Saving newborn lives in Asia and Africa: cost and impact of phased scale-up of interventions within the continuum of care

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Background Policy makers and programme managers require more detailed information on the cost and impact of packages of evidenced-based interventions to save newborn lives, particularly in South Asia and sub-Saharan Africa, where most of the world’s 4 million newborn deaths occur.

Methods We estimated the newborn deaths that could be averted by scaling up 16 interventions in 60 countries. We bundled the interventions in a variety of existing maternal and child health packages according to time period of delivery and service delivery mode, and calculated the additional running costs of implementing these interventions at scale (90% coverage) in sub-Saharan Africa and South Asia. The phased introduction and expansion of interventions was modelled to represent incremental strategies for scaling up neonatal care in developing country health systems.

Results Increasing coverage of 16 interventions to 90% could save 0.59–1.08 million lives in South Asia annually at an additional cost of US$0.90–1.76 billion. In sub-Saharan Africa, 0.45–0.80 million lives saved would cost US$0.68–1.32 billion. Additional costs for increased antenatal interventions are low, but given relatively high baseline coverage and lower impact, fewer additional newborn lives can be saved through this package (5–10%). Intrapartum care has higher impact (19–34% of deaths averted) but is costly (US$1.66–3.25 billion). Postnatal family-community care, with potential for high impact at low cost (10–27%, US$0.38–0.75 billion), has been neglected. A first phase of scaling up care in 36 high (NMR 30–45) and 15 very high (NMR >45) mortality countries would cost approximately US$0.56–1.10 and US$0.09–0.17 billion annually, respectively, and would avert 15–32% and 13–29% of neonatal deaths, respectively, in these countries. Full coverage with all interventions in the 51 high and very high mortality countries would cost US$2.23–4.37 billion, and avert 38–68% of neonatal deaths (1.13–2.05 million), at an extra cost per death averted of US$1100–3900.

Conclusions Low-cost, effective newborn health interventions can save millions of lives, primarily in South Asia and sub-Saharan Africa. Modelling costs and impact of intervention packages scaled up incrementally as health systems capacity

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increases can assist programme planning and help policy makers and donors identify stepwise targets for investments in newborn health.

Keywords Neonatal survival, neonatal mortality, scaling up, MDG-4, evidence-based interventions, developing countries, health systems, service delivery

KEY MESSAGES

- Increasing effective coverage of 16 interventions proven to save newborn lives to 90% could save 0.59–1.08 million lives in South Asia annually at an additional cost of US$0.90–1.76 billion. In sub-Saharan Africa, 0.45–0.80 million newborn lives saved would cost US$0.68–1.32 billion.

- Strengthening family-community care is an important initial step in averting neonatal deaths; however, simultaneous investment is needed in the development of integrated, skilled facility-based childbirth and postnatal care for mothers and newborns.

- A first phase of scaling up care in 36 high and 15 very high mortality countries would cost approximately US$0.56–1.10 and US$0.09–0.17 billion annually, respectively, and would avert 15–32% and 13–29% of neonatal deaths, respectively, in these countries. Full coverage with all interventions in the 51 high and very high mortality countries would cost US$2.23–4.37 billion, and avert 38–68% of neonatal deaths (1.13–2.05 million), at an extra cost per death averted of US$1100–3900.

Introduction

The Lancet Neonatal Survival Series, published in March 2005, provided an analysis of the global burden of neonatal mortality (Lawn et al. 2005a); the potential impact of simple, cost-effective interventions to save newborn lives (Darmstadt et al. 2005c); the inputs needed to scale up country programmes to address neonatal health (Knippenberg et al. 2005); and the policy, programme and research action needed to fill key gaps in the delivery of interventions where they are most needed (Horton 2005; Martines et al. 2005; Tinker et al. 2005). The series has helped to stimulate policy and programme change at global and national levels (Lawn et al. 2006). However, more detailed information is needed to enable countries to predict the impact and cost of combinations of interventions introduced in locally adapted packages and in a phased manner over time. Such information would facilitate decisions for wise investment in existing programmes and development of cost-effective new programmes.

In this paper, we provide estimates of the impact and additional running costs of providing increased coverage with evidence-based interventions in 60 countries identified as high priority countries by UNICEF. The lifesaving potential of these interventions and the additional costs needed to provide high (90%) coverage are described for a variety of intervention combinations that might be implemented at country level. We also examine the impact and cost of introducing interventions incrementally in phases in country settings with very high (>45/1000 live births) and high (30–45/1000) neonatal mortality rates (NMRs). The costs presented here represent the additional annual running costs for programmes at expanded coverage but do not include all the costs that might be incurred in expanding facilities and infrastructure to achieve high coverage.

Methods

The methods used to estimate impact and cost of evidence-based interventions have been described previously (Darmstadt et al. 2005c), with minor modifications. We included the 60 UNICEF priority countries (where 93% of all under-five deaths occur) (Table 1) and utilized the recent data available by country population figures (UNDP 2005), intervention coverage (UNICEF 2005a), and NMRs, the latter coming from recent Vital Registration data in countries with full coverage Demographic Health Surveys for the majority of countries and estimates from the World Health Organization (WHO) for the remainder (WHO 2006). The country population figures, intervention coverage estimates and NMRs used in this analysis are summarized in Web Table 1. Interventions were packaged by time period of implementation (antenatal, childbirth/intrapartum, or postnatal); service delivery mode (outreach, family-community care, or clinical care); and whether the intervention is appropriate for all settings (‘universal’), for certain settings where a condition targeted by the intervention poses a public health problem (‘situational’), or for settings with more advanced health systems capacity (‘additional’) (Tables 2 and 3). These categorizations were chosen based on their importance in developing a rational, phased approach to increasing coverage of interventions over time.

Impact estimation

For each country and each intervention, we applied the increase in coverage from current levels to target coverage, together with estimates of intervention effectiveness and neonatal deaths by cause (Bhutta et al. 2005; Darmstadt et al. 2005c) to estimate the number of avertable deaths, as described previously.
Table 1  Sixty countries in regions and sub-regions included in analyses

<table>
<thead>
<tr>
<th>Region</th>
<th>Countries in region</th>
<th>Annual births (millions)</th>
<th>Annual neonatal deaths (millions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Global (n = 60)</td>
<td></td>
<td>102.5</td>
<td>3.7</td>
</tr>
<tr>
<td>Africa (n = 41)</td>
<td></td>
<td>31.9</td>
<td>1.3</td>
</tr>
<tr>
<td>Sub-Saharan Africa sub-region (n = 37)</td>
<td>Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Central African Republic, Chad, Congo, Côte d’Ivoire, Democratic Republic of Congo, Equatorial Guinea, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Liberia, Malawi, Mali, Mauritania, Madagascar, Mozambique, Niger, Nigeria, Rwanda, Senegal, Sierra Leone, South Africa, Swaziland, Tanzania, Togo, Uganda, Zambia, Zimbabwe</td>
<td>28.4</td>
<td>1.2</td>
</tr>
<tr>
<td>North Africa sub-region</td>
<td>Djibouti, Egypt, Somalia, Sudan</td>
<td>3.5</td>
<td>0.1</td>
</tr>
<tr>
<td>Asia (n = 13)</td>
<td>South Asia sub-region PLUS</td>
<td>61.0</td>
<td>2.1</td>
</tr>
<tr>
<td></td>
<td>East Asia &amp; Pacific sub-region PLUS</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Azerbaijan, Tajikistan, Turkmenistan, Kazakhstan</td>
<td></td>
<td></td>
</tr>
<tr>
<td>South Asia sub-region (n = 4)</td>
<td>Pakistan, Bangladesh, India, Nepal</td>
<td>35.2</td>
<td>1.6</td>
</tr>
<tr>
<td>East Asia &amp; Pacific sub-region (n = 6)</td>
<td>Cambodia, China, Indonesia, Myanmar, Papua New Guinea, the Philippines</td>
<td>25.4</td>
<td>0.6</td>
</tr>
<tr>
<td>Other (n = 6)</td>
<td>Brazil, Haiti, Mexico, Iraq, Yemen, Afghanistan</td>
<td>6.1</td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3.3</td>
<td>0.2</td>
</tr>
</tbody>
</table>

Target coverage generally was set at 90% of those in need (unless otherwise specified); the population in need was calculated by identifying the general target population (e.g. all newborns, pregnant women) and multiplying by the incidence or proportion of the target population with the condition that the intervention was targeted against (see Web Table 2). Web Table 3 provides the evidence for impact of single interventions, and Web Table 2 shows the cause-specific impact for intervention packages used in the analysis.

