Health and economic benefits of scaling up a home-based neonatal care package in rural India: a modelling analysis

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Abstract

Approximately 900,000 newborn children die every year in India, accounting for 28% of neonatal deaths globally. In 2011, India introduced a home-based newborn care (HBNC) package to be delivered by community health workers across rural areas. We estimate the disease and economic burden that could be averted by scaling up the HBNC in rural India using IndiaSim, an agent-based simulation model, to examine two interventions. In the first intervention, the existing community health worker network begins providing HBNC for rural households without access to home- or facility-based newborn care, as introduced by India’s recent programme. In the second intervention, we consider increased coverage of HBNC across India so that total coverage of neonatal care (HBNC or otherwise) in the rural areas of each state reaches at least 90%. We find that compared with a baseline of no coverage, providing the care package through the existing network of community health workers could avert 48 (95% uncertainty range (UR) 34–63) incident cases of severe neonatal morbidity and 5 (95% UR 4–7) related deaths, save $4411 (95% UR $3088–$5735) in out-of-pocket treatment costs, and provide $285 (95% UR $200–$371) in value of insurance per 1000 live births in rural India. Increasing the coverage of HBNC to 90% will avert an additional 9 (95% UR 7–12) incident cases, 1 death (95% UR 0.72–1.33), and $613 (95% UR $430–$797) in out-of-pocket expenditures, and provide $55 (95% UR $39–$72) in incremental value of insurance per 1000 live births. Intervention benefits are greater for lower socioeconomic groups and in the poorer states of Chhattisgarh, Uttarakhand, Bihar, Assam and Uttar Pradesh.

Key words: Home-based neonatal care, HBNC, neonatal mortality, accredited social health activist, community health worker, India.

Key Messages
- Scaling up access to home-based neonatal care in India could avert 57 cases of severe neonatal morbidity and six related deaths per 1000 live births.
- It would also avert $5024 in private out-of-pocket expenditure for treating neonatal morbidity and provide $340 in money-metric value of insurance per 1000 live births.
- The health and economic benefits are highly progressive, accruing at a greater rate among people in lower wealth quintiles and those in the poorer states of Chhattisgarh, Uttarakhand, Bihar, Assam and Uttar Pradesh.
- In terms of cost per death averted, scaling up the intervention would be cost-saving if both government expenditures on the programme and averted private out-of-pocket treatment expenditure are considered. If only government expenditures are considered, the programme would be highly cost-effective at $382 per death averted.
Introduction

India’s neonatal mortality rate in 2013, 29.2 per 1000 live births, was much higher than the global rate or the average rate across other lower-middle income countries, both ~20 per 1000 live births (World Bank). The rate in India’s rural areas is twice the rate in its urban areas (34 vs 17), and three Indian states—Madhya Pradesh, Uttar Pradesh and Odisha—have rates that exceed 40 deaths per 1000 live births (Chand et al. 2013). Although neonatal mortality in India has fallen from the 1990 rate of 47 per 1000 live births (UNICEF 2012), it still accounts for roughly half of under-five mortality in India (Ministry of Health and Family Welfare 2011a; Liu et al. 2012).

Preterm births, low birth weight and infections (including sepsis, pneumonia, central nervous system infections, diarrhoeal disease and tetanus) account for two-thirds of the neonatal deaths in India (Bassani et al. 2010). These conditions can often be prevented or treated with proper postnatal care, but only 44.3% of newborns receive a health examination within their first 24 h (IIPS 2010).

In order to bridge the newborn care treatment gap in rural areas, the Government of India instituted a home-based newborn care (HBNC) programme in 2011 (Ministry of Health and Family Welfare 2011a). The HBNC programme uses the country’s existing network of community health workers, known as accredited social health activists (ASHAs), to perform recommended postnatal check-ups in a family’s home. ASHAs visit newborns in their first month—five times for institutionally birthed newborns and six times for home-birthed newborns—to identify and treat low birth weight and preterm neonates, diagnose potential illnesses, refer families to healthcare facilities when needed, and provide instruction on breastfeeding, keeping the infant warm, and other essential health-related skills.

This study projects the potential health and economic benefits of scaling up India’s current HBNC programme using a mathematical model. The benefits of ASHA-delivered HBNC depend on the extent to which ASHAs are available in areas currently underserved by other forms of neonatal care. Using IndiaSim, an agent-based simulation of India’s population and healthcare system that previously has been used to evaluate expanded vaccination coverage and increased access to prevention for coronary heart disease patients (Megiddo et al. 2014a,b), we model the HBNC programme, taking into account the existing network of ASHAs and the current newborn care treatment gap. We explore four categories of benefits: morbidity reduction, mortality reduction, reduced out-of-pocket expenditure and the money-metric value of insurance provided (Verguet et al. 2014). We consider these potential benefits for two alternative interventions: delivering HBNC through the current ASHA network, which covers 60.1% of India’s villages (IIPS 2010) and increasing the number of ASHAs such that 90% of the rural population in each state receives neonatal care through existing channels or the new HBNC package.

