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NEONATAL MORTALITY IN THE EMPOWERED ACTION GROUP STATES OF INDIA: TRENDS AND DETERMINANTS

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Summary. In India, the eight socioeconomically backward states of Bihar, Chhattisgarh, Jharkhand, Madhya Pradesh, Orissa, Rajasthan, Uttaranchal and Uttar Pradesh, referred to as the Empowered Action Group (EAG) states, lag behind in the demographic transition and have the highest infant mortality rates in the country. Neonatal mortality constitutes about 60% of the total infant mortality in India and is highest in the EAG states. This study assesses the levels and trends in neonatal mortality in the EAG states and examines the impact of bio-demographic compared with health care determinants on neonatal mortality. Data from India's Sample Registration System (SRS) and National Family and Health Survey (NFHS-2, 1998–99) are used. Cox proportional hazard models are applied to estimate adjusted neonatal mortality rates by health care, bio-demographic and socioeconomic determinants. Variations in neonatal mortality by these determinants suggest that universal coverage of all pregnant women with full antenatal care, providing assistance at delivery and postnatal care including emergency care are critical inputs for achieving a reduction in neonatal mortality. Health interventions are also required that focus on curtailing the high risk of neonatal deaths arising from the mothers' younger age at childbirth, low birth weight of children and higher order births with short birth intervals.

Introduction

Infant and child mortality rates are commonly used as indicators of overall health status of children and women, human development and well-being. During the last quarter of the past century, a major focus of health interventions was on reducing infant and child mortality. Infant and child mortality rates are unacceptably high in many developing countries and remain the focus of public health policy to attain improvement in infant and child survival. During the past decade, the number of infants dying worldwide has fallen by 2·2 million, or by 18% (Ahmad *et al*., 2000). However, globally 10 million children die every year before reaching the age of five, of which 2 million occur in India, the highest number in any country worldwide

(UNICEF, 2004). The reduction of infant and child mortality is therefore a major national health goal in India.

The International Conference on Population Development (ICPD) (United Nations, 1994) brought to centre stage reproductive and child health issues with the objective of enabling women to go safely through pregnancy and childbirth and providing couples with the best chance of having healthy infants. In the aftermath of the ICPD conference, the United Nations in its Millennium Declaration in 2000 framed eight Millennium Development Goals, one of them being the reduction in infant and child mortality with the target of reducing it by two-thirds between 1990 and 2015.

In India, infant mortality was very high in the decades prior to the 1970s and began to decline steadily after 1975, with a major reduction during 1981–91; currently infant mortality is 68 per 1000 live births (Registrar General, 1999, 2003). The country's population policy during the ninth five-year plan had set the goal of reducing infant mortality rate to 50 per 1000 live births by 2002. With the steady reduction of infant and child mortality rates in the mid-1980s, it appeared that the national goal was within reach, despite large disparities in infant and child mortality levels amongst the states. However, the decline in infant and child mortality has slowed down during 1990–2000, with plateauing trends in maternal and child health determinants in several states leading to serious concern (IIPS, 1995; Registrar General, 1999, 2003; IIPS & ORC, 2000; Claeson *et al.*, 2000).

There are remarkable variations in the reduction of infant and child mortality across the states of India. The demographically progressive states of Kerala, Goa and Tamil Nadu have achieved a commendable reduction in infant and child mortality. However, the eight northern states are demographically lagging behind and have very high infant and child mortality rates. This group includes the socioeconomically poorer states of Bihar, Chhattisgarh, Jharkhand, Madhya Pradesh, Orissa, Rajasthan, Uttarakhand and Uttar Pradesh. To facilitate the attainment of national health goals, the Government of India constituted the empowered action group (EAG) in 2001 in the Ministry of Health and Family Welfare consisting of members from the ministry, related ministries and the eight states. The group was constituted for the preparation and implementation of area-specific health interventions in 261 districts of these eight states. The EAG states together constitute 45% of the total population of the country, and have a higher infant mortality rate than the national average.

Neonatal morality is the largest burden contributing to nearly two-thirds of the total infant mortality in most developing countries. Neonatal mortality is the probability of dying in the first month after birth and post-neonatal mortality is the probability of dying after the first month of birth but before completion of one year. Perinatal deaths constitute nearly three-quarters of neonatal mortality occurring in the early neonatal period, the first week of life. According to recent estimates, over 4 million babies die each year in the world in the first four weeks of life and 98% of these deaths occur in developing countries; 3 million of these deaths occur in the early neonatal period (WHO, 2006). More than 50% of the 2 million child deaths under the age of five in India occur in the first month of life every year.

Neonatal mortality was around 45 per 1000 live births in 2000 in India compared with just about 4 per 1000 live births in most developed countries. The reduction in neonatal mortality has been slower than the reduction in post-neonatal and child mortality in the last two decades. The reduction of this high burden of neonatal mortality is therefore critical for achieving the national health goal on infant mortality reduction in India. Despite this, the study of neonatal mortality has not received its prominence in the health and social research agenda to strengthen public health interventions for curtailing neonatal mortality. Apparently, the common focus on infant mortality as a single measure has had a detrimental effect as it disguises the unequal share of neonatal and post-neonatal mortality. Moreover, the determinants of infant mortality tend to vary from that of the relative contribution of bio-demographic, health care and socioeconomic determinants on the decomposed components of neonatal and post-neonatal mortality.

