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Four million neonatal deaths: counting and attribution of cause of death

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Summary

Each year there are an estimated four million neonatal deaths and at least 3.2 million stillbirths. Three-quarters of the world's neonatal deaths are counted only through five-yearly retrospective household surveys. Without these surveys we would have no data, but limitations remain particularly in detecting deaths on the first day of life. Comparable reliable neonatal cause of death data through vital registration are available for less than 5% of the world's neonatal deaths, necessitating modelled estimates for the majority of the world. Improving the quantity, quality and frequency of data for numbers and causes of neonatal deaths is essential to effectively guide the increasing investments to reduce these deaths. Advancing the data requires general investment in information systems and specific improvements of tools and methods for both household surveys and verbal autopsy, particularly the use of consistent case definitions and hierarchical attribution of cause of death. An important paradigm shift is from historical categories for cause of death ('perinatal causes') to programmatic categories which are consistent with the International Classification of Diseases. If neonatal deaths remain uncounted, they cannot count in policy and in programmes.

Keywords

neonatal death; stillbirth; verbal autopsy; cause of death data

Introduction

Each year an estimated four million babies die in the first 4 weeks of life (the neonatal period),[1] and at least another 3.2 million are stillborn.[2] Almost all of these deaths (99%) occur in low- and middle-income countries,[3] and approximately half occur at home, often unnamed and uncounted.[4] While many factors account for this huge death toll, the lack of data contributes to programme, policy and social invisibility. Most publications on newborn survival, whether reporting epidemiological studies, trials or reviews, focus on the 1% of deaths in rich countries. The communities with the most stillbirths and neonatal deaths have the least information and the least access to cost-effective interventions to prevent them.[5]

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This issue of the journal includes two papers from Ghana giving information on the causes of stillbirths and neonatal deaths, and providing valuable insights into fetal and neonatal outcomes in rural West Africa.[6,7] In addition, the investigators propose the more systematic use of verbal autopsy as a tool for assigning cause of neonatal death in such settings. In this paper we summarise sources of nationally representative data on neonatal deaths and their causes and highlight some key limitations to data availability and quality, and action and research priorities to address these gaps.

Neonatal deaths count

The demand for information on neonatal deaths is growing because an increasing proportion – currently about 40% – of global under-five mortality occurs in the first 28 days of life. It is clear that the Millennium Development Goal for child survival (MDG 4, which calls for a reduction in under-five mortality by two-thirds by 2015) will not be met without substantial reductions in neonatal mortality. Between 1960 and 1990, the risk of dying in the first 5 years of life was halved – a major achievement. Since 1990, child mortality after the first month of life (i.e. from 1 month to 5 years of age) has declined by one-third, while the neonatal mortality rate (NMR) has declined by only about one-quarter, due mainly to progress in the world's richest countries and in transitional countries in South East Asia and Latin America.[8] The survival gap between rich and poor countries is such that a newborn in West Africa is over 15 times more likely to die in the neonatal period than a newborn in Western Europe (NMRs of 46 and 3 per 1000 live births respectively).[3]

In the last year there has been unprecedented attention on international health, with funding for maternal, newborn and child survival increasing by more than 60% (2006–07), although a large proportion of this is earmarked for immunisation. To ensure that this investment saves lives, especially among the poorest, we need to improve both the quality and coverage of information and national capacity to use it. Specifically, to address four million annual neonatal deaths, two-thirds of which could be prevented with existing, low-tech interventions,[9] we need better information on how many, where, when and why newborn infants are dying.

