DISCUSSION PAPER

December 2007 ■ RFF DP 07-53

Cost-effectiveness of Disease Interventions in India

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Abstract

Health improvements in India, while significant, have not kept up with rapid economic growth rates. The poor in India face high out-of-pocket payments for health care, a significant burden of infectious diseases, and a rapidly increasing burden of non-communicable diseases. Against this backdrop, the central government has proposed doubling government expenditures on health over the next few years. Planned increases in public spending will involve making difficult decisions about the most effective and efficient health interventions if they are to translate into improved population health. To inform the selection of interventions that should be included in a universal health package, this study generated and reviewed cost-effectiveness information for interventions that address the major causes of disease burden in India. We find that India has great potential for improving the health of its people at relatively low cost. Devoting just one percent of GDP (approximately US$6 billion) to a well-designed health program nationwide could save as much as 480 million healthy years of life.

Key Words: India, health expenditures, cost-effectiveness, public spending

JEL Classification Numbers: H51, H70, I10, I18

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I. Introduction

India is undergoing an epidemiological and demographic transition made possible in part by sustained economic development, which has boosted incomes and reduced poverty. Over the past half-century, male life expectancy has increased by more than 30 years. In the past decade, infant mortality has decreased by 20 percent nationwide, with some states achieving declines of 40 percent. At the same time, the aging of the population, due to declines in mortality and fertility rates, has caused greater prevalence rates of chronic disease burden, such as cardiovascular diseases, cancer, and tobacco-related illnesses. Yet a high proportion of the population, especially in rural areas, continues to suffer health problems characteristic of persistent poverty: vaccine-preventable diseases, pregnancy and childbirth-related complications, and malnutrition. With its wide disparities in health gains between prosperous and impoverished states, India has seen only modest health improvements compared to neighboring South Asian countries. For example, the infant mortality rate in India was 65 per 1,000 live births in 2002, having declined 42 percent since 1980; it was lower still in Bangladesh, Indonesia, and Nepal, at 48, 32, and 62, respectively, having declined 63 percent, 60 percent, and 50 percent over the same period (World Bank 2004).

India's slower gains can be partly attributed to weak investment in health spending. At about US$20 (in terms of purchasing power parity) per capita, public health spending is among the lowest in the world and significantly lower than would be expected at India's level of per capita GDP (Deolalikar et al. 2007). Consequently, private health spending enters the vacuum left by the low level of public spending. At four times the public expenditure, private health spending is, as a share of all health spending, among the highest in the world. This high level of private spending means that much of the burden of health expenditures falls on households, at least a quarter of who have incomes below the poverty line. High out-of-pocket health costs also are an important cause of persistent household impoverishment. Nationally, more than

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Rs.100,000 crores (1 crore = 10 million) is spent annually in household expenditures on health. However, because private sector health care is unregulated, curative treatment is often prioritized over more efficient preventative care, resulting in wasteful and ineffective health spending.

In 2005, India launched the National Rural Health Mission to provide accessible, affordable, and quality health care to its rural areas, particularly to poorer and more vulnerable populations. A central goal of the mission is increasing public expenditure on health—from the current 1.1 percent of GDP to roughly 2–3 percent of GDP within the next five years—to expand public health services, improve infrastructure and staffing, and reduce the burden of health spending on the country's poor. The mission aims to help bridge the wide gaps in health between affluent and poorer states, to sustain the health gains in the better-performing states, and to address the chronic disease burden that will increasingly strain India's health care system.

Additional public health spending must be appropriately targeted if it is to yield significant health benefits. Public spending can be more effective than private spending only if it undercuts the perverse incentive in the private sector to offer expensive, wastefully inappropriate treatments. In deciding how to use the additional resources to effectively improve health, the National Rural Health Mission should focus on interventions that generate maximum levels of health gain across the population, while improving the basic staffing and infrastructure of public health services needed to provide these interventions. Target interventions also should address disease conditions that are major sources of infant and childhood mortality and infectious disease burdens, to better address the needs of those who are underserved by the current system. Universalizing a subset of specific interventions can be more effective than providing a large range of health interventions without regard to joint costs or shared use of inputs (Bobadilla et al. 1994). Defining a package of basic interventions provided by the government simplifies planning of new investments in training and infrastructure, identifies a minimum set of necessary inputs, helps estimate financial requirements, and makes service availability and impact easier to measure and assess. Moreover, establishing a set package makes clear to citizens and health providers alike exactly which services the government will and will not fund, reducing the potential for the rent-seeking that occurs when poor consumers are not aware of their entitlements.

Selecting a minimum set of interventions that should be provided by the government will likely be influenced by political and social considerations. Nevertheless, epidemiological and economic rationale ought to play a primary role in guiding the choice of interventions. One criterion that incorporates both types of information is cost-effectiveness, the ratio of the cost of an intervention to its health benefits. Benefits can be measured in natural units, such as deaths

averted or years of life saved, as well as disability-adjusted life years (DALYs), a composite measure that combines years lived with disability and years lost to premature death in a single metric.

To inform the selection of interventions that should be included in a universal health package, this study generated and reviewed cost-effectiveness information for interventions that address the major causes of disease burden in India. There likely exists substantial heterogeneity in spending effectiveness within India, with wide gaps between India's most affluent states and its poorest. Where possible, these analyses distinguished populations living in the eight impoverished states known as the Expanded Action Group states plus Assam (EAGA), from states located in the more prosperous south (non-EAGA).

The rest of this paper proceeds as follows. First, we describe in greater detail the cost-effectiveness framework used in these analyses. We then discuss the data and methods common to all new cost-effectiveness analyses conducted for this report, as well as list the previous cost-effectiveness studies reviewed. We proceed to examine the methods and results of analyses for suites of interventions grouped by disease. Diseases are categorized as 1) communicable diseases, reproductive health, and nutritional deficiencies; and 2) noncommunicable and chronic diseases. Within each category, diseases are presented roughly in the order of their total burden within India. We conclude this study with general comparisons across diseases and interventions, and their implications.

II. Analytical framework

This study examined and compared strategies to alleviate disease burden by calculating avertable health burden in terms of disability-adjusted life years and by comparing cost-effectiveness ratios (CERs) in terms of unit cost per DALY averted, per years of life lost (YLLs), and per death averted. DALYs are a measure of healthy life years—the sum of the present value of years of future lifetime lost through premature mortality, and the present value of years of future lifetime adjusted for the average severity of the mental or physical disability caused by a disease or injury (Fox-Rushby and Hanson 2001). The DALY metric allows comparisons of alternative health strategies using a single index that combines information about mortality and morbidity. The total number of DALYs lost in a population due to a particular cause is defined as

$$DALYs = YLL + YLD_{temp} + YLD_{perm} \quad (1)$$

where YLL is the number of discounted life years lost due to mortality, and YLD_{temp} and YLD_{perm} are years of life with temporary and permanent disability, respectively, due to

morbidity. In order to account for varying disease levels among the different target groups, YLL, YLD_{temp}, and YLD_{perm} are defined as follows:

$$YLL = \Sigma_j \, T_j M_j \, (1\text{-}e^{-rL_j})(1/r)(2)$$

$$YLD_{temp} = \Sigma_k \Sigma_j \, T_j I_{kj} D_{kj} \, (1\text{-}e^{-rd_{kj}})(1/r)(3)$$

$$YLD_{perm} = \Sigma_l \Sigma_j \, T_j I_{lj} D_{lj} \, (1\text{-}e^{-rL_j})(1/r)(4$$

where T_j is the total number of people in the target group j, M_j is the mortality rate associated with the disease in question, and L_j is the average remaining life expectancy. I_{kj} is the incidence rate of temporary sequela k, D_{ij} is the corresponding disability weight, and d_{kj} is the duration of the disability. I_{lj} is the incidence rate of permanent sequela l and r is the discount rate for future life years.

The impact of a specific intervention to reduce disease burden is calculated as the DALYs averted by the intervention. The total number of DALYs averted is defined as

$$DALYs_{averted} = YLL_{averted} + YLD_{temp,averted} + YLD_{perm,averted} \; (5)$$

such that

$$YLL_{averted} = \Sigma_j \, T_j M_j^{averted} \, (1\text{-}e^{-rL_j})(1/r)(6)$$

$$YLD_{temp,averted} = \Sigma_k \Sigma_j \, T_j I_{kj}^{averted} D_{kj} \, (1\text{-}e^{-rt})(1/r)(7)$$

$$YLD_{perm,averted} = \Sigma_l \Sigma_j \, T_j I_{lj}^{averted} D_{lj} \, (1\text{-}e^{-rL_j})(1/r)(8)$$

where $M_j^{averted}$ is the reduction in the mortality rate of the target group due to the intervention, and $I_{kj}^{averted}$ and $I_{lj}^{averted}$ are reductions in the morbidity rates of temporary and permanent sequelae, respectively. The parameter t is the duration of the intervention.

We evaluate the efficiency of a particular intervention according to the ratio of its cost to its effectiveness, using the standardized Disease Control Priorities Project guidelines for economic analyses (Musgrove and Fox-Rushby 2006). Effectiveness is in terms of averted YLL, averted deaths, or averted DALYs. A greater cost-effectiveness ratio indicates a higher cost per unit of health gained. Hence, a high CER indicates low efficiency or lesser cost-effectiveness, and a low CER indicates the opposite.

Cost-effectiveness information helps underscore the variation in the cost of improving health using different interventions. The policymaker can consider the cost-effectiveness ratio as the "price" of purchasing a unit of health (Laxminarayan et al. 2006). Cost-effectiveness ratios can be used to set health priorities by establishing a threshold price above which an intervention would be considered too expensive and ineffective for the government to provide. The cost-effectiveness ratio can also be used as a comparative price of purchasing health across multiple interventions and diseases. Given limited monetary resources for public health spending, comparative prices for different interventions can inform a budget constraint. The policymaker can weigh the relative trade-offs of health gains from ameliorating different diseases and determine how to allocate a fixed budget into an optimal suite of interventions that maximizes the desired health outcomes. All else being equal, interventions with low prices should be utilized more than those that are more expensive.

How a cost-effectiveness ratio should be interpreted depends on the method of its calculation. The average cost-effectiveness of an intervention is the ratio of its total costs to total health benefits, aggregated from a baseline scenario of zero treatment. Average cost-effectiveness ratios are useful in comparing the relative efficiency of alternative, competing interventions. The incremental cost-effectiveness of an intervention is the ratio of the additional costs and health benefits of an intervention when a treatment regime for the given disease is already in place. Incremental cost-effectiveness ratios are useful for examining the relative efficiency of expanding coverage of an existing intervention, replacing an existing intervention with an alternative, or implementing an additional intervention on top of another.

Because of the limited information on disease morbidity in India, the cost-effectiveness rates of many interventions presented here are given in terms of unit costs (Rupees, Rs.) per averted YLL rather than DALYs. However, the two metrics are still appropriate for comparison

because their units are the same: Rs. per discounted year of healthy life. Since the vast majority of the disease burden in such cases typically is due to reduced life expectancy rather than disability during life, cost-effectiveness ratios that are reported in terms of Rs. per averted YLL would not be substantially lower if they took disability into account and could be reported as Rs. per averted DALY. In other words, considering only the disease burden from averted YLL results in more conservative estimates of cost-effectiveness.

Finally, the particular characteristics of each disease and treatment necessitated methodological variation across analyses. Moreover, the estimates were based on the best available data, which were often weak. We therefore encourage readers to note the order of magnitude of each estimate rather than the specific number, particularly when comparing cost-effectiveness of interventions for different diseases.

III. Data and methods

We conducted new analyses for all interventions except those for HIV/AIDS, cardiovascular diseases, and screening interventions for cervical and breast cancer, since recent cost-effectiveness analyses specific to India have been undertaken for these diseases by other researchers. For each new analysis, specific methods for calculating the costs and outcomes of disease interventions were designed based on the unique epidemiological characteristics of the disease and the nature of the investigated treatment. Detailed descriptions of the analytical methods and assumptions for each are described in their individual sections. Certain methods were common to all the analyses newly conducted for this study, though not necessarily for reviewed works.

Wide disparities in the underlying disease burden exist between states in India. The impoverished EAGA states—Assam, Bihar, Chhattisgarh, Jharkand, Madhya Pradesh, Orissa, Rajasthan, Uttar Pradesh, and Uttarakhand—have approximately 47 percent of the total population of India but account for two-thirds of all neonatal deaths and two-thirds of all maternal deaths (SRS 2006). To help account for such differences, we calculated costs and effects for India as a whole, for the EAG states and Assam (EAGA), and for all other states combined (non-EAGA) where sufficient information (e.g., state-level coverage, morbidity, and mortality rates) allowed.

These analyses considered only long-run marginal costs that vary with the number of individuals treated and did not include the fixed costs of initiating a program where none currently exists. Therefore, we did not vary the treatment costs and effectiveness rates between

the three state categories analyzed; rather, we varied only the coverage rates, underlying disease burden, and avertable disease burden. In all new analyses, we discounted costs and health benefits using a three percent discount rate. We also assumed an exchange rate of Rs.1 = US$0.022. All monetary values are presented in year-2001 currency.

The state and EAGA/non-EAGA data used to calculate cost-effectiveness ratios were drawn from several sources. Unless otherwise specified, the new analyses used population data from the 2001 Indian census, mortality rates from the Million Deaths Study by the Center for Global Health Research at the University of Toronto, and coverage information from the International Institute of Population Sciences Reproductive and Child Health District Level Household Survey (IIPS 2007).

If the prevailing coverage of an effective intervention is substantially greater than zero, then recent, empirically estimated mortality rates that do not differentiate by coverage could underestimate the underlying mortality rate among uncovered populations. Using these empirical mortality rates at face value therefore underestimates the total avertable disease burden of an intervention, as well as the incremental effectiveness of expanding coverage. Where the intervention coverage is substantial, we used the following equation to estimate the underlying mortality rate of an untreated or uncovered population:

underlying mortality rate = #deaths/[(population)*(1-coverage)+(population)*(coverage)*(1-efficacy)]

IV. Cost-effectiveness analyses and results

Communicable diseases, reproductive health, and nutritional deficiencies

1. Diarrheal diseases

Diarrhea is caused by a variety of known and emerging infectious organisms, such as viruses, bacteria, protozoa, and helminths, which are transmitted from the stool of one individual to the mouth of another. In India, diarrheal diseases are responsible for seven percent of all deaths, predominantly among children. At least 257,000 children under five years of age die from diarrhea each year, with approximately half of those deaths occurring in the EAGA states.

We calculated cost-effectiveness ratios of two diarrheal disease interventions demonstrated to be potentially cost-effective in South Asia: breastfeeding promotion and oral rehydration therapy (Keusch et al. 2006). We used diarrhea morbidity rates reported by the National Institute of Cholera and Enteric Diseases (NICED 2005). Estimates of intervention

effectiveness rates (i.e., percentage diarrheal morbidity reduction and percentage diarrheal mortality reduction) and per capita intervention costs were gathered from the literature and personal communications (see Table 1-1).

Approximately 90 percent of all cases in the developing world occur between birth and age four. In India, diarrheal diseases are responsible for 12 percent of all deaths before the age of five. Therefore, we considered the effects of each intervention on diarrheal morbidity and mortality in the under-five age group only. Uniform incidence rates, intervention effectiveness rates, and per person costs were assumed for the three state categories analyzed because state-specific information was not available. Variations in cost-effectiveness among the three categories were due to differences in the diarrhea-attributable mortality, as well as differences in demographic characteristics, such as sex ratios and life expectancy.

DALYs are averted through avoided cotemporaneous disability, using a disability weight of 0.105 (Murray and Lopez 1996), and mortality attributable to diarrhea. We did not consider long-term developmental and cognitive effects of childhood diarrhea; including these benefits would lower cost-effectiveness ratios.

Two interventions were explored: breastfeeding promotion, taking place within the first year of life, and oral rehydration therapy (ORT), which can treat an entire cohort of children under five simultaneously. For breastfeeding promotion, cost-effectiveness ratios were calculated by considering the cost of treating all newborns in a single year and the benefits (DALYs and deaths averted) from those treatments that occur over the first five years of life. These benefits include avoided mortality that allows individuals to live to the full life expectancy for the region. In contrast, since a single year of ORT yields only cotemporaneous benefits—because effectively treated individuals do not necessarily live to life expectancy, given that they are likely to be reinfected the next year—we calculated cost-effectiveness of a five-year intervention. Analysis of a five-year intervention enabled us to consider the case in which an entire cohort of zero- to four-year-olds avoids early childhood diarrheal mortality because of the intervention and receives the benefit of living to life expectancy.

Breastfeeding helps reduce diarrhea deaths by reducing the likelihood that an infant or young child ingests contaminated water. Two breastfeeding promotion strategies were considered; 1) maternity services-based breastfeeding promotion requires hospital policies and actions to encourage breastfeeding and discourage bottle feeding, and 2) community-based breastfeeding promotion involves mass media and community education alongside counseling and education provided by peers and community health workers. Efficacy rates of breastfeeding

promotion were drawn from Feachem and Koblinsky (1984), who report varying rates depending on the preintervention pattern of breastfeeding. The effectiveness estimates used in this analysis were selected based on the rates of exclusive and partial breastfeeding in India reported by Gupta and Gupta (2004). We assumed the same effectiveness rates for both strategies.

Therapies with oral rehydration solutions facilitate the uptake of water through the intestinal wall and reduce mortality by preventing dehydration when a child falls ill with diarrhea. According to the International Institute of Population Sciences (2007), 30 percent of children in India are currently treated with ORT. In the EAGA and non-EAGA states, ORT coverage is 23 percent and 42 percent, respectively. Because ORT has significant levels of current usage, we calculated the incremental cost-effectiveness and avertable disease burden of additional coverage, using the formula for underlying mortality rate described above. We assumed that ORT would not affect incidence or duration of diarrhea; hence those input variables do not change regardless of coverage. Because ORT coverage is greater in the non-EAGA states, we found that these states have a greater underlying mortality rate. In absence of ORT, we estimated that about 4 out of every 1,000 children under five would die from diarrhea. The underlying mortality rate in the EAGA states was approximately 3 out of every 1,000 children under five.

The per child treatment costs and effectiveness rates used are presented in Table 1-1. Cost per treatment of ORT varied widely depending on the type and method of ORT implemented. ORT can be as inexpensive as Rs.1 per child treated—the cost of a home remedy with sugar and salt. However, treatment can become more expensive if a manufactured solution is used or if there are substantial personnel or infrastructure costs to consider. Here we compared the costs of a home remedy of salt and sugar, home-based care using a UNICEF satchel, and facility-based care.

Cost-effectiveness rates for all interventions and state categories are reported in Table 1-2. Maternity services-based breastfeeding promotion was found to be more cost effective than community-based promotion, at Rs.2,400 per DALY compared with Rs.6,500 per DALY, respectively. The explanation is that community-based promotion was assumed to be more costly than promotion alongside maternity services, while both were assumed to have equivalent effectiveness.

In India, the cost-effectiveness of ORT ranged from Rs.70 per DALY for the home remedy to Rs.20,000 per DALY for ORT at a health facility. The cost-effectiveness of home-based care using the UNICEF satchel was essentially the same as facility-based care if only the

cost of the oral rehydration solution was considered (Rs.890 and Rs.920 per DALY, respectively). Again, because we assumed that all ORT strategies have similar effectiveness rates, the variation in the cost-effectiveness ratio among the different strategies is due to the costs only. However, the cost-effectiveness ratios of the home remedy and home-based care may be underestimated here because we did not take into account the costs of promoting and educating mothers and health workers about these treatments[1]. Both breastfeeding promotion and ORT were more cost-effective in non-EAGA states than in EAGA states because both life expectancy and, more significantly, underlying diarrhea mortality rates are greater in the non-EAGA states.

Health facility-based breastfeeding promotion was more cost-effective than facility-based ORT, but because ORT is far more effective in reducing diarrheal mortality, it has the potential to avert far greater disease burden (see Table 1-3). Expanding current coverage of ORT to all children in India would avert nearly 7 million DALYs by preventing 242,000 deaths. In comparison, breastfeeding promotion would avert 858,000 DALYs and reduce diarrhea mortality among children under five by 30,000 deaths.

[1] Because ORT does not reduce the duration of diarrhea and watery stools persist, there has been suboptimal acceptance of ORT at local levels (Ruxin 1994).

Table 1-1. Cost and effectiveness values used to calculate cost-effectiveness ratios for select interventions for diarrhea

Breastfeeding promotion

Costs

Sources	Method	Estimated cost/child (2001Rs)	Cost/child range (2001Rs)	Estimated cost/child (2001US$)	Cost/child range (2001US$)	Source regions or countries
Horton et al. 1996	Maternity services–based	85	21–148	1.86	0.46–3.26	Brazil, Honduras, Mexico
Linkages 2005	Community -based	225	182–304	4.94	4.01–6.68	Madagascar

Effectiveness (0–5 years)

Sources	Estimated diarrhea morbidity reduction	Morbidity reduction range	Estimated diarrhea mortality reduction	Mortality reduction range	Source regions or countries
Feachem and Koblinsky 1984	3%	1–5%	11.5%	5–18%	India

Oral rehydration therapy

Costs

Sources	Method	Estimated cost/episode (2001Rs)	Cost/episode range (2001Rs)	Estimated cost/episode (2001US$)	Cost/episode range (2001US$)	Source regions or countries
Keusch 2004	Home remedy	1	NA	0.02	NA	LMIC
UNICEF 1995, Edejer et al. 2005	UNICEF satchels	11	NA	0.24	NA	LMIC
Islam et al. 1994, Kamala et al. 1996	Health center or hospital setting, ORT costs only	11	3–23	0.25	0.07–0.5	India, Bangladesh
Islam et al. 1994, Kamala et al. 1996, NCMH 2005	Health center or hospital setting, including other costs	239	231–250	5.26	5.08–5.51	India, Bangladesh

Effectiveness (0–5 years)

Sources	Estimated diarrhea morbidity reduction	Morbidity reduction range	Estimated diarrhea mortality reduction	Mortality reduction range	Source regions or countries
Fontaine 2004	0%	NA	95%	NA	LMIC

Table 1-2. Average cost-effectiveness of select interventions for diarrheal disease

Rs per DALY averted

	Maternity services-based breastfeeding promotion	Community-based breastfeeding promotion	Oral rehydration therapy (home remedy)	Oral rehydration therapy (UNICEF satchel)	Oral rehydration therapy (facility care, solution costs only)	Oral rehydration therapy (facility care, other costs included)
India	2,400	6,500	70	890	920	20,000
EAGA	2,400	6,400	80	930	960	20,000
non-EAGA	2,000	5,300	50	630	650	14,000

Rs per death averted

	Maternity services–based breastfeeding promotion	Community-based breastfeeding promotion	Oral rehydration therapy (home remedy)	Oral rehydration therapy (UNICEF satchel)	Oral rehydration therapy (facility care, solution costs only)	Oral rehydration therapy (facility care, other costs included)
India	70,000	186,000	2,100	25,000	26,000	558,000
EAGA	68,000	181,000	2,200	26,000	27,000	574,000
non-EAGA	57,000	152,000	1,500	18,000	19,000	398,000

Table 1-3. Avertable burden of select interventions for diarrheal disease

Avertable DALYs

	Breastfeeding promotion*	Oral rehydration therapy**
India	858,000	6,895,000
EAGA	494,000	3,990,000
non-EAGA	457,000	3,618,000

Avertable deaths

	Breastfeeding promotion*	Oral rehydration therapy**
India	30,000	242,000
EAGA	17,000	142,000
non-EAGA	16,000	125,000

*Burden avertable following 1-year intervention.

