Adding interventions to mass measles vaccinations in India

The Harvard community has made this article openly available. Please share how this access benefits you. Your story matters

Citation
Johri, Mira, Stéphane Verguet, Shaun K Morris, Jitendar K Sharma, Usha Ram, Cindy Gauvreau, Edward Jones, Prabhat Jha, and Mark Jit. 2016. “Adding interventions to mass measles vaccinations in India.” Bulletin of the World Health Organization 94 [10]: 718-727. doi:10.2471/BLT.15.160044. http://dx.doi.org/10.2471/BLT.15.160044.

Published Version
doi:10.2471/BLT.15.160044

Citable link
http://nrs.harvard.edu/urn-3:HUL.InstRepos:29626166

Terms of Use
This article was downloaded from Harvard University’s DASH repository, and is made available under the terms and conditions applicable to Other Posted Material, as set forth at http://nrs.harvard.edu/urn-3:HUL.InstRepos:dash.current.terms-of-use#LAA
Adding interventions to mass measles vaccinations in India
Mira Johri,* Stéphane Verguet,† Shaun K Morris,‡ Jitendar K Sharma,§ Usha Ram,‖ Cindy Gauvreau,‖ Edward Jones,‖ Prabhat Jha* & Mark Jit†

Objective To quantify the impact on mortality of offering a hypothetical set of technically feasible, high-impact interventions for maternal and child survival during India's 2010–2013 measles supplementary immunization activity.

Methods We developed Lives Saved Tool models for 12 Indian states participating in the supplementary immunization, based on state- and sex-specific data on mortality from India's Million Deaths Study and on health services coverage from Indian household surveys. Potential add-on interventions were identified through a literature review and expert consultations. We quantified the number of lives saved for a campaign offering measles vaccine alone versus a campaign offering measles vaccine with six add-on interventions (nutritional screening and complementary feeding for children, vitamin A and zinc supplementation for children, multiple micronutrient and calcium supplementation in pregnancy, and free distribution of insecticide-treated bednets).

Findings The measles vaccination campaign saved an estimated 19,016 lives of children younger than 5 years. A hypothetical campaign including measles vaccine with add-on interventions was projected to save around 73,900 lives (range: 70,200–79,300), preventing 73,700 child deaths (range: 70,000–79,000) and 300 maternal deaths (range: 200–400). The most effective interventions in the whole package were insecticide-treated bednets, measles vaccine and preventive zinc supplementation. Girls accounted for 66% of expected lives saved (12,712/19,346) for the measles vaccine campaign, and 62% of lives saved (45,721/74,367) for the hypothetical campaign including add-on interventions.

Conclusion In India, a measles vaccination campaign including feasible, high-impact interventions could substantially increase the number of lives saved and mitigate gender-related inequities in child mortality.

Introduction
Measles vaccination made an important contribution to the millennium development goal to reduce under-5 mortality (MDG4), accounting for 23% of the estimated worldwide decline in all-cause child mortality from 1990 to 2008. A cornerstone of the strategy was that all children be offered a second opportunity to receive a dose of measles-containing vaccine, either through routine immunization services or through mass vaccination campaigns (known as supplementary immunization activities). Supplemental immunization targets all children, to reach those who have been missed by routine services and also those who may have failed to develop an appropriate immune response after vaccination. The strategy has been widely implemented in sub-Saharan Africa over the last decade, with measurable success in reducing mortality. India delayed implementing supplementary immunization, and this may have contributed to the slower decline in measles mortality as compared with sub-Saharan Africa. India's share of global measles mortality increased from 16% of 535,300 deaths (95% confidence interval, CI: 347,200–976,400) in 2000 to 47% of 139,300 deaths (95% CI: 71,200–447,800) in 2010.

In 2010, India introduced a second opportunity to receive measles-containing vaccine through routine immunization programmes in states with 80% or higher coverage of the first dose of measles-containing vaccine, and elsewhere through supplementary immunization activities. India's first supplementary mass measles vaccination campaign took place from 2010 to 2013 in 14 states containing 59% of India's 113 million under-5 children (authors' calculations based on census data). These 14 states have relatively weak health systems compared with the national average and poorer progress towards MDG4. The supplementary immunization activity reached 119 million children aged nine months to 10 years, achieving 91% coverage of the target population of 130,743,905. India's first round of supplementary mass measles vaccination delivered only a measles-containing vaccine dose. Planning is underway for a larger measles–rubella vaccine introduction campaign targeting children aged 1–15 years.

Campaign-style delivery has two key advantages over routine services; it can achieve high coverage even in areas where the reach of routine services is weak and it reduces access barriers. On the other hand, a weakness of campaign delivery is that it represents a one-time or cyclic event. Some countries have made strategic use of mass vaccination campaigns to offer additional health interventions such as vitamin A supplements, insecticide-treated bednets and deworming medicines. Therefore, vaccination campaigns could serve as an important platform to extend the reach of health services to underserved groups and improve maternal and child survival.

To date, India has largely not included add-on interventions with its mass vaccination campaigns and Indian health planners have expressed concerns over the potential challenges of implementing these, while agreeing that add-ons could be beneficial in principle. To inform the design of future supplementary immunization activities in India and elsewhere we

---

* Correspondence to Mira Johri (email: mira.johri@umontreal.ca).

† Centre de Recherche du Centre Hospitalier de l’Université de Montréal, Tour Saint-Antoine, Porte S03-458, 850 Rue St-Denis, Montréal, Québec, H2X 0A9, Canada.