We identified interventions for which there was good evidence of efficacy or effectiveness in reducing neonatal mortality. Since a given intervention may impact more than one cause of death, and deaths due to a specific cause may be averted by more than one intervention, we required estimates of the effect of interventions on specific causes of death in order to derive impact estimates. For many interventions, however, cause-specific effects were not reported. Therefore, for each intervention we estimated its likely effectiveness in reducing cause-specific mortality using the available literature (Bhutta et al. 2005; Darmstadt et al. 2005c), the work of the Neonatal Group of the Child Health and Epidemiology Reference Group (Bryce et al. 2003) and, when required, expert opinion (see ref 2, Table 3; Web Table 2). This process inevitably introduced substantial uncertainty. Consequently, we used a range of effectiveness estimates from low (pessimistic) to high (optimistic). These cause-specific effects were then applied to estimates of the numbers of neonatal deaths due to each cause in each of the 60 countries (WHO 2006), assuming that the population impact increases linearly with coverage. This strong but simple assumption about the relationship between coverage and impact was made in the absence of data to support a more complex form of relationship. Furthermore, we assumed a multiplicative model which estimates the relative reduction, rather than absolute reduction, in neonatal deaths due to a given intervention or intervention package. Thus, the number of deaths that would be expected to be prevented for a given cause of death by a given intervention was calculated as:

\[
\text{Deaths prevented} = \frac{N \times I \times (P_1 - P_0)}{(1 - I) \times P_0}
\]

where \(N\) = number of deaths prior to intervention

\(I\) = proportion by which intervention reduces deaths

\(P_0\) = existing coverage of intervention

\(P_1\) = target coverage for intervention

The equation was derived as follows. If the number of deaths at 0% coverage is \(N_{0}\), then the number of deaths at 100% coverage is \(N_{0} \times (1 - I)\). For any given coverage \(P\), the number of deaths can be written as: Number of deaths = \(N_{0}(1 - P \times I)\). Then, at current coverage \(P_0\), the current number of deaths is \(N = N_{0}(1 - P_0 \times I)\), and so \(N_0 = N/(1 - P_0 \times I)\). Increasing coverage to \(P_1\) will reduce the number of deaths to \(N_0(1 - P_1 \times I)\). Therefore, the deaths prevented by increasing coverage from \(P_0\) to \(P_1\) will be \(N_0(1 - P_0 \times I) - N_{0}(1 - P_1 \times I) = N_0 \times I \times (P_1 - P_0)\), and substituting \(N\) (current deaths) for \(N_0\) produces the formula above for deaths prevented. The number of deaths due to a given cause and prevented by the intervention was then subtracted from the current number of deaths, before calculating the impact of the next intervention. We calculated the deaths that could be prevented for a number of different scenarios with different combinations of interventions. Some scenarios modelled different phases in scaling up, and by comparing these scenarios the impact of phased introduction of interventions can be examined. However, within any given scenario, the order in which interventions are entered into the model has no importance because of the multiplicative nature of the model. For example, if we start with 100 deaths, reduce these by 10% (leaving 90) and then reduce the deaths which are left by 20%, we end up with 72 deaths. If we reduce
<table>
<thead>
<tr>
<th>Time period</th>
<th>Intervention</th>
<th>Description and impact</th>
<th>Service delivery mode</th>
<th>Setting</th>
<th>Cause of death addressed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preconception</td>
<td>Folic acid supplementation</td>
<td>Daily intake of 400 μg through supplements or fortification reduces incidence of neural tube defects such as spina bifida and cleft palate by 72% (1–10% of neonatal deaths due to major congenital anomalies).</td>
<td>Outreach</td>
<td>Additional</td>
<td>Congenital anomalies</td>
</tr>
<tr>
<td>Antenatal</td>
<td>TT immunization</td>
<td>Two or three injections prior to or during pregnancy reduces incidence of neonatal tetanus by 80–95%.</td>
<td>Outreach</td>
<td>Universal</td>
<td>Tetanus</td>
</tr>
<tr>
<td></td>
<td>Syphilis screening and treatment</td>
<td>Screening and antibiotic treatment effectiveness depends on prevalence; appropriate in areas where syphilis rates are high.</td>
<td>Outreach</td>
<td>Universal</td>
<td>Infection/prematurity</td>
</tr>
<tr>
<td></td>
<td>Prevention of Pre-eclampsia and eclampsia</td>
<td>Calcium supplementation prevents pre-eclampsia and eclampsia, resulting in a one-third reduction in prematurity and LBW.</td>
<td>Outreach</td>
<td>Universal</td>
<td>Prematurity</td>
</tr>
<tr>
<td></td>
<td>IPT for malaria</td>
<td>Giving a curative treatment dose of an effective antimalarial drug at predefined intervals during pregnancy prevents up to one-third of neonatal mortality and one-quarter of perinatal deaths and reduces LBW by nearly half (among first and second pregnancies). Effectiveness estimates suggest that 10–20% of neonatal deaths due to serious infections may be averted.</td>
<td>Outreach</td>
<td>Situational</td>
<td>Infection</td>
</tr>
<tr>
<td></td>
<td>Detection and treatment of bacteriuria</td>
<td>Urinalysis during antenatal visits followed by antibiotic treatment for positive diagnoses averts 40% of cases of prematurity and LBW and 5–14% of deaths due to complications of prematurity.</td>
<td>Outreach</td>
<td>Additional</td>
<td>Prematurity</td>
</tr>
<tr>
<td>Intrapartum</td>
<td>Antibiotics for PPROM</td>
<td>Antibiotics (e.g. erythromycin) combat subclinical maternal infections and reduce serious neonatal infections by one-third, and neonatal deaths due to serious infections by 3–9%.</td>
<td>Clinical care</td>
<td>Additional</td>
<td>Infection</td>
</tr>
<tr>
<td></td>
<td>Corticosteroids for preterm labour</td>
<td>Maternal corticosteroids (e.g. betamethasone) injections during premature labour hasten development of foetal lungs and avert one-quarter to one-half of deaths due to complications of prematurity. Effectiveness estimates suggest that corticosteroids may avert 20–40% of deaths due to prematurity.</td>
<td>Clinical care</td>
<td>Additional</td>
<td>Prematurity</td>
</tr>
<tr>
<td></td>
<td>Detection and management of breech, multiple pregnancy</td>
<td>Caesarian section averts up to three-quarters of peri/neonatal deaths among breech births.</td>
<td>Clinical care</td>
<td>Universal</td>
<td>Asphyxia</td>
</tr>
</tbody>
</table>
Labour surveillance (including partograph)
for early diagnosis of complications

- Monitoring labour, particularly with the use of a simple chart (partograph) to indicate when intervention is needed, followed by appropriate care, averts up to 40% of perinatal deaths.