**Burden avertable over 5-year intervention.

2. Tuberculosis

Tuberculosis (TB) is responsible for 5.6 percent of all deaths in India. Nearly 1.4 million cases are reported in India each year, with the majority, 57 percent, reported in the non-EAGA states (RNTCP 2006a). However, among the 525,000 TB deaths per year, 59 percent take place in the EAGA states.

Over the past decade, the World Health Organization (WHO) has promoted DOTS, a multi-component strategy, as the primary treatment for TB. The DOTS strategy has five elements (Dye and Floyd 2006a): political commitment by national governments; diagnosis, primarily by sputum-smear microscopy; short-course chemotherapy using first-line drugs, with case management that includes direct observation of treatment; a regular drug supply; and systematic monitoring to evaluate the outcomes of every patient.

We calculated the cost-effectiveness of DOTS to treat active sputum-smear positive (ss+) and active sputum-smear negative (ss–) TB cases. Our methods for assessing cost-effectiveness were identical in both cases, though we varied the inputs (e.g., costs of treatment, incidence) across the ss+ and ss– analyses. We obtained estimates of treatment coverage and incidence from India's Revised National Tuberculosis Control Programme (RNTCP 2006b). Methods for estimating YLL, YLD, treatment costs, efficacy, and other modeling parameters for cost-effectiveness analysis were drawn from the Disease Control Priorities in Developing Countries Project, specifically the chapter and supplementary materials on TB by Dye and Floyd (2006a, 2006b) (see Tables 2-1, 2-2, and 2-3).

We assumed that a DOTS program covered all TB cases (RNTCP 2006b), and we estimated an underlying incidence rate using a formula similar to the one for the underlying mortality rate described above. We estimated an underlying ss+ TB incidence rate of 47 per 10,000 people per year in the EAGA states and 51 per 10,000 people per year in the non-EAGA states. The incidence rates for ss– TB were 28 and 33 per 10,000 people per year in the EAGA and non-EAGA states, respectively.

We derived estimates of health gains, in terms of averted deaths and DALYs, using a dynamic TB-specific model that allowed us to evaluate the avertable disease burden due to preventing transmission to the entire population in addition to the avertable burden due to improving the health of the treated patient. We analyzed separately the effects of DOTS on treated patients and the effects of reduced transmission for the rest of the population. To calculate the health benefits received by the treated patient, we estimated the treatment success rate and the reduction in mortality relative to a baseline treatment with a non-DOTS program.[2] According to Dye and Floyd's transmission model, the number of new TB cases prevented per successfully treated case is a function of a statistically estimated parameter, *k*, and the duration of treatment, T (see Table 2-1; also see Dye and Floyd 2006b for details). We also estimated the subsequent deaths avoided due to the prevention of new cases.

We considered three components of avertable disease burden per successfully treated case: 1) DALYs averted due to the avoided mortality among patients treated with DOTS; 2) DALYs averted due to deaths prevented by avoiding transmission; and 3) DALYs averted due to the disability and morbidity prevented by avoiding transmission. The sum of these components was multiplied by the number of cases successfully treated to arrive at total DALYs averted for the population. The total avertable burden in terms of deaths and DALYs is reported in Table 2-5.

We assumed costs of approximately Rs.9,800 per course of treatment for each ss+ patient and Rs.10,300 per course for each ss– patient (Table 2-3). Costs were higher for ss– patients because of additional diagnostic costs.

We found the cost-effectiveness of DOTS to be similar regardless of whether the benefits of reduced transmission were considered. The cost-effectiveness ratios for treatment of ss+ cases

2 The efficacy of non-DOTS programs (baseline treatment) can collectively be assumed as 50 percent (see Table 2) (Dye, pers. comm.).

were Rs.740 per DALY averted when including the benefits of reduced transmission and Rs.785 per DALY averted when not. The cost-effectiveness of DOTS treatment for ss– cases with and without transmission was Rs.2,860 and Rs.3,050 per DALY averted, respectively (see Table 2-4). The difference in the ss+ and ss– results is due to variations in baseline case fatality rates, incidence, and costs. Since the case fatality rates for ss- cases are lower independent of DOTS, the addition of DOTS treatment for ss- patients has less of an impact in terms of averting deaths relative to DOTS treatment of ss+ patients. In addition, the costs of treating ss- patients are slightly higher since detecting ss- cases involves additional culturing.

Compared with a baseline of zero coverage, DOTS treatment for all TB cases in India would avert 90 million DALYs, including 5 million deaths (see Table 2-5). Most of the averted disease burden is from the non-EAGA states, which have a higher underlying mortality rate.

Effectiveness of treatment is assumed to be constant across state categories. Because the marginal costs of treatment are also constant across the country, our cost-effectiveness results are uniform for all India, EAGA, and non-EAGA even though TB incidence varies across these areas. Any differential efficiency for a region would be the result of variations in the health system's capacity to deliver DOTS, but we do not take into account those differences in this analysis. However, including such differences may not be crucial to this analysis because data suggest that the capacity to provide DOTS does not vary dramatically between the EAGA and non-EAGA states: both regions display similar DOTS treatment success rates, and the case detection rate in the non-EAGA states (70 percent) is only somewhat better than in the EAGA states (61 percent) (RNTCP 2006b).

Table 2-1. Parameters used in calculating cost-effectiveness of DOTS

	Estimate	Source	Source country
Disability-adjusted life years gained by preventing TB deaths (YLL)	18.4	Dye and Floyd 2006b	India
Disability-adjusted life years gained by preventing illness and disability (YLD)	0.76	Dye and Floyd 2006b	India
*k**	0.058 (0.057–0.059)	Dye and Floyd 2006b	N/A

*Note: *k* is a parameter of the transmission model estimated by Dye and Floyd in Annex 5 of the Disease Control Priorities Project (Dye and Floyd, 2006b).

Table 2-2. Effectiveness rates used in calculating the cost-effectiveness of DOTS

	Morbidity reduction w/DOTS	Morbidity reduction w/DOTS range	Morbidity reduction w/baseline treatment	Mortality reduction w/DOTS*	Mortality reduction w/DOTS range	Mortality reduction w/ baseline treatment	Source	Source country
ss+	84%	80–93%	33%	8.9%	4.8–13%	50%	Dye and Floyd 2006b	India
ss–	84	80–93	33	8.9	4.8–13	20	Dye and Floyd 2006b	India

*Note: This value is calculated as the average of the low and high reported estimates.

Table 2-3. Treatment costs used in calculating the cost-effectiveness of DOTS

	Costs per course of treatment (2001 US$)	Cost range (2001 US$)	Source	Source country
ss+	215	173–262	Dye and Floyd 2006b	India
ss–	226	185–272	Dye and Floyd 2006b	India

Table 2-4. Cost-effectiveness of DOTS in India

	Cost-effectiveness ratios (2001 US$ per DALY averted)		Cost-effectiveness ratios (Rs. per DALY averted)	
	Excluding the effects of reduced transmission	Including the effects of reduced transmission	Excluding the effects of reduced transmission	Including the effects of reduced transmission
ss+	17.3	16.3	785	740
ss–	67.2	62.9	3,050	2,860

Table 2-5. Avertable TB disease burden with DOTS in India, compared with baseline of no treatment

Avertable deaths		
	ss+	ss–
India	3,650,000	1,220,000
EAGA	1,650,000	567,000
Non-EAGA	1,990,000	654,000
Avertable DALYs (No transmission + transmission)		
	ss+	ss–
India	67,300,000	22,700,000
EAGA	30,500,000	10,500,000
Non-EAGA	36,800,000	12,200,000

3. Acute lower respiratory infections

Respiratory infections cause 5.1 percent of all deaths in India, primarily among children. Among children under the age of five, respiratory infections are the second-greatest cause of death, responsible for 318,000 deaths per year, or 17.9 percent of all deaths within this age group. The common infections in children are pneumonia and bronchiolitis, each caused by several possible bacteria and viruses.

The simplification and standardization of case management for early diagnosis and treatment of acute lower respiratory infections (ALRIs) have enabled significant reductions in mortality in developing countries, particularly where access to doctors is limited (Simoes et al. 2006). We evaluated case management intervention strategies for ALRIs in children under five in India. Health workers who implement case management diagnose ALRIs based on fast breathing, lower chest wall indrawing, or selected danger signs in children with respiratory symptoms. Since this method does not distinguish between pneumonia and bronchiolitis or between bacterial and viral pneumonia, we grouped these conditions into the general category of "clinical pneumonia" (see Rudan et al. 2004). This approach assumes that a high proportion of clinical pneumonia cases are of bacterial origin and that health workers can considerably reduce case fatality through breathing rate diagnosis and timely administration of antibiotics (Sazawal and Black 2003).

Our analysis addressed four categories of case management distinguished according to the severity of the infection and the assumed delivery point of treatment: nonsevere infection treated by a community health worker; nonsevere infection treated at a health facility; severe infection treated at a hospital; and very severe infection treated at a hospital. These categories and their specific inputs were drawn from a WHO report on the methodology and assumptions used to estimate costs of scaling up selected child health interventions (2005). A total of three follow-up visits were assumed for each patient treated by a community health worker, rather than the twice-daily follow-ups for 10 days as recommended by WHO. We also assumed an average patient mass of 12.5kg and a six-hour workday for a community health worker (NCMH 2005). Treatment costs were calculated using figures published in the *International Drug Price Indicator Guide* (Management Sciences for Health) by the National Commission on Macroeconomics and Health (2005) and other sources (see Table 3-1). Average per episode treatment costs for the four case management strategies are presented in Table 3-2. ALRI morbidity rates were drawn from Rudan et al. (forthcoming).

DALYs were averted through reduced illness duration and avoided mortality due to treatment. An average illness duration of 8.5 days was assumed for infected individuals left untreated, and 6 days for treated individuals. We used a case fatality reduction of 36 percent for individuals receiving treatment compared with those untreated (Sazawal and Black 2003), a diagnosis sensitivity rate of 85 percent, and a specificity rate of 78.5 percent for patients diagnosed based on breath rate alone (Simoes et al. 2006). The disability weight cotemporaneous with infection was 0.28 (Murray and Lopez 1996). Disability due to chronic sequelae of lower respiratory infections were not considered since it is unclear whether childhood LRI causes long-term impaired lung function or whether children who will develop impaired lung function are more susceptible to infection (von Mutius 2001).

Because a single year of these interventions yields only cotemporaneous benefits—effectively treated individuals do not necessarily live to life expectancy given that they are likely to be reinfected the next year—we calculated instead the cost-effectiveness of a five-year intervention. Analysis of a five-year intervention enabled us to consider the case in which an entire cohort of zero- to four-year-olds avoids early childhood clinical pneumonia because of the intervention and receives the benefit of living to life expectancy.

Table 3-3 reports the region-specific cost-effectiveness ratios of all four case management strategies as well as that for providing all four interventions. Treatment of nonsevere clinical pneumonia at the community level was most cost-effective (Rs.3,800 per DALY), and treatment of severe clinical pneumonia at the hospital level was least cost-effective (Rs.436,000 per DALY). Because effectiveness rates were held constant across intervention strategies, the variation in their cost-effectiveness ratios was due entirely to differences in the per episode treatment costs. Cost-effectiveness ratios increased with the severity of infection because of the additional costs needed to treat it. The cost-effectiveness ratio of providing all levels of treatment to India was estimated at Rs.39,000 per DALY. Because costs and efficacy were held constant across state categories, the variation in cost-effectiveness among the India, EAGA, and non-EAGA groups was due to differences in estimated mortality rates and life expectancies. Variation in the cost-effectiveness for providing all levels of care was also due to region-specific urban-to-rural population ratios, since we assumed that all patients in urban areas would seek treatment at the facility level or higher, whereas 80 percent of nonsevere cases in rural areas would receive treatment at the community level and the rest would seek treatment at the facility level.

Simoes et al. (2006) found that facility-level case management was more cost-effective than community-level treatment, whereas this analysis revealed the opposite. The discrepancy

was due to differences in the variable local costs assumed. Whereas Simoes et al. assumed a health worker hourly wage of US$1.23 (Rs.56), this analysis assumed a lower cost of Rs.12.3 per hour. Simoes et al. also assumed that a facility visit cost of US$1.72 (Rs.78), whereas we assumed a greater cost of Rs.121 per visit based on the information published by the National Commission on Macroeconomics and Health (2005). Because we assumed a higher cost for facility-level treatment and a lower cost for community-level treatment, we found community-level case management of nonsevere cases to be the most cost-effective.

Avertable burden, in terms of both DALYs and deaths, is reported in Table 3-4. Case management of pneumonia has the potential to avert more than 30 lakh (1 lakh = 100,000) DALYs, corresponding to more than 9 lakh deaths, among children under age five in India. Avertable pneumonia disease burden was greater in the EAGA states than in the non-EAGA states because of a higher death rate from lower respiratory disease in the EAGA states. Higher death rates also resulted in lower cost-effectiveness ratios in the EAGA states compared with the non-EAGA states. Discrepancies in the cost-effectiveness and burden estimates between the all-India results and the sum of the EAGA and non-EAGA categories are likely because EAGA- and non-EAGA-specific input estimates are drawn from different sources.

Table 3-1. Inputs for case management of clinical pneumonia in India.

All costs calculated from the International Drug Price Indicator Guide (MSH 2005) unless otherwise noted.

Nonsevere pneumonia at the community level

Item	Cost per unit (Rs.)	Cost per unit (2001US$)	Quantity	Percentage of patients
oral Amoxicillin (15mg/kg)	1.4/dose	0.03/dose	3 doses a day for 3 days	100
Paracetamol (100 mg tablet)	0.045/dose	0.001/dose	6 doses	100
community health worker hour*	12.3/hour	0.27/hour	1 initial 1-hr visit and 3 follow-ups	100

Nonsevere pneumonia at the facility level

Item	Cost per unit (Rs.)	Cost per unit (2001US$)	Quantity	Percentage of patients
oral Amoxicillin (15mg/kg)	1.4/dose	0.03/dose	3 doses a day for 3 days	100
Paracetamol (100 mg tablet)	0.045/dose	0.001/dose	6 doses	100
oral Salbutamol (2 mg tablet)	0.14/dose	0.003/dose	3 doses a day for 4 days	10
outpatient health facility visit*	121/visit	2.66/visit	1 visit only	100

Severe pneumonia at the hospital level

Item	Cost per unit (Rs.)	Cost per unit (2001US$)	Quantity	Percentage of patients
oral Amoxicillin (15mg/kg)	1.4/dose	0.03/dose	3 doses a day for 5 days	100
nebulized Salbutamol (2.5mg)	5.9/dose	0.13/dose	6 doses a day for 4 days	50
injectable Ampicillin (50mg/kg)	9.5/dose	0.21/dose	4 doses a day for 3 days	100
X-ray test**	276/test	6.07/test	1 only	20
oxygen (1L/min)***	910/day	20/day	3.5 days (average)	50
inpatient hospital care**	760/day	16.7/day	3 days	100

Very severe pneumonia at the hospital level

Item	Cost per unit (Rs.)	Cost per unit	Quantity	Percentage of patients

		(2001US$)		
oral Amoxicillin (15mg/kg)	1.4/dose	0.03/dose	3 doses a day for 5 days	100
nebulized Salbutamol (2.5mg)	5.9/dose	0.13/dose	6 doses a day for 4 days	50
injectable Ampicillin (50mg/kg)	9.5/dose	0.21/dose	4 doses a day for 5 days	100
injectable Gentamicin (2.5mg/kg)	6.4/dose	0.14/dose	1 injection a day for 10 days	100
oral Prednisolone (1mg/kg)	0.90/dose	0.02/dose	1 dose a day for 3 days	5
X-ray test*	276/test	6.07/test	1 only	100
oxygen (1L/min)***	910/day	20/day	5 days	100
inpatient hospital care**	760/day	16.7/day	5 days	100

*From NCMH 2005.
**Estimated from private hospital rates.
***Median cost obtained from a review of the following sources: Dobson 1991; Pederson and Nyrop 1991; WHO 1993; Schneider 2001.

Table 3-2. Average per episode treatment costs of case management interventions for clinical pneumonia (2001US$).

	Nonsevere, community level	Nonsevere, facility level	Severe, hospital level	Very severe, hospital level
2001US$	1	3	96	198
Rs.	61	133	4366	9002

Table 3-3. Cost effectiveness ratios of case management interventions for clinical pneumonia (Rs./DALY)

	Nonsevere, community level	Nonsevere, facility level	Severe, hospital level	Very severe, hospital level	entire package
India	3,800	8,200	211,400	435,900	38,900
EAGA states	3,100	6,700	172,900	356,400	31,600
non-EAGA states	3,300	7,200	185,400	382,300	34,400

Table 3-4. Avertable burden of case management interventions for clinical pneumonia

Avertable DALYs

	Nonsevere, community level	Nonsevere, facility level	Severe, hospital level	Very severe, hospital level	entire package
India	1,520,000	1,112,000	367,000	61,000	3,060,000
EAGA states	1,121,000	615,000	242,000	40,000	2,019,000
non-EAGA states	714,000	668,000	193,000	32,000	1,607,000

Avertable deaths

	Nonsevere, community level	Nonsevere, facility level	Severe, hospital level	Very severe, hospital level	entire package
India	48,700	35,600	11,800	2,000	98,100
EAGA states	37,000	20,300	8,000	1,300	66,500
non-EAGA states	22,700	21,300	6,100	1,000	51,200

4. Maternal mortality

In India, maternal conditions cause more than a quarter of all female deaths between the ages of 15 and 24. In a country where some 25 million live births take place each year, approximately 164,000 maternal deaths occur, with about two-thirds in the EAGA states. Reducing the ratio of maternal deaths to live births is an international priority not only because of the health burden, but also because maternal mortality is considered an indicator of the entire health system (Goodburn and Campbell 2001; Graham et al. 2006). The outlook in India is promising: the maternal mortality ratio has declined by 24 percent in recent years, from 398 deaths per 100,000 live births in 1997–1998 to 301 in 2001–2003 (SRS 2006).

We calculated the costs and outcomes of providing acute treatment for five principal causes of maternal death in India: unsafe or septic abortion, obstructed labour, hypertensive disorders (i.e., eclampsia), sepsis, and haemorrhage. In addition, we also computed the cost-effectiveness of providing all mothers in India with institutional deliveries, at either a community health center or a local maternity center. Estimates of maternal morbidity rates, intervention effectiveness rates, and per capita intervention costs were gathered from several sources (see Table 4-1). Uniform incidence rates, intervention effectiveness rates, and per patient costs were assumed for the three state categories because state-specific information was not available (see Table 4-1).

Cost-effectiveness was calculated as the ratio of total costs of the intervention and the total averted deaths or discounted YLL. We did not consider the cotemporaneous or long-term disability impacts due to maternal conditions that do not result in death. Including these benefits would lower cost-effectiveness ratios.

According to the most recent International Institute of Population Sciences survey, 41 percent of births in India take place in an institution. Approximately 19 percent are in public facilities, and 22 percent take place in private facilities. We used the average of state coverage rates, weighted by the yearly number of births, to calculate the institutional birth coverage in the EAGA and non-EAGA states (25 percent and 59 percent, respectively). Because of these substantial coverage levels, we calculated the cost-effectiveness and avertable disease burden of additional coverage, assuming that all additional births take place in either a community health or maternity center.

Assumed treatment costs and effectiveness rates per patient are presented in Table 4-1. Although other conditions besides those listed above cause 34 percent of the maternal mortality

in India (SRS 2006), we lacked sufficient information to estimate the impact of institutionalization and treatment on these generic causes. Therefore, these unspecified deaths were not considered in our analysis. Although neonatal deaths also occur as a result of the maternal conditions addressed here, we calculate the cost-effectiveness of neonatal mortality interventions in a separate analysis. This analysis did not include costs unrelated to medical treatment, such as transportation to the community health or maternity center, or lodging for the mother or family members around the time of birth.

Cost-effectiveness ratios for acute treatment of specific conditions, as well as for institutionalization of all deliveries, are reported by state category in Table 4-2. Though cost-effectiveness rates were relatively similar across state categories, variation is due to differences in maternal age structures and estimated underlying mortality rates. The cost-effectiveness of institutional deliveries was Rs.6,400 per YLL averted at a community health center and Rs.20,000 per YLL averted at a local maternity center. This result was found because delivery at a community health center serving a population of 100,000 was assumed to be much less expensive than delivery at a local maternity center serving a population of 25,000, according to our sources. The lower costs associated with the former may be due to economies of scale in providing manpower and other resources. A community health center, however, may be more difficult to reach in some parts of India than a maternity center, and our comparative results may not hold if transportation costs are included.

Among the acute interventions analyzed, treatment of septic abortion was most cost-effective (Rs.160 per YLL averted), and treatment of eclampsia was the least (Rs.12,000 per YLL averted). Higher per patient treatment costs generally resulted in greater cost-effectiveness ratios for specific treatments (see Table 4-1). Comparative cost-effectiveness of these acute interventions could be seen as moot, since treatment ought to be offered at delivery for any complications irrespective of its cost-effectiveness. However, such considerations, as well as the frequency and predictability of a particular condition, such as eclampsia, could help determine whether a local facility ought to have the capacity to treat it or such treatment should be reserved to a community health center or higher-level facility.

The avertable maternal burden of acute treatment and expanding coverage of institutional deliveries is reported in Table 4-3. Treatment of all maternal conditions considered resulted in a total avertable burden of 1.4 lakh YLLs, equivalent to 58,000 maternal deaths annually. The majority of the burden is due to haemorrhage during childbirth. The avertable burden with additional institutional coverage is greater in the EAGA states because current coverage levels

are less than in the non-EAGA states. Hence, maternal haemorrhage in the EAGA states accounts for more than a third of the avertable maternal mortality burden in India.

Table 4-1. Cost and effectiveness values used to calculate cost-effectiveness ratios for select maternal mortality interventions

Acute condition treated	Cost per patient (2001Rs.)*	Reduction in mortality**	Incidence rate* (cases per lakh population)
Septic abortion	980	75%	5
Obstructed labour	1948	80	32
Eclampsia	7211	76	25
Sepsis	980	75	18
Hemorrhage	3522	85	33
Institutional delivery:			
CHC	453		
Maternity center***	1725		

*Source: NCMH 2005

**Source: Graham et al. 2006

***Source: Aggarwal et al. 2006

Table 4-2. Cost-effectiveness of select interventions for maternal mortality

Rs. per maternal YLL

	Septic abortion	Obstructed labour	Eclampsia	Sepsis	Hemorrhage	Institutional delivery (CHC)	Institutional delivery (maternity center)
India	160	3,200	12,000	550	870	6,400	20,000
EAGA	160	3,200	12,000	430	820	6,800	22,000
non-EAGA	160	3,500	10,000	700	920	5,700	17,000

Rs. per maternal death

	Septic abortion	Obstructed labour	Eclampsia	Sepsis	Hemorrhage	Institutional delivery (CHC)	Institutional delivery (maternity center)
India	3,900	80,000	291,000	14,000	21,000	157,000	485,000
EAGA	4,000	75,000	313,000	10,000	20,000	166,000	527,000
non-EAGA	4,000	90,000	245,000	18,000	23,000	143,000	423,000

Table 4-3. Avertable burden of select interventions for maternal mortality

Avertable maternal YLLs

	Septic abortion	Obstructed labour	Eclampsia	Sepsis	Haemorrhage	Total
India	189,000	118,000	94,000	197,000	814,000	1,413,000
EAGA	110,000	72,000	53,000	150,000	513,000	897,000
non-EAGA	68,000	40,000	42,000	57,000	284,000	491,000

Avertable maternal deaths

	Septic abortion	Obstructed labour	Eclampsia	Sepsis	Haemorrhage	Total
India	7,700	4,800	3,800	7,900	33,000	58,000
EAGA	4,500	3,000	2,100	6,100	21,000	37,000
non-EAGA	2,700	1,600	1,700	2,200	11,000	19,000

5. Neonatal mortality

Perinatal conditions are the greatest cause of childhood death in India, resulting in about 40 percent of all deaths before the age of five years. Each year about 927,000 neonatal deaths occur in India, two-thirds of which take place in the EAGA states. Although early child death has declined at least 42 percent since 1980, progress in other South Asian countries, such as Bangladesh and Nepal, has been more rapid. Thus India has the potential to quicken the reduction in neonatal mortality, especially through the expansion of perinatal and neonatal health services.