‡ Department of Global Health and Population, Harvard TH Chan School of Public Health, Boston, United States of America.

§ Division of Infectious Diseases, Department of Pediatrics, University of Toronto, Toronto, Canada.

‖ National Health Systems Resource Centre, Ministry of Health and Family Welfare, New Delhi, India.

‖ Centre for Global Health Research, Dalla Lana School of Public Health, Toronto, Canada.

† Department of Infectious Disease Epidemiology, London School of Hygiene & Tropical Medicine, London, England.

Correspondence to Mira Johri (email: mira.johri@umontreal.ca).

Submitted: 14 June 2015 – Revised version received: 1 February 2016 – Accepted: 7 April 2016 – Published online: 5 July 2016
aimed to project the impact on mortality of a hypothetical set of technically feasible, high-impact interventions for maternal and child survival, delivered during India’s 2010–2013 mass measles vaccination campaign.

Methods

For states participating in the supplementary immunization activity, we conducted a mathematical modelling study to quantify: (i) the number of lives saved by a supplementary immunization activity delivering measles-containing vaccine alone, and (ii) the number of lives that could be saved by a supplementary immunization activity package delivering measles-containing vaccine plus a set of six hypothetical add-on interventions. The analysis baseline reflected existing coverage levels for all interventions offered through routine services. Within each state we also assessed the impact of the interventions on mortality by child’s sex. Ethics approval was not required for this study as it used only secondary data with no personal identifiable information. A technical appendix containing full details of the methods is available from the corresponding author.

Selection of interventions

We selected add-on interventions for modelling through a literature review and expert consultation. First, we used two systematic reviews to identify maternal and child health interventions that had been linked to routine immunization or vaccination campaigns (but not specific to measles) in a low- or middle-income country, identified from two systematic reviews. Then we updated the literature search from these reviews to 15 May 2015, and consulted supplementary sources. Further suggestions were contributed by programme experts, including administrators and managers involved in India’s 2010–2013 measles supplementary immunization activities. From these inputs we prepared a comprehensive list of potential add-on interventions. Next, we condensed the list based on a review of the evidence of the feasibility of interventions, matched to target population and effectiveness, in the context of a supplementary immunization activity. Finally, three experts engaged with India’s immunization programme at central and state levels prioritized the interventions to create a shortlist of interventions for analysis based on criteria of programmatic and technical feasibility and policy relevance (Table 1). A total of six interventions — generally offered in India through the routine health system — were selected: (i) nutritional screening of children linked to services for complementary feeding; (ii) vitamin A supplementation for children; (iii) preventative zinc supplementation for children; (iv) free distribution of insecticide-treated bednets; (v) multiple micronutrient supplementation for pregnant women (iron, folic acid, vitamin A); and (vi) calcium supplementation for pregnant women.

Decision modelling

We modelled the impact of the interventions on maternal and child mortality over the period 2009–2013 using the freely available Lives Saved Tool (LiST), version 4.7 (Johns Hopkins Bloomberg School of Public Health, Baltimore, United States of America). LiST is a mathematical model that synthesizes evidence on the causes of maternal and child mortality and the effectiveness of interventions to combat them. The structure of the model has been described elsewhere. LiST can be used to project the impact that multiple interventions may have on survival. LiST was chosen because its target populations are similar to those of India’s measles supplementary immunization activities. In addition, validation studies comparing actual measured mortality with modelled mortality showed that LiST provided accurate predictions in diverse geographical settings, including northern India.

State-level analyses

Model parameters

Of the 14 states targeted for supplementary immunization, two were excluded from our analysis, as data on health services coverage (Nagaland, population 1978 502) and population structure (Arunachal Pradesh, population 1 383 727) required for model parameterization were unavailable. LiST developers have made available parameterized models representing India and the state of Bihar in 2008 and we created LiST models for 11 additional supplementary immunization activity states by tailoring the Indian LiST module.

We used recent demographic projections for India to create age- and sex-structured populations for modelling. Estimates for the effectiveness of add-on interventions were taken from the child health epidemiology reference group (CHERG) systematic reviews incorporated in LiST, with the exception of vitamin A supplementation for which we used a more recent meta-analysis incorporating findings from the Deworming and Enhanced Vitamin A Trial (DEVTA) in Uttar Pradesh, India. We developed state-specific proportional mortality estimates by mapping cause-of-death data from India’s Million Deaths Study (MDS) to the LiST model categories. The MDS is a nationally representative longitudinal study of premature mortality monitoring 14 million people in India, which assigns cause of death by physician-reviewed verbal autopsy. For Manipur, Meghalaya and Tripura, state-specific mortality data were not available and for these states we used regional proportional mortality estimates. The MDS did not evaluate pertussis deaths as a separate category due to the difficulty of distinguishing pertussis from causes of death such as pneumonia when using verbal autopsy techniques. We imputed pertussis deaths using CHERG methods. To characterize immunization coverage before the supplementary immunization activity, values for other parameters were derived from Indian household surveys. The principal data source was India’s 2007–2008 district level household and facility survey; data were collected just before the measles supplementary immunization. The technical appendix with illustrations of parameter values and data sources for a sample state are available from the corresponding author. Coverage data for the 2010–2013 measles supplementary immunization were provided by the Government of India.

