE, Cousens S, Johnson HL, et al: Global, regional, and national causes of child mortality in 2008: a systematic analysis. Lancet 375: 1969-1987, 2010
4. Rajaratnam JK, Marcus JR, Flaxman AD, et al: Neonatal, postneonatal, childhood, and under-5 mortality for 187 countries, 1970-2010: a systematic analysis of progress towards millennium development goal 4. Lancet 375:1988-2008, 2010
5. Lawn JE, Cousens S, Zupan J: Four million neonatal deaths: when? Where? Why? Lancet 365:891-900, 2005
6. Shiffman J: Issue attention in global health: the case of newborn survival. Lancet 375:2045-2049, 2010
7. Knippenberg R, Lawn JE, Darmstadt GL, et al: Systematic scaling up of neonatal care in countries. Lancet 365:1087-1098, 2005
8. Darmstadt GL, Bhutta ZA, Cousens S, et al: Evidence-based, cost-effective interventions: how many newborn babies can we save? Lancet 365:977-988, 2005
9. Martines J, Paul VK, Bhutta ZA, et al: Neonatal survival: a call for action. Lancet 365:1189-1197, 2005
10. Pitt C, Greco G, Powell-Jackson T, et al: Countdown to 2015: assessment of official development assistance to maternal, newborn and child health, 2003-08. Lancet DOI:S0140-6736(10)61302-5
11. Lawn JE, Tinker A, Munjanja SP, et al: Where is maternal and child health now? Lancet 368:1474-1477, 2006
12. Bhutta ZA, Lassi ZS, Blanc A, et al: Linkages among reproductive health, maternal health, and perinatal outcomes. Semin Perinatol 34:427-434, 2010
13. Stanton C, Lawn JE, Rahman H, et al: Stillbirth rates: delivering estimates in 190 countries. Lancet 367:1487-1494, 2006
14. Yakoob MY, Lawn JE, Darmstadt GL, et al: Stillbirths: epidemiology, evidence and priorities for action. Semin Perinatol 2010;34:387-394
15. WHO. Trends in Maternal Mortality: 1990 to 2008. Estimates developed by WHO, UNICEF, UNFPA and The World Bank. Geneva, World Health Organization, 2010
16. Rohde J, Cousens S, Chopra M, et al: 30 Years after Alma-Ata: has primary health care worked in countries? Lancet 372:950-961, 2008
17. Kinney MV, Kerber KJ, Black RE, et al: Sub-Saharan Africa's mothers,

newborns, and children: where and why do they die? PLoS Med 7 e1000294, 2010

18. Lawn J, Kerber K. (eds): Opportunities for Africa's Newborns: Practical Data, Policy and Programmatic Support for Newborn Care in Africa. Cape Town, PMNCH, Save the Children, UNFPA, United Nations Children's Fund, USAID, World Health Organization, 2006

19. Bhutta Z, Chopra M, Axelson H, et al: Countdown to 2015 decade report (2000-10): taking stock of maternal, newborn and child survival. Lancet 375:2032-2044, 2010

20. Save the Children: Every one: our campaign to save children's lives, 2010. Available at: http://www.everyone.org/. Accessed: June 21, 2010

21. Chowdhury ME, Botlero R, Koblinsky M, et al: Determinants of reduction in maternal mortality in Matlab, Bangladesh: a 30-year cohort study. Lancet 370:1320-1328, 2007

22. Worldmapper. Available at: http://www.worldmapper.org/. Accessed October 19, 2009

23. StatCompiler DHS, Macro O: Measure DHS. Available at: http://www.statcompiler.com. Accessed October 19, 2009

24. Baiden F, Hodgson A, Adjuik M, et al: Trend and causes of neonatal mortality in the Kassena-Nankana district of northern Ghana, 1995-2002. Trop Med Int Health 11:532-539, 2006

25. Darmstadt GL, Lee AC, Cousens S, et al: Sixty million non-facility births: who can deliver in community settings to reduce intrapartum-related deaths? Int J Gynecol Obstet 107:S89-112, 2009 (suppl 1)