The neonatal period is defined as the first 28 days of life. According to Lawn et al. (2006), deaths during the first seven days of life account for 75 percent of all neonatal deaths. The neonatal period, especially the first week, is a critical time for promoting survival and healthy development. In this analysis, we assessed the cost-effectiveness of five intervention packages to reduce neonatal deaths:

1. **essential birth care,** including immediate drying, warmth, early breastfeeding, hygiene maintenance, and infection prevention;
2. **postnatal visits** to promote healthy home care practices, including exclusive breastfeeding, warmth protection, clean cord care, and seeking care in emergencies;
3. **neonatal resuscitation** using skilled attendants to provide stimulation for newborns who do not breathe spontaneously;
4. **extra care for small newborns** to provide extra support for low birth weight and premature newborns, including warmth, feeding, and illness identification and management; and
5. **emergency care** for the management of ill infants, especially those with neonatal infections requiring antibiotics.[3]

[3] Lawn et al. (2006) focus on emergency care to manage infection, which is the most prevalent neonatal illness and the most feasible to scale up. We analyzed emergency care using estimates of incidence and treatment costs for neonatal sepsis and pneumonia and assumed that these two diseases are the primary causes of neonatal infection.

We calculated the avertable disease burden, in terms of death and discounted YLL, and the costs associated with each intervention. Our analysis modeled the cost-effectiveness of providing these interventions for one year. We used the population of children less than one year of age, reported in India's 2001 census, as an estimate of the number of newborns in a given year. We assumed that the essential birth care and postnatal visit interventions were provided for all births, and that neonatal resuscitation, extra care for small newborns, and emergency care were provided only in acute cases requiring treatment.

Currently, 41 percent of births in India take place within a health facility, and 48 percent of newborns experience "safe delivery" in a health facility or aided by a health worker (IIPS 2007). We used the average of state coverage rates, weighted by the yearly number of births, to calculate the institutional birth and safe delivery coverage in the EAGA and non-EAGA states (see Table 5-1). Since our objective was to calculate the cost-effectiveness and avertable disease burden of additional coverage, these estimates informed our calculations of underlying mortality rates, averted deaths, and costs.

We applied the estimates for safe delivery coverage to our analysis of the essential birth care intervention. For neonatal resuscitation, extra care for small newborns, and emergency care, we applied the institutional birth coverage levels. For postnatal visits, we used coverage estimates for the South Asia region from Lawn et al. (2006).

Effectiveness estimates were taken from Lawn et al. (2006) and represent the reduction in the all-cause neonatal mortality rate in response to a given intervention. These estimates are based on geographically diverse data and therefore are reported as broad ranges (see Table 5-3). We used the underlying mortality rate along with estimates of population, effectiveness, and coverage to determine the avertable deaths and YLLs from implementing a given intervention. We did not consider the benefits of averted morbidity due to the interventions' impacts on neonatal conditions that do not result in death. Including these benefits would lower cost-effectiveness ratios.

We assumed that neonatal resuscitation, extra care for small newborns, and emergency care were applied in acute cases only, using incidence estimates drawn from the National Commission on Macroeconomics and Health (NCMH 2005) (see Table 5-2). The incidence of newborns who do not breathe spontaneously was from Lawn et al. (2006). Based on these incidence estimates and per patient costs of treatment (see Table 5-4), we determined the costs associated with treating all cases that were not yet covered. All costs were based on values published by the commission (NCMH 2005). We also assumed that essential birth care required

a midwife or community worker for one full day, and postnatal visits required a midwife or community worker for seven days.[4]

Cost-effectiveness results are reported in Table 5-5 and Figure 5-1. Essential birth care (Rs.36–56 per YLL averted) and postnatal visits (Rs.186–841 per YLL averted) emerged as highly cost-effective interventions throughout India. Emergency care for ill newborns (Rs.2,830–8,090 per YLL averted) was the least cost-effective intervention overall, primarily because of the high costs of treatment. In general, all of the interventions were relatively more cost-effective in the EAGA states, which have lower levels of current coverage. Regardless of which incidence estimate was used, neonatal resuscitation was the most cost-effective of the acute interventions we examined (Rs.250–4,810 per YLL averted). However, as the resuscitation results show, our results were sensitive to the different incidence estimates from Lawn et al. (2006) and the National Commission on Macroeconomics and Health (2005). In the case where incidence is based on the commission's data, the cost-effectiveness of resuscitation was similar to that of postnatal visits. Additionally, as shown by the error bars in Figure 5-1, the cost-effectiveness of an intervention varied widely depending on the efficacy of treatment. India-specific estimates of efficacy for these interventions would greatly improve the precision of this analysis.

Avertable health burden is reported in Table 5-6. Essential birth care and postnatal visits averted the greatest number of deaths and YLLs because they were associated with higher underlying mortality rates. Across all of the interventions, the majority (75 to 90 percent) of avertable burden exists in the EAGA states because current coverage levels are less than in the non-EAGA states.

[4] Assumptions based on average duration of labor (Liao et al. 2005) and definition of early neonatal period (Lawn et al. 2006).

Table 5-1. Coverage of institutional and aided births in India

	Institutional delivery	Safe delivery (institutional or aided by a health worker)
India (birth-weighted average)	38.5%	45.9%
EAGA (birth-weighted average)	25.2	32.7
Non-EAGA (birth-weighted average)	58.7	65.6

Source: IIPS 2007

Table 5-2. Incidence of acute cases requiring neonatal treatment interventions in India

Intervention		Source
Neonatal resuscitation		
Percentage of newborns not breathing spontaneously	5–10 (midpoint: 7.5)	Lawn et al. 2006
Cases per lakh population	25	NCMH 2005
Extra care for small newborns		
Low birth weight (1,500–1,800g): cases per lakh population	99	NCMH 2005
Low birth weight (1,800–2,500g): cases per lakh population	570	NCMH 2005
Emergency care for ill newborns		
Neonatal sepsis: cases per lakh population	25	NCMH, 2005
Acute respiratory infections (severe pneumonia): cases per lakh population	322	NCMH, 2005

Table 5-3. Effectiveness of neonatal interventions

Intervention	Reduction in all-cause neonatal mortality rate
Essential birth care	20–30%
Postnatal visits	10–40
Neonatal resuscitation	10–25
Extra care for small newborns	20–40
Emergency care for ill newborns	20–50

Source: Lawn et al. 2006

Table 5-4. Costs for neonatal interventions in India

Essential birth care	
Cost per day for midwife or community worker	Rs.11.68
Postnatal visits	
Cost per day for midwife or community worker	Rs.11.68
Neonatal resuscitation	
Cost per patient	Rs.1,440.36
Extra care for small newborns (1,500–1,800g)	
Cost per patient	Rs.1,425.78
Extra care for small newborns (1,800–2,500g)	
Cost per patient	Rs.1,297.37
Emergency care for ill newborns	
Cost per patient for pneumonia	Rs.3,940.6
Cost per patient for neonatal sepsis	Rs.6,296.29

Source: NCMH 2005

Table 5-5. Cost-effectiveness of neonatal interventions in India

		Postnatal visits	**Essential birth care**	**Resuscitation** (incidence estimates from Lawn et al. 2006)	**Resuscitation** (incidence estimates from NCMH 2005)	**Extra care for small newborns**	**Emergency care for ill newborns**
	Assumed efficacy*	*Rs./YLL averted*					
India	Low	841	57	4,810	666	6,420	8,090
	High	186	36	1,810	250	2,940	2,830
EAGA	Low	732	51	4,250	488	5,170	6,020
	High	163	33	1,640	188	2,450	2,220
Non-EAGA	Low	1,070	69	5,970	1,010	9,550	12,000
	High	237	42	2,170	368	4,140	3,850
	Assumed efficacy*	*US$/YLL averted*					
India	Low	18	1.2	106	15	141	178
	High	4.1	0.79	40	5.5	65	62
EAGA	Low	16	1.1	94	11	114	132
	High	3.6	0.72	36	4.1	54	49
Non-EAGA	Low	23	1.5	131	22	210	265
	High	5.2	0.93	48	8.1	91	85

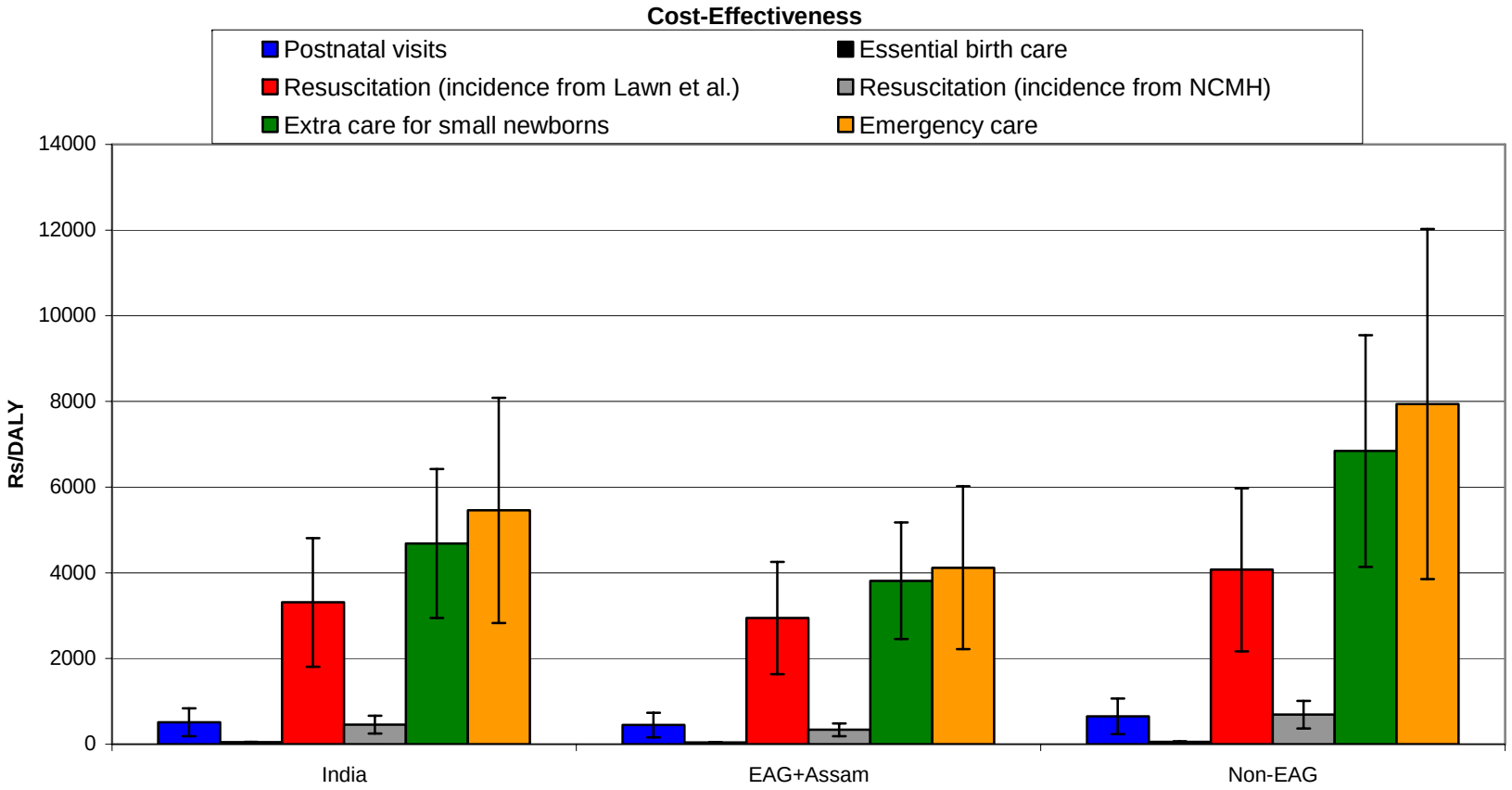
*Note: "Low" indicates that the calculations assumed the lower estimate of effectiveness as reported in Table 5-3; "high" indicates that the calculations assumed the higher estimate of effectiveness as reported in Table 5-3.

Table 5-6. Avertable burden with neonatal interventions in India

	Postnatal visits	Essential birth care	Neonatal resuscitation	Extra care for small newborns	Emergency care for ill newborns
Avertable deaths					
India	61,600–277,000	111,000–175,000	13,600–36,300	34,600–75,500	44,500–127,000
EAGA	41,000–185,000	88,900–138,000	10,900–28,300	27,200–57,500	35,000–95,100
Non-EAGA	20,600–92,800	24,600–39,900	3,100–8,600	8,100–18,800	10,500–32,700
Avertable YLLs					
India	1,740,000–7,830,000	3,120,000–4,930,000	385,000–1,020,000	977,000–2,130,000	1,260,000–3,590,000
EAGA	1,130,000–5,110,000	2,460,000–3,830,000	302,000–785,000	754,000–1,590,000	970,000–2,630,000
Non-EAGA	590,000–2,660,000	704,000–1,140,000	89,700–247,000	233,000–537,000	299,000–935,000

Note: Ranges capture the variability due to uncertain estimates of efficacy (see Table 5-3).

Figure 5-1



Note: Error bars capture the variability due to uncertain estimates of efficacy (see Table 5-3).

6. Malaria

Malaria persists as a major health problem in India. The reported incidence of malaria over the past decade was between two million and three million cases per year, with about 1,000 deaths reported annually (Dua 2005). About one-half to one-third of cases in India are caused by the deadlier species of parasite, *Plasmodium falciparum* (Pf), with most of the rest caused by the less dangerous *Plasmodium vivax* (Pv). Malaria is concentrated in the EAGA states, with the largest number of cases reported from Orissa, followed by Gujarat, Chhattisgarh, West Bengal, Jharkhand, Karnataka, Uttar Pradesh, and Rajasthan (Sharma 2006). The consensus is, however, that malaria incidence and mortality are grossly underreported. Information gathered by the National Vector-borne Disease Control Program is based only on cases treated in the public health sector and thus neglects the large proportion of cases in the private sector that are unreported. The Center for Global Health Research estimated 196,000 deaths due to malaria in India per year, with most of these (76 percent) occurring in the EAGA states.

We calculated the average cost-effectiveness of multiple strategies for providing pharmaceutical treatment for acute symptomatic malaria, as well as of implementing vector-based measures that prevent transmission. We also calculated the incremental cost-effectiveness ratio of replacing the prevailing treatment regime in India, which relies on chloroquine as the first-line treatment, with newer drugs, in addition to the incremental cost-effectiveness of undertaking preventive strategies in combination with chloroquine treatment. We used state-specific incidence rates (total and Pf) from 2003 published by the National Commission on Macroeconomics and Health (Dua 2005). Uniform intervention effectiveness rates and per capita costs were assumed for the three state categories because state-specific information was not available. Cost-effectiveness was calculated as the ratio of total costs of the intervention and the total averted deaths, discounted YLL, or DALYs. Interventions were modeled for a single year.

This analysis required several assumptions drawn from the literature. We calculated the incidence rate for Pv malaria as the difference between the total rate and the Pf rate, under the assumption that Pf and Pv account for virtually all cases of malaria in India (Breman et al. 2006). We assumed that 1 percent of Pv cases and 15 percent of Pf cases were serious and required hospitalization (Sharma 1996), with the remaining cases obtaining treatment as outpatients (RBM 2005). However, malaria mortality was assumed as entirely due to Pf infection only, given the rarity of deaths caused by Pv malaria (Mendis et al. 2001; Panda and Mohapatra 2004; Breman et al. 2006). We also assumed an average duration of illness of eight days per episode

(Konradsen et al. 1997; Mendis et al. 2001). We assumed that coverage for identification and treatment of malaria with chloroquine was 80 percent in India (RBM 2005).

Using the total number of malaria cases drawn from the National Commission on Macroeconomics and Health (Dua 2005) and the age-specific mortality information from the Center for Global Health Research, we estimated the number of cases for each age group based on the age distribution of deaths. In doing so, we assumed that the case fatality of malaria was constant across age groups.

In addition to the disease burden due to mortality, this analysis also considered three cotemporaneous and lifetime sequelae of malaria—acute infection, acute anaemia, and permanent neurological disorders—using disability weights published by Murray and Lopez (1996). Although all malaria cases cause disability due to acute infection, we assumed that only serious Pf cases requiring hospitalization were severe enough to cause anaemia and the cerebral malaria that results in permanent cognitive impairment. We assumed that 7 percent of hospitalized Pf cases were anaemic and 41 percent involved cerebral malaria (Satpathy et al. 2004; SEAQUAMAT 2005). Among patients with cerebral malaria, 5.6 percent of survivors develop permanent neurological disorders (Holding and Snow 2001). Preventive interventions were modeled as averting both disability and mortality. We assumed that pharmaceutical treatment of malaria results in averted death only, and not disability, because the disability weights for the treated and untreated forms of malaria are nearly indistinguishable, according to Murray and Lopez (1996).

Pharmaceutical interventions

Three alternative first-line treatments for malaria were investigated: chloroquine, mefloquine, and artemisinin-based combination therapy (ACT). We assumed an effectiveness rate of 100 percent for all three drugs against Pv malaria, given the extreme rarity of drug-resistant Pv (Mendis et al. 2001). Against Pf malaria, we assumed effectiveness rates of 66 percent for chloroquine, 95.5 percent for mefloquine, and 93.6 percent for ACT, based on a review of efficacy studies in India (RBM 2005). We did not consider any external effects of reduced transmission over time due to drug treatment because all interventions were modeled for a single year. We assumed that treatment had no impact on the duration of illness, given that estimates from placebo-controlled studies do not exist.

Pf and Pv can occur simultaneously in a population. Pf tends to outcompete Pv when transmission rates are high, as in sub-Saharan Africa. However, in India, where transmission rates are more moderate, both types are prevalent. Studies of relative prevalence over time in Sri

Lanka suggest that it can depend on the level of Pf resistance to chloroquine (Mendis et al. 2001). Pf infections show symptoms and are treated before the parasite passes to mosquitoes, whereas Pv infections show symptoms after mature gametocytes have already formed. This life-cycle difference has two important consequences for relative prevalence. First, drug treatment decreases transmission rates for Pf but not Pv, so after treatment is introduced to a population, Pf infection decreases relative to Pv. Second, drug treatment acts as a selective pressure favoring drug-resistant mutants of Pf, but not for Pv, so resistance occurs mainly in Pf malaria and very rarely in Pv. When Pf develops drug resistance, its prevalence relative to Pv resurges. Pf currently accounts for 47 percent of malaria in India (55 percent in EAGA states, 37 percent in non-EAGA states), and chloroquine is about 66 percent effective against Pf in India. Therefore, we assumed that Pf, Pv, and drug-resistant Pf coincide in Indian populations.

Outpatient costs were assumed to be Rs.126 per patient when accounting for wage, diagnostic, and systems costs only (NCMH 2005). We also assumed a cost of Rs.573 per patient for inpatient care, which includes costs for hospitalization, ancillary treatment, wages, and diagnostics[5] (Gogtay et al. 2003). The course of pharmaceutical treatment costs Rs.10 for chloroquine and Rs.130 for mefloquine, based on costs within India (Gogtay et al. 2003). For a course of ACT we assumed a cost of US$2.13 (Rs.97 at current exchange rates) (Sharma 2006), which is the WHO-negotiated price available to eligible developing countries, including India. We did not include travel costs incurred by the patient or the costs of lost wages due to infection.

In addition to the average cost-effectiveness of each drug intervention, we also calculated the incremental cost-effectiveness of replacing the current prevailing first-line treatment, chloroquine, with mefloquine or ACT. We also examined the average and incremental cost-effectiveness of replacing chloroquine with a newer drug for only those patients diagnosed with Pf malaria, while assuming that patients diagnosed with Pv malaria continue to receive chloroquine.

Average cost-effectiveness ratios are reported in Table 6-1. Providing ACT for Pf malaria patients only, with the rest receiving chloroquine, is the most cost-effective intervention (Rs.50 per YLL averted, Rs.970 per death averted), though essentially equivalent in cost-effectiveness to doing the same with mefloquine (Rs.53 per YLL averted, Rs.1,020 per death averted). Giving

[5] We assumed that Paracheck, a blood antigen stick test for Pf histidinerich protein 2 (HRP2) made domestically within India, would be used for Pf diagnosis. Diagnostic costs are present in all treatment strategies regardless of whether they differentiate treatment according to Pv and Pf, because of the potential deadliness of Pf.

either of the newer drugs for all malaria patients was generally less cost-effective than providing chloroquine because of the high cost of the newer drugs. Moreover, chloroquine still has a relatively moderate effectiveness rate in India, and Pf malaria has yet to reach the levels of resistance prevalent in some other countries. Interventions were more cost-effective in the EAGA states than in the non-EAGA states because of the higher malaria mortality rates in the former.

Incremental cost-effectiveness ratios of replacing the prevailing chloroquine treatment with the two drug alternatives are reported in Table 6-2. Replacing chloroquine with ACT for Pf patients only is most cost-effective, at only Rs.33 per YLL averted (Rs.640 per death averted). Replacing chloroquine with mefloquine for the Pv patients is similarly cost-effective (Rs.43 per YLL averted, Rs.830 per death averted).

Total avertable disease burden, given 80 percent treatment coverage, is reported in Table 6-3. Mefloquine interventions avert the most disease burden, 61 lakh YLLs equivalent to 3.2 lakh deaths, because of this drug's higher efficacy rate, with ACT interventions a close second (60 lakh YLLs, 3.1 lakh deaths). The total avertable burden for treating all malaria patients with the newer drug is the same as treating just the Pf patients because we assumed the averted burden in both cases would come from reduced Pf mortality only.

Preventive interventions

Two alternative interventions to prevent the transmission of malaria were analyzed: in-house residual spraying with insecticide ("spraying"), and insecticide-treated bed nets ("nets"). We assumed that spraying would reduce malaria cases by 31 percent and that providing nets would reduce cases by 57 percent, based on results from India reported by Bhatia et al. (2004). We also assumed that reduction rates would be the same for Pv and Pf malaria, as well as for both morbidity and mortality, in effect assuming constant case fatality ratios for Pf malaria, and constant efficacy of intervention regardless of malaria species or severity. Again, we did not consider any external effects of reduced transmission rates in the long run due to preventive action because all interventions were modeled for a single year. We assumed that the annual cost per person protected was Rs.55 for spraying and Rs.61 for nets (Bhatia et al. 2004). We also assumed 80 percent coverage, the same as for drug treatment coverage. In addition to the average cost-effectiveness of spraying or providing nets, we also calculated the incremental cost-effectiveness relative to the baseline intervention of chloroquine treatment for all cases. The incremental cost of preventive intervention was calculated as the total cost minus the averted costs of treatment for the prevented cases. The incremental effect of the intervention was

calculated as the total averted burden minus the deaths or YLLs averted had the prevented cases been treated with chloroquine.

Providing nets is more cost-effective than spraying because of its greater efficacy at similar cost. The cost-effectiveness ratios for preventive interventions are quite high, at Rs.23,000 per DALY averted for spraying and Rs.13,000 per DALY averted for nets (Table 6-1), the result of high per capita costs and moderate effectiveness rates. Each death averted costs Rs.4,41,000 with spraying and Rs.2,61,000 with nets. Incremental cost-effectiveness ratios are also quite high: Rs.66,000 per DALY averted with spraying and Rs.39,000 per DALY averted with nets. The cost per averted disease burden is greater in the non-EAGA states than in the EAGA states because of the greater mortality rates in the latter.