Data and methods

Population data

For this simulation, IndiaSim models an in silico population of ~2.36 million Indians and ~55 000 childbirths every year. The model population is randomly drawn from the District Level Household Survey 2007–08 (DLHS-3) of India, a nationally representative cross-sectional survey focused on reproductive, maternal and child health. DLHS-3 includes more than 720 000 Indian households, of which ~78% are rural. These data are available from the International Institute for Population Sciences (http://www.iipsindia.org/). The data include details on a range of household and individual indicators: demographic characteristics, living conditions, asset ownership, healthcare-seeking behaviour and healthcare access. They also provides information on the availability of physical infrastructure and amenities in villages and the availability and quality of medical instruments, supplies and staff at various public healthcare facilities.

Data on disease epidemiology, treatment and neonatal care package

Study parameters related to disease, prevention and treatment come from the existing literature on neonatal morbidity and mortality. However, some parameters have been adjusted using assumptions to overcome data limitations. For example, Bang et al. (2001) observed that a rural neonate’s risk of suffering from high-risk morbidity (such as neonatal sepsis, a congenital anomaly or birth asphyxia) was 48.2%. Since this risk is likely to be lower because of progress made in healthcare since 2001, in the absence of more recent data, we project the risk of severe neonatal morbidity in 2011 to be 30%.

Our projection is based on the 2011 neonatal mortality rate of 31 per 1000 live births in India (World Bank) and the case fatality rate from severe morbidity of 10.3% (Bang et al. 2001). We considered only households that currently have no access to any form of neonatal care (or choose not to access it). There is no information on whether health benefits to neonates from HBNC are superior or inferior to those from existing sources of neonatal care. Therefore, we consider the HBNC package complementary to existing care.

We consider the uncertainty surrounding the true morbidity and mortality risks of newborns by conducting a detailed sensitivity analysis (discussed later). We consider a HBNC package targeted only at rural households that did not receive home- or facility-based newborn care in the baseline (either because they could not access care or chose not to access it). Using DLHS-3, we estimate that 60.2% of rural newborn children in India did not receive any home- or facility-based newborn care during the first 10 days of life. Among the children who received care, 81% visited a health facility, 15% received care at home from a doctor, nurse or auxiliary nurse midwife and 3% received it from other sources. Because the neonatal care package has only recently been introduced, we assume a baseline coverage rate of zero.

The HBNC package analysed here has been evaluated in the field by Bang et al. (1999, 2001, 2003b,d) in Gadchiroli (in Maharashtra, central India) and Kumar et al. (2008) in Shivgarh (in Uttar Pradesh, northern India). Following these studies, we assume that the HBNC package would reduce the risk of neonatal morbidity by 50.4% (Bang et al. 2003b) and neonatal mortality by 54% (Kumar et al. 2008).

The effect sizes observed in the Gadchiroli and Shivgarh studies have been replicated in more recent studies. A recent study from Odisha and Jharkhand found that a community intervention involving group learning by women reduced neonatal mortality by 45% (Tripathy et al. 2010). Another recent meta-analysis of 13 controlled trials showed that community-based newborn care could reduce neonatal mortality substantially in many South and South-east Asian countries (Gogia et al. 2011). For example, neonates receiving a home visit from health workers on the first and second days of life in Bangladesh were 67% and 64% less likely to die. The authors also found that community-based care was more effective for children with a higher baseline burden of neonatal morbidity as compared with children with lower burden.
Because our analysis is focused on households without access to home- or facility-based newborn care in the baseline, the HBNC package is likely to have a greater effect on the health of neonates in this sub-population than in the general population. In order to capture the uncertainty in the effectiveness of HBNC, we varied the resultant reduction in neonatal morbidity between 35.2% and 65.5%, and the reduction in mortality in the range of 37.8–70.2% in our sensitivity analysis. We also present estimates separately from a scenario in which the HBNC leads to a lower mortality reduction of 34%, observed by Baqui et al. (2008) in Bangladesh.