Context and objectives

The limited attention to the study of neonatal mortality in India has arisen due to a variety of factors. Firstly, it is difficult to ascertain the causes of neonatal mortality in the Indian context where the majority of deliveries and neonatal deaths occur at home and are usually not attended by health professionals. Secondly, many factors that contribute to neonatal mortality have their origin long before a baby is born. These are termed ‘endogenous’ causes, and are primarily influenced by genetic make-up or circumstances arising before or during birth. Infants suffering from congenital malformation, low birth weight and prematurity are at a higher risk of neonatal mortality. They become even more vulnerable due to the poor physical condition of their mothers, which affects the mothers’ capacity to provide adequate milk and nurturing. Thirdly, for analyses of neonatal mortality, information on maternal health and related factors is an important requirement. Lastly, neonatal deaths are often subsumed in the more widely used indicators of infant and child mortality although the factors determining decomposed mortality indicators such as neonatal, post-neonatal and child mortality vary substantially.

Due to the above constraints, including lack of historical data, very little attention has been focused on understanding the causes and determinants of neonatal mortality in developing countries such as India. The level of neonatal mortality is very high in the EAG states compared with the rest of the Indian states due to a variety of factors, including poor maternal and child health care coverage. The reduction of neonatal mortality ought to be the major focus. With this background, the aim of this paper is to assess the levels and trends in neonatal mortality in the EAG states and to examine the importance of the role of health care factors compared with bio-demographic determinants in the persistently high neonatal mortality of the EAG states. To establish the theoretical background of the study, evidence from previous literature relating to the direction and magnitude of the relationship between bio-demographic and health care factors with neonatal mortality are reviewed below.

Determinants of neonatal mortality: a review

The pioneering framework for child survival by Mosley & Chen (1984) focused on a variety of biological, socioeconomic and environmental factors as determinants of child survival. It has been demonstrated previously that biosocial and demographic factors tend to have a greater influence on neonatal mortality than socioeconomic determinants. More recent literature, however, has brought out the critical role of health services utilization along with bio-demographic factors as important determinants of neonatal mortality (Rutstein, 2000).

In most populations, male mortality is generally higher than female mortality for all ages, because males are considered biologically weaker than females and thus have greater vulnerability to infectious diseases and higher risk of mortality (Mahy, 2003). Excess male mortality is highly pronounced in the first month of life, the neonatal period, and diminishes considerably during the post-neonatal period, tending to disappear during the childhood period of 12–59 months (Bicego & Ahmad, 1996). In India, mortality for females is 14% lower than for males during the neonatal period. This, however, is swiftly reversed, with a 19% higher female than male mortality in the post-neonatal period and about 40% excess female mortality in the childhood ages of 1–4 arising from the cultural context of son preference and discrimination of female children in nutrition and health care (Pandey *et al*., 1998; Arokiasamy, 2004).

The relationship between birth order and neonatal mortality is a U-shaped curve. Neonatal mortality tends to be higher for the first-born child and higher order births of order 4 and above compared with second and third order births (Mahy, 2003). For India and for most states of India, neonatal mortality follows a U-shaped relationship when birth orders of children are distributed from 1 and 6+. Shorter birth intervals are associated with elevated neonatal mortality risks. The most pronounced effect of short birth interval on childhood mortality occurs during the neonatal period and it is weakest at 1–4 years of age (Bicego & Ahmad, 1996). However, the birth interval and birth order effects tend to be compounded as a larger proportion of higher order births are likely to be spaced with shorter birth interval. This suggests that the use of a composite variable of birth order with combinations of shorter and longer birth interval will be effective to disaggregate the effects of birth order and birth interval on neonatal mortality.

Mother's age at birth of the child has health ramifications for children. A pronounced effect of mother's age at birth on child survival occurs during the first month of life, although the excess child mortality risk persists throughout the five-year period (Bicego & Ahmad, 1996). Younger women under the age of 20 are likely to experience a greater risk of pregnancy and delivery complications, and their children an increased risk of having low birth weight and prematurity. A higher proportion of births to mothers under the age of 20 and for those aged above 30 is associated with a higher risk of neonatal mortality. Maternal depletion is a key factor leading to higher neonatal mortality risks for births following shorter birth intervals of less than 24 months (James *et al*., 2000).

The potential contribution of health care provision during pregnancy and delivery has been shown to be a major determinant of neonatal mortality in recent frameworks of child mortality (Claeson & Waldman, 2000). The health-seeking behaviour of women, especially during pregnancy and at the time of childbirth, and follow-up care during the post-neonatal period have a major influence on the health of the newborn (Visaria, 1988). The EAG states of India continue to present a dismal picture of the provision of antenatal care, institutional delivery coverage and postnatal health care.

Neonatal mortality declines with the increase in the number of antenatal care visits, as these improve access to and utilization of health care services for mothers and children. The percentage of women who had a minimum of three antenatal check-ups varies between 15% for Uttar Pradesh and 47% in Orissa among the EAG states (IIPS & ORC, 2000). Tetanus vaccination is an important recommended component of antenatal care. The magnitude of neonatal deaths associated with neonatal tetanus is very high in the EAG states. Nearly 38% of childhood deaths in the slum population of Lucknow, north India, are reported to be due to the lack of tetanus vaccination (Awasthi & Pandey, 1998).

Delivery in medical institutions and professional health assistance during delivery are major determining factors of neonatal mortality rate. A higher level of institutional delivery uptake is associated with sharp reductions in neonatal mortality. A continuum of care during pregnancy and delivery through regular interaction with health personnel, both for preventive care and treatment of illnesses, is essential to curtail neonatal mortality. For example, institutional delivery uptake is more than 80% in Kerala and Tamil Nadu with correspondingly low levels of neonatal mortality. However, the EAG states with overall institutional delivery coverage of less that 20% have neonatal mortality greater than 50 (IIPS & ORC, 2000; Registrar General, 2003).