Although we find that spraying and nets are not relatively cost-effective, their cost-effectiveness improves with higher baseline levels of malaria morbidity and mortality. Bhatia et al. (2004) estimated the incremental cost per malaria case averted at Rs.3,410 for spraying and Rs.2,019 for nets in a high-risk district in Gujarat. Using the DALYs-to-case-averted ratios generated in our analysis, these cost-effectiveness ratios are approximately equivalent to Rs.754 per DALY averted with spraying and Rs.448 per DALY averted with nets, a substantial improvement.

Our analysis also confirms the improved cost-effectiveness in settings of greater malaria risk, particularly when combined with increased Pf prevalence. Orissa, where incidence is 11 malaria cases per 1,000 people per year and 83 percent of these are Pf, has the highest malaria incidence in India. Assuming that the case fatality and the age distribution of malaria mortality for Orissa are similar to those of other EAGA states, the average cost-effectiveness ratios are Rs.1,200 per DALY averted for spraying and Rs.720 per DALY averted for nets (Rs.24,000 and Rs.14,000 per death averted, respectively). The incremental cost-effectiveness ratios in Orissa for spraying and nets were Rs.2,700 and Rs.1,600 per DALY averted, respectively. Therefore, spraying and nets are more appropriate when targeted at specific areas with high risk.

The total avertable disease burden with preventive treatment is lower than with drug coverage because of the lower effectiveness rates of such strategies. Spraying prevents 20 lakh DALYs, including 1 lakh deaths in India. Alternatively, nets prevent 37 lakh DALYs, including 1.9 lakh deaths.

Table 6-1. Average cost-effectiveness ratios of interventions against malaria

Rs. per YLL averted

	CQ for all	CQ for Pv; ACT for Pf	ACT for all	CQ for Pv; MQ for Pf	MQ for all	IRS	ITN
India	57	50	61	53	67	23,000	13,000
EAGA	37	33	39	35	43	11,000	6,000
non-EAGA	55	46	60	48	67	33,000	20,000

Rs. per DALY averted

Rs. per death averted

	CQ for all	CQ for Pv; ACT for Pf	ACT for all	CQ for Pv; MQ for Pf	MQ for all	IRS	ITN
India	1110	970	1180	1020	1300	441,000	261,000
EAGA	730	660	770	700	850	211,000	125,000
non-EAGA	1260	1050	1360	1090	1510	762,000	451,000

Rs. per death averted

CQ = chloroquine

MQ = mefloquine

IRS = in-home residual spraying with insecticide

ITN = insecticide-treated bed net

Table 6-2. Incremental cost-effectiveness relative to current malaria treatment strategy (chloroquine only for all patients)

Rs. per additional YLL averted — Rs. per DALY averted

	CQ for Pv; ACT for Pf	ACT for all	CQ for Pv; MQ for Pf	MQ for all	IRS	ITN
India	33	70	43	90	66,000	39,000
EAGA	24	44	31	56	31,000	18,000
non-EAGA	24	71	31	92	98,000	58,000

Rs. per additional death averted — Rs. per death averted

	CQ for Pv; ACT for Pf	ACT for all	CQ for Pv; MQ for Pf	MQ for all	IRS	ITN
India	640	1400	830	1700	1,290,000	760,000
EAGA	480	900	620	1100	620,000	370,000
Non-EAGA	540	1600	700	2100	2,240,000	1,320,000

CQ = chloroquine

MQ = mefloquine

IRS = in-home residual spraying with insecticide

ITN = insecticide-treated bed net

Table 6-3. Total avertable disease burden by malaria intervention (at 80 percent coverage)

YLL or DALYs

	CQ for all (YLL)	CQ for Pv; ACT for Pf (YLL)	ACT for all (YLL)	CQ for Pv; MQ for Pf (YLL)	MQ for all (YLL)	IRS (DALYs)	ITN (DALYs)
India	4,200,000	6,000,000	6,000,000	6,100,000	6,100,000	2,000,000	3,700,000
EAGA	4,300,000	6,100,000	6,100,000	6,200,000	6,200,000	2,000,000	3,800,000
non-EAGA	1,500,000	2,200,000	2,200,000	2,200,000	2,200,000	700,000	1,300,000

Deaths

	CQ for all (YLL)	CQ for Pv; ACT for Pf (YLL)	ACT for all (YLL)	CQ for Pv; MQ for Pf (YLL)	MQ for all (YLL)	IRS (DALYs)	ITN (DALYs)
India	220,000	310,000	310,000	320,000	320,000	100,000	190,000
EAGA	220,000	310,000	310,000	310,000	310,000	100,000	190,000
non-EAGA	70,000	90,000	90,000	100,000	100,000	30,000	60,000

CQ = chloroquine

MQ = mefloquine

IRS = in-home residual spraying with insecticide

ITN = insecticide-treated bed net

7. Childhood vaccinations: Expanding coverage and adding antigens

India's Universal Immunization Program (UIP) is one of the largest in the world. Launched in 1985 to replace immunization policies in place since the 1960s, the objectives of the program were to rapidly increase immunization coverage; improve service quality, establish a reliable cold chain, introduce a district system for monitoring performance, and achieve self-sufficiency in vaccine production. National immunization has resulted in the steady decline in infant mortality from 129 deaths per 1,000 live births in 1971 to 63 deaths per 1,000 live births in 2002 (Government of India 2005). Despite this improvement, the objectives of the UIP have yet to be fully achieved. Childhood-cluster diseases have persisted, currently causing 4.7 percent of all deaths in India among children under five years of age.

We calculated the costs and outcomes of expanding coverage of the childhood vaccines commonly provided on the current UIP schedule (Government of India 2005). We also computed the cost-effectiveness of adding antigens to the schedule: a second dose of measles vaccine, hepatitis B (HepB), *Haemophilus influenzae* type B (Hib), *Streptococcus pneumoniae*, and rotavirus. In addition, we calculated the cost-effectiveness of replacing the current diphtheria-tetanus-pertussis (DTP) inoculation with a DTP-HepB combination vaccine or a DPT-HepB-Hib pentavalent vaccine.

Costs and outcomes of providing immunization to a single cohort of children born in one year were calculated. Uniform durations of immunity, effectiveness rates, and dosage costs were assumed across the three state categories because state-specific data were not available (see Table 7-1). Effectiveness rates were obtained from Brenzel et al. (2006), except for Bacille Calmette Guerine vaccine (BCG) (Trunz et al. 2006), HepB (WHO 2000), and rotavirus (author's calculations). The dosage costs listed in Table 7-1 are estimates of the antigen price only. Aside from these costs, this analysis also included the costs of service delivery, human resources and training, cold chain, injection safety, and monitoring. Based on information from the Multi-Year Strategic Plan costing exercise by the Government of India (Government of India 2005), we estimated the additional cost of providing these vaccination-related services at Rs.17 per vaccination opportunity per child. Current coverage information for UIP antigens was obtained from the International Institute of Population Sciences Reproductive and Child Health District Level Household Survey (IIPS 2007) (see Table 7-2).

Cost-effectiveness was calculated as the ratio of total costs of the intervention and the total averted deaths and discounted YLL. We did not consider the long-term disability impacts due to vaccine-preventable illness, given the relatively small impact of morbidity compared with

that of deaths in children under five. Including these benefits would lower cost-effectiveness ratios.

In India, vaccinations are provided both in public health facilities and by private doctors. Although states may occasionally conduct outreach or information campaigns to bolster coverage, we did not include the costs of those activities in this analysis.

Table 7-3 reports the cost-effectiveness of expanding UIP coverage and including additional vaccines, and Table 7-4 lists the avertable disease burden. Here we look at the methods and results for each analysis.

Expanding Universal Immunization Program coverage

Approximately 120,000 childhood and adolescent deaths in India each year are caused by tubercular meningitis, diphtheria, tetanus, pertussis, polio, and measles, mostly in the EAGA states where immunization coverage is lower (see Table 7-2). We calculated the cost-effectiveness of expanding coverage to the proportion of the population not fully immunized against these diseases. Under the UIP schedule, the BCG vaccine is given for protection against tuberculosis, oral polio vaccine against polio, and a combination diphtheria-tetanus-pertussis conjugate vaccine against those three diseases. Multiple doses spaced weeks apart are required for complete immunization against polio and DPT (which requires three inoculations, hence DTP3). Individuals who did not receive a full course of a particular vaccine were not considered part of the covered population because of the uncertain and waning efficacy of partial immunization. We considered only those vaccines that are scheduled through the first year of life because we lack information on coverage of booster doses given after that time. Our results are reported in terms of YLL and deaths averted; thus we did not include the disability cotemporaneous with infection and long-term developmental disability in the averted burden.

BCG vaccination has proven highly effective against miliary and meningitis forms of tuberculosis—the two principal causes of TB-related deaths among young children—but not against pulmonary TB. We assumed a ratio of miliary to meningitis TB at 0.375 (Trunz et al. 2006).

The cost-effectiveness ratio of expanding UIP coverage in India is approximately Rs.190 per YLL averted, or Rs.5,100 per death averted (see Table 7-3). We found lower cost-effectiveness ratios for the EAGA and non-EAGA states, Rs.150 and Rs.90 per YLL averted, respectively. These ratios are lower likely because of the higher mortality rates reported in the

Center for Global Health Research data for each EAGA and non-EAGA state than for all India combined.

Expanding UIP vaccines from current coverage rates to full coverage in India would result in at least 107 lakh YLLs averted, equivalent to 4.1 lakh deaths (see Table 7-4). Full coverage would avert 112 lakh YLLs in the EAGA states and 47 lakh YLLs in the non-EAGA states. Again, the averted burden in both categories do not sum to the averted burden calculated for all India because of discrepancies in the Center for Global Health Research mortality data.

Adding a second dose of measles vaccine

India suffers 50,000 measles deaths per year, with at least 60 percent occurring in the EAGA states. We calculated the cost-effectiveness of adding a second dose of measles to the UIP schedule. This would occur at 12 months of age, 3 months after the first measles dose—thus within the first year of life, when parents are still actively seeking (or being reminded by doctors to obtain) vaccinations for their children. We assumed that measles immunization is 85 percent effective after one dose at 9 months and 98 percent effective after a second dose (Brenzel et al. 2006). The effect of the second dose was therefore calculated as the averted disease burden due to the additional efficacy. Our results are reported in terms of YLL and deaths averted; we did not include the disability cotemporaneous with infection and long-term developmental disability in the averted burden.

We calculated the cost-effectiveness of a second measles dose at Rs.1,900 per YLL averted, equivalent to Rs.48,000 per death averted (see Table 7-3). A second measles dose is more cost-effective in the non-EAGA states (Rs.900 per YLL averted) than in the EAGA states (Rs.1600 per YLL averted) because of the greater underlying measles mortality in the former. These relatively high cost-effectiveness ratios suggest that a second dose of measles would have a low marginal impact relative to other vaccines that could be included in the schedule (see Table 7-4). Scheduling a second measles dose in the non-EAGA states would have three times the health impact of doing so in the EAGA states because of the higher prevailing immunization coverage in the non-EAGA states.

Adding hepatitis B and Haemophilus influenzae type B vaccines

Up to 100 times more infectious than HIV, hepatitis B is second only to tobacco as a recognized cause of cancer worldwide (Davey 2002). Most infections are due to mother-to-child and child-to-child transmission, and one in four children infected before age seven become long-term carriers with no symptoms until later in life. There are nearly 40,000 liver cancer deaths in

India each year, mostly in the non-EAGA states, and as many as 80 percent of these are due to HepB. Moreover, HepB contributes to 60 percent of other liver diseases in India. The UIP has introduced the HepB antigen as part of the immunization schedule in a pilot project of 33 districts and slums of 15 major cities, but implementation has been slow because of poor health care delivery in urban slums (Government of India 2005).

Haemophilus influenzae type B is a leading cause of pneumonia in developing countries, causing up to 20 percent of severe pneumonia as well as two-thirds to one-half of bacterial meningitis in children (Davey 2002). In India, it is the cause of at least 57,000 deaths per year, largely in the EAGA states.

We calculated the cost-effectiveness of multiple strategies for including HepB into the UIP schedule, both as a standalone antigen and as part of a DTP-HepB conjugate vaccine. We also calculated the cost-effectiveness of a standalone Hib vaccine, as well as that of a DTP-HepB-Hib pentavalent vaccine. In the cost-effectiveness analyses involving the HepB antigen, we assumed that 80 percent of liver cancer deaths and 60 percent of liver cirrhosis deaths were due to HepB virus. We also assumed that the Hib bacterium caused 20 percent of deaths from acute lower respiratory illness (ALRI) and approximately 42 percent of meningitis (Davey 2002). Because these vaccines would either replace or be given at the same time as DTP, we estimated the costs and outcomes of providing the new vaccines to the population currently receiving the full DTP course coverage only.

The DTP-HepB or DTP-HepB-Hib vaccines would replace the current DTP vaccine, so we calculated the net cost of including these vaccines by taking the estimated dose prices of each (Rs.43 and Rs.148, respectively) and subtracting the current cost per dose of DTP vaccine (Rs.1.12) from the Multi-Year Strategic Plan costing exercise by the Government of India (Government of India 2005). We assumed that switching to these new vaccines would result in no additional costs associated with service delivery, human resources and training, cold chain, injection safety, and monitoring beyond what is already spent on the current DTP vaccine. Our results are reported in terms of YLL and deaths averted; we did not include the disability cotemporaneous with infection and long-term developmental disability in the averted burden.

The cost-effectiveness of a standalone HepB antigen was Rs.1,100 per YLL averted and Rs.6,400 per death averted (see Table 7-3). The cost-effectiveness ratio was greater in the EAGA states than in the non-EAGA states (Rs.2,100 and Rs.900 per YLL averted, respectively) because of the higher underlying mortality rates from liver cancer and liver cirrhosis in the latter. The cost-effectiveness of the DTP-HepB conjugate vaccine was Rs.1,500 per YLL averted in India,

suggesting that the cost savings from combining the two vaccines, Rs.50 for all three doses, did not surpass the greater expense of the vaccine itself. Because we did not vary efficacy with the delivery vector, the avertable disease burdens from HepB and DTP-HepB vaccines, at current DTP3 coverage levels, were identical at 1.6 lakh YLL averted, or 4.1 lakh deaths averted (see Table 7-4). The majority of this avertable disease burden occurred within the non-EAGA states because of their higher mortality rates and greater baseline vaccine coverage.

The cost-effectiveness of a standalone Hib antigen was Rs.2,500 per YLL averted, equivalent to Rs.66,000 per death averted (see Table 7-3). Hib vaccination is similarly cost-effective in the EAGA and non-EAGA states (Rs.1,600 and Rs.1,500 per YLL averted, respectively) because of the similar mortality rates from ALRI and meningitis. The avertable burden via Hib vaccination was 32 lakh YLL, or 1.2 lakh deaths, at baseline DTP3 coverage levels (see Table 7-4). Despite similar cost-effectiveness ratios, the avertable burden in the non-EAGA states was three times that of the EAGA states because of the greater coverage in the former.

The cost-effectiveness of replacing the current DTP vaccine with a pentavalent DTP-HepB-Hib conjugate vaccine was Rs.3,000 per YLL averted, or Rs.27,000 per death averted (see Table 7-3). As with the DTP-HepB conjugate vaccine, the cost savings from combining the three vaccines did not surpass the greater expense of the vaccine itself. And as with the DTP-HepB conjugate vaccine, the reduced disease burden with the pentavalent vaccine was the same as for the standalone antigens (see Table 7-4).

Adding a Streptococcus pneumoniae *vaccine*

Streptococcus pneumoniae is the most common cause of bacterial ALRI in children. The bacterium also often causes otitis media, bacteraemia, sepsis, and meningitis in early childhood (Sinha et al. 2007). It is responsible for at least 200,000 deaths per year in India.

In calculating the cost-effectiveness of adding *Streptococcus pneumoniae* antigen to the UIP schedule, we assumed that the vaccine is 70 percent effective against pneumonia and 92 percent effective against meningitis caused by *S. pneumoniae* (Cutts et al. 2005). Because we lack disease burden information specific to *S. pneumoniae*, we assumed that 80 percent of ALRI deaths, under the presumption that *S. pneumoniae* and Hib are the predominant causes of ALRI mortality. We also assumed that 13 percent of meningitis deaths are caused by *S. pneumoniae* (Lazoff 2005).

The *Streptococcus pneumoniae* vaccine is relatively new and discounted prices for developing countries have yet to emerge. We used a cost per dose of Rs.73 (Sinha et al. 2007), under the assumption that the two-tiered pricing scheme used in international public vaccine markets will apply to pneumococcal vaccine. India is eligible for financial support from the Global Alliance for Vaccines and Immunization.

We found the cost-effectiveness of providing pneumococcal vaccine to be Rs.620 per YLL averted, or Rs.16,500 per death averted. Providing immunization at current DPT3 coverage levels could prevent 85 lakh YLLs due to ALRI and meningitis, equivalent to 3.2 lakh deaths.

Adding a rotavirus vaccine

Rotavirus infection is the leading cause of severe acute gastroenteritis and diarrhea among children worldwide (Podewils et al. 2005). In India, about a quarter of all hospitalized diarrhea cases are due to rotavirus (Kang et al. 2005). In 1998, approximately 98,000 childhood deaths were caused by rotavirus (Kang et al. 2005), with greater disease burden in the EAGA states than in the non-EAGA states.

Because a commercialized rotavirus vaccine has only recently been introduced and has not yet been made available to developing countries at a discounted rate, we calculated the cost-effectiveness based on the midpoint of a range of estimates. A course of rotavirus immunization could cost US$2 at the low end (Podewils et al. 2005) and US$14 at the high end (Glass 2006). We therefore assumed the midpoint, US$8 or about Rs.364, as the vaccine cost for the full course of two doses. This price is higher than all other dosage costs assumed for other antigens in this analysis.

Efficacy rates for an attenuated human rotavirus vaccine were taken from Ruiz-Palacios et al. (2006). We had morbidity and mortality data only on diarrhea deaths in general, without information on specific causes. Hence, we estimated that 8.1 percent of diarrhea episodes (Parashar et al. 2003) and one-third of diarrhea deaths (Keusch et al. 2006) were due to rotavirus. Incidence of diarrhea, 1.71 episodes per child per year in rural areas and 1.09 episodes per child per year, were drawn from the National Institute of Cholera and Enteric Diseases (2005). We estimated each episode to last six days. Since the rotavirus vaccine is relatively new, the duration of protection is also currently unknown. Therefore, we considered the benefits of protection from diarrhea illness and death, in terms of DALYs averted, for the first five years of life only. Approximately 90 percent of all cases in the developing world occur between birth and age four.

Therefore, considering the effects of rotavirus immunization through age five only did not grossly underestimate the benefits.

We found the rotavirus immunization to be relatively cost-effective compared with the other antigens addressed in this exercise, at Rs.52 per DALY averted (see Table 7-3). The cost-effectiveness ratio was also low in terms of cost per death averted, at Rs.1,500, indicating that the comparatively low cost-effectiveness was not due to the inclusion of morbidity effects. Cost-effectiveness was Rs.52 per DALY averted in the EAGA states and slightly lower, at Rs.43 per DALY averted, in the non-EAGA states because of the latter's slightly higher diarrhea mortality rates. Rotavirus immunization is cost-effective despite its relatively high dosage cost because of the large amount of disease burden it could potentially reduce.

Rotavirus immunization of a cohort of newborns within a single year, provided at levels of current DTP3 coverage, could potentially avert 1.5 crore DALYs in India, equivalent to 51 lakh deaths among children under the age of five (see Table 7-4). The majority of this avertable disease burden occurred in the non-EAGA states, where baseline vaccine coverage is greater and where diarrhea mortality rates are slightly higher. Because of the high diarrheal disease-related morbidity and mortality rates, rotavirus immunization could reduce disease burden at a magnitude greater than all the other vaccines addressed in this analysis combined.

Summary of childhood vaccination results

Expanding coverage of UIP schedule vaccines was found to be relatively cost-effective, given a convenient and functional delivery system. Replacing DTP with a DTP-HepB or DTP-HepB-Hib conjugate vaccine would generally be less cost-effective than including HepB and Hib as standalone antigens because the cost savings associated with combined service delivery, human resources and training, cold chain, injection safety, and monitoring would not compensate for the increased cost of the vaccine itself. These additional costs are as low as Rs.16 because of economies of scale. Inclusions of rotavirus and streptococcus antigens were more cost-effective than other vaccines, but only by assuming discounted prices for developing countries. Among the standalone antigens, the addition of Hib was least cost-effective, followed by the addition of a second measles dose.

Among the actions evaluated in this analysis, the inclusion of rotavirus vaccine into the UIP schedule was by far the most cost-effective intervention, yielding quite high avertable disease burden and deaths. Avertable disease burden from expanding coverage was on par with the avertable burden from introducing streptococcus vaccine. The introduction of Hib and HepB antigens would relieve comparatively moderate levels of disease burden, and inclusion of a

second measles dose would avert the fewest deaths. These results suggest that inclusion of rotavirus vaccine into the UIP schedule should be a high priority, given its potential to prevent a substantial level of disease burden at current vaccination coverage levels.