We also assume that the cost of the HBNC package to the government will be similar to the cost of the Integrated Management of Childhood Illnesses (IMCI) programme delivered by ASHA workers in India. We assume that the cost of implementing HBNC through the existing network of ASHAs (covering 60.1% of the population) would equal the annual per child cost of the IMCI programme, or Rs. 87 ($1.69) (Prinja et al. 2013b). To achieve a 90% coverage of HBNC, the cost per neonate (including the cost of deploying additional ASHAs) is assumed to be an additional Rs. 31 ($0.60), which is the incremental cost of delivering IMCI (Prinja et al. 2013b). In addition, ASHAs receive a cash incentive of Rs. 250 ($2.85) per neonate to whom they deliver care. Therefore, the total government costs per neonate of 60.1% and 90% HBNC coverage are assumed to be Rs. 337 ($6.54) and Rs. 368 ($6.94), respectively. All costs are in 2013 US$, adjusted for inflation using the World Bank.

Finally, in the absence of any data on treatment demand, we assume that 75% of households with neonates suffering from severe morbidity seek intensive care, if available, with an out-of-pocket treatment expenditure of $108.97 (Prinja et al. 2013a). We relax this assumption in two ways. First we conduct a rigorous sensitivity analysis by considering a wider range of the demand for intensive care and the associated out-of-pocket cost (described later and also shown in Table 1). Second, we acknowledge that irrespective of the demand for intensive care, its actual usage may be restricted by lack of access. For example, although all secondary public healthcare facilities (community health centres) in India are equipped with Newborn Stabilization Units which can manage a few newborn conditions, as of March 2013, only 49% of the districts were covered by functional Special Newborn Care Units (SNCU) (Gol 2013).

SNCUs are established in tertiary public care facilities (district and sub-district hospitals) and can provide full intensive care for sick newborn babies except for assisted ventilation and major surgeries. In order to incorporate the low availability of SNCUs in our analysis, we consider an additional scenario where among the 75% of household who seek neonatal intensive care, only 49% can obtain the care at a cost of $108.97 per neonate.

Model

The IndiaSim model is based on population and healthcare infrastructure data from DLHS-3 and has been described in earlier works (Megiddo et al. 2014a,b). Our analysis includes the rural areas of 34 states and Union Territories. Nagaland was not surveyed in DLHS-3 and is excluded from our analysis.

Our model follows an iterative Markov process with a daily time step. Each day, population dynamics, disease dynamics and health-care choices are simulated based on individual- and household-level characteristics. A household-level demand for children function is estimated (Megiddo et al. 2014a,b), and who are born on the basis of this function ‘stay’ (i.e. are analysed) in the model for their first 30 days of life. Within this period, each neonate is in one of two disease states on each day: healthy or suffering from severe morbidity. The risk of developing severe morbidity is based on a stochastic function. Households with neonates suffering from disease seek intensive care at a public or private healthcare provider. The model is simulated for 1 year.

Interventions

We considered two interventions covering our target households, defined as rural households that did not access (or did not have access to) home- or facility-based neonatal care at baseline. In intervention 1, we assumed an expansion of responsibilities of existing ASHAs to deliver the HBNC package to target households. We used DLHS-3 to provide information on whether each rural household is located in a village covered by an ASHA. Households with an ASHA in their village are therefore given the HBNC package. In intervention 2, the coverage of ASHAs (and thus the coverage of the HBNC package) is assumed to increase such that at least 90% of rural households in each state are covered either by the new HBNC package or existing home- or facility-based neonatal care.

Table 1. Disease, treatment and intervention input parameters

<table>
<thead>
<tr>
<th>Parameter type</th>
<th>Value</th>
<th>Reference</th>
<th>Sensitivity range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disease parameters</td>
<td>Disease: Severe neonatal morbidity</td>
<td>World Bank data</td>
<td>0.211–0.391</td>
</tr>
<tr>
<td>Incidence</td>
<td>0.301</td>
<td>Bang et al. 2005</td>
<td>0.072–0.134</td>
</tr>
<tr>
<td>Case fatality rate</td>
<td>0.103</td>
<td></td>
<td></td>
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<tr>
<td>Treatment parameters</td>
<td>Treatment: Intensive-care treatment</td>
<td>Assumed</td>
<td>$52.5–97.5%</td>
</tr>
<tr>
<td>Demand for treatment</td>
<td>75%</td>
<td>Prinja et al. 2013</td>
<td>$76.28–$141.66</td>
</tr>
<tr>
<td>Cost of treatment</td>
<td>$108.97</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intervention parameters</td>
<td>Intervention: Home-based neonatal care</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>similar to Bang et al. 2005 [13]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baseline coverage of intervention</td>
<td>0%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baseline coverage of community</td>
<td>60.1%</td>
<td>DLHS-3</td>
<td></td>
</tr>
<tr>
<td>health workers</td>
<td>Cost at 60.1% coverage</td>
<td>Prinja et al. 2013</td>
<td>$4.12–$7.66</td>
</tr>
<tr>
<td>Cost at 90% coverage</td>
<td>US$6.54 per neonate</td>
<td>Prinja et al. 2013</td>
<td>$4.58–$8.30</td>
</tr>
<tr>
<td>Risk reduction in incidence</td>
<td>0.304</td>
<td>Bang et al. 2005</td>
<td>$0.352–0.655</td>
</tr>
<tr>
<td>Risk reduction in mortality</td>
<td>0.54</td>
<td>Kumar et al. 2008</td>
<td>0.378–0.702</td>
</tr>
</tbody>
</table>