In populations with poor health care service availability, socioeconomic factors tend to have significant effects on neonatal mortality. Public health-related interventions such as improved water and sanitation have certainly contributed to child survival, as has immunization and curative health care of diseases and malnutrition (WHO, 2006). An improvement in household environmental sanitation has been shown to lead to a significant negative effect on neonatal mortality (Jain, 1985; Rutstein, 2000).

Methods

Data from India's Sample Registration System (SRS: Registrar General, 1999, 2003) and the National Family Health Survey-2 (IIPS, 1998–99) were used in this analysis. The SRS in India is a dual record system in which data are collected through the registration of births and deaths and verified through survey after every six months. The SRS provides reliable yearly estimates of the levels of neonatal and infant and child mortality for the country and states by rural and urban areas as well as by sex of the child. The NFHS-2 is a nationwide survey that provides data on neonatal, infant and child morality and the factors associated with the survival of young children, including bio-demographic and socioeconomic characteristics and information on utilization of maternal and child health services for children born in the last three years. In the survey, detailed information was gathered for the last two births during 1995–98. A total of 32,393 births were reported in the last three years (1995–98) prior to the survey for the country as a whole, of which 14,720 births occurred in the EAG states. Of the 14,720 births, 1178 child deaths (0–35 months) occurred and 676 deaths were in the neonatal age (0–28 days). This analysis is based on the sample of 14,720 births and 676 neonatal deaths during the three-year period prior to the survey for the EAG states.

In survey data analysis, it is important to provide a brief discussion of the quality of NFHS-2 data on neonatal mortality. An assessment of data quality suggests that there are no apparent data limitations that are likely to bias the estimates of neonatal mortality. First, under-reporting of deaths and misreporting of date of birth or age at death of neonates are likely to be more pronounced for children born in the past than those born in the recent time period. In this study's analysis, data of children born in the last three years are used, and therefore under-reporting and misreporting will not seriously bias the estimates of neonatal mortality. Second, data on day-wise age at death of children in NFHS-2 show heaping of age at death of neonates at ages 3, 5, 10, 15, 20 and 25 days. Since neonatal mortality in this analysis is defined as infant deaths that occur in the first four weeks of life (0–28 days), such misreporting will not bias the overall estimate of neonatal mortality with data aggregated for four weeks (IIPS & ORC, 2000). Third, in the case of selective under-reporting of neonatal deaths, evidence of an abnormally low ratio of neonatal to infant mortality is common. However, the ratio of neonatal deaths to infant deaths is consistently high at between 64 and 67% for the different time periods preceding the survey in NFHS-2. Also the ratio of deaths under seven days to all neonatal deaths is consistently high at between 70 and 74% for different time periods preceding the survey in NFHS-2.

In this paper, the analysis consists of two stages. First, the levels and trends of neonatal and infant mortality in India and the EAG states are compared based on SRS data. Second, adjusted neonatal mortality rates by health care, bio-demographic and socioeconomic factors are estimated. Unadjusted univariate lifetable estimates of neonatal mortality rate by these factors are presented for comparison.

The proportional hazard model is applied to estimate neonatal mortality by bio-demographic, health care and socioeconomic factors and assess their relative influence. The proportional hazard model is a multivariate extension of the lifetable, combining the regression model with cohort lifetable analysis. Hazard coefficients are estimated on data for EAG states combined as a block as they provide sufficient numbers of cases of neonatal deaths to estimate neonatal mortality by health care, bio-demographic and socioeconomic factors. The use of proportional hazard modelling also has an added advantage, as data of three-year births can be used without truncation. The hazard coefficients of the covariates are then converted into adjusted neonatal mortality rates with the help of Multiple Classification Analysis (MCA).

Levels and trends in neonatal mortality

The trend in infant and neonatal mortality presented in Fig. 1 has been constructed for the last 30 years using SRS data for India and the EAG states. Throughout, the EAG states have a consistently higher infant mortality rate (IMR) compared with that of India. Uttar Pradesh had the highest IMR among all the EAG states in early 1970s; however, this has declined faster in Uttar Pradesh compared with other EAG states in recent years. Since 1986, Orissa and Madhya Pradesh have had a high IMR. Orissa, which had the third highest IMR in 1970, emerged with the highest IMR by the end of 2000 for the reason that IMR decline was slower in Orissa compared with the rest of the EAG states in the last three decades. Some of the important reasons for the high IMR in Orissa are the very high incidence of low birth

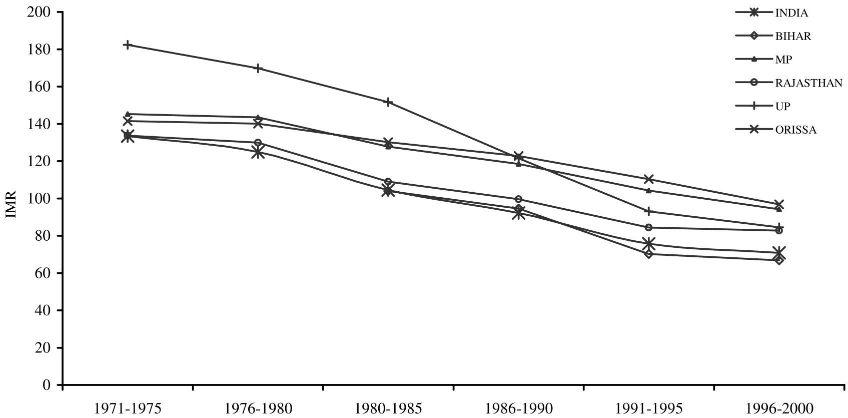

Fig. 1. Trend in infant mortality rate (IMR), India and EAG states, 1971–2000. Source: Registrar General, Sample Registration System, 1971–2000, Government of India, Delhi. Note that the states of Bihar, Madhya Pradesh and Uttar Pradesh include respectively the newly created states of Jharkhand, Chhattisgarh and Uttarakhand.