Integrated vaccination campaign package

We modelled the supplementary immunization activity as occurring in all states in a single year (2010). The campaign would confer a one-time increase in measles vaccination coverage. Some of the hypothetical interventions, such as delivering vitamin A supplements and carrying out nutritional screening, could be completed at the time of vaccination. For these interventions, increases in coverage were modelled as a function of measles-containing vaccine coverage.
Table 1. Appraisal of potential add-on interventions for supplementary immunization activities in India

| Intervention | Feasible in a single contact | Match to SIA target population | Effective (reduces mortality) in SIA context | Outcome of appraisal |
|--------------|------------------------------|--------------------------------|-------------------------------------------|----------------------|
| Child health intervention | | | | |
| Nutritional screening | Yes | Yes | Likely | Selected\(^a\) |
| Vitamin A supplementation | Yes | Yes | Likely | Selected\(^b\) |
| Promotion of oral rehydration salts or therapy | Yes | Yes | Uncertain | Recommended\(^c\) |
| Free distribution of oral rehydration salts | Yes | Yes | Uncertain | Recommended\(^d\) |
| Deworming | Yes | Yes | No | Recommended\(^e\) |
| Preventive zinc supplementation | Yes | Yes | Uncertain | Selected\(^f\) |
| Free distribution of insecticide-treated bednets | Yes | Yes | Yes | Selected\(^g\) |
| Oral polio vaccine | Yes | Yes | No | Recommended\(^h\) |
| DTP vaccine catch-up/booster dose | Yes | Yes | Likely | Challenging\(^i\) |
| Japanese encephalitis vaccine | Yes | Yes | Likely | Challenging\(^i\) |
| Pneumococcal vaccine | Yes | Yes | Likely | Challenging\(^i\) |
| Rubella (measles–rubella) vaccine | Yes | Yes | Likely | Recommended\(^i\) |
| Cholera vaccine | Yes | Likely | Yes | Challenging\(^i\) |
| Pregnancy intervention\(^4\) | | | | |
| Multiple micronutrient supplementation (iron, folic acid, vitamin A) | Yes | To some extent | Yes | Selected\(^d\) |
| Calcium supplementation | Yes | To some extent | Yes | Selected\(^d\) |
| Deworming | Yes | To some extent | No | Recommended\(^d\) |
| Tetanus toxoid vaccine | Yes | To some extent | Yes | Challenging\(^i\) |
| Promotion of breastfeeding | Yes | To some extent | Uncertain | Potentially valuable\(^a\) |
| Additional intervention | | | | |
| Family planning | No | Yes | Uncertain | Potentially valuable\(^a\) |
| Screening for unmet needs and health service referrals | Yes | Yes | Likely | Recommended\(^h\) |

SIA: supplementary immunization activity; DTP: diphtheria–tetanus–pertussis.

\(^a\) Interventions selected for modelling in this analysis.

\(^b\) Interventions recommended as appropriate but lower priority for this analysis due to low impact on mortality or lack of evidence.

\(^c\) With the exception of combination vaccines, offering additional vaccines was viewed as challenging due to issues of logistics, safety and human resources.

\(^4\) Scope for pregnancy interventions depends on the proportion of children brought by mothers to receive measles vaccine and the proportion of pregnant women.

\(^i\) Interventions judged to be potentially valuable but lower priority for this analysis due to the need for empirical investigation.

Note: Further details of the appraisal are available from the corresponding author.

Achieved by the supplementary immunization. Vitamin A supplements for children should be given twice per year; a single dose of vitamin A represents half the annual recommended dose. We therefore calculated the increase in vitamin A coverage conferred by the supplementary immunization as achieved coverage divided by 2. Nutritional screening is effective only when linked to programmes and services. Based on expert opinion, we assumed that 90% of children screened and found nutritionally deficient would be linked to follow-up services, including complementary feeding, through programmes such as India’s integrated child development services. Several other interventions would require additional follow-through to be effective. For three interventions (multiple micronutrient and calcium supplements for pregnant women and preventive zinc for children), we modelled the causal chain between being offered in the supplementary immunization activity and increased intervention coverage as depending on measles-containing vaccine achievement and compliance. For these interventions, we used an average compliance scenario of 70% and considered two additional scenarios bounding reasonable ranges of low (50%) and high (90%) compliance. We assumed that 73% of freely distributed long-lasting insecticide-treated bednets would be used.\(^7\)

The analytic assumptions are outlined in Table 2 (available at: http://www.who.int/bulletin/volumes/94/10/15-160044), with further details available from the corresponding author.

**Sensitivity analyses**

Additional analyses explored the effect of using different sources of data for proportional mortality (i.e. comparing proportional mortality data for India from CHERG and state-specific proportional mortality data from the MDS). We also quantified the impact of parameter uncertainty related to the effectiveness of vitamin A supplementation on diarrhoea mortality for children aged 6–59 months. To do this we contrasted the DEVTA meta-analysis midpoint estimate of 11%\(^9\) with the 47% mortality benefit incorporated in LiST.\(^3\) Finally, we developed the Dynamic Measles Immunization Calculation Engine, a transmission dynamic measles model\(^11\) that enabled us to consider factors not captured in LiST, such as age-specific
vaccine efficacy for measles first and second doses, and herd immunity, to model the impact on mortality of the supplementary immunization activity delivering only measles-containing vaccine.