Table 7-1. Characteristics of current Universal Immunization Program vaccines and additional vaccines

Vaccine	Dose schedule	Efficacy	Assumed duration of immunity	Cost per dose (Rs.)	Cost per dose (US$)	Wastage factor	Cost source
Current antigens							
BCG	Birth	69% (TB meningitis) 77% (miliary TB)	Childhood (5 years)	1	0.02	2	Government of India 2005
Oral polio	Birth, 6, 10, 14 weeks	85%	Lifelong	3	0.07	1.33	Government of India 2005
DPT	6, 10, 14 weeks	87% (diptheria) 95% (tetanus) 80% (pertussis)	5 years (diptheria) 10 years (tetanus) 10 years (pertussis)	1	0.02	1.33	Government of India 2005
Measles	9 months	85%	Lifelong	8	0.17	1.33	Government of India 2005
Additional antigens							
2nd measles	12 months	98%	Lifelong	6	0.13	1.33	Government of India 2005
HepB	6, 10, 14 weeks	95%	Lifelong	15	0.34	1.33	UNICEF procurement price, Davey 2002
Hib	6, 10, 14 weeks	95%	5 years	120	2.65	1.33	UNICEF procurement price, Davey 2002
DTP-HepB	6, 10, 14 weeks	95% (HepB)	Lifelong (HepB)	42	0.92	1.33	PATH India 2007
DTP-HepB-Hib	6, 10, 14 weeks	95% (HepB)	Lifelong (HepB)	147	3.23	1.33	UNICEF procurement price, Davey 2002

Rotavirus	6, 14 weeks	8% (all diarrhea morbidity) 33% (all diarrhea mortality)	5 years	182	4.00	1.33	Podewils et al. 2005; Glass 2006
Streptococcus	6, 10, 14 weeks	70% (pneumonia) 92% (meningitis)	5 years	73	1.60	1.33	Sinha et al. 2007

Table 7-2. Coverage levels of Universal Immunization Program vaccines (percentage of children aged 12–35 months)

Vaccine	India	EAGA	Non-EAGA
BCG	74.7	61.1	91.5
Oral polio*	58.2	41.0	78.5
DPT	59.0	41.6	79.8
Measles	58.0	40.8	78.8

Source: IIPS 2007

Table 7-3. Cost-effectiveness of expanding UIP vaccine coverage and introducing new vaccines

Rs. per YLL averted

	Expanding UIP coverage	2nd measles	HepB	Hib	DTP-HepB (replacing DTP)*	DTP-HepB-Hib (replacing DTP)**	Rotavirus***	Streptococcus
India	190	1,900	1,100	2,500	1,500	3,000	52	620
EAGA	150	1,600	2,100	1,600	2,700	3,600	52	170
Non-EAGA	90	900	900	1,500	1,200	1,500	43	300

Rs. per death averted

	Expanding UIP coverage	2nd measles	HepB	Hib	DTP-HepB (replacing DTP)*	DTP-HepB-Hib (replacing DTP)**	Rotavirus***	Streptococcus
India	5,100	48,000	6,400	66,000	6,000	27,000	1,500	16,500
EAGA	4,000	41,000	8,600	44,000	11,200	51,000	1,500	4,400
Non-EAGA	2,500	22,000	5,700	41,000	5,300	16,000	1,200	8,100

*Incremental cost-effectiveness of replacing DTP with DTP-HepB vaccine

**Incremental cost-effectiveness of replacing DTP with DTP-HepB-Hib vaccine

***Rs per DALY

Table 7-4. Avertable burden of expanding UIP vaccine coverage and introducing new vaccines

Avertable YLL

	Expanding UIP coverage*	2nd measles**	HepB**	Hib**	DTP-HepB (replacing DTP)***	DTP-HepB-Hib (replacing DTP)***	Rotavirus****	Streptococcus**
India	10,700,000	700,000	1,600,000	3,200,000	1,600,000	4,900,000	147,000,000	8,500,000
EAGA	11,200,000	300,000	400,000	1,900,000	400,000	2,300,000	59,700,000	12,500,000
non-EAGA	4,700,000	900,000	1,200,000	3,100,000	1,200,000	4,300,000	105,600,000	10,100,000

Avertable deaths

	Expanding UIP coverage*	2nd measles**	HepB**	Hib**	DTP-HepB (replacing DTP)***	DTP-HepB-Hib (replacing DTP)***	Rotavirus**	Streptococcus**
India	410,000	30,000	410,000	120,000	410,000	530,000	5,110,000	320,000
EAGA	420,000	10,000	90,000	70,000	90,000	160,000	2,110,000	470,000
non-EAGA	180,000	30,000	270,000	110,000	270,000	380,000	3,630,000	370,000

*Expansion of coverage from current levels to 100%

**At current coverage levels, equivalent to DTP3 coverage.

***Incremental averted burden at current coverage levels, equivalent to DTP3 coverage.

****Avertable DALYs, at current coverage levels, equivalent to DTP3 coverage.

8. HIV/AIDS

The first serological evidence of HIV in India appeared in 1986 among female sex workers in Tamil Nadu. Since then, HIV has been found in 29 of India's 32 states and territories, with generalized epidemics in Andhra Pradesh, Karnataka, Maharastra, Manipur, Nagaland, and Tamil Nadu (Over et al. 2004). Currently, approximately 3.8 million people in India are infected with HIV, 81 percent of who reside in the non-EAGA states. AIDS is responsible for 26,000 deaths per year.

Cost-effectiveness ratios of interventions against HIV/AIDS in India were drawn from the World Bank (1999) and Over et al. (2004). The cost-effectiveness analyses in both studies were based on a dynamic compartmental simulation model for the HIV-1 epidemic in India, described in Nagelkerke et al. (2002). The model assumed that unsafe sex work was the main driver of the epidemic and that populations were closed.

The World Bank (1999) changed the appropriate model parameters[6] to calculate the costs and outcomes of six interventions aimed at reducing transmission: targeted interventions for sex workers, targeted interventions for high-risk men, voluntary counseling and testing, education programs among youth, syndromic management of sexually transmitted infections (STIs), and prevention of mother-to-child transmission. Targeted sex worker interventions involved condom promotion programs, assumed to result in 80 percent condom use among all sex workers after five years. The authors also assumed that 50 to 80 percent of infections came from sex workers, and that interventions could reduce transmission by at least 66 percent. Targeted interventions for high-risk men involved peer-group promotion of condom use among 80 percent of all sex worker clients, with an assumption of 0.1 HIV-infected individuals per infected client. The authors assumed that voluntary counseling and testing could be delivered to a third of the sexually active population of India, resulting in a 50 percent reduction in risky sexual behavior over five years. Youth education programs, delivered through schools and peer education programs, aim to reduce risky behavior, especially among youth sex worker clients. The authors assumed that youths constituted 30 percent of the sexually active population in India and that intervention resulted in a 50 percent reduction in risky sex. Syndromic management of sexually

6 The World Bank (1999) analyses additionally assumed that incidence of HIV in India was approximately one-third of prevalence, and that approximately one percent of the Indian sexually active female population was involved in commercial sex work. The authors used universally applicable international data on infectivity and biological transmission. Intervention efficacy was drawn from randomized clinical trials or longitudinal observational studies.

transmitted infections included laboratory tests and drug costs. The authors assumed that STI management resulted in a 40 percent reduction in HIV incidence from reduced likelihood of transmission.

In examining mother-to-child transmission interventions, the authors examined multiple options: the drug azidothymidine (AZT) alone; AZT with formula feeding and no breastfeeding; AZT, formula, and delivery by caesarian section; and highly active antiretroviral therapy (HAART). The authors found that AZT-and-formula tended to be the most cost-effective intervention (Rs.6,192 per DALY averted) and that more comprehensive interventions were cost-prohibitive. The authors assumed that mother-to-child transmission was 33 percent at baseline, and transmission reduction was 33 percent for AZT alone and 80 percent for AZT with formula and Caesarian section.

Results from the World Bank study are summarized in Table 8-1. Sex worker interventions (Rs.128 per DALY averted) and STI management (Rs.113 per DALY averted) were the most cost-effective strategies to reduce disease burden caused by HIV/AIDS. Among the three strategies involving sex workers and their clients, intervention targeting the sex workers was the most cost-effective and could potentially avert the greatest number of infections after five years. Interventions for sex worker clients (Rs.744 per DALY averted), though capable of averting the same degree of disease burden as sex worker interventions, were less efficient because of the high ratio of clients to workers.

Over et al. (2004) modified the HIV-1 epidemic simulation model[7] to investigate alternative strategies involving antiretroviral (ARV) therapy in India. The authors assumed that, at baseline, 15 percent of adult males were sex worker clients, with 1.1 percent of the females acting as sex workers. They also assumed that condoms were used in half of all commercial sex transactions, in each case reducing the probability of infection to zero. They assumed that half of all HIV-positive individuals in India had AIDS or significant AIDS-related illnesses, making them eligible for ARV therapy. This eligibility period typically included about 5 of the 10 years between initial HIV infection and death.

[7] The model used epidemiological and biological parameters informed by the most recent international and Indian HIV/AIDS literature. These parameters described transmission, disease progression, and the pathways from infection to death, varying according to viral resistance and availability of ARV. The model simulates the progression of HIV for 5 years, beginning in 1998, and projects 30 additional years in the future.

Over et al. evaluated three policy options. First was ADHERE, described as a program to maintain the quality of unstructured ARV therapy at its current level by providing government financing to train private physicians and laboratories in ARV therapy and diagnostic testing. The program would also subsidize laboratory tests, the portion of treatment for which patients are least willing to pay. Maintaining the quality of ARV therapy slows the evolution and transmission of drug-resistant HIV strains while increasing the period of time during which each patient can infect others. The authors' second option was government-financed ARV therapy for all prospective mothers and their husbands who show symptoms of AIDS, to prevent mother-to-child transmission (MTCT). The MTCT+ program would also test all pregnant women receiving government antenatal care and provide nevirapine-based preventive strategy to all mothers testing positive for nonresistant HIV. The third option, Below the Poverty Line, was fully subsidized access to diagnostic testing and structured ARV therapy for the poorest 40 percent of people with symptomatic HIV.

The authors assumed that ARV therapy would postpone disease progression by three years and increase life expectancy by four years. Because ARV delays the onset of AIDS, the authors calculated estimated costs net of the reduction due to the postponed costs of treating opportunistic infections, using a discount rate of 10 percent. The authors also assumed an adherence rate of at least 80 percent for structured therapy and less than 80 percent for unstructured therapy. Structured treatment was considered to have the following components: standardized training and mandated competence levels for physicians, prescription of a nationally standard drug regimen, access to a counselor and nutritionist, access to a good-quality testing laboratory, regular monitoring, and provision of counseling to prevent transmission.

The costs, avertable disease burden, and cost-effectiveness of the three strategies are listed in Table 8-2. ADHERE increased the number of people with HIV/AIDS because the beneficial effect of reduced transmission was more than offset by the extended time during which a patient could infect others. However, extended patient survival offset the larger number of people with HIV/AIDS, resulting in a positive cost-effectiveness ratio of Rs.6,640 per YLL averted. ADHERE was also the most cost-effective of the three policies. The cost-effectiveness rates for MTCT+ (Rs.9,050 per YLL averted, Rs.90,000 per averted infection) were similar in magnitude to those found by the World Bank (1999), described above. The Below the Poverty Line strategy, though least cost-effective (Rs.12,700 per YLL averted), was capable of averting 1.7 million infections and 25.2 million YLL over 35 years, more than any other intervention.

Table 8-1. Summary of cost-effectiveness analyses for HIV/AIDS interventions reported by the World Bank (1999).

Strategy	HIV infections averted after 5 years	Infant HIV infections averted after 5 years	Program cost over 5 years (million Rs.)	Cost per HIV infection averted (Rs.)	Cost per DALY averted (Rs.)	HIV prevalence after 5 years
Sex worker intervention	5,610,000	160,000	14,400	2,600	128	0.8%
STI management	3,230,000	90,000	37,600	2,300	113	1.1%
High-risk men intervention	5,610,000	160,000	91,000	14,900	744	0.8%
Voluntary counseling and testing	3,520,000	110,000	37,700	9,600	480	1.0%
Youth intervention	3,520,000	110,000	250,900	63,900	3,192	1.0%
Mother-to-child transmission intervention (with AZT and formula)	350,000	350,000	43,300	123,800	6,192	1.5%

Table 8-2. Summary of cost-effectiveness analyses for ARV interventions reported by Over et al. (2004).
All values are discounted at 10 percent.

Strategy	Cost per patient-year (Rs.)	Incremental* infections averted over 35 years	Incremental* YLL averted over 35 years	Incremental* program cost over 35 years (million Rs.)	Cost per averted infection (Rs.)	Cost per YLL averted (Rs.)
ADHERE	5,000	-100,000	11,500,000	76,000	n.a.	6,640
MTCT+	23,000	300,000	3,000,000	27,000	90,610	9,050
Below the Poverty Line	23,000	1,700,000	25,200,000	321,000	188,700	12,700

*Incremental to current ARV expenditures

9. Vitamin A deficiency

Vitamin A deficiency is an important nutritional problem in India. With more than 20 million children with some form of this deficiency and roughly 330,000 deaths due to it each year, India has the greatest number and the greatest percentage of vitamin-A-deficient children in the world. The deficiency also affects many women, specifically causing night blindness, anaemia, and increased maternal morbidity and mortality during pregnancy and lactation.

Among vulnerable groups, vitamin A deficiency results in clinical eye symptoms related to xerophthalmia, such as night blindness, Bitot's spots, and corneal xerosis, or keratomalacia. It also causes an increased risk of severe morbidity and mortality due to anaemia and depressed resistance to infectious disease. Although vitamin A deficiency in a population is typically measured by determining the prevalence of clinical eye symptoms, most deficiency is subclinical, causing anaemia and greater susceptibility to infectious disease yet discernible only by biochemical (e.g., serum retinol concentrations), histopathologic (e.g., abnormal conjunctival cytology), or functional (e.g., dark adaptation) examination (West and Darnton-Hill 2001).

In India, clinical vitamin A deficiency has declined significantly in magnitude over the past few decades, but it persists as a public health problem (Kapil 2004). The overall prevalence of xerophthalmia among children is 1.7 percent (Mason et al. 2005). Approximately 0.8 percent of all children suffer from Bitot's spots (NNMB 2003),[8] though local rates in certain states can vary from 5 to more than 10 percent. According to WHO, childhood Bitot's spots prevalence of at least 0.5 percent constitutes a public health problem (WHO 1996). Also, more than 12 percent of all mothers nationwide experience night blindness during pregnancy, particularly in rural areas (IIPS 2000). Christian (2002) suggests that a maternal night blindness prevalence of at least five percent constitutes a public health problem. At least 19 states exceed this threshold, further underscoring vitamin A deficiency as a public health problem in India. Subclinical deficiency is even more prevalent, with recent estimates (31 percent to 57 percent of children under six) placing India among the highest in the world (West 2002; Mason et al. 2005). However, no comprehensive survey data (e.g., serum retinol levels) exist for India. The states worst afflicted are Bihar and Jharkhand in the east, Uttar Pradesh in the north, Maharastra in the west, Tamil Nadu and Andhra Pradesh in the south, and Madhya Pradesh in central India (TERI no date). An estimated 330,000 child deaths are caused or precipitated by vitamin A deficiency each year (UNICEF and MI 2004).

We evaluated the costs and benefits of massive-dose vitamin A supplementation as a remedy for xerophthalmia and mortality related to vitamin A deficiency. State estimates of incidence were gathered from several sources (NNMB 2002, 2003; NIN 2001; TERI 2006; Chakravarty and Ghosh 2000; Toteja et al. 2002). Uniform effectiveness rates and costs were assumed for the three state categories because state-specific information was not available.

We considered a vitamin A supplementation program that provides semiannual doses of 200,000IU to children one to four years of age. We focused on this age group for several reasons. Vitamin A supplementation of infants younger than six months has generally not been shown to benefit early infant survival (Daulaire et al. 1992; WHO/CHD 1998; West et al. 1995; Katz et al. 2000). Preschool children are more responsive to high-potency vitamin A supplementation than older children, and the incidence of corneal xerophthalmia peaks at two to three years (West and Darnton-Hill 2001). Moreover, the national vitamin A supplementation program that exists in India concentrates on children 9 to 36 months old (ICMR 2004). We considered a vitamin A

[8] The National Nutrition Monitoring Bureau surveyed Bitot's spots prevalence among children from 1 to <5 years.

supplementation program lasting four years, the duration of intervention necessary for a single cohort of one- to four-year-old children to avoid the period of increased early childhood mortality, as well as the period of onset for vitamin A deficiency-induced blindness. Averted DALYs were calculated based on avoided disability due to clinically apparent morbidity from vitamin A deficiency, and avoided mortality due to subclinical and clinical vitamin A deficiency.

Averted morbidity included cotemporaneous disability (i.e., during the four-year intervention) due to Bitot's spots and night blindness, as well as lifetime disability due to blindness.[9] Bitot's spots and night blindness were treated as temporary diseases, the durations of which were taken at one year to avoid inflation of DALYs.[10] Because information on prevalence rates was scant, other sequelae of xerophthalmia due to vitamin A deficiency, such as corneal xerosis and keratomalacia, were not considered. Consequently, estimates for averted cotemporaneous disability were conservative. The exception to the omission of other sequelae was total blindness, since this deficiency is the leading cause of blindness in developing countries and should not be ignored. Approximately half of all corneal xerophthalmia cases lead to blindness without treatment (West and Darnton-Hill 2001). However, data on the prevalence of deficiency-induced blindness and corneal xerophthalmia in India were lacking. Instead, this analysis assumed the prevalence of corneal cases to be one tenth of the prevalence of Bitot's spots, since the prevalence of corneal xerophthalmia is usually less than that of Bitot's spots and typically within an order of magnitude (see Rao et al. 1961; Swaminathan et al. 1970; Solon et al. 1979; Cohen et al. 1987; Rahmatullah et al. 1990; Swami et al. 2002). Therefore, the incidence of blindness was conservatively calculated as 0.05 times the prevalence of Bitot's spots (see Table 9-1). We assumed the same prevalence of clinical sequelae for populations with and without public health subcenter coverage.

Because we lacked baseline information on the marginal effectiveness of vitamin A supplementation in India, we instead draw a range of possible effectiveness reported in the literature. At the low end, we assumed 26 percent reduction of Bitot's spots, 46 percent reduction in night blindness, and 43 percent reduction in blindness based on results from Cohen et al.

9 The disability weights are 0.25for Bitot's spots, 0.15 for night blindness, and 0.5 for blindness (Zimmerman and Qaim 2004). Years of averted disability are discounted at three percent.

10 Duration is taken as one year because we use prevalence rates rather than incidence rates (Brenzel 1993; Murray 1994; Murray and Lopez 1996).

(1987).[11] At the high end, we assumed 75 percent effectiveness for preventing Bitot's spots and blindness (West and Sommer 1987; West and Darnton-Hill 2001). Though the efficacy of high-dose vitamin A prophylaxis in preventing xerophthalmia can be as high as 90 percent (Sommer and West 1996), we used 75 percent as, a conservative estimate. For night blindness, we assumed a maximum of 100 percent elimination, based on results by Sinha and Bang (1976).[12]

Avoided mortality was calculated as the estimated percent attributable risk (PAR) due to vitamin A deficiency times the underlying mortality rate (see Table 9-1). To obtain PAR, we calculated the mortality relative risk of a supplemented population (RR_{SUPP}), as described in Mason et al. (2003), such that RR_{SUPP} was taken as 1.0 at zero prevalence of clinical vitamin A deficiency, and increased linearly up to a prevalence of 1 percent, to an RR_{SUPP} of 0.77 (from Beaton et al. 1994), remaining at 0.77 thereafter. We used the prevalence of Bitot's spots as a proxy for prevalence of clinical deficiency. Since Bitot's spots is only one among several sequelae for clinical deficiency and is typically an early symptom in vitamin A-deficient individuals, this method again erred on the conservative side. To examine the sensitivity of our results to the PAR estimates, we also calculated averted mortality based on an effectiveness rate of 10 percent (World Bank 1993).

Two supplementation strategies were considered. Among populations served by a public health subcenter, prophylactic supplementation with vitamin A syrup, the prevailing method in India, costs Rs.2.58 per child per year. The other program, supplementation via vitamin A capsules, costs Rs.1.98 per child per year. These estimates include the cost of two doses of vitamin A per year, shipping, storage, delivery, and wastage (Anand et al. 2004). For populations without access to a public health subcenter, we estimated the supplementation cost at Rs.23 per child per year, which includes the cost of expanding subcenter coverage (Lakshman, pers. comm.). We also include an additional cost of Rs.2.96 per child per year to account for training, promotional and educational materials, and program monitoring and evaluation (Micronutrient Initiative 2006). We did not consider costs for startup, program infrastructure, or other fixed

[11] In the study by Cohen et al. (1987), the reduction was significant only for night blindness. We assume a 43 percent reduction in blindness based on the reduction of corneal xerosis (X2).

[12] The results by Sinha and Bang are from a study that administered 200,000IU of vitamin A every four months rather than semiannually, as is the case with the other studies cited. Nevertheless, we assume 100 percent elimination of night blindness because it is the earliest clinical manifestation of vitamin A deficiency and presumably the sequela most easily prevented with supplementation.

costs. The two supplementation strategies were not considered to have different effectiveness rates.

Cost-effectiveness ratios for both strategies are reported in Table 9-2. Assuming avertable mortality at PAR, cost-effectiveness of vitamin A supplementation with syrup in India was Rs.530–660 per DALY averted, Rs.23,000 per death averted, and Rs.70,000–122,000 per case of blindness averted. Assuming a 10 percent mortality reduction with supplementation increased the cost-effectiveness ratios, but not substantially. Cost-effectiveness ratios were slightly lower for capsule supplementation than for syrup supplementation because of the lower cost per person for capsule supplementation. Vitamin A supplementation was also less cost-effective in the EAGA states than in the non-EAGA states because of the latter's lower prevalence rates of vitamin A deficiency and lower childhood mortality rates.

Assuming avertable mortality at PAR, perfect coverage of vitamin A supplementation in India could reduce disease burden by 27 lakh to 34 lakh DALYs. This burden would include 2.1 lakh to 3.7 lakh cases of blindness and 77,000 deaths related to vitamin A deficiency. The vast majority of the avertable disease burden occurred in the EAGA states because of their higher levels of both vitamin A deficiency and childhood mortality relative to non-EAGA states. Because of its relatively high disability weight of 0.5, a substantial proportion of the averted DALYs was due to averted cases of blindness.

Table 9-1. Assumptions related to burden of disease caused by vitamin A deficiency

	Bitot's spot prevalence	Night blindness prevalence	Blindness prevalence	Percent attributable risk
India	0.80%	6.0%	0.04%	18.4%
EAGA	3.27	7.3	0.16	22.0
non-EAGA	0.51	3.7	0.03	10.8

Table 9-2. Cost-effectiveness of vitamin A supplementation

Vitamin A syrup

		Percent attributable risk mortality averted		10% mortality averted	
	Rs. per blindness averted	Rs. per DALY averted	Rs. per death averted	Rs. per DALY averted	Rs. per death averted
India	70,000–122,000	530–660	23,000	760–1040	43,000
EAGA	17,000–29,800	240–340	14,000	330–530	31,000
non-EAGA	110,000–192,000	1,340–1,900	84,000	1,380–2,000	91,000

Vitamin A capsules

		Percent attributable risk mortality averted		10% mortality averted	
	Rs. per blindness averted	Rs. per DALY averted	Rs. per death averted	Rs. per DALY averted	Rs. per death averted
India	62,000–109,000	480–590	21,000	680–930	38,000
EAGA	15,000–27,000	210–300	12,000	290–480	27,000
non-EAGA	98,000–171,000	1,190–1,700	75,000	1,230–1,780	81,000

Table 9-3. Averted disease burden with vitamin A supplementation

		Percent attributable risk mortality averted		10% mortality averted	
	Blindness	DALYs	Deaths	DALYs	Deaths
India	211,000–369,000	2,723,000–3,354,000	77,000	1,714,000–2,345,000	42,000
EAGA	452,000–790,000	2,824,000–3,950,000	68,000	1,776,000–2,902,000	31,000
non-EAGA	63,000–111,000	441,000–627,000	10,000	419,000–606,000	9,000

10. Iodine deficiency

Iodine is an essential micronutrient necessary for human growth and development. Iodine deficiency results in goiter, growth stunting, and neurological impairment, as well as deaf-mutism, malformed limbs, spastic motor disorders, and cretinism in more severe cases. Approximately 6.6 million children are born each year with mental impairment attributable to iodine deficiency in mothers (Micronutrient Initiative 2006), and 2.2 million suffer from cretinism.

Globally, salt iodization is the most common strategy to increase dietary iodine consumption. However, government mandates for iodized salt have met with controversy in India. Critics question the health benefits of iodized salt and assert that required iodization hurts small-scale salt producers while benefiting larger and multinational producers (Weiss 2001; Pallavi 2006). A ban on non-iodized salt, enacted in 1997, was repealed just two years later. Subsequently, households consuming iodized salt declined from 50 percent in 1999 to 37 percent in 2003 (Micronutrient Initiative 2005).

We calculated the costs and outcomes of expanding iodine-fortified salt coverage to all of India for 10 years. Averted disease burden was calculated in terms of DALYs. In calculating the effects of fortification, three sequelae of iodine deficiency were explored: goiter, mild neurological disorder, and cretinism. Goiters are enlargements of the thyroid gland caused by iodine deficiency. Grade 1 goiters are swellings that are palpable but generally not visible to the naked eye. Grade 2 goiters are larger growths that can interfere with breathing and swallowing as they exert pressure on the windpipe and esophagus. Iodine deficiency is also the leading cause of preventable mental retardation in the form of impaired cognitive function and psychomotor development. Congenital hypothyroidism during pregnancy results in cretinism, where

individuals are born with mild to severe impairment of both physical and mental growth and development. Disability weights and underlying prevalence rates of goiters, neurological disorders, and cretinism due to iodine deficiency in India are listed in Table 10-1. Although iodine deficiency can be a contributing factor to premature mortality, it is seldom a direct cause of death. Hence, we did not consider avoided mortality as part of the benefits of iodine salt fortification. We model goiters and mild cognitive impairment averted as benefits that occur cotemporaneous with the availability of iodized salt. We also considered the discounted lifetime benefits of a cohort of children born without the congenital hypothyroidism that leads to cretinism.