Counting neonatal deaths

High-coverage vital registration systems provide countries with data on numbers of births and deaths, and on causes of death, reasonably quickly: the time lag is usually 1 or 2 years.[10] However, while there have been recent improvements in vital registration coverage and quality in some transitional countries (81 countries now have systems with high coverage), these only account for 27% of the world's births (Table 1). For three million neonatal deaths per year, we are dependent on other methods. The most important of these is the household survey, of which there are two major providers: Demographic and Health Surveys (DHS), funded largely by USA government aid but usually in partnership with national statistics offices; and Multiple Indicator Cluster Surveys (MICS), run by UNICEF. Such surveys use a questionnaire to ask women about previous births and child deaths, and tend to be repeated every 5 years. DHS report under-five mortality, neonatal mortality and stillbirth rates for over 80 countries which account for two-thirds of the world's births, although only around 50 have data within the last 5 years. The data and results are open access (http://www.measure.dhs.com). MICS report under-five mortality and coverage of interventions in many of the same countries, but do not routinely analyse or report on stillbirths or neonatal deaths. Indeed, MICS do not directly measure under-five deaths through a birth history, but use indirect methods. Summary results are available (http://www.childinfo.org). Availability of neonatal mortality data would be increased if this outcome was estimated from MICS survey results, also giving uncertainty bounds as MICS are not usually powered for neonatal

mortality estimation. However, Malawi's MICS did increase sample size specifically to estimate the national NMR.

For a smaller group of countries accounting for about 5% of births, there are no nationally representative data on neonatal deaths (Table 1). These are either conflict or post-conflict settings, or small nations such as Pacific islands. For these countries, under-five mortality is estimated annually by the United Nations Child Mortality Group[11] and, intermittently, the World Health Organisation (WHO) has used these estimates to predict NMRs.[3,12] The uncertainty around these may be considerable. While it has not been customary to present uncertainty bounds around estimates of child or neonatal mortality, detailed descriptions of inputs, methods and uncertainty estimates are becoming the norm to which global health estimates aspire.[13,14]

Without household surveys we would have little idea of global child mortality or coverage of priority interventions, but their very importance makes recognition of their limitations essential. One important limitation is their frequency. The expense and challenge of data collection and analysis in low-resource settings – using a survey tool with over 700 questions in the case of DHS – means that in most countries they are only conducted every 5 years. Their ability to detect rapid changes in mortality or to disentangle contributory factors is therefore limited. With increasing investment in maternal, newborn and child health there is a desire on the part of governments and donors for data capable of detecting short-term trends, particularly in the years up to 2015, the target for the MDGs. This would require huge increases in sample size. For example, in Nigeria it would mean a fivefold expansion from the sample of 7225 households that already constitutes a major feat of organisation.

Clearly, the long-term solution is to improve routine registration systems to achieve high coverage of births and deaths.[15] In the interim, demographic surveillance sites are another valuable source of data on trends, especially if they are selected to be nationally representative. Such sample registration systems are being tried in China and India, with the support of the Health Metrics Network and similar initiatives. In other countries, demographic surveillance sites which are not nationally representative may nevertheless provide useful data on mortality trends (http://www.indepth-network.org/). In the short term there is a move to increase the frequency of UNICEF's MICS, using fewer questions and focusing on coverage of selected interventions, to provide more responsive data on programme if not on mortality outcomes.

Surveys, which depend on recall, also have particular limitations with respect to neonatal deaths and stillbirths, of which the most important is the potential for under-ascertainment of deaths compared with prospective surveillance. There are limited systematic analyses of the extent of this problem, but one study from rural India suggests that under-reporting, especially in traditional societies, may halve the numbers of deaths captured.[16] Even in transitional societies, early neonatal deaths are often unregistered and stillbirths rarely so.[4] Ghana's Kintampo study took advantage of intensive monthly household surveillance established for a trial of vitamin A supplementation during pregnancy to obtain high-quality data in a country where vital registration remains low, although in this particular population over half of the births were in facilities. There are no retrospective survey data with which to compare the findings, although interestingly the NMR of 32 per 1000 is lower than the Ghana national NMR of 43 reported by the DHS. Other issues of data quality include age-heaping on certain days, notably days 7, 14 and 30, and miscoding between day zero and day one.[1]

Misclassification between stillbirths and early neonatal deaths is another important issue, and was one of the arguments in favour of the combined measure of perinatal mortality,

although expert opinion now favours separate reporting of stillbirths and neonatal deaths.[17] Most DHS surveys use birth histories, and so the stillbirth data may rely on other sections of the questionnaire such as analysis of contraceptive calendar data which does result in much wider uncertainty.[2] The use of pregnancy history in all DHS would be a major step forward in increasing the quantity and quality of stillbirth rate data, and possibly also reducing under-ascertainment of early neonatal deaths although there is a dearth of systematic comparison of birth history and pregnancy history data.[2] Meanwhile, more systematic analytical work is required to develop objective scores of quality and methods to improve the quality of the data on neonatal death and also stillbirths, in retrospective surveys. Such an analysis could provide a basis for adjusting estimates to correct for biases in survey data.