weight, malnutrition, premature births, low coverage of institutional delivery, poor sanitation coverage and high levels of household poverty (Pradhan & Arokiasamy, 2006).

In the 1990s, the IMR of Bihar declined at a greater pace and the state currently has a lower IMR than the national average. The rest of the EAG states continue to have a higher IMR than the country as a whole. The pace of IMR decline in the EAG states, as well as in India, has been very slow during 1990–2000, remaining more or less constant, pointing to a stage of clear plateauing.

Figure 2 compares the trends in neonatal mortality for India and the EAG states. The general trend of neonatal mortality decline is oscillatory in nature but similar to the trend in infant mortality. However, the rate of decline in neonatal mortality has been very slow during the last 30 years compared with that of infant mortality. Neonatal mortality was high in Uttar Pradesh in the early 1970s but reached a lower level compared with Orissa by 1987. By 2000, neonatal mortality in Uttar Pradesh declined to reach the fourth highest in the country. Consistent with the trend in infant mortality, Orissa, which had the lowest neonatal mortality rate in the early 1970s, stagnated in the late 1970s emerging with the highest level of neonatal mortality among all the EAG states in 2000. Bihar is a surprise with both neonatal and infant mortality rates lower than the rest of the EAG states, despite having similar socioeconomic and health care conditions as in Uttar Pradesh. Understanding such unique context requires more detailed exploration of trends in determining factors. Overall, the trend line of neonatal and infant mortality in the EAG states, with a 48% share of the country's population, is closer to the trend line of India.

Figure 3 shows the trends in neonatal mortality in the EAG states by place of residence. Trend bars indicate that neonatal mortality has been higher in the rural areas compared with urban areas.

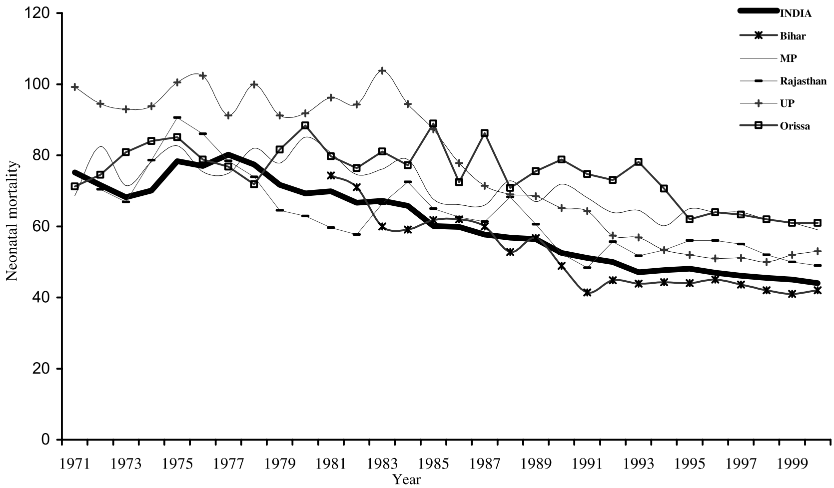

Fig. 2. Trend in neonatal mortality rate, India and EAG states, 1971–2000. Source: Registrar General, Sample Registration System, 1971–2000, Government of India, Delhi. Note that the states of Bihar, Madhya Pradesh and Uttar Pradesh include respectively the newly created states of Jharkhand, Chhattisgarh and Uttarakhand.

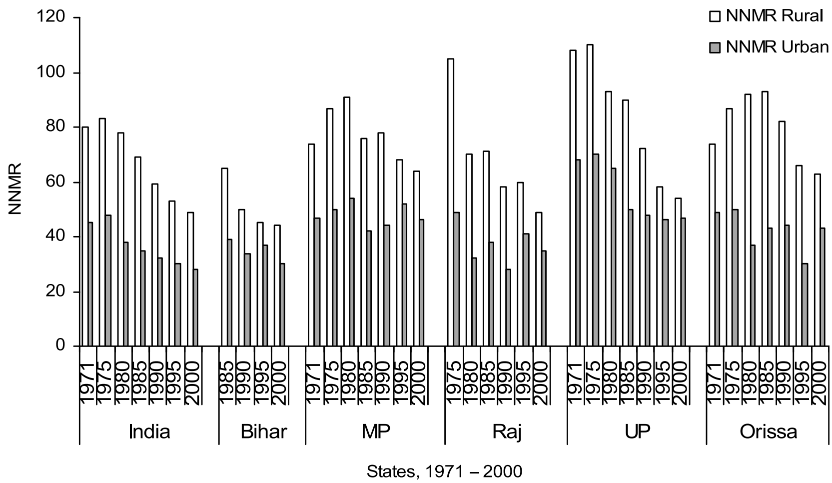

Fig. 3. Trend in neonatal mortality rate (NNMR) by place of residence, India and EAG states, 1971–2000. Source: Registrar General, Sample Registration System, 1971–2000, Government of India, Delhi. Note that the states of Bihar, Madhya Pradesh and Uttar Pradesh include respectively the newly created states of Jharkhand, Chhattisgarh and Uttarakhand.