Input variables were obtained from the literature and other sources. Disability weights were drawn from Murray and Lopez (1996). The baseline prevalence of goiters was assumed at 25.3 percent (Mason et al. 2005). We divided this underlying rate into grade 1 and grade 2 goiters based on the ratio reported in India by Toteja et al. (2004). We also assumed that availability of iodized salt causes a decrease in goiter prevalence by 15 to 94 percent (Chen and Wu 1998; Li and Wang 1987 ref. in Allen and Gillespie 2001). We also assumed that salt iodization is 100 percent effective against mild neurological disorders caused by iodine deficiency, as well as 100 percent effective in preventing cretinism (Li and Wang 1987 ref. in Allen and Gillespie 2001).

Currently in India, 37 percent of households consume iodized salt. The coverage rate of iodized salt in India has been decreasing over the past decade (Micronutrient Initiative 2005). Because the current prevalence of developmental impairment and cretinism is associated with past levels of salt iodization, we used an earlier estimate of coverage (50 percent) to calculate the underlying rate of iodine deficiency (Government of India 2001; Micronutrient Initiative 2005).

The cost of salt iodization is uncertain. Published estimates of costs, including the expenses of iodine, processing costs, packing, shipping, administration, promotion, and monitoring, range from Rs.0.45 to Rs.18 per person per year (Micronutrient Initiative 2006; Gandhi quoted in D'Monte 2005). We calculated the cost-effectiveness ratio using both of these estimates.

Cost-effectiveness ratios of salt iodization in India are reported in Table 10-2. Assuming a low cost per person for iodization, the cost-effectiveness was Rs.85–92 per DALY averted. With the higher cost of iodization, the cost-effectiveness was around Rs.3,500 per DALY averted.

Outcomes of providing iodized salt to the 63 percent of households that lack it are listed in Table 10-3. Increase in coverage of salt iodization could avert as many as 480 lakh DALYs over 10 years, mostly from 2.5 lakh cases of cretinism prevented per year.

Table 10-1. Characteristics of sequelae due to iodine deficiency

Disorder	Disability weight	Underlying prevalence
Goiter grade 1	0.001	24.7%
Goiter grade 2	0.025	0.6
Mild neurological disability	0.006	1.3
Cretinism	0.804	1.6

Table 10-2. Cost-effectiveness of salt iodization in India

Cost per person per year (Rs.)	Cost-effectiveness ratio (Rs. per DALY)
0.45	85–92
18	3,400–3,700

Table 10-3. Averted disease burden with salt iodization in India

Disorder	Averted cases per year (lakh)	Averted DALYs over 10 years (lakh)
Goiter grade 1	240–1,500	1.8–11.5
Goiter grade 2	20–150	4.7–29.1
Mild neurological disability	2.1	2.7
Cretinism	2.5	440
Total		440–480

Noncommunicable diseases

11. Cardiovascular disease

Cardiovascular disease (CVD) accounts for 17.5 percent of all mortality in India and is by far the greatest cause of death in both EAGA and non-EAGA states. Major risk factors, such as tobacco use, elevated blood pressure and blood cholesterol, elevated LDL cholesterol, high blood glucose levels, obesity, physical inactivity, and low fruit and vegetable intake, have all increased several-fold in recent years (Prabhakaran et al. 2006). Despite this high burden of disease, CVD control programs in India are almost nonexistent.

Costs and avertable disease burden of interventions against CVD, defined here as myocardial infarction, angina, or ischaemic stroke, in India were provided by Thomas Gaziano, based on the model described in Gaziano et al. (2006), who developed a Markov state-transition model with probabilities of disease events and mortality that vary by age. The model defined absolute risk groups for a cardiovascular event for adults aged 35 to 74 years. Risks for either a first event for primary interventions or a subsequent event for secondary interventions were based on separate Framingham risk functions for each event. The cohort transitioned between five health states: disease-free, postmyocardial infarction, angina, postcerebrovascular accident, and death. Input parameters, including relative risk values, effectiveness rates of interventions, and unit costs, were detailed in Gaziano et al. (2006), Rodgers et al. (2006), and Willett et al. (2006).

Three interventions were evaluated compared with a baseline of no treatment: pharmaceutical management of acute myocardial infarction with aspirin and beta-blocker; secondary prevention with a polypill containing a statin, aspirin, beta-blocker, an angiotensin-converting enzyme inhibitor, and a thiazide; and legislation to limit trans fats in processed food. The first treatment strategy involved 162.5mg of aspirin and 100mg of atenolol each per day for 30 days following an acute myocardial infarction. The polypill would include half the standard doses of lovastatin, aspirin, atenolol, lisinopril, and hydrochlorothiazide. The analysis assumed that all adults with at least 35 percent absolute risk of a CVD event over 10 years would receive polypill treatment for five years. Legislation limiting trans fats in food would mandate the replacement of trans fat from partial hydrogenation with polyunsaturated fat. This analysis assumed that substituting two percent of the energy from trans fat with polyunsaturated fat would cost US$0.50 per adult per year and reduce coronary artery disease by seven percent over 10 years. The cost was relatively low because trans fat can be eliminated from personal diets at the source of food manufacture rather than require changes in individual behavior.

Costs and outcomes are reported in Table 11-1. The cost-effectiveness of aspirin and beta-blocker for acute myocardial infarction was Rs.500 per DALY averted. Secondary prevention of CVD with polypill was notably less efficient in averting disease burden than the other two interventions. Legislation to reduce trans fats was a more cost-effective preventive intervention. However, trans fat legislation is less effective, capable of preventing less than a fifth of the disease burden as the polypill over the same period of time.

Table 11-1. Cost-effectiveness of interventions against cardiovascular disease in India

Intervention	Total intervention cost (million Rs.)	Total intervention cost (thousand US$)	Avertable disease burden (DALYs)	Avertable disease burden (deaths)	Cost per DALY averted (Rs.)	Cost per DALY averted (US$)
Pharmaceutical management of acute myocardial infarction with aspirin and beta-blocker (annual)	72	1,573	143,039	143,000	500	11
Polypill for secondary prevention, over 5 years	653,180	14,369,964	46,960,667	978,853	13,909	306
Legislation to limit trans fats in processed food, over 10 years	8,636	190,000	17,272,727	519,089	1,727	38

12. Diabetes

There are more than 30 million cases of diabetes in India, and the International Diabetes Federation estimates that five to eight percent of the Indian population is diabetic. Type I and Type 2 diabetes account for approximately two percent of deaths in India. Type 1 diabetes results from the loss of insulin-producing cells due to an autoimmune attack and requires treatment with insulin injections indefinitely. Type 2 diabetes develops because of the emergence of insulin resistance within the body and can usually be treated with medication and lifestyle adjustments to restore insulin sensitivity. Research suggests that though Indians have a genetic predisposition to diabetes, lifestyle factors relating to diet and physical activity are the predominant drivers of the epidemic (Mohan et al. 2007). The distribution of the diabetes disease burden suggests that lifestyle is the dominating factor: 60 to 70 percent of cases occur in urban populations, mortality is greater in the wealthier non-EAGA states, and incidence is more prominent in younger age groups.

This analysis assessed the cost-effectiveness of metformin as a preventive intervention for Type 2 (i.e., adult onset) diabetes in adults in India. We used prevalence data from Indrayan (2005) specifying the number of adult diabetes cases in India, broken down by sex and 10-year age groups. We applied the regional proportions observed in the mortality data (i.e., EAGA diabetes deaths as a percentage of total diabetes deaths in India) to the prevalence data to obtain regional estimates of diabetes prevalence. We utilized forecasted prevalence from Indrayan (2005) and diabetic-specific[13] mortality data to estimate the yearly incidence of diabetes (see Table 12-1)[14].

There is scant information on the proportion of diabetes cases in India that are Type 1 versus Type 2. Most Type 1 cases are diagnosed in children and young adults, whereas the vast majority of Type 2 cases are diagnosed after the age of 30. For the 20–29-year-old age cohort

[13] Adjusted to account for case fatality rates as well as underlying mortality rates.

[14] Indrayan (2005) reports prevalence data in 10-year age groups, forecasted from 2000 in five-year intervals. We subtracted the prevalence for the year 2000 from the forecasted prevalence for 2010 and adjusted for the diabetic-specific deaths that would have occurred during the 10-year period. We divided this value by 10 to obtain an estimate of annual incidence. This method precluded us from having incidence estimates for the highest reported age group (ages 70–79). In addition, for some age groups, this method produced a negative value for incidence. We ignored these age groups in our final analysis and attributed this result as well as other inconsistencies (e.g., the sum of EAGA and non-EAGA absolute prevalence and incidence is not always equal to the national numbers) to a mismatch of (forecasted) prevalence and (current) mortality data.

only, we assumed that 40.01 percent of new cases were Type 2 diabetes (Roy 2006). For all other cohorts, we assumed that 100 percent of new cases were Type 2. In other words, we assumed that new Type 1 cases in the 20–29-year-old cohort cases were newly discovered cases and that no new Type 1 cases were discovered after age 30.[15] Similarly, we assumed that 40.01 percent of cases in the 20–29-year-old cohort were Type 2. Under the assumption that 100 percent of new cases after age 30 were Type 2, we calculated estimates of Type 2 prevalence as a proportion of total prevalence. Our estimates of Type 2 prevalence rates, adjusted mortality rates for diabetics, and case fatality rates (along with population and mortality structures) were input into a state-transition model (DisMod II) to calculate the duration of Type 2 diabetes (WHO 2001) [16]. Duration was calculated by age, sex, and region (EAGA and non-EAGA). Since we assumed that there was no remission for diabetes patients, we used the calculated duration as the life expectancy of an individual suffering from diabetes.

Research findings report that metformin intervention results in a 25 to 31 percent reduction in the incidence of Type 2 diabetes among people at high risk (Narayan et al. 2006; Herman et al. 2005; Diabetes Prevention Program Research Group 2002). However, based on the limited time horizons of these studies,[17] we preferred not to assume that this reduction would be permanent. Instead, we assumed that metformin delayed the onset of Type 2 diabetes by an average of three years (Herman et al. 2005). Note that Herman et al. (2005) modeled the lifetime results of the metformin intervention to find that incidence was permanently reduced by 25 percent. Therefore our assumptions may underestimate the total avertable disease burden.

To assess the cost-effectiveness of the metformin intervention, we calculated the total DALYs lost by a population because of the disease, with and without treatment, and then divided the difference by the treatment cost. We assumed that metformin was effective for 25 to 31 percent of patients, who would experience three years of healthy life before the onset of diabetes. Following the onset, metformin treatment would cease and the individual would suffer from

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15 The onset of Type I cases can occur during adulthood in rare circumstances. We ignore those cases in this analysis, under the assumption that such rarity renders their impact negligible.

16 DisMod uses age-structured population, mortality, and epidemiological data to estimate the full epidemiology of a disease following a Markov process. The calculations in DisMod are all based on three fundamental equations describing epidemiological relationships: the dynamics of the healthy population, the dynamics of the diseased population, and the death rate of the diseased population.

17 Herman et al. have a three-year trial period and use a simulation model to project lifetime effects; the Diabetes Prevention Program Research Group had an average followup time of 2.8 years with the subjects.

diabetes for the duration of illness, calculated as described above, until death. We assumed a disability weight of 0.012 for years of life following the onset of Type 2 diabetes (Murray and Lopez 1996). We found that metformin could reduce the health burden in India by 368,400 to 456,800 DALYs averted, predominantly from the non-EAGA states (Table 12-2).

We assumed that an individual diagnosed at high risk of diabetes took metformin twice a day, at an annual cost of Rs.666 (Geiders et al. 2006). The cost of medical inputs, such as manpower, testing, and system requirements, were estimated at Rs.496 (NCMH 2005). The number of new Type 2 diabetes cases, calculated as described above, was used as a proxy for the number of high-risk individuals. All high-risk individuals were assumed to be treated for one year, after which the 25 to 31 percent for whom metformin was effective would be evident. After the first year, treatment continued for only this population.

The ratios of costs to health gains are presented in Table 12-3. Our results suggest that metformin is fairly cost-effective, at Rs.5,100–5,900 per DALY averted, and that its cost-effectiveness does not vary greatly between the EAGA and non-EAGA regions.

Table 12-1. Incidence of Type 2 diabetes by age, sex, and region*

	20–29		30–39		40–49		50–59		60–69	
	Males	Females	Males	Females	Males	Females	Males	Females	Males	Females
All India	80,347	71,507	239,510	283,491	223,328	236,991	23,735	79,216	40,135	–5,002
EAGA	49,821	46,625	96,459	116,487	4,798	10,472	–6,792	4,628	1,280	–8,622
Non-EAGA	36,670	31,563	112,293	133,455	113,178	119,058	11,141	39,029	–8,938	–33,368

* For males and females over age 70, see footnote13.

Table 12-2. Health gains from metformin

	DALYs averted*
All India	368,400–456,800
EAGA	82,100–102,000
Non-EAGA	164,800–204,300

*Range represents variation in efficacy of treatment with respect to incidence reductions during the period of delay.

Table 12-3. Cost-effectiveness of metformin

	Cost-effectiveness* (Rs. per DALY averted)
All India	5,100–5,900
EAGA	6,000–6,900
Non-EAGA	5,400–6,200

*Range represents variation in efficacy of treatment with respect to incidence reductions during the period of delay.

13. Epilepsy

In India, an estimated 5.5 million people suffer from epilepsy (Sridharan and Murthy 1999), resulting in about 40,000 deaths per year. A substantial portion of the disease burden of epilepsy comes from disability caused by recurring seizures during living years. The lost productivity and other indirect costs associated with epilepsy exceed Rs.10,000 per patient, or 64 percent of per capita GNP (Thomas et al. 2001).

There are several methods of treating epilepsy. Older antiepilepsy drugs, such as phenobarbital, phenytoin, and carbamazepine, effectively help patients achieve terminal remission in 70 to 80 percent of cases. A newer drug, such as lamotrigine, can be given to unresponsive patients in combination with the first-line drugs. Of patients who require lamotrigine, 20 to 40 percent show improvement. An alternative to lamotrigine is epilepsy surgery, which results in remission or reduced seizure frequency for most eligible[18] patients in developed countries (Engel et al. 2003). Patients who are not totally seizure free following surgery should continue to take antiepilepsy drugs.

We calculated and compared the cost-effectiveness ratios for three interventions incremental to no treatment: phenobarbital for nonrefractory patients, lamotrigine for patients refractory to phenobarbital alone, and epilepsy surgery for refractory patients. In each scenario,

[18] Eligibility is determined by mesial temporal pathology observed on MRI.

we calculated the total DALYs lost by a population due to the disease, with and without treatment, and then divided the difference by the treatment cost. We assumed that successfully treated patients suffered no disability, and a disability weight of 0.15 was applied to patients who were not in remission.

Even patients responsive to phenobarbital are currently not receiving treatment. Thus, as a first step, if all patients with epilepsy are given phenobarbital, at least the majority of patients responsive to phenobarbital will be appropriately treated. Other anticonvulsant medications such as phenytoin and carbamazepine were not considered in our analysis, since the cost of these drugs is much greater than that of phenobarbital but their effectiveness is essentially the same (Meador et al. 1990). Although their use may be justified for specific medical reasons, they are inferior to phenobarbital from a cost-effectiveness perspective. We assumed direct medical costs, including outpatient consultation, diagnostic investigations, and hospitalization, to average Rs.1,140 per epilepsy patient per year (Thomas et al. 2001). We also assumed that phenobarbital entails an annual drug cost of Rs.45 per patient per year (Chandra et al. 2006). We found phenobarbital for responsive patients to be quite cost-effective, at Rs.3,900 per DALY averted. Long-term phenobarbital treatment for all new responsive cases arising within a single year could avert as many as 1.5 million DALYs.

We analyzed other options for patients who were refractory to treatment with phenobarbital. Such cases were assumed to be treated either with a combination of phenobarbital and lamotrigine or with a combination of phenobarbital and surgery. The medical costs of the phenobarbital/lamotrigine combination were assumed to be the same as for the phenobarbital treatment alone, except with an additional Rs.6,550 per year for the cost of lamotrigine. For epilepsy surgery, we used a cost of Rs.120,000, based on a study from Colombia (Malmgren et al. 1996; Tureczek et al. 2000). We assumed that roughly half of surgery recipients experienced no more seizures, and the remaining half continually managed their seizures with phenobarbital. Our evaluation of the surgical option included the cost of MRI, EEG, and other diagnostic services for patients who underwent surgery. We also included the costs associated with screening patients who might ultimately not be eligible for surgery, estimated at Rs.55,000 per screening. For patients who were refractory to phenobarbital, the cost-effectiveness of the phenobarbital-lamotrigine combination treatment was Rs.126,000 per DALY averted, and the efficiency of the surgical option plus phenobarbital was Rs.125,000 per DALY averted.

Among refractory epilepsy patients eligible for surgery (i.e., they had mesial temporal pathology) and based on the postoperative outcome studies conducted in developed countries, surgery may be of comparable cost-effectiveness to treatment with a combination of

phenobarbital and lamotrigine. However, because of its greater efficacy, surgery has the potential to avert more disease burden (182,000 DALYs) than the phenobarbital-lamotrigine combination (97,000 DALYs). This calculation is based on cost estimates from a study in Colombia and the estimate of effectiveness of surgery from developed countries, since effectiveness data are not available from developing countries. If the surgical outcome in developing countries is worse than in developed countries, the cost-effectiveness of surgery would also be lower. Furthermore, limitations on the use of surgery in refractory epilepsy, particularly in developing countries, and the lack of long-term follow-up data on the outcome of surgery, must be noted. We cannot stress enough that the primary treatment of epilepsy is with phenobarbital and the effective treatment of epilepsy lies in more efficient use of this highly cost-effective drug to close the treatment gap.

14. Tobacco-attributable deaths

Cardiovascular diseases, tuberculosis, respiratory ailments, and cancer are the four greatest causes of mortality in people over 25 years of age in India, accounting for more than half of all adult deaths. Tobacco use, which has been widespread for many decades among Indian men, can be associated with a substantial proportion of these deaths (Gajalakshmi et al. 2003). Thirty percent of the population 15 years or older—about 195 million people, 47 percent of men and 14 percent of women—either smoke or chew tobacco (Rani et al. 2003). Smoking of cigarettes and *bidis*, hand-rolled smoking tobacco common in rural areas in Southeast Asia, currently causes about 700,000 deaths per year in India (Gajalakshmi et al. 2003), with approximately 54 percent occurring in the non-EAGA states (authors' calculations).

The costs and avertable disease burden of alternative tobacco control policies in India were generated using a static model of a cohort of smokers in 2001, an earlier version of which was described in Ranson et al. (2002). Following Ranson et al. and utilizing an updated version of the model reported by Jha et al. (2006), we evaluated three policies: price increases, nicotine replacement therapy, and a package of nonprice interventions other than nicotine replacement. We modified the model settings to use information on population, smoking prevalence, and GDP specific to India. Disease burden was calculated in terms of DALYs. For all three interventions, 40 percent of smokers were assumed to ultimately die from smoking-related causes. Only individuals who quit smoking entirely were considered to benefit from the interventions.

The model by Ranson et al. (2002) calculated the costs and outcomes of a 10 percent price increase in the cost of cigarettes and bidis. They assumed a short-run price elasticity range of –0.4 to –1.2 for all low- and middle-income countries, including India. The authors also assumed that half of the price effect was on smoking prevalence and half on the reduced demand

of continuing smokers, with constant effects across age groups. Additionally, they assumed that 95 percent of quitters aged 15–29 years, 90 percent aged 30–39 years, 70 percent aged 40–49 years, 65 percent aged 50–59 years, and 25 percent aged 60 or older would avoid tobacco-related death.

Nicotine replacements include chewing gum, transdermal patches, nasal spray, inhalers, sublingual tablets, and lozenges. The model assumed that they had an overall effectiveness of one to five percent. The authors also assumed that adults aged 30–59 years would be 1.5 times more willing and financially capable of using nicotine replacement therapy for smoking cessation than other age groups.

Nonprice interventions other than nicotine replacement include bans on advertising and promotion of tobacco, dissemination of information on the health consequences of using tobacco, and restrictions on smoking in public and work spaces. The model assumed that a package including all three strategies would reduce prevalence by 2 to 10 percent.

The authors used the same annual public sector costs, estimated at 0.02 to 0.05 percent of GDP, for both price increases and the nonprice interventions other than nicotine replacement. The costs of nicotine replacement therapy included similar public sector costs, covering administration and education, in addition to the individual costs of therapy. The model assumed a per person cost of US$25 to US$50. Costs were discounted at 3 to 10 percent per year.

Midlevel results generated from the model are listed in Table 14-1. A price increase of 10 percent was notably more cost-effective than nicotine replacement therapy and other nonprice interventions because of its lower cost. The price increase could also prevent 7.8 million deaths in India, equivalent to 58 million DALYs. In comparison, nicotine replacement at 5 percent effectiveness and other nonprice interventions would prevent only 19 million and 29 million DALYs, respectively, and at a higher total cost each. These results are within the estimated ranges for the South Asia World Bank region, to which India belongs, reported by Jha et al. (2006).

Table 14-1. Costs and avertable disease burden from interventions to encourage smoking cessation

Strategy	Total intervention cost (thousand US$)	Avertable disease burden (DALYs)	Avertable disease burden (deaths)	Cost per DALY averted (Rs.)	Cost per DALY averted (US$)
10% price increase	166,950	58,325,605	7,821,581	319	7
Nicotine replacement therapy at 5% effectiveness	2,809,694	18,969,335	1,549,600	6,733	148
Other nonprice interventions	2,059,101	28,766,303	1,806,557	10,931	240

15. Breast and cervical cancers

Cancers are a leading cause of adult mortality in India, more so for women than for men, accounting for 8.3 percent of adult female deaths in the EAGA states and 14 percent in the non-EAGA states. Breast cancer causes 22,000 deaths per year, and cervical cancer causes 10,000 deaths per year. Mortality from these two types of cancer could be dramatically reduced in India because with proper screening, they are highly preventable. Also, a highly effective vaccine has recently been developed for human papillomavirus (HPV), which causes virtually all cases of cervical cancer.

Screening interventions for breast and cervical cancers

Cost-effectiveness of breast cancer screening strategies in India was drawn from Brown et al. (2006). This analysis used a state-transition model of breast cancer screening that simulates individual life histories of disease states (van Oortmarssen et al. 1990). Screening strategies, varying by frequency and target age range, were evaluated for two testing methods: clinical breast exam and mammography. Outcomes of screening were calculated by comparing the histories with and without screening intervention for each individual. The model was calibrated

to correctly predict the age-specific incidence and mortality of breast cancer in India and its stage distribution at clinical diagnosis. The authors calculated total costs by comparing the differential costs of breast cancer screening, diagnosis, initial therapy, adjuvant therapy, follow-up, and advanced disease in the case of screening versus no screening. Because cost data from India are lacking, the authors extrapolated estimates from Dutch unit costs. The authors assumed that the screening program would last for 25 years and have an attendance rate of 100 percent. They also assume a population of one million women, but for the purposes of this summary, we scale up their results according to the female population reported in the 2001 Indian census.

Brown et al. found that clinical breast exam once every five years for women ages 40 to 60 was the most cost-effective screening strategy. Biennial exams for the same age group was similarly cost-effective but capable of averting approximately twice the disease burden as exams every five years. Strategies involving mammography were generally less favorable than those with clinical breast exam. Total cost, avertable burden, and cost-effectiveness strategies for all screening strategies are reported in Table 15-1.