Clean childbirth practices

- At childbirth, clean hands, a clean birthing surface, nothing unclean in the vagina, a clean cord-cutting implement, and proper cord care prevent 10–20% of neonatal deaths due to serious infections and reduce deaths due to neonatal tetanus by approximately three-quarters.

Clinical care Universal Asphyxia

Postnatal

Newborn resuscitation

- Resuscitating asphyxiated newborns using mouth-to-mouth, bag-and-mask, or tube-and-mask ventilation with positive pressure averts between one-quarter and one-half of neonatal deaths due to birth asphyxia.

Clinical care Universal Asphyxia

Breastfeeding

- Immediate (within 1 hour after birth) and exclusive (no prelacteal feeds or other fluids/food) breastfeeding averts nearly 10% of all neonatal deaths.

Family/community care Universal Infection

Prevention and management of hypothermia

- Maintenance of room warmth, immediate drying and wrapping, prompt recognition of hypothermia, and re-warming of hypothermic infants averts up to 40% of neonatal deaths.

Family/community care Universal Infection

Kangaroo mother care (LBW infants in health facilities)

- Skin-to-skin contact between mothers and newborns, particularly LBW and/or preterm newborns, maintains warmth, encourages nursing, discourages over-handling, and enhances maternal recognition of newborn problems, reducing infection rate by about half.

Family/community care Universal Infection in preterm/LBW infants

Community-based pneumonia case management

- Administration of antibiotics to children with pneumonia by community health workers reduces overall neonatal mortality by an estimated 20–25%, and averts neonatal deaths due to serious infections by 20–55%.

Family/community care Universal Infection

Postnatal

*See also Table 1 in Reference 4.

IPT = intermittent presumptive treatment (of malaria); LBW = low birth weight; PPROM = preterm premature rupture of membranes; TT = tetanus toxoid.
ANC = antenatal care; IPT = intermittent presumptive treatment (of malaria); LBW = low birth weight; PPROM = preterm premature rupture of membranes.

100 deaths first by 20% (leaving 80) and then those remaining by 10%, we again end up with 72 deaths.

We purposefully have not shown data on impact by individual intervention by country. This modelling exercise, while generating such figures for use in deriving summary global and regional estimates for intervention impact, is meant to be illustrative and serve to facilitate the formulation of policy and programme guidelines, while avoiding either comparisons among countries or a ‘one size fits all’ approach.

Cost estimation

Running costs, or the value of the resources used when the services are up and running at an expanded level of coverage of interventions over and above costs for current levels of coverage, were estimated using a spreadsheet approach as described previously (Bryce et al. 2005; Darmstadt et al. 2005c). Details regarding costing assumptions and data used in calculations are summarized in Web Table 1. Costs included commodities (medicines, equipment, supplies), in-service training, salaries and supervision of the health care providers, and depreciation and maintenance costs of health care facilities, amortized over 30–50 years. The costs for an intervention were calculated by: adding a unit cost for the service provision (either facility- or community-based) plus the costs for the drugs or equipment required for the intervention times the estimated number of interventions in the country. In addition, for some interventions, hospital and/or operating costs were added. We estimate only the costs to providers of delivering these interventions, and have not included other economic costs borne by the family. We did not include the costs for expanding infrastructure related to these interventions, given the lack of country-specific information required to make

Table 3 Description of intervention packages

<table>
<thead>
<tr>
<th>Package</th>
<th>Description of package components</th>
</tr>
</thead>
<tbody>
<tr>
<td>ANC I</td>
<td>Medical history and physical examination, including assessment of blood pressure, weight gain and fundal height; screening for anaemia, proteinuria, pre-eclampsia and other pregnancy complications</td>
</tr>
<tr>
<td>ANC II</td>
<td>TT immunization</td>
</tr>
<tr>
<td>ANC III</td>
<td>Syphilis screening and treatment</td>
</tr>
<tr>
<td>All ANC</td>
<td>Combines ANC I, II, III; IPT; PLUS Detection and treatment of bacteriuria</td>
</tr>
<tr>
<td>Family package I</td>
<td>Promotion of birth preparedness, emergency readiness, care-seeking for obstetric and newborn complications, and demand for quality clinical care; counselling and preparation for newborn care; community mobilization and engagement; promotion of thermal care, clean cord care, and early and exclusive breastfeeding</td>
</tr>
<tr>
<td>Family package II (Clean home childbirth and clean cord care)</td>
<td>Promotion and practice of clean childbirth and immediate cord care for home births</td>
</tr>
<tr>
<td>Skilled maternal and immediate neonatal care</td>
<td>Skilled attendant at birth; labour surveillance; encouragement of supportive companion; assistance to birth (including vacuum extraction); early detection, clinical management and referral of maternal or foetal complications to first-level emergency obstetric care; resuscitation of the newborn infant and referral of complications of prematurity and serious infections</td>
</tr>
<tr>
<td>Emergency obstetric care</td>
<td>Detection and management of complications such as obstructed labour, breech, haemorrhage, pre-eclampsia/eclampsia, puerperal sepsis and preterm labour using instrumental childbirth, Caesarian section, blood transfusion, magnesium sulfate/nifedipine, antibiotics</td>
</tr>
<tr>
<td>All childbirth/intrapartum care</td>
<td>Combines Family package II; Skilled maternal and immediate neonatal care PLUS Antibiotics for PPROM; Emergency obstetric care PLUS Corticosteroids for preterm labour</td>
</tr>
<tr>
<td>Community-based care of LBW infants</td>
<td>Extra home visits; support for breastfeeding, thermal care, and hygienic cord care; early recognition and care-seeking for illness</td>
</tr>
<tr>
<td>Family and community care</td>
<td>Combines Family package I, II; Community-based care of LBW infants; Community-based pneumonia case management</td>
</tr>
<tr>
<td>Emergency neonatal care</td>
<td>Facility-based care for ill newborns, especially sepsis management, birth asphyxia, and complications of prematurity</td>
</tr>
<tr>
<td>Postnatal family and community care</td>
<td>Combines Family package I; Community-based care of LBW infants; Community-based pneumonia case management</td>
</tr>
<tr>
<td>All postnatal care</td>
<td>Combines Family package I; Community-based care of LBW infants; Community-based pneumonia case management; Emergency neonatal care</td>
</tr>
<tr>
<td>All universal/situational interventions</td>
<td>Combines ANC I, II, III; IPT; Skilled maternal and immediate neonatal care; Family package I, II; Community-based care of LBW infants; Community-based pneumonia case management; Emergency obstetric care; Corticosteroids for preterm labour; Emergency neonatal care</td>
</tr>
<tr>
<td>All interventions</td>
<td>Combines ANC I, II, III; IPT; Periconceptual folic acid supplementation; Detection and treatment of asymptomatic bacteriuria; Skilled maternal and immediate neonatal care; Antibiotics for PPROM; Family package I, II; Community-based care of LBW infants; Community-based pneumonia case management; Emergency obstetric care; Corticosteroids for preterm labour; Emergency neonatal care</td>
</tr>
</tbody>
</table>

aSee also Table 2 in Reference 4.

PLUS denotes an intervention that would be considered as health systems capacity develops.
these estimates. There was no discounting as costs are an estimate of the current costs to provide 90% coverage of the critical interventions in 2006, if the infrastructure were available.