For India as a whole, neonatal mortality shows a declining trend in both rural and urban areas. However, in the EAG states neonatal mortality was very high in rural areas in the 1970s and continued to be so in the recent decade of 1990–2000. Comparatively, trends in neonatal mortality show a somewhat faster decline in urban

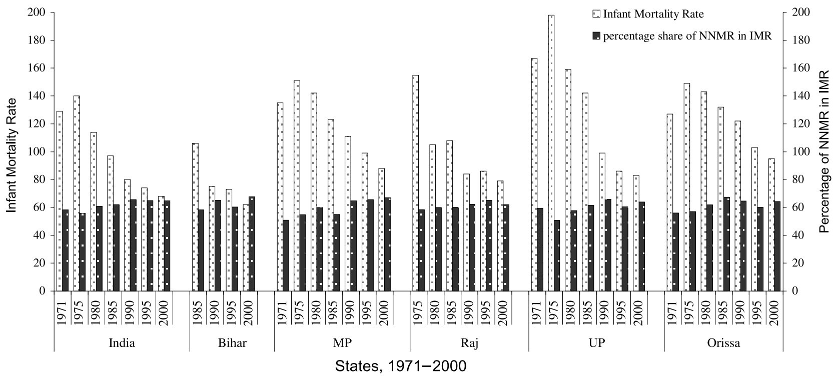

Fig. 4. Infant mortality with percentage share of neonatal mortality (NNM), 1971–2000. Source: Registrar General, Sample Registration System, 1971–2000, Government of India, Delhi. Note that the states of Bihar, Madhya Pradesh and Uttar Pradesh include respectively the newly created states of Jharkhand, Chhattisgarh and Uttarakhand.

than in rural areas in Bihar and Uttar Pradesh, with a stagnating trend in Madhya Pradesh and Orissa.

Figure 4 provides comparative trends in infant mortality with the percentage share of neonatal mortality in IMR for the EAG states. The infant mortality rate for India declined by almost a half during the past three decades of 1971–2000. The percentage share of neonatal mortality showed a concomitant increase over the years in India with a similar trend seen in all the EAG states. Consequently, with the decline of infant mortality in the last 30 years, the percentage of neonatal mortality has become a dominant burden of the total infant mortality in the EAG states. A more significant fall in the infant mortality rate in India and the EAG states, will therefore, mainly depend on the pace of reduction in neonatal mortality in the coming years.

Births and neonatal deaths distribution

Table 1 shows the percentage distribution of births and deaths of children born in the last three years preceding the survey period and the share of the neonatal deaths of the total child deaths at age 0–35 months by health care, bio-demographic and socioeconomic factors. The combined data from the eight EAG states are used in the analysis. The data for Bihar, Madhya Pradesh and Uttar Pradesh include those of the respective newly created states of Jharkhand, Chhattisgarh and Uttarakhand. Of the total births in the EAG states, Uttar Pradesh has the highest proportion of births (29%) followed by Rajasthan (21%) and Bihar (20%). Correspondingly, the proportion of neonatal deaths of total neonatal deaths in the EAG states is also higher in Uttar Pradesh (29%). About 60% of the total deaths at age 0–35 months occur at the neonatal stage in Bihar and Rajasthan, and this declines to about 55% in all the other EAG states. However, the variations by state are not statistically significant.

The sex-wise distribution of births and deaths shows a higher percentage of male births as well as male neonatal deaths than females. The percentage share of the

Table 1. Percentage distribution of births and deaths of children born in the last three years with percentage share of neonatal deaths by bio-demographic, health care and socioeconomic status variables in the EAG states (combined), 1998–99

Variables	Births (3 years preceding survey)	All deaths (0–35 months)	Neonatal deaths (0–28 days)	Percentage share of neonatal deaths among total child deaths (with χ^2 test)	
State					
Bihar	20·0	18·3	19·4	60·9	
Madhya Pradesh	19·6	22·3	21·7	55·8	
Rajasthan	20·8	20·4	21·0	59·2	
Uttar Pradesh	29·4	29·1	28·7	56·5	
Orissa	10·2	9·9	9·2	52·9	**ns**
Bio-demographic variables					
Sex of the child					
Male	51·8	50·7	54·3	61·4	
Female	48·2	49·3	45·7	53·3	**
Age of mother at birth of the child					
12–19 years	17·3	24·4	26·3	61·7	
20–30 years	67·7	60·8	60·4	56·8	
30+ years	14·9	14·8	13·3	51·5	ns
Birth order & birth interval					
2/3rd birth order & birth interval >2yrs	29·2	22·3	22·2	57·0	
1st birth order	23·9	27·7	32·5	67·5	
2/3rd birth order & birth interval ≤2yrs	11·0	13·8	13·3	55·2	
3rd+ birth order & birth interval >2yrs	27·0	22·1	19·1	49·6	
3rd+ birth order & birth interval ≤2yrs	8·8	14·1	12·9	52·4	**
Health care variables					
Tetanus toxoid injection[a]					
Not received	44·0	59·3	59·8	58·2	
Yes, received	56·0	40·7	40·2	56·8	ns
Iron/folic acid tablets					
Not received	69·7	79·7	78·3	56·3	
Yes, received	30·3	20·3	21·7	61·5	ns
Antenatal[b] and delivery care					
Child delivered at home, mother received no ANC and assistance[c]	69·5	80·1	69·2	56·8	
Child delivered at home, mother received ANC but no assistance	9·6	6·8	9·8	51·3	