Cost-effectiveness of cervical cancer screening strategies in India was drawn from Goldie et al. (2005). This study used a state-transition model (described in Goldie et al. 2001) to simulate the natural history of HPV-induced cervical neoplasia and cervical cancer screening, diagnosis, and treatment. The authors utilized primary data from India to evaluate three screening tests—visual screening with ascetic acid, DNA test for human papillomavirus (HPV), and cytological screening—followed by treatment with cryosurgery. The authors varied these strategies by targeted age, frequency, and number of clinic visits required. The model was calibrated to reflect the incidence of cervical cancer and mortality rate according to the best available empirical data. The authors used a quantity-and-price approach to assess the direct medical, time, and program costs.

The authors assumed screenings starting at age 35 with additional screenings performed at five-year intervals. The single-visit strategies were assumed to involve screening and treatment provided in the same day. Two-visit strategies also consisted of screening during the first visit followed by treatment in the second. Three-visit strategies included an initial screening test on the first visit, colposcopy and biopsy in case of positive results on the second, and treatment on the third. The authors assumed that screening and treatment were performed at a primary health center, with women ineligible for cryosurgery referred to a district hospital or other secondary-level facility.

Goldie et al. (2005) reported that the most cost-effective strategies were those that required the fewest visits, which resulted in improved follow-up testing and treatment. Screening once per lifetime reduced the lifetime risk of cancer by 25 to 36 percent, with an additional 40 percent reduction in relative cancer risk with a second screening. Average cost-effectiveness rates of screening strategies relative to no screening are listed in Table 15-2. One-visit visual screening and two-visit cytological screening were found to be the most cost-effective strategies. Three-visit cytological screening was least cost-effective.

Based on the total discounted lifetime costs, screening specificity, and cryosurgery effectiveness reported by Goldie et al. (2005), as well as cervical cancer mortality rates in India provided by Center for Global Health Research and population numbers from the 2001 Indian census, we calculated the total costs and total avertable deaths for one-visit visual screening with ascetic acid, one-visit HPV DNA testing, and two-visit cytological screening (Table 15-3). These estimates assume a 100 percent attendance rate, with zero screening at baseline. Visual screening with ascetic acid is least costly, followed by HPV DNA testing and cytological screening. HPV DNA testing has the greatest screening specificity and thus is also capable of the greatest avertable burden, followed by visual screening and cytology.

HPV vaccination

We calculated the cost and outcomes of providing HPV vaccinations to a single annual cohort of girls aging 5 to 15 years old in India, using the standardized Disease Control Priorities Project guidelines for economic analyses (Musgrove and Fox-Rushby 2006). In our analysis we used cervical cancer mortality rates from the Center for Global Health Research, population information from the 2001 India Census, and life tables from the Indian Sample Registration System. We assumed a vaccine efficacy of 100 percent against HPV16 and HPV18, which account for 70 percent of cervical cancer (Lowy and Schiller 2006). Although the initial price in the U.S. market is US$120/dose for the three-dose vaccine, we assumed a vaccine cost of US$1/dose, based on the long-term discounted prices of newer vaccines made available to developing countries (Saxenian and Hecht 2006). We took into account the disease burden averted from prevented death only and ignored disease burden due to sequelae cotemporaneous with cervical neoplasmia.

Costs, outcomes, and cost-effectiveness are reported in Table 15-4. HPV vaccination is more cost-effective in non-EAGA states than in EAGA states because of the lower cervical cancer mortality in the latter. However, cost-effectiveness rates of HPV vaccination are far less favorable than those of universal cervical cancer screening, reported above, despite discounted

costs for the vaccine. Moreover, these lower prices are unlikely to occur until 2015 or later (Saxenian and Hecht 2006), making HPV vaccination a less likely prospect in India.

Table 15-1. Costs and outcomes of breast cancer screening strategies in India

	Clinical breast exam				Mammography		
	Biennial, ages 40–60	**Annual, ages 40–60**	**Biennial, ages 50–70**	**Five-yearly, ages 40–60**	**Biennial, ages 40–60**	**Biennial, ages 50–70**	**1 per lifetime, age 50**
Cost per death averted (lakh Rs.)	3.2	4.5	2.9	2.7	11.1	8.6	5.6
Cost per life year saved (Rs.)	23,727	32,818	26,455	20,455	83,909	77,682	41,000
India							
Screening tests performed over 25 years (millions)	1,152	2,198	805	525	1,151	804	105
Deaths averted over 25 years (lakhs)	1.8	2.6	1.6	0.9	3.0	2.8	0.5
Life years saved over 25 years (lakhs)	24.3	36.0	17.2	12.2	39.5	30.7	7.1
Differential costs (million Rs.)	57,621	118,027	45,520	25,023	331,301	238,283	28,930
Discounted cost per year (Rs.)	2,305	4,721	1,821	1,001	13,252	9,531	1,157
EAGA states							

Screening tests performed over 25 years (millions)	540	1,031	378	246	540	377	49
Deaths averted over 25 years (lakhs)	0.8	1.2	0.7	0.4	1.4	1.3	0.2
Life years saved over 25 years (lakhs)	11.4	16.9	8.1	5.7	18.5	14.4	3.3
Differential costs (million Rs.)	27,041	55,390	21,362	11,743	155,479	111,826	13,577
Discounted cost per year (Rs.)	1,082	2,216	854	470	6,219	4,473	543
Non-EAGA states							
Screening tests performed over 25 years (millions)	611	1,166	427	278	611	427	56
Deaths averted over 25 years (lakhs)	0.9	1.4	0.8	0.5	1.6	1.5	0.3
Life years saved over 25 years (lakhs)	12.9	19.1	9.1	6.5	21.0	16.3	3.7
Differential costs (million Rs.)	30,579	62,637	24,157	13,280	175,822	126,457	15,353
Discounted cost per year (Rs.)	1,223	2,505	966	531	7,033	5,058	614

Source: calculated from Brown et al. 2006

Table 15-2. Cost-effectiveness of cervical cancer screening strategies in India (Rs. per DALY)

	Visual screening with acetic acid		HPV DNA testing		Cytology screening	
	1 visit	2 visits	1 visit	2 visits	2 visits	3 visits
1 x per lifetime	150	720	435	765	195	4,543
2 x per lifetime	1,365	1,994	2,534	2,609	915	5,548
3 x per lifetime	4,019	4,663	7,212	6,523	2,384	7,827

Source: calculated from Goldie et al. 2005

Table 15-3. Total cost and avertable disease burden of cervical cancer screening strategies in India

			India		EAGA states		non-EAGA states	
	Screening specificity	Cryosurgery effectiveness	Averted deaths per year	Total cost per year (million Rs.)	Averted deaths per year	Total cost per year (million Rs.)	Averted deaths per year	Total cost per year (million Rs.)
Visual screening with ascetic acid, 1 visit, 1 x per lifetime at age 35	0.76	0.8	6,400	2,430	2,000	1,040	1,800	1,390
HPV DNA screening, 1 visit, 1 x per lifetime at age 35	0.88	0.8	7,400	2,640	2,300	1,130	2,100	1,510
Cytoloty screening, 2 visits, 1 x per lifetime at age 35	0.63	0.8	5,300	3,370	1,700	1,440	1,500	1,930

Source: calculated from Goldie et al. 2005

Table 15-4. Costs and outcomes of HPV vaccination of a single annual cohort of girls (ages 5-15) in India

	India	EAGA states	non-EAGA states
Total cost of vaccination (million Rs.)	362	189	174
Total discounted deaths averted (lakh)	0.7	0.2	0.2
Total discounted YLL averted (lakh)	3.4	1.0	1.1
Cost per death averted (lakh Rs.)	0.5	0.8	0.7
Cost per YLL averted (lakh Rs.)	2.3	3.9	3.8

16. Blindness

Blindness is an important public health problem in India, with a national prevalence estimated at 8.5 percent of all individuals aged 50 years or older (Murthy et al. 2005). At least 62.4 percent of these cases are caused by cataracts, the clouding of the ocular lens commonly resulting from natural aging. Over the past decade, the Government of India has implemented a World Bank–supported cataract control project in seven populous states that account for two-thirds of India's blind population. Since the increase in cataract surgeries accompanying this project, the prevalence of blindness dropped from 9.8 percent of all individuals aged 50 years or older to the current 8.5 percent.

Costs and outcomes of cataract surgery interventions to treat blindness were drawn from Baltussen et al. (2004). The authors used a state-transition model to evaluate the cost-effectiveness of two types of surgical interventions in terms of DALYs. In intracapsular cataract extraction using aphakic glasses, the whole lens is removed from the eye, and eyesight is restored through use of special eyeglasses. Extracapsular cataract extraction with implantation of a posterior chamber intraocular lens involves the removal of the lens and the front portion of the capsule and the insertion of an artificial replacement lens. The effectiveness of both procedures was assumed to be 95 percent, with the 5 percent loss of effectiveness due to complications. The

authors also assumed that noncompliance in terms of failing to wear glasses also reduced the effectiveness of intracapsular cataract extraction by 27 to 82 percent. Estimated costs included program-level resource inputs above the level of treatment, such as central planning, policy, training, and administration; patient costs, such as supplies and equipment used in treatment; and unit costs of program-level and patient-level resource inputs, such as administrator salaries, capital costs, and costs per inpatient and outpatient visits. All costs and effects were discounted at three percent.

Baltussen et al. (2004) calculated the costs and avertable DALYs for the evaluated interventions by WHO region. We estimated the costs and avertable burden specific to India by calculating the fraction of the Indian population to the total population of the region (approximately 81 percent), and multiplying the resulting ratio to the aggregate cost and averted burden results for Southeast Asia Region-D. The results are reported in Table 16-1. Aggregate costs of both procedures are similar. However, the extracapsular procedure is more cost-effective than intracapsular cataract extraction because of the latter's lower effectiveness from noncompliance. Cost-effectiveness ratios are similar across levels of coverage but most cost-effective at 80 percent coverage. Because many program-level costs, such as administration and planning, are independent of the number treated, these interventions benefit from economies of scale. At higher coverage, however, the marginal benefits of intervention begin to diminish.

Table 16-1. Costs and avertable burden of cataract surgery in India

Strategy	Coverage	Total cost (million Rs.)	Total avertable burden (million DALYs)	Cost-effectiveness ratio (Rs./DALY)
Intracapsular cataract extraction	50%	4,377	2.8	1,600
	80	6,113	4.5	1,400
	95	7,714	5.3	1,400
Extracapsular cataract extraction	50	4,628	5.1	900
	80	6,515	8.3	800
	95	8,193	9.9	800

V. Comparative analysis

The most efficient interventions examined in this study—those with cost-effectiveness ratios of less than Rs.500 per DALY or year of life lost YLL averted—were mostly strategies that targeted sources of disease burden that persist among poor populations. Among the exceptionally cost-effective interventions considered in this study were many that target infectious diseases: malaria, diarrheal diseases, vaccine-preventable childhood-cluster diseases, and HIV/AIDS. The cost-effectiveness of drug treatments for malaria was as low as Rs.50 per YLL averted for the most cost-efficient scenario.[19] Even the most expensive drug regime for malaria treatment, mefloquine for all cases as a first-line treatment, cost only Rs.67 per YLL averted. Also remarkably efficient was the inclusion of rotavirus vaccine into the Universal Immunization Program schedule, at a low cost of Rs.52 per DALY averted even when assuming the relatively high price, for India, of Rs.364 for the full course of immunization. Another intervention addressing diarrheal diseases—oral rehydration therapy with a home remedy of sugar and salt—was potentially highly cost-effective at Rs.70 per DALY, but only if the costs of promotion and educating mothers and health workers were negligible. Expansion of the immunization program, without adding any new antigens to the current schedule, also was extremely cost-effective, at Rs.90 per YLL averted.

Several interventions that target HIV/AIDS also had particularly low cost-effectiveness ratios. These included management of sexually transmitted infections (Rs.113 per DALY averted), condom promotion among sex workers (Rs.128 per DALY averted), and voluntary counseling and testing (Rs.480 per DALY averted). However, other interventions, such as government subsidization of structured antiretroviral therapies (Rs.12,700 per DALY averted), lie at the other end of the spectrum and are quite cost-ineffective for India.

Because of their large health gains in terms of YLL averted, perinatal and neonatal interventions to prevent infant death are also outstandingly cost-effective. Providing essential birth care, resuscitation, extra care for small newborns, and emergency antibiotics in all institutionalized births cost Rs.180 per YLL averted. Also, postnatal visits by a health worker cost Rs.456 per YLL averted.

[19] Chloroquine for all Pv cases, ACT for all Pf cases.

Several interventions that addressed noncommunicable and chronic illnesses cost less than Rs.500 per DALY or YLL averted. Once-per-lifetime screening for cervical cancer cost between Rs.150 and Rs.435 per YLL, depending on the method. A 10 percent price increase in tobacco to reduce smoking and related illnesses was also superbly cost-effective, at Rs.319 per DALY averted.

We consider highly efficient interventions as those with cost-effectiveness ratios less than Rs.4,500 per DALY or YLL averted. This benchmark, though arbitrary, has been endorsed by the World Bank (Laxminarayan et al. 2006). Many of the interventions examined here fall in this category. Highly cost-effective interventions against infectious diseases included the following:

- the addition of Streptococcus, hepatitis B, a second measles dose, and *Haemophilus influenzae* type B to the Universal Immunization Program vaccination schedule (Rs.620–3,000 per YLL averted, depending on the antigen);
- directly observed chemotherapy short course for TB patients (Rs.740–2,900 per DALY averted);
- condom promotion among high-risk men and youths (Rs.744 and Rs.3,200 per DALY averted, respectively);
- maternity services–based breastfeeding promotion to prevent diarrhea (Rs.2,400 per DALY averted); and
- community-level case management of nonsevere lower respiratory infections (Rs.3,800 per DALY averted).

Interventions addressing micronutrient deficiencies, such as vitamin A supplementation and salt iodization, were also highly cost-effective (Rs.530–1,000 per DALY averted and Rs.85–3,700 per DALY averted, respectively).

Highly cost-effective interventions against noncommunicable diseases were these:

- aspirin and betablocker for acute MI (Rs.500 per DALY averted);
- legislation to limit trans fats (Rs.1,700 per DALY averted);
- cataract surgery for blindness (Rs.830–1,400 per DALY averted, depending on the procedure); and
- phenobarbital for epilepsy (Rs.3,900 per DALY averted).

Moderately cost-effective interventions—that is, those with cost-effectiveness ratios between Rs.4,500 and Rs.10,000 per DALY or YLL averted—were the following:

- diabetes prevention with metformin (Rs.5,500 per DALY averted);
- mother-to-child HIV transmission intervention (Rs.6,200 per DALY averted);
- the expansion of institutionalized birth coverage at the community health center (Rs.6,400 per YLL averted);
- community-based breastfeeding promotion (Rs.6,500 per DALY averted);
- subsidized lab tests for antiretroviral therapy (Rs.6,600 per YLL); and
- nicotine replacement therapy (Rs.6,700 per DALY averted).

Some of these interventions, such as mother-to-child HIV transmission intervention and expansion of institutionalized births at community health centers, have no clear substitutes: no other treatments address the specific sources and vectors of these disease burdens. Hence, health planners should seriously consider them when designing a health entitlement package, even though they are less cost-effective than other interventions.

Interventions with cost-effectiveness ratios above Rs.10,000 per DALY or YLL averted are quite cost-*in*effective and should be included in a health entitlement package only if the targeted disease burden is high and no clear alternatives exist. Inefficient interventions against infectious diseases included the following:

- structured antiretroviral therapy (Rs.12,700 per YLL averted);
- human papilloma virus vaccination (Rs.48,300 per YLL averted);
- hospital-based oral rehydration therapy for young children with diarrhea (Rs.20,000); and
- case management of all lower respiratory infections regardless of severity (Rs.38,900 per DALY averted).

Among interventions against noncommunicable diseases, inefficient interventions included these:

- nonprice interventions against tobacco (Rs.10,900 per DALY averted);
- polypill for secondary prevention of cardiovascular disease (Rs.13,900 per DALY averted);

- breast cancer screening (Rs.20,400–83,900 per YLL averted);
- interventions for epilepsy cases that are refractory to the first-line treatment (Rs.124,000–125,000 per DALY); and
- expansion of institutionalized birth coverage via local maternity clinics (Rs.20,000 per YLL averted).

Reasonable alternatives that were more cost-effective exist for many of those interventions. For example, expansion of institutionalized birth coverage is more efficient at community health centers than at local maternity clinics because many community health centers already exist and have lower marginal costs of providing safe deliveries. A robust screening program for cervical cancer would also be far more cost-effective than inoculations for human papilloma virus, even with a low vaccine price of Rs.45 per dose. Price increases are clearly more efficient than nonprice interventions to reduce tobacco use. However, other cost-ineffective interventions, such as screening for breast cancer, have no clear alternatives and could be considered for inclusion into a health package if the burden of disease is high.

Preventive interventions against malaria are quite cost-ineffective for India as a whole, at Rs.13,000 per DALY averted for insecticide-treated bed nets and Rs.23,000 per DALY averted for in-home residual spraying. However, these interventions can be highly cost-effective in areas with high levels of malaria prevalence. For example, they are very cost-effective in Orissa, where malaria incidence is India's highest. There, the cost-effectiveness ratio for nets and spraying are only Rs.720 and Rs.1,200 per DALY averted, respectively.

Health planners should prioritize disease interventions that not only are cost-effective but also have the potential to reduce substantial disease burden. Moreover, interventions for a particular disease should be as different as possible, such that they do not focus on similar target groups and disease vectors. Overlapping of targeted disease burden runs the risk of redundancy, which could decrease the cost-effectiveness of the intervention. For example, although condom promotion among both sex workers and sex worker clients is very cost-effective, a program that targets both groups could be just marginally more effective than a program that targets only one while substantially increasing the cost. In this case, condom promotion among sex workers is the preferred strategy because it is more efficient than targeting clients. Table 17-1 lists some of the top unique interventions that should be considered for all of India.

Table 17-1. Priority disease interventions based on avertable disease burden and cost-effectiveness

Disease	Intervention	Total intervention cost (million Rs.)	Avertable disease burden per year (million DALYs or YLL)	Cost per DALY or YLL averted (Rs.)
Diarrheal disease	Inclusion of rotavirus vaccine in the Universal Immunization Program schedule at current coverage rates	7,712	147.0	52
Tuberculosis	Directly observed short-course chemotherapy for ss+ TB patients	49,754	67.3	740
HIV/AIDS	Management of sexually transmitted diseases	37,636	66.4	113
Tobacco-related illnesses	10% price increase in tobacco	7,589	58.3	319
Tuberculosis	Directly observed short-course chemotherapy for ss– patients	64,835	22.7	2,857
HIV/AIDS	Condom promotion targeted at sex workers	14,409	22.5	128
Cervical cancer	Cytology screening, 2 visits, 1 x per lifetime at age 35	3,375	17.3	195
HIV/AIDS	Youth interventions	250,955	15.7	3,192
HIV/AIDS	Voluntary counseling and testing	37,727	15.7	480

Childhood cluster diseases	Expansion of Universal Immunization Program coverage to all children	2,063	10.7	190
Blindness	Extracapsular cataract extraction with implantation of posterior chamber intraocular lens	8,193	9.9	830
Neonatal mortality	Expansion of institutionalized birth coverage to all births (perinatal care incremental to maternal care)	15,685	8.7	180
Streptococcus	Inclusion of Streptococcus vaccine in Universal Immunization Program schedule at current coverage rates	3,493	8.5	620
Malaria	Chloroquine for all Pv cases; mefloquine for all Pf cases at 80% coverage	324	6.1	53

VI. Concluding remarks

India has great potential for improving the health of its people at relatively low cost. Devoting just one percent of GDP (approximately US$6 billion) to a well-designed health program nationwide could save as much as 480 million healthy years of life. Concentrating that expenditure in only the EAGA states would help preserve 200 million years of healthy life.

However, these estimates should be approached cautiously, with the following important caveats in mind. The analyses assume an efficient, well-functioning health system, free of graft that can conveniently provide care to patients. In reality, the health system in India is weak in many areas and prone to rent-seeking, especially in the EAGA states. Nationwide, the publicly provided health system suffers from serious deficiencies in infrastructure, equipment, staffing, and training at all levels of care (see Appendix A).

The state of India's public health system, however, does not render the cost-effectiveness estimates in this analysis irrelevant. At a relatively small per capita cost of approximately Rs.40 per person, or 0.2 percent of per capita GDP, India's public health system can be improved to a level that can efficiently provide quality care.

Appendix A. Cost of improving health infrastructure in India

Synthesizing state-level data from a variety of sources, we estimated the deficiencies in the public health infrastructure of India, the EAG states and Assam (EAGA), and other states (non-EAGA). We considered four levels of care: the district hospital (DH), community health center (CHC), primary health center (PHC), and health subcenter (SC). State data on the infrastructure, equipment, and training capacity of existing public health service providers were drawn from the International Institute of Population Sciences (2005). Data on the number of functioning CHCs, PHCs, and SCs were drawn from the Ministry of Health and Family Welfare 2005–2006 annual report (Government of India 2006). Population data were taken from the 2001 Indian census.

We estimated the shortfall in functioning CHCs, PHCs, and SCs by calculating the ideal numbers of each, based on Government of India goals, and comparing them with the number of existing providers in each state. We assumed, at minimum, there should be one CHC for every 100,000 people, one PHC for every 30,000 people, and 1 SC for every 5,000 people in each state. This assumption conservatively underestimated the number of necessary PHCs and SCs, because there ought to be 1 PHC per 20,000 people and 1 SC per 3,000 people in inaccessible areas. We assumed that at least 1 DH exists in each district in India; hence there is no shortfall in the number of functioning DHs. Table A1 reports the shortfall in India and in the EAGA and non-EAGA states.

We summarize the capacity data reported by the International Institute of Population Sciences to estimate the percentage of functioning public health providers inadequately equipped with durable resources, such as infrastructure, durable equipment, and training. We did not consider deficiencies in staffing and disposable medical supply (e.g., the health care kits provided to SCs) because these are variable costs accounted for in the cost-effectiveness calculations for individual conditions and interventions. The institute considers a health service provider adequately equipped with infrastructure, equipment, and training if it possesses 60 percent of critical inputs. The critical inputs for the levels of care considered here are listed in Table A2. Because the institute evaluates the adequacy of training at the PHC level only, we estimated the need for additional training at the DH and CHC levels based on institute surveys on the percentage of institutions with staff trained in sterilization, medical termination of pregnancy (MTP), respiratory tract infections (RTI), sexually transmitted infections (STI), newborn care, and reproductive and child health (RCH). At the SC level, we estimated the need for additional training based on the percentage of institutions with staff trained in intrauterine device (IUD)

insertion, oral rehydration therapy (ORT), immunization, safe motherhood, newborn care, RCH, and acute respiratory infection (ARI) management. The status of existing DHs, CHCs, PHCs, and SCs is reported in Table A3.

Capacity, in infrastructure, staff, supply and equipment, of PHCs and CHCs in the individual EAGA states is illustrated in Figures A1-1 to A1-9. There are stark differences in capacity between EAGA and non-EAGA states at the PHC level, with EAGA states generally having a lower percentage of facilities with adequate infrastructure, staff, supply, equipment, and training. In contrast, at the CHC level, many EAGA states meet or exceed the average capacity of the non-EAGA states. However, Bihar is a poor performer at both levels of care.