Notes: Risk reduction in incidence is calculated as the average of reduction from infections-related incidence (0.553) and care-related incidence (0.454) obtained from Bang et al. (2005) [13]. The sensitivity range is over 70% to 130% of the parameter value. All costs are in 2013 US$, adjusted for inflation using the International Monetary Fund (IMF) gross domestic product (GDP) deflator.
Under the interventions, a newborn receiving the HBNC package is 50.4% less likely to experience severe morbidity than at baseline (Bang et al. 2005c), with reductions varied in the sensitivity analysis. This results in fewer cases of severe morbidity and therefore reduced out-of-pocket treatment expenditure and associated financial risk. The intervention also reduces the number of deaths due to severe neonatal morbidity.

The outcomes of intervention 1 are reported incremental to the baseline, whereas those of intervention 2 are reported incremental to intervention 1. The health benefits of HBNC are measured in terms of reduced neonatal morbidity and deaths averted. The economic benefits are measured by out-of-pocket treatment expenditure averted and the value of financial risk protection provided. The value of risk protection, also referred to as the money-metric value of insurance (Verguet et al. 2014), measures 'risk premium'—that is, the amount of money that a neonate’s household is willing to pay to avoid the risk of financial shock associated with severe morbidity. A detailed discussion on value of insurance in provided in the Supplementary Appendix.

We conduct a 100-simulation Latin hypercube sampling sensitivity analysis on the incidence of neonatal illness, case fatality rate, demand for intensive care, efficacy of the care package and costs of treatment and intervention (considering a range of 70–130% of the initial parameter value). Results from the sensitivity analysis are used to produce 95% uncertainty ranges (UR) for our mean estimates. These ranges are reported in the results below. Table 1 shows the input parameters and sensitivity ranges used in our analysis.

**Results**

According to DLHS-3 data, 60.1% India’s villages are covered by ASHAs. Coverage varies widely by state, ranging from nearly universal to very low coverage rates (Figure 1). In general, coverage was higher in northern and eastern states. Coverage exceeds 75% in Uttar Pradesh, Haryana, Chhattisgarh and Assam. ASHA coverage rates in 11 other states (including Bihar, Rajasthan, Jammu and Kashmir, Madhya Pradesh and Uttar Pradesh) exceed the national average. West Bengal, Maharashtra, Goa, Karnataka and Tamil Nadu have ASHA coverage rates of <25%.

According to DLHS-3, 39.8% of rural newborns receive home- or facility-based newborn care during the first 10 days of life. More than 70% of rural newborn children in Delhi, Andhra Pradesh, Maharashtra, Punjab, Tamil Nadu, Kerala and Goa receive newborn care. In Kerala and Goa, 99% of newborn children are covered. In Tripura, Bihar, Meghalaya, Uttar Pradesh, Jharkhand, Odisha and

![Figure 1. Current coverage of ASHA workers across rural India.](https://academic.oup.com/heapol/article-abstract/31/5/634/2355739/637)

Note: ASHA, accredited social health activist. Coverage of ASHAs is calculated from DLHS-3. The colour gradient represents the proportion of rural households in a state that are in villages covered by ASHAs. Nagaland was not surveyed in DLHS-3.
Uttar Pradesh, less than 30% of newborn children receive such care (Figure 2).

Table 2 presents the incremental health benefits of scaling up the HBNC package among children who did not receive any home- or facility-based neonatal care at baseline. Adding HBNC to the set of tasks performed by existing ASHAs (intervention 1) would avert 48 (95% UR 34–63) incident cases of severe neonatal morbidity and 5 (95% UR 4–7) related deaths for every 1000 live births, compared with the baseline. Intervention 2, which increases the coverage of ASHAs and the HBNC package such that the total coverage of all types of neonatal care reaches at least 90% in each state, will avert an additional 9 (95% UR 7–12) incident cases of severe neonatal morbidity and 1 (95% UR 0.72–1.33) death per 1000 live births.