Table 1. *Continued*

Variables	Births (3 years preceding survey)	All deaths (0–35 months)	Neonatal deaths (0–28 days)	Percentage share of neonatal deaths among total child deaths (with χ^2 test)	
Child delivered at home, mother received assistance but no ANC	6·5	4·3	6·6	56·9	
Child delivered at home, mother received ANC and assistance	3·3	1·3	3·4	46·7	
Child delivered in medical institution with no delivery complications[d] and mother received ANC	10·1	6·1	10·0	69·4	
Child delivered in medical institution with delivery complications and mother received no ANC	1·1	1·4	1·0	81·3	*
Size of baby at birth					
Large	11·7	10·8	11·7	62·2	
Average	60·8	49·8	46·0	52·9	
Small	27·6	39·4	42·3	61·6	**
Background variables					
Place of residence					
Rural	83·3	87·6	86·7	56·7	
Urban	16·7	12·3	13·3	61·6	ns
Mother's education					
Illiterate	72·2	82·6	80·6	56·0	
Up to middle school	19·2	14·3	15·5	62·5	
High school and above	8·6	3·1	3·8	70·3	*
Sanitation facility					
Flush toilet[e]	12·5	7·9	8·1	59·1	
Pit toilet	6·4	4·9	5·6	65·5	
Others	81·1	87·2	86·2	56·8	ns
Total	**100**	**100**	**100**	**57·4**	
Number of unweighted cases	14,720	1178	676	—	

[a]At least two injections.
[b]At least three ANC visits.
[c]Assisted by doctor/nurse/midwife.
[d]Delivered through Caesarian section.
[e]Includes access to both public and private flush toilet.
*$p<0{\cdot}05$; **$p<0{\cdot}01$; ns, not significant.

neonatal deaths in total child deaths is also very high for males (61%) compared with females (53%) and the difference is statistically significant. This is a reconfirmation of evidence for the theoretical position that males are biologically weaker than females and are more prone to neonatal mortality risks. The high percentage share of male compared with female births is due to both the expected higher biological share of male births and greater extent of son preference prevailing in these states (Arokiasamy, 2004).

Women of peak and biologically ideal childbearing age of 20–30 with 68% of total births experienced 60% of the total neonatal deaths. However, as expected, young teenage mothers aged 12–19, with 17% of total births, have experienced a relatively higher proportion of neonatal deaths (26%) of the total neonatal deaths. The share of neonatal deaths of the total child deaths is also higher (62%) among teenage mothers compared with older women aged 30 years and above (52%), but the differences are not statistically significant. The percentage share of neonatal deaths out of total child deaths shows statistically significant variations by the composite variable of birth order and birth interval.

The share of child deaths in total child deaths (28%) and that of neonatal deaths in total neonatal deaths (33%) are higher for children of first-birth order, though they constitute only 24% of total births. The proportion of neonatal deaths of the total neonatal deaths is 19% and 22% respectively for children of 2–3 birth orders and children of 3+ birth orders, both with birth interval longer than two years. The share of neonatal deaths to total child deaths is also lower for children of 2–3 birth orders (57%) and 3+ birth orders (49%) with birth interval longer than two years compared with children of first order (68%).

The EAG states are well known for their extremely poor maternal and child health care service coverage. Less than three-quarters of women (23%) had at least three antenatal visits and only 19% of births were delivered in medical institutions. A continuum of antenatal, delivery and newborn care is essential to the survival and well-being of neonates. Considering this linkage, a composite variable of antenatal care (ANC; three visits) and delivery care was used to study their effects on neonatal mortality. In EAG sates, neonatal deaths constitute 69% of the total neonatal deaths among home-delivered children of mothers who did not receive the recommended three ANC visits and assistance during delivery. The differences in the percentage share of neonatal deaths out of total child deaths by this composite variable of ANC and delivery care are statistically significant. For women who delivered in medical institutions with delivery complications (child delivered through Caesarian section) but who received no antenatal care, the percentage share of neonatal deaths out of total child deaths is 81%. However, just 1% of total neonatal deaths occurred in these high-risk women. The percentage share of neonatal deaths out of total child deaths is also relatively high at 69% among women who delivered in medical institutions with no delivery complications but who received ANC care. The lowest percentage share of neonatal mortality (51%) is observed for women who delivered at home, but received three ANC checks and professional assistance during delivery.

High deprivation in social and economic conditions is yet another common feature of EAG states. The level of female literacy in the EAG states is the lowest in the country. Seventy-two per cent of all births have occurred to illiterate women with just

9% of the births occurring to women with high school and above education. The proportion of all child deaths is 83% and that of neonatal deaths is 81% for illiterate woman. However, as expected the percentage share of neonatal to total child deaths is higher among high school and above educated women (70%) compared with illiterate women (56%). Eighty-one per cent of births occurred to women in households with no sanitation facility, with 86% total child deaths and 86% of total neonatal deaths.

Differentials in neonatal mortality

The second major focus of this analysis is to study the extent of variations in neonatal mortality rate by health care, bio-demographic and socioeconomic determinants controlling for the interrelationship among the covariates. As stated earlier, the hazard coefficients are converted into adjusted probabilities of neonatal mortality through MCA conversion in an Excel spreadsheet. The adjusted estimates of neonatal mortality by women's age at birth of the child, sex of the child, birth order of the child by birth interval, size of baby at birth, provision of tetanus injection and iron and folic acid tablets during pregnancy, antenatal checks and use of delivery care, place of residence, mother's education and household sanitation are presented in Table 2. The unadjusted univariate lifetable estimates of neonatal estimates are also presented by these covariates for comparison.