**Equity impact**

Equity analyses were done on a state-by-state basis and assumed that increases in supplementary immunization coverage reached both sexes equally. To quantify the impact of the mass vaccination campaign on sex differences in child mortality, we used sex-specific proportional mortality data from the MDS and sex-specific coverage data from the third round of the district level household and facility survey and other sources (further details are available from the corresponding author). We assessed the impact on gender equity of the campaign delivering measles vaccine only and the hypothetical campaign delivering measles vaccine and add-on interventions by comparing the proportion of hypothetical lives saved by the campaign for girls versus boys, and the under-5 mortality rate per 1000 live births for girls versus boys in the years before (2009) and after (2010) the measles campaign.

**Results**

**Overall results**

India's decision to introduce a second opportunity for measles vaccination via mass vaccination campaign saved the lives of an estimated 19016 under-5 children in the 12 states included in our analysis, of whom 11,121 (58%) were in the state of Uttar Pradesh (Table 3).

Table 4 shows the projected lives saved in these states by a hypothetical supplementary immunization package that included measles vaccine and high-impact add-on interventions for children and pregnant women. This was based on a scenario of 70% compliance with interventions (when applicable) and on mortality data from India's MDS. Maternal lives saved were due to calcium supplementation in pregnancy; all other lives saved represented under-5 children. Summing over all states, including maternal and child health interventions in the measles supplementary immunization campaign would have saved around 73,900 (range: 70,200–79,300), preventing 73,700 child deaths (range: 70,000–79,900) and 300 maternal deaths (range: 200–400). The hypothetical campaign offering measles vaccine with add-on interventions was therefore projected to increase the number of lives saved by a factor of 3.89 (range: 3.69 to 4.17) compared with offering measles vaccine alone. The benefits of the add-ons were also distributed among states more closely to the proportion of the population (Table 3 and Table 4; supplementary data are available from the corresponding author). For example, Uttar Pradesh, which had 30.7% of the under-5 target population for the supplementary immunization, gained 58.5% of lives saved from the measles-only supplementary immunization (Table 3) and 36.0% of lives saved from the package of measles supplementary immunization with add-ons (Table 4).

We explored which add-on interventions in the whole package contributed most to the anticipated reductions in mortality (Table 4). Summing over all states for the average (70%) compliance scenario, the effectiveness of the interventions in descending order were: insecticide-treated bednets (24,933 lives saved), measles vaccine (18,235), preventive zinc supplementation (15,529), complementary feeding (4284), vitamin A supplementation (2093), multiple micronutrients supplementation during pregnancy (18,235), and calcium supplementation during pregnancy (7376). Some of the lives saved by the supplementary immunization with add-ons could not be attributed to specific interventions and are presented instead by syndrome, including diarrhoea (1838 lives saved), pneumonia

---

**Table 2. Assumptions used in the analysis of measles vaccine with a package of six add-on interventions for the supplementary immunization activity in India**

| Assumption                                                                 | Value   | Source                      |
|---------------------------------------------------------------------------|---------|-----------------------------|
| Efficacy of measles vaccine in reducing measles mortality                 | 0.85    | Published study             |
| Duration of benefit conferred by SIA interventions                        | 3 years | Published study             |
| Insecticide-treated bednets                                               | Lifelong | Published study             |
| Measles vaccine                                                           | <1 year | Published study             |
| All other interventions                                                   | 73%     | Published study             |
| Proportion of individuals likely to use SIA add-on interventions           | 70% compliance (50% low, 90% high) | Expert opinion and field data |
| Insecticide-treated bednets                                               | 70% compliance (50% low, 90% high) | Expert opinion and field data |
| Preventive zinc for children                                              | 70% compliance (50% low, 90% high) | Expert opinion             |
| Proportion of children identified in the SIA as having nutritional deficiencies and linked to services for complementary feeding and supplementation | Varies by state, range 21% to 52% | Calculated |
| Proportion of pregnant women reached by the SIA                          | SIA coverage divided by 2⁴ | Calculated |
| Increase in vitamin A coverage achieved through the SIA                   | SIA coverage divided by 2⁴ | Calculated |
| SIA reaches male and female children equally                              | –       | Published study             |
| SIA does not reduce coverage of routine services                          | –       | Assumed |

SIA: supplementary immunization activity.
² This category comprises nutritional screening; vitamin A supplementation for children; preventive zinc supplementation for children; multiple micronutrient supplementation in pregnant women (iron, folic acid, vitamin A); and calcium supplementation in pregnant women.
³ Further details of compliance scenarios are available from the corresponding author.
⁴ This estimate for linkage to services is based on the mandate and capacity of India’s integrated child development services programme.
⁵ As Vitamin A supplements should be given twice per year, this represents half an annual dose.
Table 3. Estimated number of under-5 lives saved in 12 states participating in India’s 2010–2013 measles supplementary immunization activity

| State               | Under-5 lives saved by measles vaccine | Under-5 population in SIA statesa |
|---------------------|---------------------------------------|----------------------------------|
| Assam               | 378 (2.0)                             | 3 556 222 (4.8)                  |
| Bihar               | 3 436 (18.1)                          | 13 811 150 (19.2)                |
| Chhattisgarh        | 79 (0.4)                              | 3 014 655 (3.8)                  |
| Gujarat             | 262 (1.4)                             | 6 293 984 (8.2)                  |
| Haryana             | 435 (2.3)                             | 2 763 215 (3.6)                  |
| Jharkhand           | 353 (1.9)                             | 4 022 926 (5.5)                  |
| Madhya Pradesh      | 1 864 (9.8)                           | 8 899 016 (11.2)                 |
| Manipur             | 32 (0.2)                              | 257 601 (0.4)                    |
| Meghalaya           | 33 (0.2)                              | 416 638 (0.6)                    |
| Rajasthan           | 996 (5.2)                             | 8 852 191 (11.0)                 |
| Tripura             | 27 (0.1)                              | 339 014 (0.5)                    |
| Uttar Pradesh       | 11 121 (58.5)                         | 24 945 895 (30.7)                |
| All statesb         | 190 016 (100.0)                       | 77 172 507 (100.0)c              |

SIA: supplementary immunization activity.

a Author’s calculations based on Government of India census statistics.b
b All participating states in the 2010–2013 SIA states.
c SIA states contained 59% of the under-5 population of India.d

Note: Analyses use proportional mortality from the Million Deaths Study22 and vitamin A effectiveness from the Deworming and Enhanced Vitamin A Trial.28 Lives saved were calculated for the period 2010–2013.