Projected health gains for intervention 1 are progressive across wealth quintiles—poor households benefit more with this intervention relative to the baseline (see Table 2). In this intervention, there are 53 (95% UR 37–69) incident cases of severe morbidity averted per 1000 live births in the poorest wealth quintile. The benefits decrease as wealth increases, and incident cases averted fall to 35 (95% UR 25–46) per 1000 live births in the highest wealth quintile. In intervention 2, the incremental health gains continue to be progressive, with 12 (95% UR 9–15) and 8 (95% UR 6–11) incident cases averted per 1000 live births in the poorest and richest wealth groups, respectively. A similarly progressive pattern across wealth quintiles is observed for related fatality. In intervention 1, incremental deaths averted gradually fall from 6 (95% UR 5–8) per 1000 live births in the poorest wealth quintile to 4 (95% UR 3–5) per 1000 live births in the richest wealth quintile. In intervention 2, one additional death is averted per 1000 live births across wealth quintile.

Assuming that the HBNC reduces neonatal mortality by 34% (instead of 54% reduction) (Baqui et al. 2008), interventions 1 and 2 would avert 3.3 and 3.9 neonatal deaths per 1000 live births respectively. The number of deaths averted is generally progressive under both interventions, with more neonatal deaths averted among the poorer wealth quintiles. However, as we consider a lower impact of the HBNC package only on mortality, the other health and economic outcomes will not change.

Figure 3 illustrates the incremental health benefits of interventions by state. The distribution of benefits under intervention 1 mirrors the ASHA coverage map in Figure 1, with greater benefits accruing to states with higher existing coverage rates of ASHAs. Chhattisgarh, Uttarakhand, Bihar, Assam, Uttar Pradesh and Tripura gain the most, with each averting more than 60 incident cases and 6 deaths per 1000 live births compared with the baseline. Gains in Tamil Nadu, Kerala, Goa, Maharashtra, Karnataka and West Bengal are relatively low because of high baseline levels of

![Figure 2. Current coverage of home- or facility-based neonatal care across rural India.](https://academic.oup.com/heapol/article-abstract/31/5/634/2355739)
facility- or home-based neonatal care coverage. As HBNC coverage is scaled up in intervention 2, additional health benefits are mostly attributed to this latter group of states, reducing regional disparity. However, because states that did not have high baseline levels of neonatal care generally have high existing ASHA coverage, intervention 1 increases the coverage of neonatal care (ASHA-provided or otherwise) to high levels in most states. As a result, the incremental health gains from intervention 2 are low.

The economic outcomes of our analysis, measured in 2013 US$, are presented in Table 3. We find that intervention 1 saves $4411 (95% UR $3088–$5735) in out-of-pocket treatment expenditure compared to the baseline, and intervention 2 averts another $613 (95% UR $430–$797) in out-of-pocket cost per 1000 live births. In intervention 1, the neonates in the lowest wealth quintile have the highest out-of-pocket expenditure averted per 1000 live births, at $4807 (95% UR $3365–$6250), which gradually diminishes to $3393 (95% UR $2376–$4411) per 1000 live births for the highest wealth quintile. The incremental benefit of intervention 2 is similarly progressive, with out-of-pocket expenditure averted ranging from $799 (95% UR $560–$1040) per 1000 live births in the poorest wealth quintile to $491 (95% UR $344–$639) per 1000 live births in the wealthiest. If we consider an alternative scenario in which only 49% of households who seek neonatal intensive care are able to obtain it (due to low coverage of SNCU at public hospitals), intervention 1 would avert $2161 in out-of-pocket treatment cost compared with the baseline, and intervention 2 would save another $300 out-of-pocket expenditure per 1000 live births.

The cost to the national government of providing the HBNC package (programme costs and the monetary incentive to ASHAs) is $1911 (95% UR $1338–$2484) per 1000 live births in intervention 1. In intervention 2, the cost to the government (programme costs, incentive payments, and the cost of new ASHAs) increases by $364 (95% UR $255–$474) per 1000 live births. Since the existing coverage of ASHAs is higher in many poorer northern and eastern states, adding the HBNC package to the current responsibilities of ASHAs will direct additional resources to the poor. Therefore, we find that the government cost of intervention 1 is highest for the poorest wealth quintile, at $2099 (95% UR $1470–$2729) per 1000 live births, and it reduces to $1389 (95% UR $973–$1806) per 1000 live births for the highest wealth quintile. For intervention 2, additional government costs are similarly highest for the poor, ranging from $460 (95% UR $322–$598) to $277 (95% UR $194–$361) per 1000 live births in lowest and the highest wealth quintiles, respectively.

The incremental money-metric value of insurance provided by intervention 1 is $285 (95% UR $200–$371) per 1000 live births. Intervention 2 provides $55 (95% UR $39–$72) in additional insurance value per 1000. The insurance value is highly progressive over wealth quintiles. The poorest wealth group attains more than seven times the benefit received by the highest wealth quintile in intervention 1 and almost 10 times the incremental benefit in intervention 2.