Consistent with the trends based on SRS data, controlling for the above covariates, adjusted neonatal mortality is lowest in Bihar (38) among the EAG states, though the difference in neonatal mortality by states is not statistically significant. Other EAG states have between 5% and 18% higher neonatal mortality than Bihar, with Rajasthan showing the highest neonatal mortality rate of 45 among the EAG states. The confidence intervals of adjusted neonatal mortality at the 95% level of significance vary from the lower limits of 33–37 and upper limits of 45–53 across the states. Adjusted neonatal mortality is 5% lower for females than males. As expected, neonatal mortality is higher for women in the high-risk young age group of 12–19 years compared with women of peak childbearing age, i.e. 20–30 years. Average sized babies at birth are found to have significantly lower risk of neonatal mortality compared with both large and small sized babies at birth. Small sized babies at birth have almost a 33% higher likelihood of neonatal mortality than average sized babies at birth.

The composite variable of birth order and birth interval demonstrates very significant differentials in neonatal mortality. Children of higher birth orders 3 and above and born within shorter birth interval of less than 2 years have a 37% higher neonatal mortality compared with children of lower birth orders 2–3 and born with longer birth of interval greater than 2 years. Children of births of order 2 and 3 and born with a birth interval of less than 2 years also have a 24% higher neonatal mortality risk than children of births of order 2 and 3 and born with more than 2 years of birth interval. Children of births of order 3 and above with birth interval greater than 2 years have the lowest neonatal mortality rate of 31.

Among the various components of the antenatal health care services, the vaccination of pregnant mothers with at least two doses of tetanus toxoid injection

Table 2. Unadjusted and adjusted neonatal mortality (NNM) rates by bio-demographic, health care and socioeconomic status variables for EAG states (combined), 1998–99

Covariates (with categories)	Neonatal mortality rates[a] (per 1000 live births)			Adjusted NNM difference with reference category (%)
	Unadjusted	Adjusted	CI (at 95%) for adjusted values	
EAG states				
Bihar (Ref.)	44	38	35–46	—
Madhya Pradesh	51	42	36–49	+11
Rajasthan	46	45	37–53	+18
Uttar Pradesh	45	39	33–45	+3
Orissa	41	40	34–46	+5
Sex of the child				
Male (Ref.)	48	41	38–42	—
Female	44	39	35–43	− 5
Age of mother at birth of the child				
12–19 years (Ref.)	69	42	35–45	—
20–30 years	41	39	44–57	− 7
30 years	40	41	33–50	− 2
Birth order & birth interval				
2/3rd birth order & birth interval >2yrs (Ref.)	35	37	36–45	—
1st birth order	62	50**	44–57	+35
2/3rd birth order & birth interval ≤2yrs	55	46**	39–54	+24
3rd+ birth order & birth interval >2yrs	32	31	26–37	− 16
3rd+ birth order & birth interval ≤2yrs	67	51**	41–55	+37
Size of the baby at birth				
Large (Ref.)	46	43	35–46	—
Average	35	36*	30–42	− 16
Small	70	48	42–55	+11
Tetanus toxoid injection[b]				
Not received (Ref.)	60	47	38–52	
Yes, received	32	35**	31–39	− 30
Iron/folic acid tablets received				
Not received (Ref.)	51	41	39–42	—
Yes, received	33	38	33–44	− 10
Antenatal[c] and delivery care				
Child delivered at home, mother received no ANC and assistance[c] Ref.)	52	42	37–43	

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Table 2. *Continued*

Covariates (with categories)	Neonatal mortality rates[a] (per 1000 live births) Unadjusted	Adjusted	CI (at 95%) for adjusted values	Adjusted NNM difference with reference category (%)
Child delivered at home, mother received ANC but no assistance[d]	29	36	28–44	− 14
Child delivered at home, mother received assistance but no ANC	30	33	25–43	− 21
Child delivered at home, mother received ANC and assistance	14	23	12–40	− 45
Child delivered in medical institution with no delivery complications[e] and mother received ANC	37	44	36–54	+7
Child delivered in medical institution with delivery complications and mother received no ANC	84	50**	34–66	+19
Place of residence				
Urban (Ref.)	36	40	35–46	—
Rural	48	44	34–47	+10
Mother's education				
Illiterate (Ref.)	51	42	38–42	—
Up to middle school	27	38*	32–43	− 10
High school and above	31	25**	17–36	− 40
Sanitation facility[f]				
Flush toilet (Ref.)	30	36	32–46	—
Pit toilet	41	42	31–54	+17
Others	49	41	32–50	+14

[a]For births in the last three years.
[b]At least two injections.
[c]At least three ANC visits.
[d]Assisted by doctor/nurse/midwife.
[e]Delivered through Caesarian section.
[f]Includes access to both public and private flush toilet.
*$p<0.05$; **$p<0.01$. Ref., reference category.

shows a large statistically significant effect on neonatal mortality. Neonatal mortality is lower by 30% for children of mothers who received at least two doses of tetanus injection during pregnancy. Neonatal mortality is also seen to be lower for children whose mothers received iron and folic acid tablets supplements as part of antenatal care.