Discussion

Measles vaccination is important for reduction of child mortality, yet global coverage of the first dose of measles-containing vaccine has been stagnant since 2009.23 Mass vaccination campaigns are resource-intensive and planners must assess their value among a range of options for health improvement and resource expenditure. Our analysis demonstrated that India’s introduction of a second opportunity for measles vaccination through large-scale campaigns from 2010 to 2013 made an important contribution to reducing mortality from measles. Our model-based analysis of 12 of the 14 participating states found that India’s measles supplementary immunization activity likely saved the lives of approximately 19 000 under-5 children, corresponding to roughly 29% (range: 24% to 35%) of India’s annual measles mortality.24 We also found that a hypothetical supplementary immunization package delivering measles vaccine and a set of additional interventions of known effectiveness would increase the impact on mortality of the mass measles vaccination campaign more than threefold. Despite variation among states, the most important interventions in the package overall were insecticide-treated bednets, measles vaccine and preventive zinc supplementation. This reflects the high burden of infectious disease and undernutrition among Indian children, the impact of malaria in some areas and the relatively low coverage of these key interventions.25

Child mortality in India differs markedly by sex, with higher mortality rates recorded for girls.26,27 Caregiver bias associated with preference for a male child likely contributes to the mortality differentials due to lower use of regular health services for girls. Vaccination campaigns, however, show a more equal pattern of use.28 We found...
that, due to the high coverage achieved in states with weak health systems, supplementary immunization helped to mitigate gender-related inequities in child mortality. We also studied differences in mortality for subgroups defined by household wealth status (quintiles) and area of residence (rural/urban). However, the results were uninformative due to the absence of state- and stratum-specific proportional mortality data (available from the corresponding author).

The components of this integrated health package for a supplemental mass vaccination campaign were designed based on a systematic appraisal of the evidence and a quantitative projection of likely impact. Add-on interventions were systematically selected using the published scientific literature and expert guidance. A key advantage of this approach is that it presents the evidence and assumptions in a transparent framework that permits alternatives to be explored. We placed particular emphasis on defining options for analysis that were evidence-based, feasible and relevant to the Indian context. Cause-of-death data from India’s MDS enabled us to show state- and sex-specific mortality patterns, while data from recent household surveys facilitated an accurate portrayal of health services coverage. LiST is a validated policy model that enables competing mortality risks to be considered. In addition, we validated the LiST projections of the impact of measles-containing vaccine using a transmission dynamic model that takes into account both herd immunity and age-specific vaccine efficacy. As anticipated, the dynamic model results were consistent with LiST results but showed a somewhat higher impact on mortality for the supplementary immunization with measles vaccine.

We highlight five limitations of the analysis. First, the LiST model focuses only on mortality. Many of the add-on interventions studied also reduce morbidity, and some potentially important interventions, such as antihelminthic drugs, were not considered as their direct impact is exclusively on morbidity. Second, limited availability of data forced us to exclude two states of less than 2 million inhabitants each. Third, uncertainty concerning parameter values for vitamin A effectiveness, proportional mortality due to malaria, and compliance were found to influence mortality projections. Fourth, our mortality projections represent a specific point in time, whereas child survival and health services coverage are changing rapidly in India. Finally, due to constraints of logistics, it may not be possible in practice to offer as many add-on interventions as we have modelled for this analysis. Our primary purpose was to demonstrate the potential benefits of bundling proven interventions with a vaccination campaign. We also showed the utility of an evidence-based approach for planning add-ons for supplementary immunization—

---

### Table 4. Projected number of lives saved due to a hypothetical package of measles vaccine with a set of additional maternal and child health interventions during the measles supplementary immunization activity, India 2010–2013