To obtain costs for a given intervention or package of interventions, we derived and summed costs for each component of each intervention in each country pertinent to the analysis. Interventions that were packaged together and delivered at the same time period or in a single visit to a clinic or by a health worker shared the cost of the clinic or health worker visit. We calculated the increase from current to target coverage, which enabled calculation of expanded or running costs, or new investments needed to support the incremental increase in coverage. We then determined the health service delivery inputs needed to increase the provision of the interventions from current to target levels of coverage, either in domiciliary settings by a family member or community health worker, at a clinic by a health care provider, or in a hospital (including days of hospitalization required). Drug costs were calculated based on the amount of first-line drug that would be used for treatment, and the estimated current price on the UNICEF Supply website (UNICEF 2005b). Similarly, commodity costs were obtained from the UNICEF Supply website and applied to all countries, since the commodities are available in all countries at these costs; we did not take into account local variations in supply or costs. Unit costs for inpatient care and outpatient services were obtained from the WHO CHOICE database (Adam et al. 2003). Unit costs for service provision increased stepwise with level of coverage, from 0–50%, 50–80% and 80–90%, to reflect the increasing unit costs for providing services to those harder-to-reach; the scaling-up factor was derived from WHO CHOICE (Mulligan et al. 2003). Unit costs for community-based care were based on 75% of the hourly costs for a midwife (including 30% additional costs for training and supervision), with data on midwife costs drawn from previous work (World Bank 2004). Costs were calculated using the year 2006 US$ applied to the base populations from the year 2006. Therefore, all costs have to be increased to reflect population growth in order to estimate the actual costs for target levels of service provision based on the year the targets would be reached.

While we have utilized the basic framework and assumptions for interventions as stated in The Lancet Neonatal Survival Series (Darmstadt et al. 2005c) (see Web Tables 1 and 2), the costs of some delivery strategies may differ in certain situations; for example, use of peer counselling versus community support groups for family and community packages. To reflect the uncertainty and variation inherent in the cost estimates, we performed a sensitivity analysis to obtain a range on the estimates for additional costs by varying the three primary assumptions driving cost estimates: (1) the costs of services provided, (2) the costs of drugs and equipment, and (3) the current level of coverage of these services. We set the costs of service provision and costs of drugs and equipment at 25% less than currently calculated to generate the lower bound in costs. In addition, we assumed that current coverage would be 25% higher (yielding a smaller population in need). Similarly, for the upper bound, we assumed 25% higher costs for services, drugs and equipment, and 25% lower (or 0, whichever is higher) current coverage levels. These ranges do not represent a statistical confidence interval around the estimated additional costs, but represent a sensitivity analysis of the effect of the key assumptions driving the cost estimates.

The range of cost was utilized to calculate cost per capita. Cost per death averted was calculated using ranges for both cost and impact, a sensitivity analysis which resulted in the widest possible uncertainty. Thus, the lower end for the range was calculated as the higher bound for the cost estimate divided by the low estimate for impact. Similarly, the upper end of the range was calculated as the lower bound for cost divided by the high estimate for impact.

**Phased introduction and expansion of interventions**

To derive estimates of incremental impact and health systems costs during programme expansion, we created scenarios wherein interventions were packaged by time period and service delivery mode of implementation to optimize feasibility and model programme approaches to implementation (Figure 1), with interventions introduced within existing maternal and child health packages and coverage increased in phases to simulate developing health systems. Prior cost-effectiveness analyses guided this approach, including an Expansion Path (Evans et al. 2005) showing the order in which interventions would be purchased at given levels of resource availability, if cost-effectiveness was the only consideration (Adam et al. 2005; Darmstadt et al. 2005c). The scenarios are purely illustrative and not prescriptive for any particular country or region; a phased programme would require tailoring to the local epidemiological and health system context. Due to anticipated differences in initial programme emphases and time required to achieve full coverage, we modelled different phasing scenarios for 15 very high NMR (>45) and 36 high NMR (30–45) countries (Figure 1). Costs were then summed for these 51 countries for each phase in scale-up. The total number of annual deaths in these 51 countries is 2.88 million, approximately three-quarters of the global burden of neonatal mortality (Lawn et al. 2005a).

In creating the phased approach to scaling up intervention coverage, we used several guiding principles: (1) initial emphasis, particularly in very high mortality countries, was placed on expanding outreach coverage [particularly tetanus toxoid (TT) immunization against high tetanus incidence in settings with poor outreach services] and family-community care; (2) clinical care was simultaneously strengthened in an integrated, graduated fashion; (3) integrated programmes for mothers and newborns were developed across service delivery modes; and (4) additional interventions were phased in as health systems capacity developed, achieving full coverage earlier in high compared with very high mortality countries. Thus, for example, in very high mortality countries, expansion in coverage of skilled maternal and immediate newborn care was assumed to begin with phase 2, following an initial phase emphasizing expansion in coverage of family-community and outreach services, and some strengthening of facility-based emergency obstetric and neonatal care. In high mortality countries, however, expansion of skilled maternal and immediate newborn care was assumed to start immediately by building on existing health systems capacity.
Figure 1 Scenario illustrating phased implementation of interventions\textsuperscript{a} in very high mortality (NMR >45)\textsuperscript{b} and high mortality (NMR 30–45)\textsuperscript{c} settings.

\textsuperscript{a}See Table 3 for descriptions of intervention packages. \textsuperscript{b}Very high mortality (NMR >45) countries (n = 15) included: Afghanistan, Angola, Central African Republic, Côte d’Ivoire, Democratic Republic of the Congo, Gambia, Guinea, Guinea-Bissau, Iraq, Liberia, Mali, Nigeria, Pakistan, Sierra Leone, Somalia. \textsuperscript{c}High mortality (NMR 30–45) countries (n = 36) included: Azerbaijan, Bangladesh, Benin, Botswana, Burkina Faso, Burundi, Cambodia, Chad, Congo, Djibouti, Equatorial Guinea, Ethiopia, Gabon, Ghana, Haiti, India, Kenya, Madagascar, Malawi, Mauritania, Mozambique, Myanmar, Nepal, Niger, Papua New Guinea, Rwanda, Senegal, Swaziland, Tajikistan, Tanzania, Togo, Turkmenistan, Uganda, Yemen, Zambia, Zimbabwe. ANC = antenatal care; IPT = intermittent presumptive treatment (of malaria); LBW = low birth weight; PPROM = preterm premature rupture of membranes.
To facilitate country planning and in hopes of stimulating investments in neonatal health, we disaggregated the costs and impact for delivering interventions at high coverage. This was done for regions and for smaller packages of care by time period and by service delivery mode. This information is needed when planning to add certain interventions for newborns to existing maternal and child health programmes, or when starting new programmes with limited resources. We then synthesized and applied the lessons from this analysis in a set of scenarios illustrative of a phased, incremental approach to scaling-up programmes in a health systems context in countries.

### Regional impact and cost

We first calculated the cost and the potential of interventions to save newborn lives on a regional basis. The greatest number of births and of newborn deaths is in Asia and hence most lives would be saved there (0.75–1.47 million annually). Approximately three-quarters of the deaths averted (0.59–1.08 million) would be in four countries of the South Asia sub-region (Table 4). An estimated 0.48–0.86 million newborn lives could be saved annually in Africa, 93% of these (0.45–0.80 million) in the sub-Saharan sub-region. Eighty per cent of the lives saved in sub-Saharan Africa would be realized in 10 countries (Nigeria, Ethiopia, Democratic Republic of Congo, Tanzania, Uganda, Côte D’Ivoire, Mozambique, Angola, Mali and Kenya). The proportion of lives saved is similar for the South Asia (38–70%) and sub-Saharan Africa (38–67%) sub-regions. The total additional cost is higher in South Asia (US$0.90–1.76 versus US$0.68–1.32 billion) but the per capita cost in South Asia may be lower (US$0.59–1.15 versus US$0.95–1.86 billion) as the cost is spread over a larger population (Table 1). Beyond these two regions, the large populations and high numbers of newborn deaths in China and Indonesia in the East Asia and Pacific region warrant concerted programme action, as do several other countries outside these sub-regions.