26. Lawn JE, Yakoob MY, Haws RA, et al: 3.2 million stillbirths: epidemiology and overview of the evidence review. BMC Pregnancy Childbirth 9:S2, 2009 (suppl 1)

27. Lawn JE, Lee AC, Kinney M, et al: Two million intrapartum-related stillbirths and neonatal deaths: where, why, and what can be done? Int J Gynecol Obstet 107:S5-18:S9, 2009 (suppl 1)

28. Hogan MC, Foreman KJ, Naghavi M, et al: Maternal mortality for 181 countries, 1980-2008: a systematic analysis of progress towards millennium development goal 5. Lancet 375:1609-1623, 2010

29. Li XF, Fortney JA, Kotelchuck M, et al: The postpartum period: the key to maternal mortality. Int J Gynecol Obstet 54:1-10, 1996

30. Lawn J, Shibuya K, Stein C: No cry at birth: global estimates of intrapartum stillbirths and intrapartum-related neonatal deaths. Bull World Health Org 83:409-417, 2005

31. Ronsmans C, Chowdhury ME, Dasgupta SK, et al: Effect of parent's death on child survival in rural Bangladesh: a cohort study. Lancet 375:2024-2031, 2010

32. Lawn JE, Kinney M, Lee AC, et al: Reducing intrapartum-related deaths and disability: can the health system deliver? Int J Gynecol Obstet 107 suppl 1:S123-S140:S40-S42, 2009

33. WHO, UNICEF, USAID, Save the Children: WHO-UNICEF Joint Statement on Home Visits for the Newborn Child: a Strategy to Improve Survival. Geneva, World Health Organization, 2009

34. Baqui AH, Ahmed S, El Arifeen S, et al: Effect of timing of first postnatal care home visit on neonatal mortality in Bangladesh: a observational cohort study. BMJ 339:b2826, 2009

35. Lawn JE, Wilczynska-Ketende K, Cousens SN: Estimating the causes of 4 million neonatal deaths in the year 2000. Int J Epidemiol 35:706-718, 2006

36. Bryce J, Daelmans B, Dwivedi A, et al: Countdown to 2015 for maternal, newborn, and child survival: the 2008 report on tracking coverage of interventions. Lancet 371:1247-1258, 2008

37. Baqui AH, Darmstadt GL, Williams EK, et al: Rates, timing and causes of neonatal deaths in rural India: implications for neonatal health programmes. Bull World Health Organization 84:706-713, 2006

38. Darmstadt GL, Walker N, Lawn JE, et al: Saving newborn lives in Asia and Africa: cost and impact of phased scale-up of interventions within the continuum of care. Health Policy Plan 23:101-117, 2008

39. Ganatra HA, Zaidi AK: Neonatal infections in the developing world. Semin Perinatol 34:416-425, 2010

40. The Young Infant Clinical Signs Study Group: Clinical signs that predict severe illness in children under age 2 months: a multicentre study. Lancet 371:135-142, 2008

41. Expert consultation on Community-Based Approaches for Neonatal Sepsis Management, September 26-28, 2007. Report of a Meeting.

London, UK, Save the Children, USAID, World Health Organization, 2008

42. Darmstadt GL, Baqui AH, Choi Y, et al: Validation of community health workers' assessment of neonatal illness in rural Bangladesh. Bull World Health Org 87:12-19, 2009

43. WHO: Maternal and Neonatal Tetanus Elimination: Progress Toward Global MNT Elimination. Geneva, World Health Organization, 2005

44. Blencowe H, Lawn J, Vandelaer J, et al: Tetanus toxoid immunization to reduce mortality from neonatal tetanus. Int J Epidemiol 39:i102-i109, 2010 (suppl 1)

45. Wall S, Lee AC, Carlo W, et al: Reducing intrapartum-related neonatal deaths in low- and middle-income countries—what works? Semin Perinatol 34:395-407, 2010