Figure 4 shows the state-level distribution of economic gains from the interventions. In intervention 1, Madhya Pradesh, Chhattisgarh, Bihar, Assam, Uttar Pradesh and Tripura obtain the highest benefits, each with more than $4800 in out-of-pocket expenditure averted and $400 in value of insurance per 1000 live births. Kerala, Goa, Maharashtra, Karnataka, West Bengal and Punjab are among the states that see the lowest reduction in out-of-pocket expenditure. Intervention 2 provides higher economic benefits in states that received lower benefits in intervention 1, thereby reducing regional disparity in outcomes. However, as with health outcomes, the additional economic benefit of intervention 2 is generally low for all states.

### Discussion

Integration and scaling up of newborn care into the public healthcare have been advocated through three possible mechanisms—outreach, family community and facility-based clinical care—with home-based care forming components of the first two mechanisms (Darmstad et al. 2005). Evidence supports the cost-effectiveness of all of these approaches, especially family community and facility-based approaches (Haws et al. 2007; Lassi et al. 2010; Lawn et al. 2010; Schiffman et al. 2010).

However, evidence on neonatal care packages that are primarily home based is limited. Fortunately, the few studies that do exist are mostly based in India and other South Asian countries, providing reliable estimates of effectiveness that we used in our model. One of
the early and most cited studies of HBNC in India is Bang et al. (1999), which reported a 25% or greater reduction in neonatal mortality over a 3-year period. The package cost an estimated $150.50 per death averted and $6.78 per disability-adjusted life year averted (both in 2001 US$) (Bang et al. 2005a). Kumar et al. (2008) reported an even higher reduction in neonatal mortality, 54%, from another study site (Shivgarh, India).

Baqui et al. (2008) conducted a large-scale cluster-randomized trial of HBNC, similar to that implemented by Bang et al. (1999), in the Sylhet district of Bangladesh. In addition to home-based care, the study included a second intervention arm to evaluate community-based care. The home-care intervention consisted of trained female community health workers delivering two antenatal and three postnatal visits, plus referrals for sick children. This package was found to reduce neonatal mortality rates by 34%. At US$2995 (including health system costs) per neonatal death averted, the intervention was highly cost-effective. However, in Mirzapur district of Bangladesh, a trial of a maternal and newborn care package found no significant effect on neonatal mortality (Darmstadt et al. 2010). In a pilot study in rural Pakistan, home-based care delivered through community health workers reduced neonatal mortality from 57.3 to 41.3 per 1000 live births (Bhutta et al. 2008).

Figure 3. Geographic distribution of health outcomes, per 1000 live births.

Note: Nagaland is excluded from our analysis because it was not covered by DLHS-3. Negative deaths averted (in other words, deaths incurred due to intervention) occur in small Union territories (e.g. Daman and Diu, Andaman and Nicobar islands) and are aberrations caused by small populations for these areas in the simulation. The outcomes of intervention 1 are incremental to the baseline; those of intervention 2 are incremental to intervention 1.
The Eleventh Five Year Plan of India (2007–12) advocated HBNC as the main strategy for reducing infant mortality (Planning Commission of India 2008), and in 2011, the National Rural Health Mission formally introduced the HBNC package through ASHAs in India. Under the programme, an ASHA earns Rs. 250 ($4.10) per Neonate by visiting homes and providing care. Our simulation suggests that scaling up HBNC to a nearly universal level should have a tremendous impact on reducing neonatal morbidity and associated costs in India. Compared with the baseline level of no HBNC coverage, 90% coverage of neonatal care (HBNC or otherwise) can potentially avert up to 57 cases of severe morbidity and 6 neonatal deaths per 1000 live births. It could also reduce out-of-pocket treatment expenditure by up to $5024 and provide $340 in insurance value for every 1000 live births. Regionally targeted scaling up could also reduce the disparities in disease and financial burdens on households across states.

The health and economic indicators examined in our study can be used for a multiple-criteria comparison of the benefits of HBNC package with other child health interventions in India. For example, Megiddo et al. (2014a) have shown that increasing the coverage rates of existing routine immunization and a new rotavirus vaccine to 90% in India could avert 0.6 deaths from vaccine-preventable diseases and $2818.4 in related out-of-pocket treatment expenditure per 1000 children under 5 years. Introducing rotavirus vaccine in India (at an initial coverage rate of 76.8%) in their analysis produces a value of insurance ranging from $5.21 in Delhi to $67.56 in Bihar per 1000 under-five children. In comparison, intervention 1 in our analysis yields a value of insurance ranging from $18.7 in Delhi to $925.8 in Bihar per 1000 live births.