We used the costs listed by the National Commission on Macroeconomics and Health (2005) to estimate the per capita cost necessary both to eliminate the shortfall in facilities and to improve the infrastructure, equipment, and training of functioning DHs, CHCs, PHCs, and SCs (Table A4). Because the costs incurred are fixed costs for relatively durable resources, we consider the cost spread out over 10 years. Per capita costs per year are listed in Table A5. Expanding and improving facilities at all levels of care would cost 41 Rs./person/year in the EAGA states and 35 Rs./person/year in the non-EAGA states.

Table A1. Shortfall in existing public health service facilities

	India	EAGA	Non-EAGA
Minimum additional community health centers needed to meet ideal ratio (1 per 100,000 pop.)	7,096	3,408	3,689
Minimum additional primary health centers needed to meet ideal ratio (1 per 30,000 pop.)	11,598	4,893	6,705
Minimum # of additional health subcenters needed to meet ideal ratio (1 per 3,000 pop.)	64,325	28,640	35,684

Table A2. Fixed critical inputs for public health service providers considered in this analysis

Level of care	Infrastructure	Medical staff	Equipment	Training
District hospitals and community health centers	Overhead tank and pump facility, electricity in all parts of the hospital, availability of generator, telephone, functional vehicle, laboratory, operating theatre, separate aseptic labour room	Gynaecologist-obstetrician, anaesthetist and paediatrician	Boyle's apparatus, oxygen cylinder, shadowless lamp	At least one doctor trained in sterilization, RTI/STI, laparotomy/ caesarian, MTP, and delivery, and at least one paramedical staff trained in IUD insertion, BP checking, RCH, and management of ARI
Primary health centers	Continuous water supply, electricity, labour room, laboratory, telephone, functional vehicle	At least one medical officer, one laboratory technician, and all health assistants, including males and females (sanctioned posts filled)	At least one functioning deep freezer, vaccine carrier, BP instrument, autoclave, MTP suction aspirator, and labour room table and equipment	At least one doctor trained in sterilization, RTI/STI, laparotomy/ caesarian, MTP, and delivery, and at least one paramedical staff trained in IUD insertion, BP checking, RCH, and management of ARI

Table A3. State of existing public health service facilities

	India	EAGA	Non-EAGA
Percentage of district hospitals with inadequate infrastructure	7.3	9.3	4.2
Percentage of district hospitals with inadequate equipment	15.9	15.5	16.7
Percentage of district hospitals with doctors needing additional training	45.8	56.6	42.2
Percentage of community health centers with inadequate infrastructure	46.8	29.9	37.2
Percentage of community health centers with inadequate equipment	55.5	56.7	54.0
Percentage of community health centers with staff needing additional training	90.9	87.6	93.5
Percentage of primary health centers with inadequate infrastructure	68.2	85.1	39.1
Percentage of primary health centers with inadequate equipment	58.7	74.6	40.3
Percentage of primary health centers with staff needing additional training	80.1	85.2	73.5
Percentage of health subcenters without electricity	57.9	76.7	40.4
Percentage of health subcenters without tap water	81.1	95.2	68.0
Percentage of health subcenters without toilet	29.4	35.8	23.4
Percentage of health subcenters with staff needing additional training	99.0	98.8	99.2

Table A4. Unit costs of improving health infrastructure

Activity	Unit cost (lakh Rs.)
Multiskill training for medical officers (gynae/obs, paeds, public health, anaesthesia)	1.45
Strengthen and maintain existing SC (building and equipment)	5.74
Infrastructure (building, staff quarters, furniture only)	4.68
Equipment only	0.2568
Open new subcenter	8.28
Strengthen and maintain existing PHC (building and equipment)	34.15
Infrastructure (building, staff quarters, furniture only)	38.25
Equipment only	1.115
Open new PHC	55.99
Strengthen and maintain existing CHC (building and equipment)	126.6
Infrastructure (OT, LR, staff quarters, furniture only)	80.4
Equipment only	22.19
Open new CHC	172.58
Strengthen secondary institutions (DH, SDH)	150

(Source: NCMH 2005)

Table A5. Minimum costs to upgrade capacity of public health service system

Rs. per capita per year over 10 years	India	EAGA	non-EAGA
Strengthen infrastructure and equipment at district hospitals	0.2	0.2	0.1
Ensure proper training of medical officers at district hospitals	0.01	0.01	0.01
Establish new community health centers to address shortfall	11.9	12.1	11.7
Strengthen infrastructure and equipment at existing community health centers	1.4	1.5	1.2
Ensure proper training of medical officers at existing community health centers	0.04	0.04	0.05
Establish new primary health centers to address shortfall	6.3	5.6	6.9
Strengthen infrastructure and equipment at existing primary health centers	5.7	7.8	3.8
Ensure proper training of paramedical staff at existing primary health centers	0.2	0.2	0.2
Establish new health subcenters to address shortfall	5.2	4.9	5.4
Strengthen infrastructure at existing health subcenters (lack of electricity as proxy for need)	4.7	6.2	3.2
Ensure proper training of existing health subcenter staff	2.0	2.0	2.0
Total cost per capita per year	**37.6**	**40.6**	**34.7**

Figure A1.

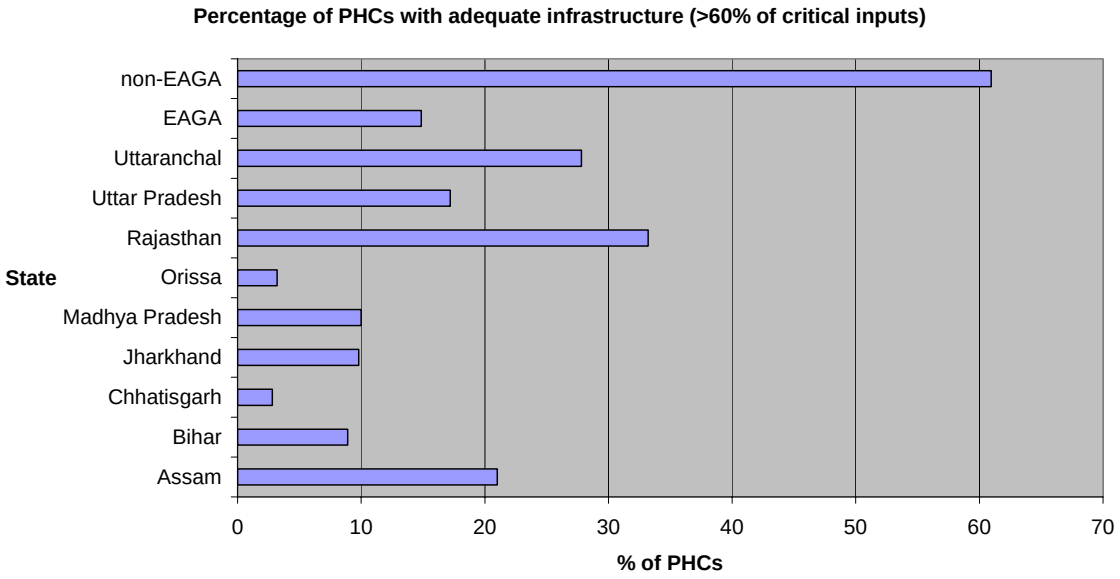


Figure A2.

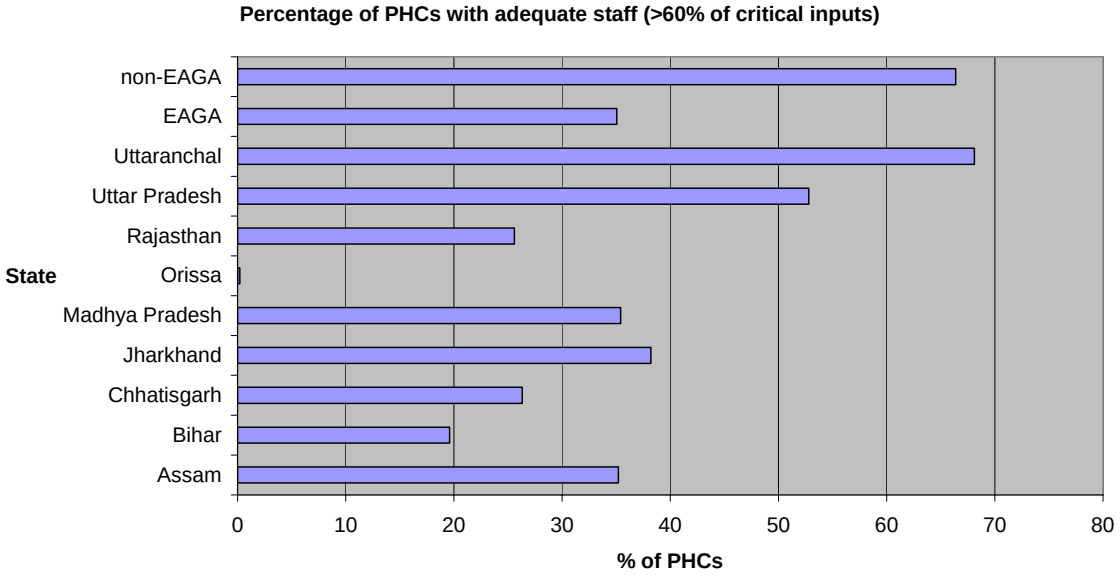


Figure A3.

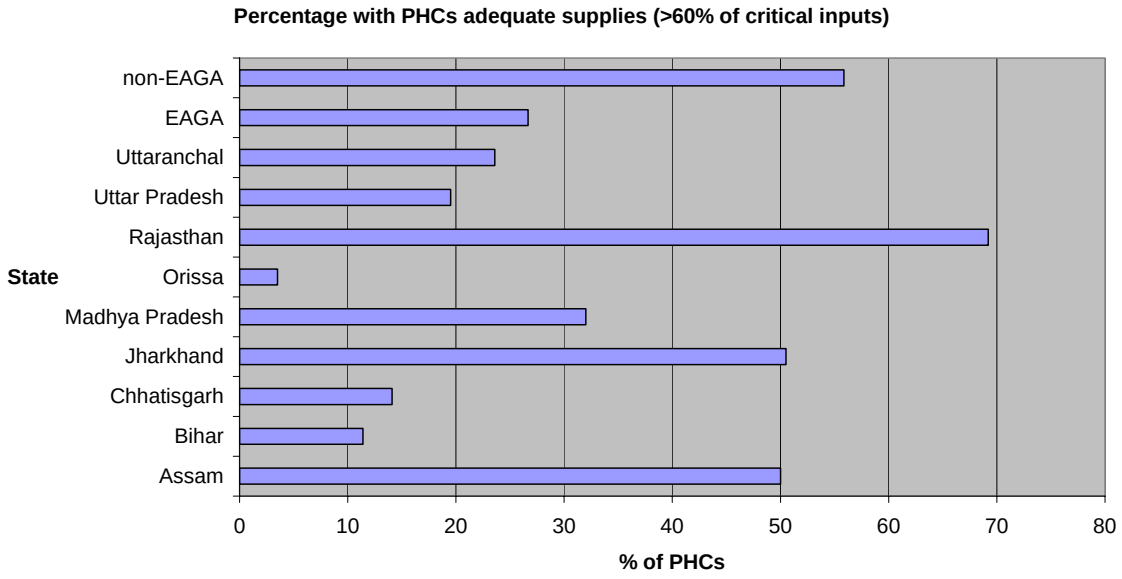


Figure A4.

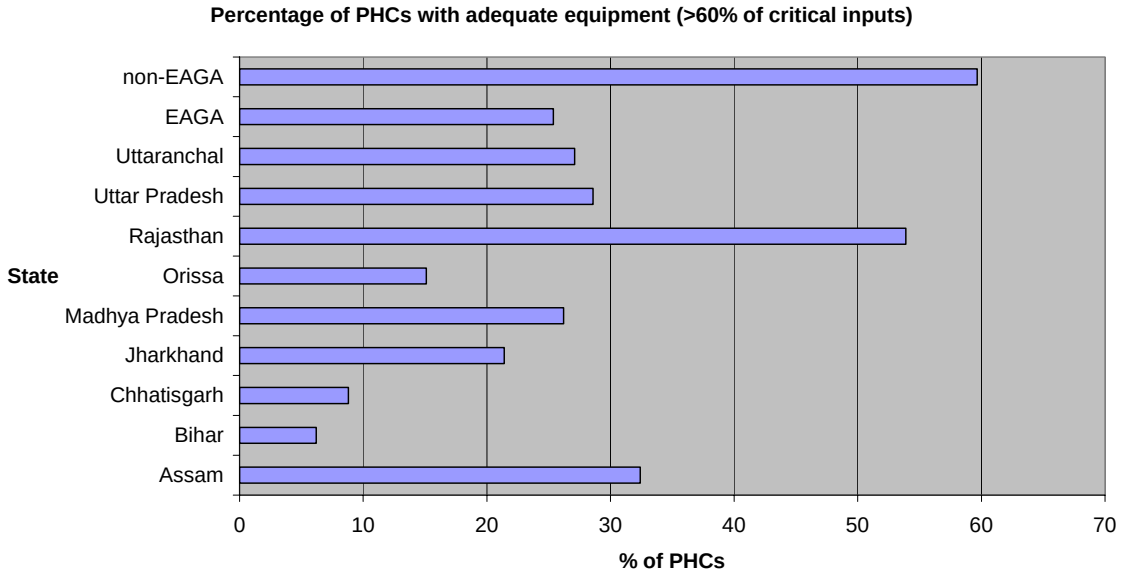
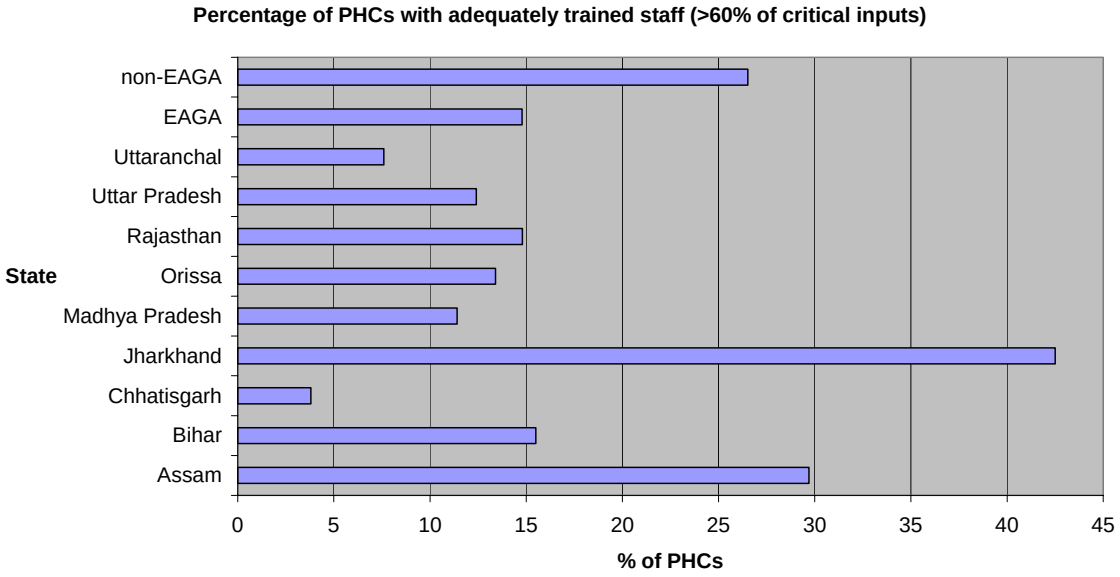


Figure A5.



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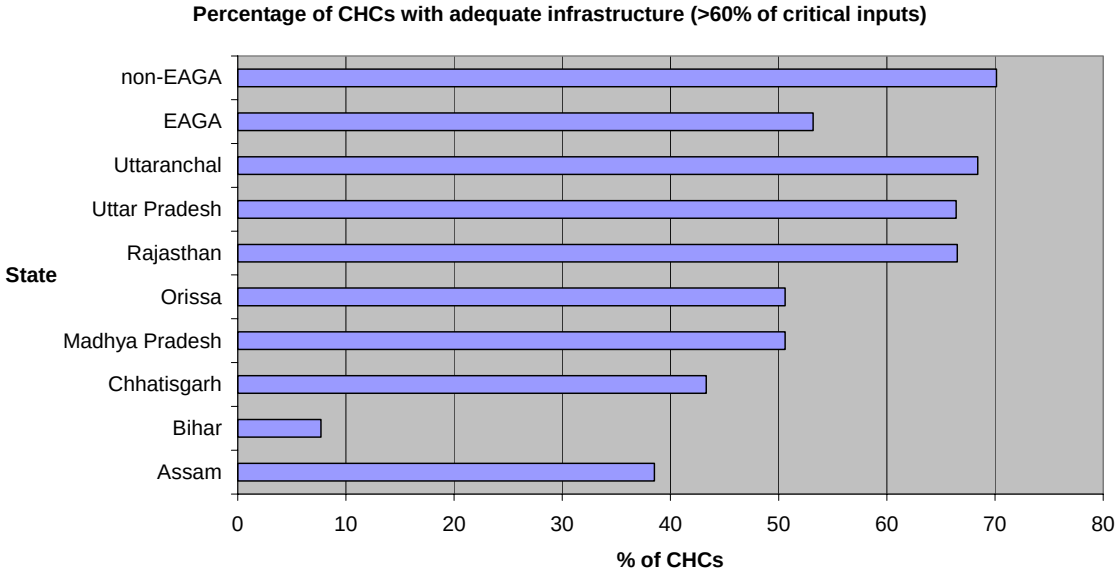

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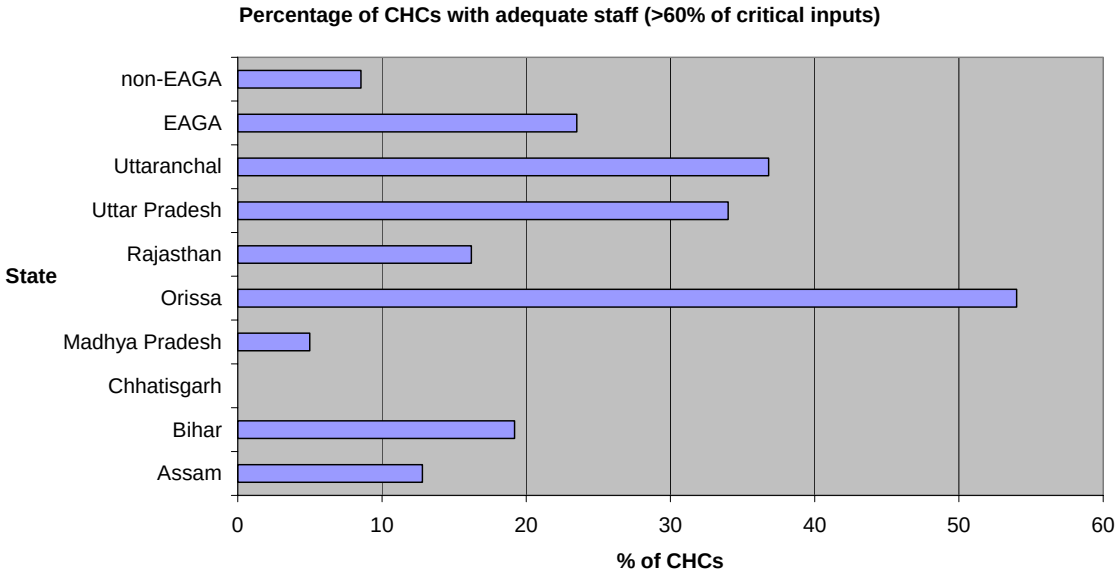


Figure A8.

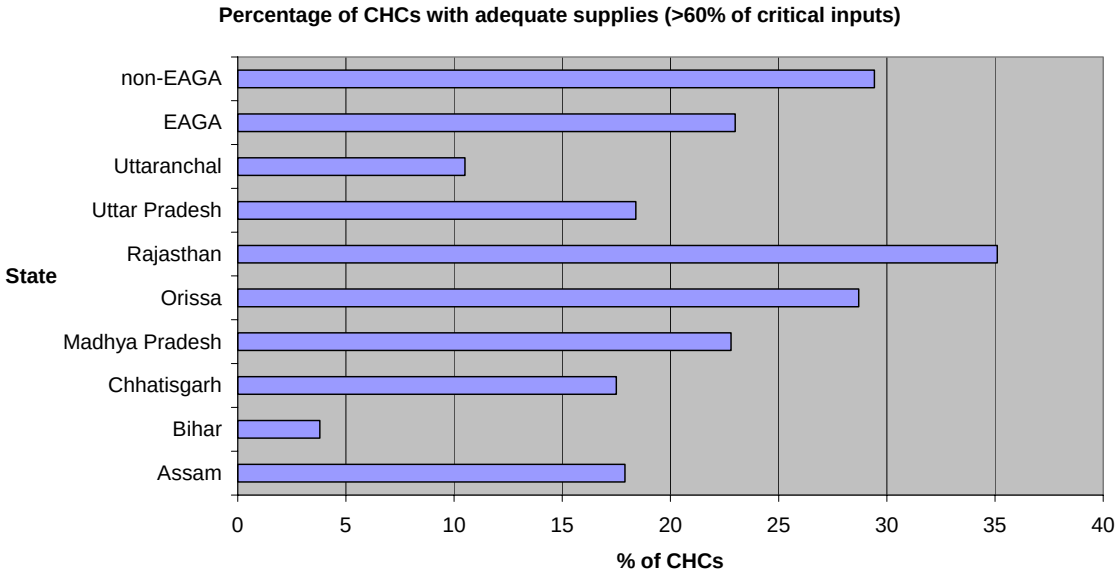
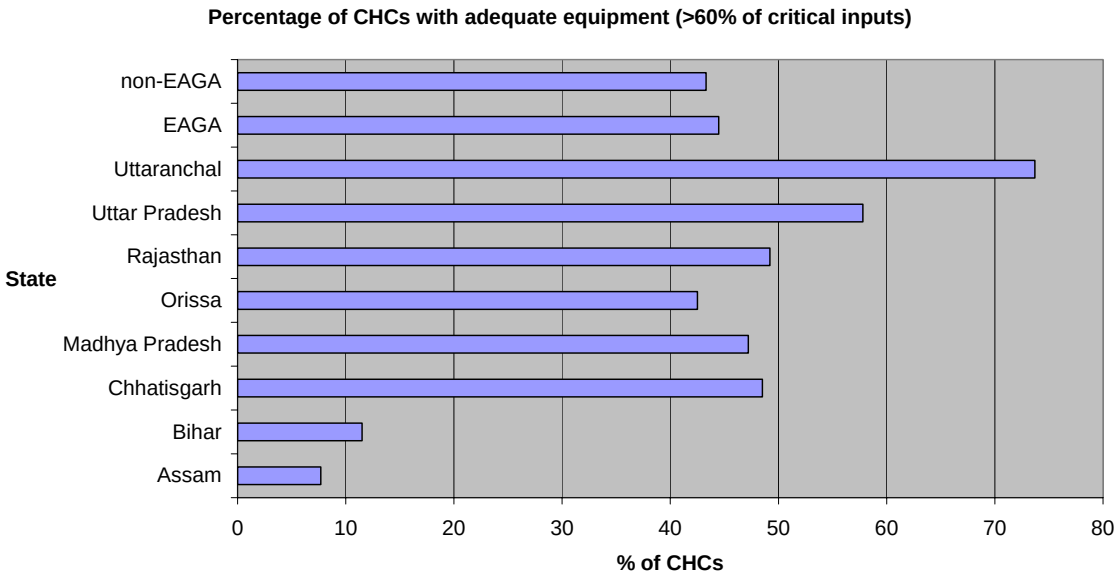


Figure A9.


Percentage of CHCs with adequate equipment (>60% of critical inputs)
non-EAGA
EAGA
Uttaranchal
Uttar Pradesh
Rajasthan
Orissa
Madhya Pradesh
Chhatisgarh
Bihar
Assam
State
0
10
20
30
40
50
60
70
80
% of CHCs

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