### Intervention packages

Next, we modelled the impact and cost of interventions individually (Table 2) and packaged (Table 3) according to time period of implementation and linking with existing maternal and child health packages (Table 5), an important factor in programme feasibility.

### Antenatal

Interventions delivered to mothers during the antenatal period have limited additional potential to save newborn lives (Table 5). Intermittent presumptive treatment (IPT) for malaria would make little difference in South Asia, due to the low burden of malaria-related newborn deaths there. In sub-Saharan Africa, only an estimated 2–5% of neonatal deaths would be averted, at an additional cost of US$0.03–0.05 billion. IPT has benefits, however, which extend well beyond the neonatal period (Jones et al. 2003) and also extend to the mother (Shulman et al. 1999; Mbaye et al. 2006). An estimated 4–7% of neonatal deaths could be averted in 60 countries if routine antenatal care (ANC)—including routine antenatal visits and examinations (as recommended by WHO, Villar et al. 2001), TT immunization, screening and treatment of syphilis in endemic areas, and IPT—was implemented at high (90%) coverage. Even if testing and treatment for bacteriuria was added to the ANC package, which requires a relatively well-developed health system, only 5–10% of neonatal deaths could be averted. All antenatal interventions would have greater impact in sub-Saharan Africa than in South Asia (7–14% versus 4–9% of deaths averted), despite the higher current levels of ANC attendance in Africa compared with Asia (AbouZahr and Wardlaw 2004), because conditions addressed by antenatal interventions, such as malaria, neonatal tetanus and syphilis, are more prevalent in Africa.
Table 5 Annual expanded running costs and neonatal deaths averted resulting from increased implementation of interventions\(^a,b\) from current to 90% coverage

<table>
<thead>
<tr>
<th>Intervention/package</th>
<th>Expanded costs (US$ billion)</th>
<th>Deaths averted (%)</th>
<th>Expanded costs (US$ billion)</th>
<th>Deaths averted (%)</th>
<th>Expanded costs (US$ billion)</th>
<th>Deaths averted (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Antenatal care</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IPT</td>
<td>0.03–0.05</td>
<td>0.8–1.5</td>
<td>0.02–0.05</td>
<td>2–5</td>
<td>0.0002–0.0004</td>
<td>0–&lt;0.1</td>
</tr>
<tr>
<td>ANC I, II, III, &amp; IPT</td>
<td>0.21–0.42</td>
<td>4–7</td>
<td>0.08–0.17</td>
<td>7–12</td>
<td>0.08–0.16</td>
<td>3–5</td>
</tr>
<tr>
<td>All ANC (ANC I, II, III; IPT, PLUS(^c) Detection and treatment of bacteriuria)</td>
<td>0.23–0.45</td>
<td>5–10</td>
<td>0.09–0.17</td>
<td>7–14</td>
<td>0.09–0.17</td>
<td>4–9</td>
</tr>
<tr>
<td><strong>Childbirth/intrapartum care</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clean childbirth (home and facility, infection prevention only)</td>
<td>0.06–0.11</td>
<td>5–8</td>
<td>0.02–0.04</td>
<td>6–9</td>
<td>0.02–0.04</td>
<td>6–9</td>
</tr>
<tr>
<td>Skilled maternal and immediate neonatal care</td>
<td>0.46–0.90</td>
<td>11–17</td>
<td>0.14–0.28</td>
<td>12–18</td>
<td>0.19–0.37</td>
<td>11–18</td>
</tr>
<tr>
<td>Skilled maternal and immediate neonatal care PLUS Antibiotics for PPROM</td>
<td>0.47–0.92</td>
<td>11–18</td>
<td>0.15–0.29</td>
<td>12–20</td>
<td>0.19–0.38</td>
<td>12–19</td>
</tr>
<tr>
<td>Emergency obstetric care</td>
<td>0.63–1.24</td>
<td>3–11</td>
<td>0.15–0.30</td>
<td>4–11</td>
<td>0.24–0.47</td>
<td>4–11</td>
</tr>
<tr>
<td>Emergency obstetric care PLUS Corticosteroids for preterm labour</td>
<td>0.86–1.67</td>
<td>8–21</td>
<td>0.21–0.42</td>
<td>8–20</td>
<td>0.31–0.60</td>
<td>9–22</td>
</tr>
<tr>
<td>Childbirth/intrapartum care (Skilled maternal and neonatal care + Emergency obstetric care + Family package II)</td>
<td>1.44–2.81</td>
<td>13–24</td>
<td>0.35–0.69</td>
<td>14–25</td>
<td>0.49–0.96</td>
<td>14–24</td>
</tr>
<tr>
<td>All childbirth/intrapartum care</td>
<td>1.66–3.25</td>
<td>19–34</td>
<td>0.42–0.82</td>
<td>19–34</td>
<td>0.56–1.09</td>
<td>20–36</td>
</tr>
<tr>
<td><strong>Postnatal care</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Family package I</td>
<td>0.30–0.59</td>
<td>2–8</td>
<td>0.06–0.11</td>
<td>3–9</td>
<td>0.05–0.11</td>
<td>2–8</td>
</tr>
<tr>
<td>Family package I + Community-based care of LBW infants</td>
<td>0.36–0.71</td>
<td>6–19</td>
<td>0.07–0.13</td>
<td>5–18</td>
<td>0.08–0.15</td>
<td>7–21</td>
</tr>
<tr>
<td>Community-based pneumonia case management</td>
<td>0.02–0.03</td>
<td>4–12</td>
<td>0.003–0.005</td>
<td>5–13</td>
<td>0.003–0.005</td>
<td>4–12</td>
</tr>
<tr>
<td>Postnatal family and community care (Family package I + Community-based care of LBW infants + Community-based pneumonia case management)</td>
<td>0.38–0.75</td>
<td>10–27</td>
<td>0.07–0.14</td>
<td>10–27</td>
<td>0.08–0.15</td>
<td>10–29</td>
</tr>
<tr>
<td>Emergency neonatal care (health facilities)</td>
<td>0.29–0.57</td>
<td>9–24</td>
<td>0.07–0.14</td>
<td>8–23</td>
<td>0.13–0.26</td>
<td>10–26</td>
</tr>
<tr>
<td>All postnatal care</td>
<td>0.67–1.31</td>
<td>17–39</td>
<td>0.14–0.27</td>
<td>16–38</td>
<td>0.21–0.41</td>
<td>18–42</td>
</tr>
<tr>
<td><strong>Continuum of care (care across &gt;1 time period)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Family package I &amp; II</td>
<td>0.64–1.26</td>
<td>7–14</td>
<td>0.11–0.22</td>
<td>7–15</td>
<td>0.12–0.23</td>
<td>7–14</td>
</tr>
<tr>
<td>Family package I &amp; II + Community-based care of LBW infants</td>
<td>0.70–1.38</td>
<td>10–24</td>
<td>0.12–0.24</td>
<td>10–24</td>
<td>0.14–0.27</td>
<td>11–27</td>
</tr>
<tr>
<td>Family and community care (Family package I &amp; II + Community-based care of LBW infants + Community-based pneumonia case management)</td>
<td>0.72–1.41</td>
<td>14–32</td>
<td>0.12–0.24</td>
<td>14–32</td>
<td>0.14–0.27</td>
<td>14–34</td>
</tr>
<tr>
<td>All antenatal/outreach care + family and community care</td>
<td>0.82–1.61</td>
<td>17–37</td>
<td>0.15–0.30</td>
<td>20–39</td>
<td>0.18–0.35</td>
<td>18–40</td>
</tr>
<tr>
<td>Emergency services for mothers and newborns (Emergency obstetric care + Emergency neonatal care)</td>
<td>0.93–1.82</td>
<td>12–34</td>
<td>0.22–0.43</td>
<td>12–34</td>
<td>0.37–0.73</td>
<td>13–37</td>
</tr>
<tr>
<td>Skilled clinical care in facilities (Skilled maternal and immediate neonatal care + Emergency obstetric care + Emergency neonatal care)</td>
<td>1.39–2.71</td>
<td>21–44</td>
<td>0.37–0.71</td>
<td>22–45</td>
<td>0.56–1.10</td>
<td>23–47</td>
</tr>
<tr>
<td>All universal/situational</td>
<td>2.32–4.55</td>
<td>31–60</td>
<td>0.57–1.12</td>
<td>34–62</td>
<td>0.78–1.53</td>
<td>33–63</td>
</tr>
<tr>
<td>All</td>
<td>2.68–5.24</td>
<td>36–66</td>
<td>0.68–1.32</td>
<td>38–67</td>
<td>0.90–1.76</td>
<td>38–70</td>
</tr>
</tbody>
</table>