46. Adam T, Lim SS, Mehta S, et al: Cost effectiveness analysis of strategies for maternal and neonatal health in developing countries. BMJ 331: 1107, 2005

47. Wall SN, Lee AC, Niermeyer S, et al: Neonatal resuscitation in low-resource settings: what, who, and how to overcome challenges to scale up? Int J Gynecol Obstet 107:S47-S62:S3-S4, 2009 (suppl 1)

48. Thompson CM, Puterman AS, Linley LL, et al: The value of a scoring system for hypoxic ischaemic encephalopathy in predicting neurodevelopmental outcome. Acta Paediatr 86:757-761, 1997

49. Ellis M, Manandhar N, Shrestha PS, et al: Outcome at 1 year of neonatal encephalopathy in Kathmandu, Nepal. Dev Med Child Neurol 41:689-695, 1999

50. Simmons LE, Rubens CE, Darmstadt GL, et al: Preventing preterm birth and neonatal mortality: exploring the epidemiology, causes and interventions. Semin Perinatol 34:408-415, 2010

51. Lawn JE, Mwansa-Kambafwile J, Horta BL, et al: Kangaroo Mother Care to prevent neonatal deaths due to preterm birth complications. Int J Epidemiol i1-i10, 2010

52. Darmstadt GL, Kumar V, Yadav R, et al: Introduction of community-based skin-to-skin care in rural Uttar Pradesh, India. J Perinatol 26: 597-604, 2006

53. Kumar V, Mohanty S, Kumar A, et al: Effect of community-based behaviour change management on neonatal mortality in Shivgarh, Uttar Pradesh, India: a cluster-randomised controlled trial. Lancet 372:1151-1162, 2008

54. Yasmin S, Osrin D, Paul E, et al: Neonatal mortality of low-birth-weight infants in Bangladesh. Bull World Health Org 79:608-614, 2001

55. Beck S, Wojdyla D, Say L, et al: The worldwide incidence of preterm birth: a systematic review of maternal mortality and morbidity. Bull World Health Org 88:31-38, 2010

56. Barros FC, Bhutta ZA, Batra M, et al: Global report on preterm birth and stillbirth (3 of 7): evidence for effectiveness of interventions. BMC Pregnancy Childbirth 10:S3, 2010 (suppl 1)

57. Jha P, Kumar R, Vasa P, et al: Low female[corrected]-to-male [corrected] sex ratio of children born in India: national survey of 1.1 million households. Lancet 367:211-218, 2006

58. Nielsen BB, Liljestrand J, Hedegaard M, et al: Reproductive pattern, perinatal mortality, and sex preference in rural Tamil Nadu, south India: community based, cross sectional study. BMJ 314:1521-1524, 1997

59. Kerber KJ, de Graft-Johnson JE, Bhutta ZA, et al: Continuum of care for maternal, newborn, and child health: from slogan to service delivery. Lancet 370:1358-1369, 2007

60. Bhutta ZA, Chopra M, Axelson H, et al: Countdown to 2015 decade report (2000-10): taking stock of maternal, newborn, and child survival. Lancet 375:2032-2044, 2010

61. Bhutta ZA, Ahmed T, Black RE, et al: What works? Interventions for maternal and child undernutrition and survival. Lancet 371:417-440, 2008

62. Kumar V, Kumar A, Darmstadt GL: Behavior change for newborn survival in resource-poor community settings: bridging the gap between evidence and impact. Semin Perinatol 34:446-461, 2010

63. Bang AT, Bang RA, Baitule SB, et al: Effect of Home-Based Neonatal Care and Management of Sepsis on Neonatal Mortality: Field Trial in Rural India. Lancet 354:1955-1961, 1999

64. Baqui AH, El-Arifeen S, Darmstadt GL, et al: Effect of community-based

newborn-care intervention package implemented through two service-delivery strategies in Sylhet district, Bangladesh: a cluster-randomised controlled trial. Lancet 371:1936-1944, 2008