Cause of death attribution for neonatal deaths

Information regarding causes of neonatal death, particularly in the first week of life when three-quarters of neonatal deaths occur, is fundamental for developing public health strategies. To be useful, cause of death data must meet several criteria.

First, the circumstances surrounding the death must be recorded in enough detail to attribute a cause and record it accurately. There are a variety of data sources for causes of neonatal death, but good-quality, nationally representative data for low-income countries are rare (Table 2). While around one-quarter of births occur in countries with nationally representative vital registration data, fewer countries (45) have vital registration systems with both high coverage and high quality of cause of death classification. In analyses undertaken during 2004, less than 3% of the world's neonatal deaths had certificate data meeting inclusion criteria for quality and comparability.[18] Household surveys such as DHS and MICS do not routinely investigate cause of death, although in some countries follow-up studies have used verbal autopsy to investigate perinatal[19,20] or child deaths.[14] In most countries without high coverage of vital registration the only sources of cause of death data are health facility audits, or special studies using community verbal autopsy (a questionnaire interview administered to surviving family members after a death). National studies have been undertaken in some countries, the example of Jamaica being well-known.[21]

The correct attribution of cause requires standardised case definitions and an attribution hierarchy, bearing in mind that several causes often coexist. For example, if a moderately preterm baby dies of an infection, the International Classification of Disease (ICD) would attribute the death to infection, with preterm as a contributing factor;[22] but if an extremely preterm baby dies of hyaline membrane disease, prematurity is the underlying or main cause. This is not an academic nicety because it has implications for the public health strategy required.

Second, cause of death classification should be meaningful for programmatic action. The classification used for neonatal deaths is enmeshed in history. In the World Health Report and the Global Burden of Disease the biggest single number of deaths falls under the heading 'perinatal causes' – 2.6 million deaths grouped together.[23] The grouping is poorly understood by both epidemiologists and programme managers, and is often assumed to include stillbirths. In fact, 'perinatal cause' refers to any code in the perinatal chapter of the ICD.[22] This approach combines several distinct causes of death with differing programmatic solutions, which together account for approximately two-thirds of neonatal deaths, while omitting important causes including most neonatal infections, neonatal tetanus and congenital abnormalities. Neonatal infections, the single largest cause of neonatal deaths, are not distinguishable, despite being the least difficult to prevent in low-income settings with appropriate strategies in place.[24] Adopting programmatically relevant categories for cause of death is an important first step in using data to reduce neonatal mortality. The Child Health

Epidemiology Reference Group, working with the WHO and UNICEF, selected six causes of neonatal deaths: preterm birth complications, birth asphyxia, severe neonatal infections (sepsis, pneumonia and meningitis), neonatal tetanus, diarrhoea, congenital abnormalities and a combined 'other' category comprising specific causes of neonatal death such as jaundice and haemorrhagic disease of the newborn.[18] These were considered the minimum set of distinguishable categories with differing programmatic implications.

A recent, extensive exercise to identify population-based neonatal cause of death data (providing comparable cause of death for five or more of the selected categories) was able to identify only 46 published studies and 10 unpublished datasets from all the countries without useable vital registration data.[18] These data were used to develop a model to estimate proportionate mortality for countries without reliable cause of death data.[18] However, there were large geographical gaps (Fig. 1),[25] and at the time none was available from Ghana. This makes the findings from the Kintampo[6,7] and Navrongo[26] demographic surveillance sites particularly welcome. Important knowledge gaps remain in central and north-east Africa, and in China, for which relatively few data are available given the size of its population.