Both of our interventions are cost-saving, measured by cost per death averted, if we consider the net benefit of out-of-pocket expenditure averted and the government cost of intervention in our analysis. If we consider only the government cost of the HBNC programme, intervention 1 costs $382 per death averted, and intervention 2 costs $379 per death averted from the baseline, making both ‘very cost-effective’ by an accepted threshold measure of less than the GDP per capita (WHO 2003). The HBNC package is potentially much cheaper than other methods of delivering neonatal care. A community-based women’s participatory intervention for essential newborn care in Nepal, for example, costs $3442 (2004 US$) per newborn death averted (Manandhar et al. 2004).

Our estimated cost-effectiveness ratios are much smaller than those reported by Baqui et al. (2008) and Manandhar et al. (2004), primarily because we assumed a lower intervention cost and higher efficacy rate. If we consider alternative estimates of HBNC programme cost, such as a $14 cost per neonate of delivering postnatal care by community health workers, as estimated by Prinja et al. (2014), the cost of intervention 1 to the government would be ~$4542 per 1000 live births or $908 per death averted. If we assume the cost of HBNC in our study per neonate to be $34.97, i.e. the same as in the trial in Sylhet, Bangladesh (LeFevre et al. 2013), total government expenditure for intervention 1 would be about $11345 per 1000 live births or $2268 per death averted (2008 US$). Under both these alternative scenarios, the intervention remains cost-effective.

Among health policies that aim to reduce the burden of maternal and child mortality in India, Janani Suraksha Yojana (Jsy, ‘Safe Motherhood Scheme’) is the most noteworthy. Introduced in 2005, Jsy provides a cash incentive of up to Rs. 1400 ($22.97, assuming Rs. 60.94 as in 2013) to pregnant women for delivering their babies at a public or accredited private healthcare facility. The programme is administered with the help of ASHAs who themselves earn a monetary incentive of up to Rs. 60 for facilitating institutional childbirth. The programme had more than 11 million beneficiaries as of 2011 (Ministry of Health and Family Welfare 2011b). A study by Lim et al. (2010) suggested that Jsy averted 2.3–2.4 neonatal deaths per 1000 live births, though other studies have questioned Jsy’s

### Table 3. Financial outcomes (per 1000 live births) of interventions, by wealth quintile

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Wealth quintile</th>
<th>ASHA coverage level</th>
<th>Value</th>
<th>95% UR</th>
<th>Value</th>
<th>95% UR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incremental out-of-pocket expenditure averted</td>
<td>I</td>
<td>$4807</td>
<td>$3365–$6250</td>
<td>$799</td>
<td>$560–$1040</td>
<td></td>
</tr>
<tr>
<td></td>
<td>II</td>
<td>$4906</td>
<td>$3435–$6378</td>
<td>$577</td>
<td>$405–$751</td>
<td></td>
</tr>
<tr>
<td></td>
<td>III</td>
<td>$4258</td>
<td>$2981–$5356</td>
<td>$554</td>
<td>$388–$721</td>
<td></td>
</tr>
<tr>
<td></td>
<td>IV</td>
<td>$3716</td>
<td>$2602–$4831</td>
<td>$494</td>
<td>$346–$642</td>
<td></td>
</tr>
<tr>
<td></td>
<td>V</td>
<td>$3393</td>
<td>$2376–$4411</td>
<td>$491</td>
<td>$344–$639</td>
<td></td>
</tr>
<tr>
<td>Overall</td>
<td></td>
<td>$4411</td>
<td>$3088–$5735</td>
<td>$613</td>
<td>$430–$797</td>
<td></td>
</tr>
<tr>
<td>Incremental cost to government</td>
<td>I</td>
<td>$2099</td>
<td>$1470–$2729</td>
<td>$460</td>
<td>$322–$598</td>
<td></td>
</tr>
<tr>
<td></td>
<td>II</td>
<td>$2136</td>
<td>$1496–$2778</td>
<td>$332</td>
<td>$233–$433</td>
<td></td>
</tr>
<tr>
<td></td>
<td>III</td>
<td>$1846</td>
<td>$1293–$2400</td>
<td>$336</td>
<td>$236–$438</td>
<td></td>
</tr>
<tr>
<td></td>
<td>IV</td>
<td>$1596</td>
<td>$1117–$2075</td>
<td>$325</td>
<td>$228–$423</td>
<td></td>
</tr>
<tr>
<td></td>
<td>V</td>
<td>$1389</td>
<td>$973–$1806</td>
<td>$277</td>
<td>$194–$361</td>
<td></td>
</tr>
<tr>
<td>Overall</td>
<td></td>
<td>$1911</td>
<td>$1338–$2484</td>
<td>$364</td>
<td>$255–$474</td>
<td></td>
</tr>
<tr>
<td>Incremental value of insurance</td>
<td>I</td>
<td>$776</td>
<td>$544–$1009</td>
<td>$186</td>
<td>$131–$243</td>
<td></td>
</tr>
<tr>
<td></td>
<td>II</td>
<td>$549</td>
<td>$385–$714</td>
<td>$92</td>
<td>$65–$121</td>
<td></td>
</tr>
<tr>
<td></td>
<td>III</td>
<td>$358</td>
<td>$251–$465</td>
<td>$66</td>
<td>$47–$87</td>
<td></td>
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<tr>
<td></td>
<td>IV</td>
<td>$223</td>
<td>$157–$291</td>
<td>$41</td>
<td>$29–$53</td>
<td></td>
</tr>
<tr>
<td></td>
<td>V</td>
<td>$99</td>
<td>$70–$129</td>
<td>$19</td>
<td>$14–$25</td>
<td></td>
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<tr>
<td>Overall</td>
<td></td>
<td>$285</td>
<td>$200–$371</td>
<td>$55</td>
<td>$39–$72</td>
<td></td>
</tr>
</tbody>
</table>