\(^a\)See Table 2 for description of individual interventions.

\(^b\)See Table 3 for description of intervention packages.

\(^c\)PLUS denotes an intervention that would be considered as health systems capacity develops.

ANC = antenatal care; IPT = intermittent presumptive treatment (of malaria); LBW = low birth weight; PPROM = preterm premature rupture of membranes.
Overall, the additional cost for all antenatal interventions (US$0.23–0.45 billion) is 8% of the total needed to deliver all 16 interventions (US$2.68–5.24 billion).

Childbirth/intrapartum
Achieving high coverage of clean childbirth care practices during home and facility-based births would avert an estimated 5–8% of deaths in 60 countries (Table 5) at a cost of US$0.06–0.11 billion, assuming that clean childbirth kits are used during home births. Comprehensive skilled care at birth, including facilitated referrals for emergency obstetric and neonatal care, could avert 13–24% of deaths. Focusing solely on emergency obstetric care would have relatively low impact (3–11%) on newborn deaths, although maternal deaths would be reduced. However, the additional cost is high (US$0.63–1.24 billion). Adding corticosteroids for preterm labour to the emergency obstetric care package increases the impact (8–21%), but is usually feasible only in referral hospitals, and even in industrialized countries is often poorly implemented. High coverage of all intrapartum interventions, including clean home childbirth, skilled maternal and immediate neonatal care, emergency obstetric care, and additional interventions could avert up to one-third of neonatal deaths (19–34%), but at relatively high cost (US$1.66–3.25 billion), representing 62% of the additional funds needed for all interventions in 60 countries. Skilled intrapartum care becomes less costly, however, when bundled with emergency postnatal care for newborns, since the same health facilities can care for both mothers and newborns.

Postnatal
In settings with high NMRs, limited resources and poor health systems, initial emphasis on family and community-based interventions can avert a substantial proportion of neonatal deaths at relatively low cost (Darmstadt et al. 2005c; Knippenberg et al. 2005). Promotion of immediate and exclusive breastfeeding, keeping the baby warm, and clean cord care for all newborns (i.e. family package 1, see Table 3), with special attention to feeding and hygiene for low birth weight (LBW) infants (i.e. community-based care of LBW infants), can avert 6–19% of deaths in 60 countries at a cost of US$0.36–0.71 billion (Table 5). Adding pneumonia case management by community-based health workers boosts the impact to 10–27% at little additional cost, since the same health workers who promote healthy home practices can be trained and equipped to detect and manage pneumonia (Bang et al. 2005). Implementation of all postnatal interventions, including facility-based emergency neonatal care, could avert 17–39% of deaths. This is slightly higher than the impact of intrapartum interventions, but similarly short of the goals of Millennium Development Goal (MDG) 4.

Delivering all postnatal care interventions globally would cost US$0.67–1.31 billion, 40% of the cost of all intrapartum interventions, and 25% of the total price tag for all antenatal, intrapartum and postnatal interventions.

Packaging of interventions by service delivery mode to achieve a continuum of care
Integrating care across a continuum of time periods and service delivery modes maximizes benefits and minimizes the costs for mothers, newborns and children (Table 5). Combining family and community care across time periods (i.e. family packages 1 and 2, community-based care of LBW infants, community-based pneumonia case management) could avert 14–32% of neonatal deaths in 60 countries, at a cost of US$0.72–1.41 billion. Combining all outreaches (antenatal interventions) and family and community care interventions could avert 17–37% of deaths for US$0.82–1.61 billion. Emergency care for newborns in-hospital could avert 9–24% of deaths at a relatively low expanded cost of US$0.29–0.57 billion. By bundling emergency obstetric care with emergency neonatal care, 12–34% of deaths could be averted for US$0.93–1.82 billion.

Reductions in neonatal deaths of 50% and upwards are required if MDG-4 for child survival is to be realized (de Zoyza et al. 1998; Bryce et al. 2003; Darmstadt et al. 2005c; Freedman et al. 2005; Lawn et al. 2005a; Paul 2006). An integrated and equitable approach that simultaneously strengthens outreach and family-community care, while creating demand for and providing clinical services, is required (Knippenberg et al. 2005). Such an approach combining all but additional interventions across all time periods and service delivery modes could avert 31–60% of neonatal deaths. Incorporating the additional interventions as health systems capacity improves could increase impact to 36–66%.

Phased introduction and expansion of interventions
Packaging interventions across time periods and service delivery modes increases cost effectiveness (Knippenberg et al. 2005). However, countries require information on the cost and impact of programmes that introduce various intervention packages at different points in programme maturity and are scaled up incrementally. For this analysis, we focused on the highest mortality countries, largely in Asia and sub-Saharan Africa, resulting in higher estimates of impact at lower cost than might be found in lower mortality settings.

We estimated that an initial phase (i.e. Phase 1 for both high and very high mortality countries, Figure 1) of implementing interventions packaged across various time periods (i.e. antenatal, intrapartum, postnatal) and service delivery modes at incrementally increased coverage would avert an estimated 14–31% of deaths at an estimated cost of US$0.65–1.27 billion per year in the 51 very high (NMR >45) and high (NMR 30–45) mortality countries combined (Figure 2). Considering very high and high mortality countries separately, Phase 1 would cost US$0.09–0.17 billion per year and avert 13–29% of deaths in the 15 very high mortality countries, and would cost US$0.56–1.10 billion per year and avert 15–32% of deaths in 36 high mortality countries. In very high mortality countries alone in Phase 1, outreach and family-community care combined would cost US$0.04–0.07 billion per year (Figure 3). By the end of Phase 2, 23–47% of deaths in both high and very high mortality countries could be averted at a total cost of US$1.28–2.51 billion.