Verbal autopsy methods have progressed in recent years and there have been several attempts to develop structured standard questionnaires. The Health Metrics Network has recently published a set of verbal autopsy questionnaires for adults, children and neonates.[27] The neonatal verbal autopsy included some stillbirth questions and drew on several tools including the one used in the Kintampo, Ghana study.[27] However, results are highly dependent on the cause of death categories chosen, the case definitions (for example, if the case definition for birth asphyxia excludes preterm) and the hierarchy used for coding cause of death – essentially, the order in which categories appear in a flow chart. The Kintampo study describes one hierarchy, adapted from the Child Health Epidemiology group;[18] other work has examined the effect of varying case definitions and hierarchies.[28] Additional questions with regard to verbal autopsy use include comparing computerised algorithms with expert opinion of cause of death (or with expert opinion channelled through an algorithm), or using probabilistic approaches to allocate cause of death.[29] All of these hold potential to make verbal autopsy both more standardised but also less reliant on time-intensive expert input.

Increasing the availability of useful, comparable cause of death data to inform public health decision-making will require wide application of a standard set of programmatically relevant cause of death categories, with standard case definitions and a consistent hierarchy that can be applied to both vital registration and verbal autopsy data. A standard verbal autopsy questionnaire is an important step, but will not necessarily prevent questionable variation in cause-proportionate mortality patterns if subsequent steps remain unstandardised. Data collected at health facilities may differ systematically from community data – the case mix, for example, might show a higher proportion of asphyxia deaths in high-risk and referred infants. While facility data might, after correction through modelling, provide a useful and inexpensive tracking method, the use of uncorrected facility data in populations with very low proportions of facility births likely underplay the importance of neonatal tetanus and sepsis, the most easily preventable categories of neonatal death.

Conclusion

Collecting and interpreting reliable, representative data on the numbers and causes of neonatal deaths remain a challenge in the countries where most deaths occur. While improved, transparent estimation methods are important, they should be an interim measure rather than a goal. The quantity and quality of the empirical data must be improved. Sample

registration systems in countries without adequate universal vital registration offer one route towards better data on both rates and causes. Data from individual demographic surveillance sites, though not nationally representative, may be useful for assessing trends and correcting biases in survey data. Improving cause of death data requires further advances in verbal autopsy methods, including consistent case definitions and application of hierarchical cause of death coding, such as used in the Kintampo analysis. Without systematic investment in information systems and more innovation we will still be relying on uncertain estimates – stumbling in the dark[30] – when we reach 2015, the target year for the MDGs.

Acknowledgments

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Figure 1.
The distribution of identified studies meeting inclusion criteria for population-based, comparable neonatal cause of death data in 2005 in countries without full coverage of vital registration data (56 studies, number of neonatal deaths = 13 685). Source: Data from Lawn *et al.*[18] and Rudan *et al.*[25]

Table 1

Sources of data for numbers and rates of neonatal deaths around the year 2005

	Countries	% of world's births
Vital registration	81	27
Population-based survey		
Since 2003	41	39
Before 2003	48	29
No available data (estimates based on regression on under-five mortality)	33	5
Nationally representative sample surveillance sites	2 (India and China in process)	–
Demographic surveillance sites e.g. INDEPTH network in Africa	Subnational and currently not suitable for national estimates	–

Data from Lawn *et al.*[1] and WHO[3].

Table 2

Sources of data for causes of neonatal deaths around the year 2005

	Countries	% of neonatal deaths
Vital registration (>90% coverage and comparable ICD 10 coding)	45	3
Facility-based audit or confidential enquiry (>90% coverage)	Many northern European countries	<1
No available national data		–
Estimated from model for low mortality countries based on vital registration data	37	
Estimated from model for high mortality countries based on special study data	111	
Nationally representative sample surveillance sites	2 (India and China in process with neonatal Verbal Autopsy)	–
Demographic surveillance sites and special studies e.g. INDEPTH network in Africa	Subnational and currently not suitable for national estimates	–

Data from Lawn *et al.*[18].