| Compliance scenario and state | Measles vaccine | Bednets | Zinc | Complementary feeding | Micronutrients | Vitamin A | Calcium | Diarrhoea | Pneumonia | Measles |
|------------------------------|-----------------|---------|------|-----------------------|----------------|-----------|---------|-----------|-----------|---------|
| **By state (70% scenario)**  |                 |         |      |                       |                |           |         |           |           |         |
| Assam                        | 365             | 3611    | 810  | 254                   | 149            | 131       | 16      | 121       | 93        | 31      | 5581    |
| Bihar                        | 3265            | 3981    | 3030 | 1076                  | 595            | 415       | 43      | 417       | 421       | 169     | 13412   |
| Chhattisgarh                 | 76              | 1691    | 301  | 123                   | 126            | 41        | 10      | 33        | 56        | 8       | 2465    |
| Gujarat                      | 256             | 733     | 677  | 156                   | 250            | 107       | 11      | 63        | 75        | 53      | 2381    |
| Haryana                      | 421             | 374     | 246  | 61                    | 122            | 50        | 5       | 23        | 19        | 15      | 1336    |
| Jharkhand                    | 338             | 2945    | 773  | 192                   | 172            | 101       | 13      | 92        | 100       | 24      | 4750    |
| Madhya Pradesh              | 1791            | 4240    | 2163 | 532                   | 499            | 264       | 28      | 234       | 301       | 97      | 10149   |
| Manipur                      | 31              | 177     | 62   | 42                    | 12             | 8         | 1       | 46        | 53        | 35      | 467     |
| Meghalaya                   | 32              | 180     | 82   | 9                     | 14             | 10        | 1       | 48        | 56        | 35      | 467     |
| Rajasthan                   | 962             | 2256    | 1604 | 268                   | 479            | 175       | 34      | 95        | 204       | 41      | 6118    |
| Tripura                     | 27              | 206     | 69   | 9                     | 10             | 10        | 1       | 4         | 6         | 1       | 343     |
| Uttar Pradesh               | 10671           | 4539    | 5712 | 1562                  | 1333           | 781       | 108     | 662       | 643       | 449     | 26460   |
| **All states**              |                 |         |      |                       |                |           |         |           |           |         |         |
| 70% scenario                 | 18235           | 24933   | 15529 | 4284                   | 3761           | 2093      | 271     | 1838      | 2027      | 958     | 73929   |
| 50% scenario                 | 18314           | 24929   | 13346 | 4292                   | 2687           | 2109      | 196     | 1647      | 1806      | 829     | 70155   |
| 90% scenario                 | 18159           | 24934   | 19849 | 4235                   | 4838           | 2080      | 350     | 1870      | 2061      | 945     | 79321   |

---

*Notes:* Including 12 states participating in India’s 2010–2013 measles supplementary immunization activity. Analyses use proportional mortality from the Million Deaths Study and vitamin A effectiveness from the Deworming and Enhanced Vitamin A Trial.

---

References...

---

*doi: http://dx.doi.org/10.2471/BLT.15.160044*
Table 5. Projected number of lives saved for under-5 children due to measles vaccine only or due to a hypothetical package of measles vaccine with a set of additional maternal and child health interventions during the measles supplementary immunization activity, India 2010–2013, by child’s sex

| State              | Lives saved by measles vaccine only | Lives saved by measles vaccine with add-on interventions* |
|--------------------|-------------------------------------|----------------------------------------------------------|
|                    | Total, no. | Girls, no. (%) | Boys, no. (%) | Total, no. | Girls, no. (%) | Boys, no. (%) |
| Assam              | 379        | 242 (64)       | 138 (36)      | 5 579      | 3 090 (55)     | 2 489 (45) |
| Bihar              | 3 439      | 2 231 (65)     | 1 209 (35)    | 13 373     | 8 456 (63)     | 4 917 (37) |
| Chhattisgarh       | 77         | 34 (45)        | 42 (55)       | 2 438      | 1 169 (48)     | 1 270 (52) |
| Gujarat            | 299        | 200 (67)       | 99 (33)       | 2 396      | 1 397 (58)     | 999 (42)  |
| Haryana            | 430        | 269 (62)       | 161 (38)      | 1 334      | 850 (64)       | 484 (36)  |
| Jharkhand          | 355        | 225 (63)       | 130 (37)      | 4 695      | 2 493 (53)     | 2 202 (47) |
| Madhya Pradesh     | 1 899      | 999 (53)       | 900 (47)      | 10 379     | 5 730 (55)     | 4 649 (45) |
| Manipur            | 32         | 14 (45)        | 18 (55)       | 329        | 158 (48)       | 171 (52)  |
| Meghalaya          | 33         | 15 (46)        | 18 (54)       | 337        | 164 (49)       | 173 (51)  |
| Rajasthan          | 1 080      | 831 (77)       | 249 (23)      | 6 292      | 4 268 (68)     | 2 024 (32) |
| Tripura            | 27         | 13 (49)        | 14 (51)       | 376        | 199 (53)       | 176 (47)  |
| Uttar Pradesh      | 11 296     | 7 639 (68)     | 3 657 (32)    | 26 839     | 17 747 (66)    | 9 093 (34) |
| Total              | 19 346     | 12 712 (66)    | 6 635 (34)    | 74 367     | 45 721 (61)    | 28 647 (39) |

* Add-on interventions were nutritional screening linked to complementary feeding; vitamin A supplementation for children; preventive zinc supplementation for children; free distribution of insecticide-treated bednets; multiple micronutrient supplementation in pregnant women (iron, folic acid, vitamin A); and calcium supplementation in pregnant women.

Table 6. Projected under-5 mortality in the years before (2009) and after (2010) the measles supplementary immunization activity, India 2010–2013, by child’s sex