Figure 3 shows the relatively greater cost in the early phases of programme development for outreach and family-community care, and the relatively higher investment in clinical care services in later phases, as health system capacity expands. The lower incremental impact during Phase 2 (an additional 9–16%
of deaths averted) compared with Phase 1 reflects the fact that high coverage of outreach interventions is reached in Phase 1 in a number of countries. By the end of Phase 4, for an additional cost of US$2.23–4.37 billion, all interventions would be delivered at 90% coverage and could avert a total of 38–68% of neonatal deaths, or a total of 1.13–2.05 million lives each year. The extra cost per life saved when interventions are at full coverage in high and very high mortality countries is US$1100–3900, at US$0.86–1.68 per capita. In very high mortality countries, saving 0.40–0.70 million lives would cost an additional US$0.49–0.96 billion, or US$700–2400 per death averted, at US$0.98–1.92 per capita. In high mortality countries, saving 0.73–1.35 million lives would cost an additional US$1.74–3.41 billion, or US$1300–4700 per death averted, at US$0.83–1.62 per capita.

Discussion and conclusions

Several principles for scaling up programmes to avert neonatal deaths emerge from this analysis (Box 1). Consideration of the geographic distribution of neonatal deaths (Lawn et al. 2005a) and regional analysis of the number of preventable deaths confirms that South Asia and sub-Saharan Africa have the greatest need. Both regions face unique challenges that demand locally adapted solutions. While the absolute burden of deaths averted tends to be slightly higher in Asia than in Africa, neonatal mortality rates, which more closely reflect inequity than total burden, tend to be higher in Africa.

Our data suggest that expanded coverage of antenatal interventions may have limited additional potential to save newborn lives. Two factors explain this finding: (1) current ANC coverage levels are high relative to many other interventions, and thus the incremental increase in reaching 90% coverage is small, and (2) antenatal interventions are less effective at preventing neonatal deaths than many intrapartum and postnatal interventions (Darmstadt et al. 2005b). Nevertheless, ANC remains a foundation for health education and birth and child-rearing preparedness, and is a critical point of contact between health services and the community, encouraging care-seeking and fostering a continuum of care (Tinker et al. 2005). If women come for ANC and receive high quality services, they may be encouraged to deliver in a facility, bring a sick neonate to a facility for care, or seek immunizations (Kwast 1998). Our previous cost-effectiveness analyses for sub-Saharan African regions (Adam et al. 2005; Darmstadt et al. 2005c) suggested that ANC interventions are highly cost-effective (Adam et al. 2005; Darmstadt et al. 2005c; Hogan et al. 2005).

Clean childbirth practices to prevent tetanus and other serious neonatal infections, such as sepsis arising from umbilical cord infections, could have substantial impact. Hygienic cord care along with high TT coverage as a routine part of ANC is thus a high priority, particularly in very high mortality settings where neonatal tetanus remains a problem (Lawn et al. 2005a). For clean childbirth kits (Tsu 2000; Crook 2002; Beun and Wood 2003; Winani et al. 2005) to be effective they must be introduced as part of a behaviour change programme that increases users’ awareness, understanding and use of clean childbirth techniques in the context of other improved essential newborn care practices, such as hygiene practices (e.g. hand-washing) (Beun and Wood 2003; Winani et al. 2005). Thus, our figure for the cost of clean childbirth is an underestimate, as we did not consider the cost of social marketing and behaviour change.

Universal access to skilled care at birth is fundamental to reducing maternal mortality, and is also important and cost-effective in reducing neonatal deaths (Adam et al. 2005; Darmstadt et al. 2005c). Major challenges exist, however, in training, placing and supervising skilled birth attendants, particularly in the underserved, very high mortality areas where they are needed most (Piper 1997). For skilled birth attendants to be optimally effective, they must be linked to a
health facility that provides emergency obstetric and neonatal care to manage complications. Thus, major investments in health systems are required and these costs are not captured by this current work. Postnatal interventions, including breastfeeding, thermal care, hygiene, promoted through behaviour change communications, community-based care of LBW infants and case management for pneumonia can all be provided by the same worker through a family-community service delivery mode, contributing to the relatively low cost (US$0.38–0.75 billion) of integrated postnatal family and community care. Despite the fact that postnatal interventions are overall more cost-effective than antenatal or intrapartum interventions (Adam et al. 2005; Darmstadt et al. 2005c), postnatal care remains one of the most neglected aspects of health care in developing countries (Seims 2004). Further integration of family and community care with facility-based emergency newborn care as well as emergency maternal care is essential to meet the community demand to provide for the care of sick newborns and mothers created through effective family-community-based interventions (Darmstadt et al. 2005a).

**Continuum of care**

The strategy advanced by The Lancet Neonatal Survival Series (Darmstadt et al. 2005c; Knippenberg et al. 2005; Martines et al. 2005; Paul 2006), and voiced by others too (Costello et al. 2004; Freedman et al. 2005; WHO 2005), for averting neonatal deaths, calls for an integrated and equitable system of outreach, family-community and facility-based clinical care. Emergency obstetric services must be available to substantially reduce maternal mortality (Koblinsky et al. 1999; Paxton et al. 2005; Rosenfield and Schwartz 2005), whereas effective community-based care is recognized as a key to child survival (Bryce et al. 2003; Victora et al. 2003; Costello et al. 2004). Thus, neonatal health serves as a bridge between

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**Box 1 Prioritizing, phasing and pricing intervention packages**

**Priority regions**

- South Asia and sub-Saharan Africa have the most newborn deaths, the highest rates of deaths and the biggest numbers of preventable deaths.

**Packages along the continuum of care**

- **Antenatal care**: The impact of expanding coverage of antenatal care appears to be limited, particularly in South Asia. Cost of antenatal care is relatively low and thus cost-effectiveness is high.
- **Skilled intrapartum care**, including skilled attendance and emergency obstetric and neonatal care, is an essential long-term goal for any programme for women and children, although the investment required is relatively high.
- **Postnatal family-community care** is highly cost-effective, yet neglected.

**Packages according to service delivery mode**

- Strengthening family-community care is an important initial step in averting neonatal deaths.
- Simultaneous investment is needed in the development of integrated, skilled facility-based childbirth and postnatal care for mothers and newborns.
- Outreach services provide an important linkage between families and communities and the health system, and a platform for the delivery of other essential interventions.

**The price**

- The price tag in 60 countries for scaling up interventions to high coverage (90%) to avert up to two-thirds of neonatal deaths is an estimated US$2.68–5.24 billion in additional running costs.
- The extra cost per death averted when full coverage of interventions is reached in high and very high mortality countries is an estimated US$1100–3900.

**Phasing of the cost**

- An initial phase of implementing interventions packaged across various time periods and service delivery modes at increased incremental coverage would cost an estimated US$0.90–0.17 billion and avert 13–29% of deaths in 15 very high mortality (NMR >45) countries, and would cost an estimated US$0.56–1.10 billion and avert 15–32% of deaths in 36 high mortality (NMR 30–45) countries.

**Priority gaps**

- A major obstacle to programme success is the nearly complete lack of information on the cost, effectiveness and process of scaling up interventions in a health systems context.
- Emphasis must be placed on obtaining data from developing country health systems on the actual costs and impact of programmes.
- A consensus country planning tool is needed to guide selection of interventions, resource allocation and phasing.
maternal and child care, and development of health systems approaches to neonatal health that link community and facility-based care will also strengthen health services for mothers and older children. Two-thirds of the per capita cost to implement the 16 interventions considered here will also benefit mothers and older children (Martines et al. 2005). Further integration of maternal, neonatal and child health care, as advanced by the newly formed Partnership for Maternal, Neonatal and Child Health (PMNCH 2005), as well as reproductive health, including optimal birth spacing (Rutstein 2002), will further improve programme cost-effectiveness due to utilization of common health workers and health systems whenever possible to deliver the interventions (Bryce et al. 2005; Darmstadt et al. 2005c; Lawn et al. 2005a; Martines et al. 2005; Morris et al. 2005). Work is underway to determine the combined cost of averting deaths across the maternal–neonatal–under-five continuum of care, which will further demonstrate the gains possible through integrating care.