65. Martines J, Qazi SA, Bahl R: Why is continuum of care from community to health facilities essential to improved perinatal survival? Semin Perinatol 34:477-485, 2010

66. Shiffman J, Baqui AH, Agarwal S, et al: Community-based intervention packages (CBIPs) for improving perinatal health in developing countries: a review of the evidence. Semin Perinatol 34:462-476, 2010

67. Rosenfield A, Maine D: Maternal health in third world. Lancet 1:691, 1987

68. Waiswa P, Kallander K, Peterson S, et al: Using the three delays model to understand why newborn babies die in eastern Uganda. Trop Med Int Health 15:964-972, 2010

69. Darmstadt GL, El Arifeen S, Choi Y, et al: Household surveillance of severe neonatal illness by community health workers in Mirzapur, Bangladesh: coverage and compliance with referral. Health Policy Plan 25:112-124, 2009

70. Simoes EA, Peterson S, Gamatie Y, et al: Management of severely ill children at first-level health facilities in sub-Saharan Africa when referral is difficult. Bull World Health Organization 81:522-531, 2003

71. Friberg IK, Kinney MV, Lawn JE, et al: Sub-Saharan Africa's mothers, newborns, and children: how many lives could be saved with targeted health interventions? PLoS Med 7 e1000295, 2010

72. Lee AC, Lawn JE, Cousens S, et al: Linking families and facilities for care at birth: what works to avert intrapartum-related deaths? Int J Gynecol Obstet 107:S65-S85:S6-S8, 2009 (suppl 1)

73. Lawn JE, Rudan I, Rubens C: Four million newborn deaths: is the global research agenda evidence-based? Early Hum Dev 84:809-814, 2008

74. Lawn JE, Gravett MG, Nunes TM, et al: Global report on preterm birth and stillbirth (1 of 7): definitions, description of the burden and opportunities to improve data. BMC Pregnancy Childbirth 10:S1, 2010 (suppl 1)

75. Lawn JE, Osrin D, Adler A, et al: Four million neonatal deaths: counting and attribution of cause of death. Paediatr Perinat Epidemiol 22:410-416, 2008

76. Thatte N, Kalter HD, Baqui AH, et al: Ascertaining causes of neonatal deaths using verbal autopsy: current methods and challenges. J Perinatol 29:187-194, 2009

77. Lawn JE, McCarthy BJ, Ross SR: The Healthy Newborn: A Reference Guide for Program Managers Atlanta, GA, CDC and Christian Action Research & Education for Europe, 2001

78. Saving Newborn Lives in Nigeria: Newborn Health in the Context of the Integrated Maternal, Newborn and Child Health Strategy. Abuja, Federal Ministry of Health, Save the Children, ACCESS, 2009

79. Bryce J, Friberg IK, Kraushaar D, et al: LiST as a catalyst in program planning: experiences from Burkina Faso, Ghana and Malawi. Int J Epidemiol 39:i40-i47, 2010 (suppl 10)

80. Africa Newborn Network: Healthy Newborn Network, 2010. Available at: http://www.healthynewbornnetwork.org/partner/africa-newborn-network. Accessed: June 21, 2010

81. Shiffman J: Generating political priority for maternal mortality reduction in 5 developing countries. Am J Public Health 97:796-803, 2007

82. Stover J, McKinnon R, Winfrey B: Spectrum: a model platform for linking maternal and child survival interventions with AIDS, family planning and demographic projections. Int J Epidemiol 39:i7-10, 2010 (suppl 1)

83. Friberg IK, Bhutta ZA, Darmstadt GL, et al: Comparing modelled predictions of neonatal mortality impacts using LiST with observed results of community-based intervention trials in South Asia. Int J Epidemiol 39:i11-i20, 2010 (suppl 1)

84. Gravett MG, Rubens CE, Nunes TM: Global report on preterm birth and stillbirth (2 of 7): discovery science. BMC Pregnancy Childbirth 10:S2, 2010 (suppl 1)