| State            | Measles vaccine only | Measles vaccine with add-on interventions* |
|------------------|----------------------|--------------------------------------------|
|                  | Deaths per 1000 live births | Difference (2010–2009) | Deaths per 1000 live births | Difference (2010–2009) |
|                  | Girls | Boys | 2009 | 2010 | 2009 | 2010 | Girls | Boys | 2009 | 2010 |
| Assam            | 87.0  | 66.3 | 79.0 | 78.7 | 0.0  | 0.3  | 87.9  | 83.4 | 79.9 | 76.3 |
| Bihar            | 79.0  | 78.6 | 80.0 | 59.0 | 0.7  | 0.0  | 68.3  | 63.3 | 60.3 | 57.4 |
| Chhattisgarh     | 61.0  | 60.9 | 61.0 | 60.9 | 1.0  | 0.1  | 62.2  | 59.8 | 62.2 | 59.9 |
| Gujarat          | 59.0  | 59.7 | 52.0 | 51.9 | 0.3  | 0.1  | 60.5  | 58.9 | 52.5 | 51.4 |
| Haryana          | 50.0  | 50.8 | 50.5 | 51.0 | 1.0  | 0.5  | 60.2  | 57.5 | 52.2 | 50.7 |
| Jharkhand        | 45.0  | 45.2 | 45.0 | 58.7 | 0.8  | 0.3  | 59.9  | 56.1 | 59.9 | 56.7 |
| Madhya Pradesh   | 50.0  | 49.2 | 82.0 | 81.0 | 1.1  | 1.0  | 85.4  | 81.0 | 82.4 | 78.9 |
| Manipur          | 70.0  | 78.5 | 79.0 | 78.3 | 0.5  | 0.7  | 89.5  | 87.7 | 89.5 | 87.5 |
| Meghalaya        | 70.0  | 78.6 | 79.0 | 78.5 | 0.4  | 0.5  | 89.8  | 88.0 | 89.8 | 87.8 |
| Rajasthan        | 70.0  | 78.0 | 60.0 | 59.7 | 1.0  | 0.3  | 79.5  | 75.7 | 60.5 | 58.7 |
| Tripura          | 70.0  | 78.6 | 79.0 | 78.6 | 0.4  | 0.4  | 87.2  | 84.6 | 87.2 | 85.0 |
| Uttar Pradesh    | 80.0  | 83.8 | 71.0 | 69.5 | 3.2  | 1.5  | 87.2  | 81.1 | 71.2 | 68.1 |

* Add-on interventions were nutritional screening linked to complementary feeding; vitamin A supplementation for children; preventive zinc supplementation for children; free distribution of insecticide-treated bednets; multiple micronutrient supplementation in pregnant women (iron, folic acid, vitamin A); and calcium supplementation in pregnant women.

Results were calculated without applying background trends in acquired immune deficiency syndrome mortality.

Note: Including 12 states participating in India’s 2010–2013 measles supplementary immunization activity. Analyses use proportional mortality from the Million Deaths study and vitamin A effectiveness from the Deworming and Enhanced Vitamin A Trial. Lives saved were calculated for the period 2010–2013. Data are based on the 70% compliance scenario (see Table 2) and apply to multiple micronutrients and calcium during pregnancy, and preventive zinc for children.
Mass measles vaccination campaigns in many countries have offered additional interventions, but the choice of which interventions to include has generally been made in an ad hoc way rather than through a systematic analysis such as the one illustrated here. Although the interventions we examined were all deemed by Indian health planners to be technically feasible to incorporate into mass vaccination campaigns, implementation research is needed to assess the feasibility and impact on health systems of offering these interventions. We also need to assess the cost-effectiveness of supplementary immunization activities that include measles vaccine and add-on maternal and child health interventions in India. As vaccination campaigns must be repeated periodically, this research has the potential to revitalize political support for accelerated measles control strategies, as well as for other maternal and child interventions delivered through mass campaigns, such as rubella and polio.

CONCLUSIONS

We thank Peter Strebel, Raymond Hutubessy, Marty Roper, Narendra K. Arora, Ritesh Sharma, Nikhil Utture, Sahil Chopra, Natasha Crowcroft, Myriam Cielo Perez Osorio, Annie Li, Catherine Arsenault, and Georges K. Koné.

Funding: The World Health Organization Initiative for Vaccine Research funded this work.

Competing interests: None declared.

Acknowledgements

Development of the “Lives Saved Tool” was supported by a grant from the Bill and Melinda Gates Foundation (INV-000914) and the World Health Organization. The World Health Organization also provided support for a second international modeling meeting on maternal and child health interventions in India, held in New Delhi, India, in 2010. We thank Peter Strebel, Raymond Hutubessy, Marty Roper, Narendra K. Arora, Ritesh Sharma, Nikhil Utre, Sahil Chopra, Natasha Crowcroft, Myriam Cielo Perez Osorio, Annie Li, Catherine Arsenault, and Georges K. Koné.

Arsenault, and Georges K. Koné.

We thank Peter Strebel, Raymond Hutubessy, Marty Roper, Narendra K. Arora, Ritesh Sharma, Nikhil Utre, Sahil Chopra, Natasha Crowcroft, Myriam Cielo Perez Osorio, Annie Li, Catherine Arsenault, and Georges K. Koné.

Funding: The World Health Organization Initiative for Vaccine Research funded this work.

Competing interests: None declared.

Acknowledgements

Development of the “Lives Saved Tool” was supported by a grant from the Bill and Melinda Gates Foundation (INV-000914) and the World Health Organization. The World Health Organization also provided support for a second international modeling meeting on maternal and child health interventions in India, held in New Delhi, India, in 2010. We thank Peter Strebel, Raymond Hutubessy, Marty Roper, Narendra K. Arora, Ritesh Sharma, Nikhil Utre, Sahil Chopra, Natasha Crowcroft, Myriam Cielo Perez Osorio, Annie Li, Catherine Arsenault, and Georges K. Koné.
Mira Johri et al.

Resumen
Adición de intervenciones a las vacunaciones antisarampiónas en masa en la India

Objetivo Cuantificar el impacto en la mortalidad del hecho de ofrecer un conjunto hipotético de intervenciones técnicamente viables y de alto impacto para la supervivencia de madres e hijos durante la actividad de inmunización suplementaria antisarampionosa en la India entre 2010 y 2013.