Scaling-up
We modelled programme scale-up in phases to include more interventions and higher coverage as health systems capacity grows. This analysis suggests that the proportion of deaths that can be averted is similar in very high and high mortality countries. In the phased approach that we propose, initial investments are focused on developing outreach and community care, with greater emphasis on expanding clinical care coming later, although investments in health systems development are needed from the outset.

The programme expansion phases that we used in modelling impact and cost in health systems in very high and high mortality countries may be useful as a general guide to programme expansion, but are not meant to be prescriptive. Selection of interventions, their order of introduction and expansion of coverage will need to be decided locally.

The reality of scaling up care to achieve the level of mortality reduction that our modelling suggests is possible is fraught with many challenges and constraints that have not been fully factored into our analyses (Knippenberg et al. 2005). In our exhaustive review of the evidence for impact of interventions on neonatal mortality, we found only 10 studies that took place in a health systems context, and all of these studies tested just a single intervention, not an integrated package, under conditions of efficacy, not effectiveness (Bhutta et al. 2005). Furthermore, in our review of the impact of packages of interventions on neonatal health, we could not identify any data that addressed the issue of effectiveness in a health systems context (Haws et al. 2007). A similar lack of effectiveness data for under-five children has been reported (Bryce et al. 2003; Claeson et al. 2003). Thus, many important questions remain about how to deliver interventions effectively in a health systems context.

We have included estimates of uncertainty around our impact and cost figures based on sensitivity analysis. However, at present there is a near complete lack of information on the process and actual costs and impact (effectiveness) of scaling up interventions in a health systems context. Only two studies have reported cost-effectiveness of a programme of neonatal health interventions implemented at high coverage, albeit in small populations [e.g. 40 000 in rural India (Bang et al. 1999), 180 000 in rural Nepal (Manandhar et al. 2004; Borghi et al. 2005)]. Cost per life saved was derived using widely different methods and reported to be US$595 (Bang et al. 1999) and US$3442 (Manandhar et al. 2004) (US$4397 including costs of health-service strengthening activities), a range which encompasses the estimates derived through our analysis. None of these studies, however, have included the costs for construction of new health facilities or the roads and other infrastructural investments that may be needed to support an expanded health system. A recent analysis based on five sub-Saharan African countries and five Indian states produced a range of US$2800–7800 per newborn life saved for the first 20% increase in coverage from baseline, including extensive infrastructural investments (Lawn et al. 2005b). This is in line with the Nepal findings (Manandhar et al. 2004).

Emphasis must be placed on obtaining data from developing country health systems on the actual costs and impact of programmes, an objective of Countdown to 2015 (Lawn 2005). While this work is underway, in the meantime, we have tried in this analysis figures to guide donors, policy makers and programme managers regarding programme costs and impact that could be anticipated under good programme conditions. We hope these figures will provide impetus for the investments that are needed to realize the MDGs for maternal and child survival. Furthermore, these analyses provide a framework for investing in health systems in a rational, incremental manner that evidence suggests can save millions of lives.

Finally, these analyses are not meant to be used to evaluate the cost-effectiveness of different interventions, either generally or for specific countries. Rather, one purpose was to develop estimates of the costs associated with running these interventions at scale so that they could be compared with other costing exercises at the global level, such as those done for HIV and AIDS and child survival using similar methods (Schwartländer et al. 2001; Stover et al. 2002; Bryce et al. 2005; Stover et al. 2006). This type of broad comparison suggests that efforts to reduce neonatal mortality can be as effective as those proposed for HIV and AIDS, and at lower estimated costs. Moreover, as argued in The Lancet Neonatal Survival Series (Darmstadt et al. 2005c; Martines et al. 2005), investment leading to broad expansion of neonatal health interventions (US$0.59–1.15 in additional costs per capita per year to achieve 90% coverage with proven interventions in South Asia, US$0.95–1.86 in sub-Saharan Africa) is achievable, and an opportunity that countries cannot afford to miss.

Country by country, feasibility and impact will vary based on existing health system resources, the cost of labour and supplies, and unique barriers to intervention implementation (Knippenberg et al. 2005). Calculating the cost of scaling up a package of 16 neonatal and child health interventions, Stenberg et al. (2007) found that the per capita scale-up cost was greatest (US$3.40) in those countries least ready to scale up, compared with those most ready (US$1.00). Readiness to scale up is strongly inversely correlated with mortality; the highest mortality countries are the least ready to scale up. The countries most ready to scale up, despite lower per capita costs, accounted for approximately half of the global price tag,
primarily because this category had many countries with large populations. On average, governments will have to increase their budgets by at least 26% to implement the interventions Stenberg et al. (2007) assessed, but some of the poorest countries will require increases of 74% or more.

In The Lancet Neonatal Survival Series, Knippenberg et al. (2005) considered not only intervention implementation costs per capita but also considerable inputs for health system strengthening activities, and estimated that Ethiopia (a high mortality country) will require additional inputs of US$9.50 per capita per year to implement a package of interventions of benefit to neonatal health because of its weak health system, as opposed to Madagascar (a high mortality country with a more developed health system) which will require only US$5 per capita per year. Still, investments for both countries are significant, reflecting a 3-fold increase in health expenditures for Ethiopia and a 2-fold increase for Madagascar. Very high mortality countries, which will need to increase their budgets by a higher percentage, are unlikely to be able to reallocate within their existing budgets. Countries need guidance on how to proceed most efficiently and effectively toward this goal.

External donor inputs, ideally solicited by countries themselves (Martines et al. 2005), will be required in most countries, despite efforts of some to reallocate existing government budgets to improve health services for maternal, newborn and child health programmes and services (e.g. Tanzania, Armstrong Schellenberg et al. 2004). Stenberg et al. (2007) note the difficulties among the countries with weakest health systems to mobilize the comparatively greater sums needed for scale-up. For countries that need external assistance, international funding must increase. Powell-Jackson et al. (2006) found that influxes of international aid in 2003–2004 for maternal, newborn and child health accounted for just 2% of gross aid disbursements to developing countries, and the 60 priority countries accounting for the majority of child and newborn deaths received just US$3.10 per capita, insufficient to reach MDGs 4 and 5 by our and others’ estimates if health systems strengthening activities are undertaken to support the running costs, as shown here, of recommended intervention packages. Clearly, an increased international commitment to funding maternal, newborn and child health programmes is needed alongside national efforts to prioritize maternal and newborn health.

As countries prepare to scale up interventions that can save newborn lives, several potential tools exist that donors, policymakers and programme managers can use to inform programme planning, intervention selection and resource allocation, including development of estimates of impact and cost of country-specific interventions. These include the modelling approach used here and in the Child Survival and Neonatal Survival series in The Lancet (Bryce et al. 2005; Darmstadt et al. 2005c; Knippenberg et al. 2005), Marginal Budgeting for Bottlenecks (MMB) by the World Bank and UNICEF (Soucat et al. 2002; Knippenberg et al. 2005), CHOICE (Edejer et al. 2003; Evans et al. 2005) and other costing tools by WHO (Stenberg et al. 2007). There is now an urgent need for a consensus planning toolkit to guide local selection and phasing of interventions and cost-effective allocation of resources for maternal, newborn and child health programmes.

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