Notes: Estimates are for 100 births in each wealth quintile. The overall estimates are for per 1000 live births in the overall study population. ASHA, accredited social health activist. UR, uncertainty range, which is estimated from sensitivity analysis using a Latin hypercube sampling method (100 simulations). The outcomes of intervention 1 are incremental to the baseline; those of intervention 2 are incremental to intervention 1. All estimates are in 2013 US$.
effectiveness in reducing mortality rates (Das et al. 2011; Powell-Jackson et al. 2015) and noted that the programme has reduced, but not eliminated, home births (Amudhan et al. 2013).

Although the HBNC programme can potentially bring substantial health and economic benefits to rural India, it faces several operational challenges. First, expanding HBNC in areas without current ASHA coverage is a difficult task in itself, considering the need for engaging, training and deploying additional workers. Second, the effectiveness of HBNC depends not only on coverage, but also on the incentives and quality of training provided to ASHAs, and regular monitoring and evaluation. A recent study of HBNC in Uttar Pradesh found that ASHAs assessed a majority of newborn health outcomes poorly, including misclassifying the illness of 80% of infants, and failing to examine critical breastfeeding issues or following correct steps to measure weight for more than two-thirds of the babies (Das et al. 2014). Finally, the HBNC programme cannot succeed without improving higher-level healthcare facilities to which the ASHAs can refer sick newborns. As of March 2013, only 49% of Indian districts had a functioning SNCU capable of providing a full range of intensive care (GoI 2013). Among 184 districts designated as ‘high-priority’ under the programme because of worse maternal and child health outcomes, the availability of SNCUs was

Figure 4. Geographic distribution of financial outcomes, per 1000 live births.

Notes: Nagaland is excluded from our analysis because it was not covered by DLHS-3. OOP, out-of-pocket. The outcomes of intervention 1 are incremental to the baseline; those of intervention 2 are incremental to intervention 1. All estimates are in 2013 US$.
even lower at 41%. Furthermore, just 53.1% and 48.5% of functional units reported having adequate doctors and nurses respectively. Together, the SNCUs in India handled just 489 000 newborn admissions in 2012–13. The units often face severe challenges related to maintenance, sustainability and bed occupancy and shortage of skilled medical staff (Neogi et al. 2011; Rao et al. 2011).

Our analysis has some limitations. First, the National Rural Health Mission policy that introduced ASHAs in 2005 focused on 10 ‘low-performing states’ considered socioeconomically disadvantaged—Jammu and Kashmir, Uttar Pradesh, Uttarakhand, Bihar, Jharkhand, Madhya Pradesh, Chhattisgarh, Assam, Rajasthan and Odisha. The programme has achieved a high coverage of ASHAs in these states but lower coverage elsewhere (e.g. in West Bengal, Maharashtra, Karnataka, Himachal Pradesh, Kerala and Tamil Nadu). The low existing coverage of ASHAs in non-priority states may imply that community health workers have a lower effectiveness in those states, either because baseline neonatal health outcomes are better, or because alternative modes of neonatal care delivery are more effective. Therefore, we may overestimate the incremental benefits of the HBNC package delivered through ASHAs when coverage is expanded in these states. Second, disease data specific to a given wealth group or state do not exist, so we extrapolate national-level data to these population subgroups. However, we adjust for the lack of precision by conducting rigorous sensitivity analysis on the input parameters. Finally, due to lack of data, we do not consider the impact of the new HBNC workload on the existing services delivered by the ASHAs.

Supplementary data
Supplementary data are available at HEAPOL online.

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Ethics Statement
This study uses publicly available household survey data from the International Institute for Population Sciences (http://www.iipsindia.org/) of India. An ethics statement was not required for this work.

Conflicts of interest
None declared.

References