Métodos Se desarrollaron los modelos de la herramienta “Live Saved Tool” para 12 estados indios participantes en la inmunización suplementaria, en base a información según el estado y el sexo sobre la mortalidad recopilada en el estudio “Million Deaths Study” de la India y sobre la cobertura de servicios sanitarios de las encuestas domésticas realizadas en la India. Se identificaron posibles intervenciones adicionales a través de un análisis de documentos y consultas a expertos. Se cuantificó el número de vidas salvadas durante una campaña que ofrecía la vacuna antisarampionosa frente a una campaña que ofrecía la
vacuna antisaramponiosa con seis intervenciones adicionales (revisión nutricional y alimentación complementaria para niños, suplementos de vitamina A y zinc para niños, varios micronutrientes, suplemento de calcio durante el embarazo y distribución gratuita de mosquiteros tratados con insecticida).

**Resultados** La campaña de vacunación antisaramponiosa salvó unas 19 016 vidas de niños menores de 5 años. Se estimó que una campaña hipotética que incluía la vacuna antisaramponiosa e intervenciones adicionales salvaría unas 73 900 vidas (alcance: 70 200–79 300), evitando 73 700 muertes infantiles (alcance: 70 000–79 000) y 300 muertes maternas (alcance: 200–400). Las intervenciones más eficaces de todo el paquete fueron los mosquiteros tratados con insecticida, la vacuna antisaramponiosa y el suplemento preventivo de zinc. Las niñas representaron un 66% de las vidas salvadas (12 712/19 346) durante la campaña de vacuna antisaramponiosa y un 62% de las vidas salvadas (45 721/74 367) durante la campaña hipotética que incluye las intervenciones adicionales.

**Conclusión** En la India, una campaña de vacunación antisaramponiosa que incluya intervenciones viables y de gran impacto podría incrementar enormemente el número de vidas salvadas y mitigar la desigualdad de género en la mortalidad infantil.

**Referencias**

1. The millennium development goals report 2015. New York: United Nations, 2015.

2. Progress in global measles control, 2000–2010. Wkly Epidemiol Rec. 2012 Feb 3;87(5):45–52 doi: http://dx.doi.org/10.1515/wer-2011-0781 PMID: 21661160

3. van den Emm DD, Brown DW, Hoekstra EJ, Christie A, Cochi SL. Measles mortality reductions are substantially due to reductions in mortality among children less than five years of age, 1990–2008. Infect Dis: 2011 Jul;204 Suppl 1 S18–23. doi: http://dx.doi.org/10.1093/infdis/jir171 PMID: 21613968

4. Measles vaccines – WHO position paper. Wkly Epidemiol Rev. 2009 Aug 28;34(3):349–60. doi: http://dx.doi.org/10.1515/wer-2009-0750 PMID: 19676119

5. Otten M, Kezaala R, Fricks J, Wannemuehler K, Anand A, Burton A, et al. Assessment of the 2010 global measles mortality reduction goal: results from a model of surveillance data. Lancet. 2012 Jun 9;379(9823):2173–8. doi: http://dx.doi.org/10.1016/S0140-6736(12)60721-9 PMID: 22670401

6. Measles catch-up immunization campaign: guidelines for planning and implementation. New Delhi: Government of India, Ministry of Health and Family Welfare, 2010.

7. Population tables: India: census 2011. 1-14 five year age group data by residence and sex. New Delhi: Government of India, Ministry of Home Affairs, 2014.

8. John M, Sharma JK, M, J, V, S. Use of measles supplemental immunization activities as a delivery platform for other maternal and child health interventions: opportunities and challenges. Vaccine. 2013 Feb 18;31(19):1259–63. doi: http://dx.doi.org/10.1016/j.vaccine.2012.09.044 PMID: 23041086

9. Ram U, Jha P, Ram P, Kumar R, Awasthi S, Shet A, et al. Neonatal, 1–59 month, and under-5 mortality in 597 Indian districts; 2001 to 2012: estimates from national demographic and mortality surveys. Lancet Glob Health. 2013 Oct;1(4):e219–26. doi: http://dx.doi.org/10.1016/S2214-109X(13)70073-1 PMID: 25104347

10. Measles supplemental immunization activity coverage India 2010–2013. New Delhi: Government of India, Ministry of Health and Family Welfare, 2014.

11. Multi-year plan strategic plan 2013–17: Universal immunization program: reaching every child. New Delhi: Government of India, Ministry of Health and Family Welfare, 2014.

12. Wallace A, Dietz V, Cairns KL. Integration of immunization services with other public-health impact of accelerated measles control in the WHO African Region – 2003. Lancet. 2005 Sep 3–9;366(9488):832–9. doi: http://dx.doi.org/10.1016/S0140-6736(05)67216-9 PMID: 16139658

13. Otten M, Kezaala R, Fall A, Marambe B, Martin R, Cairns L, et al. Public-health impact of accelerated measles control in the WHO African Region – 2003. Lancet. 2005 Sep 3–9;366(9488):832–9. doi: http://dx.doi.org/10.1016/S0140-6736(05)67216-9 PMID: 16139658

14. Doherty T, Chopra M, Tomlinson M, Oliphant N, Nsibande D, Mason J. Moving towards integrated delivery of health services during outreach visits: a literature review of program experience through a routine outreach visits: a literature review of program experience through a routine