In settings with very low institutional coverage of deliveries, it is common to find higher neonatal mortality for children delivered in medical institutions compared with those delivered at home. This might arise because deliveries with complications are rushed to institutional settings. However, delays in reaching the health facility and health services provider result in higher neonatal mortality risks. In such contexts, considering that health care factors such as antenatal and deliver care are likely to have interrelated effects on neonatal mortality, a composite variable of antenatal care, place of delivery and type of assistance at delivery is used in order to understand the pathways of influence of health care factors on neonatal mortality with greater clarity.

The results of various combinations of antenatal and delivery care indicate the highest neonatal mortality rate of 50 for children delivered in medical institution with delivery complications and whose mothers received no antenatal care at all. This high-risk category, however, constitutes just 1% of total births and 1% of total neonatal deaths. The next highest neonatal mortality rate of 44 is seen for children delivered in medical institutions with no delivery complications but whose mothers had three ANC checks. In contrast, the lowest neonatal mortality rate of 23 is observed for children delivered at home but whose mothers received both three ANC checks and professional health assistance during delivery.

Among the socioeconomic factors, mother's education emerges as a very strong determinant, with large variations in neonatal mortality. Compared with illiterate mothers, mothers with high school and above education have 40% lower neonatal mortality. Compared with children in households with better sanitation facility, those infants in households without any sanitation facilities have 15% higher neonatal mortality. Adjusted for other covariates, neonatal mortality is 10% higher in rural than urban areas.

Conclusion

In India, the demographically lagging EAG states with the largest share of the population have the highest infant mortality rate in the country. In these states, more than 60% of infant deaths are neonatal deaths. The trend line of neonatal mortality decline from 1970 until 1990 was oscillatory in nature, though substantial variations are seen among the EAG states. However, evidence suggests an overall slow down in infant mortality decline and a greater slow down in neonatal mortality during 1991–2000 in all the EAG states. Among the EAG states, Orissa, which had the lowest neonatal mortality in 1970, has emerged with the highest in 2001, with Uttar Pradesh and Bihar improving their positions.

Consistent with this slow down in infant mortality reduction, the *per capita* government revenue expenditure (state plus central) on health and family welfare is the lower in all the EAG states except Rajasthan. In these states, health interventions targeting neonatal mortality reduction require a prominent agenda in order to achieve further reductions in infant mortality, and neonatal mortality in particular. It is important to recognize that both preventive neonatal health care and treatment of various illnesses of neonates such as septicaemia, meningitis and pneumonia, which are referred to as sepsis, involves specialized skills for community health workers for home-based neonatal health care interventions (Bang *et al.*, 1999). And the fact remains that hospital-based delivery and neonatal health care services are either inaccessible and inadequate or expensive.

The results of neonatal mortality variations by health care determinants provide evidence of a strong impact of health care services provision during pregnancy and delivery on neonatal mortality. Tetanus vaccination of mothers during pregnancy shows reduction in neonatal mortality of more than a third compared with mothers who did not receive tetanus injections. Neonatal mortality variation by combinations of use of both antenatal and delivery care suggests two patterns. In the EAG states with overall institutional delivery coverage of less than 20%, children of mothers delivering in medical institutions are largely self-selected with cumulated high risks of delivery complications and the absence of antenatal care during pregnancy leading to Caesarian section. Consequently these children are found to experience very high neonatal mortality. Home-delivered children are seen to have lower neonatal mortality risks if their mothers received full antenatal care and were assisted by a health professional during delivery.

Apparently, the implication is that full antenatal care and timely professional health assistance during delivery are more important than merely rushing a complicated delivery arising from a prolonged labour and prematurity to a medical institution. The absence of antenatal care, inadequate facilities at the medical institution and lack of emergency care during transportation to deal with intra-partum and postnatal complications such as asphyxia and sepsis and premature hospital discharge add to the very high neonatal mortality risks. It emerges that a continuum of care during pregnancy, childbirth and the postpartum period is critical for improving neonatal survival, as this helps in early detection and management of infections and complications of pregnancy and delivery (WHO, 2006).

This analysis further provides an understanding of the extent of variations in neonatal mortality by bio-demographic and socioeconomic determinants. Among the bio-demographic factors, the composite variable of birth order and birth interval shows large variations in neonatal mortality. Children of birth orders 1 and those of 4 and above and born within shorter birth intervals of less than 2 years experience about a two-thirds higher risk of neonatal mortality compared with children of birth orders 2 and 3 and born after a longer birth interval of greater than 2 years. Children of average size at birth are found to be at a lower risk of death compared with small and large sized babies, and mothers aged 20–30 years have lower neonatal mortality risks compared with those of younger and older ages. The incidence of low birth weight is a major determinant of neonatal mortality and is important to be tackled through good maternal nutrition and prevention and management of anaemia.

Among socioeconomic factors, mother's education emerges as a powerful determinant of neonatal mortality in the EAG states, for the reason that mother's education is known to be associated with better utilization of health care services during pregnancy and delivery leading to lower neonatal mortality. The risk of neonatal mortality is 40% lower among mothers with high school and above education compared with their counterparts with no education.

In sum, health interventions have to be intensely focused in all EAG states in order to halve neonatal and infant mortality. Targeting neonatal health care interventions in the EAG states is very important in view of the above evidence of variations. It implies the need for concentrated maternal and child health care including neonatal care interventions for reducing the high risk of neonatal deaths arising from the detrimental influence of mother's young age at birth, higher order births coupled with shorter birth interval, low birth weight of children and the poor use of health services by illiterate mothers.

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