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Economic evaluation of Japanese encephalitis vaccination programme in Uttar Pradesh, India: A cost-benefit study

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ABSTRACT

Background & objectives: Japanese encephalitis (JE) is a major cause of child mortality and disability in the state of Uttar Pradesh. The disease is vaccine preventable since 1941. Yet no major vaccination was available for public health intervention. After a massive breakout in 2005, the government launched vaccination programme in 11 most endemic districts and is planning to incorporate the vaccine in routine immunization with DPT (Diptheria, pertussis and tatanus) booster dose. The paper aims to estimate discounted net benefits and internal rate of return (IRR) to evaluate the economic feasibility for elimination of JE by utilizing available secondary information.

Methods: Cross-sectional data were collected from different sources to estimate societal costs and benefits from JE interventions with a 5 yr project period. Total costs are estimated based on the unit cost of inputs used for interventions. The benefits are derived from resources saved due to the reduction of JE incidence. Net benefits and IRRs are estimated based on standard procedures used in the field of economics.

Results: A total discounted net benefit of JE vaccination is ₹ 598.52 million with 291% IRR. The result suggests that for every rupee invested in vaccination at present will yield ₹ 11 benifit per person over five years. The regional benefits from the interventions will be greater than the sum of benefits gained by the individual country due to its nature of public goods.

Conclusion: Vaccination against JE is a good investment opportunity despite all operational issues associated with it.

Key words Cost-estimation; direct and indirect cost; immunization; Japanese encephalitis, population density; Uttar Pradesh; vaccination

INTRODUCTION

Japanese encephalitis (JE), a mosquito-borne viral infection, remains a major public health problem in Asia, reportedly causing 16,000 to 50,000 acute encephalitic episodes and 5000 to 10,000 deaths annually. The syndromes caused by the virus range from encephalomyelitis to mild febrile illness. Where JE is endemic it is principally a disease of children, the highest rates occurring in children aged under 10 yr living in rural areas, especially where rice is grown and pigs are reared[1]. Furthermore, long-term neurological disability occurs in an appreciable fraction of JE survivors[2].

The disease is spread by the bite of female *Culex* mosquito and the virus is harboured and multiplied in pigs and birds. The main control strategies are vector control and surveillance but vaccination is most effective of all. An effective vaccine is available since as early as 1941. However, due to limited productivity and high price it was not affordable for widespread public health use. In Japan and the Republic of Korea, national programmes of routine immunization with inactivated JE vaccine have nearly eliminated the disease, even in the areas of highest risk[1].

In India, at present 15 states report JE (under AES–Acute encephalitis syndrome) cases and among these states Uttar Pradesh is the worst affected. In U.P. alone from 2003 to 2009, a total of 19,644 cases and 4331 deaths have been reported. In 2005, a massive outbreak caused >6000 cases and 1500 deaths in the state following a vaccination programme was initiated in 11 of the highest risk districts of the country in 2006, 27 districts in 2007, 22 districts in 2008 and 30 districts in 2009. Children between the age group of 1 and 15 yr were vaccinated with a single dose of SA14-14-2 vaccine. In an earlier experiment vaccination has shown very encouraging results in the control of the disease in the states of Tamil Nadu and Andhra Pradesh. Thus, to control JE, the Government of India has decided to introduce and expand JE vaccination to the JE endemic districts of the country in a phased manner[3].

Vaccination against JE is proven to be the most effective measure for the control of the disease. However, vaccine is limited in supply, costly in use and application and its introduction will add resource burden to the health system. Moreover, when the vaccine is introduced in the routine immunisation it will require a constant resource

investment for a sustainable period of the time. Before this investment of resources can be committed the decision makers must be informed about the potential return from the investment and its comparison with the return from the alternative uses of these resources in other public projects. In economics, this purpose is best achieved by a cost benefit analysis. Only when net benefit from the investment is positive (that is benefit is more than cost) then the project should be undertaken. Moreover, the internal rate of return should be estimated so that the project can be compared across the sectors. This study is an attempt to evaluate the cost of introducing the JE vaccination programme in routine immunization programme to its potential benefits over a period of 5 yr in the state of Uttar Pradesh.

The study will help to understand the resource allocation required to undertake and continue the project. It will also describe the various cost and benefits associated with the intervention. The economic information will be helpful to the programme managers, policy makers and those working in the area of JE control.

METHODS

Research setting

Uttar Pradesh which is the paddy growing *Terai* area lies between latitudes 24° and 31° north and longitudes 77° and 84° east and is a completely land locked state. Uttar Pradesh is the most populous state in India, accounting for 16.4% of the total population of the country. Population density of this state is 689 persons/km^2 while it is 324 persons/km^2 for the country. Children aged 0 to 6 yr make up 18.35% of the population, of which 9.58% are males and 8.77% are females, while approximately 40% of the total population belongs to the 0–12 yr age group. The rural population is 79.22%[4]. There are three distinct seasons, summer (March to June, temperatures ranging from 27.5°–32.5°C, with a max 45°C); monsoon (July to October, with rainfall of 1000–2000 mm in the east, and 600–1000 mm in the west); and winter (November to February, temperatures ranging from 12.5°–17.5°C). The entire state has a tropical monsoon climate.

Description of interventions

The Government of India has decided to introduce and expand JE vaccination to the endemic districts of the country in a phased manner based on the following strategy.

A one-time mass campaign will be performed to cover all children in the age group of 1–15 yr in the districts. Followed by integration of the JE vaccine into the routine immunization programme to cover the new cohort (children attaining >1 yr of age) in the districts covered previously under the JE vaccination campaign. The children between 1 and 2 yr of age would be administered the JE vaccine along with the DPT booster dose, under the routine immunization programme. Both rural and urban population will be covered. For this purpose live attenuated SA14-14-2 JE vaccine manufactured at Chengdu Institute of Biological Products (CDIBP), China will be procured. As per the operational guidelines of the Government of India, the introduction of vaccine in routine immunization would not require any major capital infrastructure. The recurrent expenditure is mostly the cost of the vaccine procurement, storage, distribution and monitoring. In 0.005% of the cases, the vaccine causes adverse reaction which requires the treatment[3].

All the children not receiving vaccination are at risk of developing the disease. The disease requires treatment by admission in the hospital. The treatment of JE is nonspecific, prolonged, costly and is associated with uncertain results. Under present policy a case of JE is admitted in hospital and receives treatment free of cost. However, household has to bear the expenses associated with the transport, food, some medications and other associated costs such as investigations. Moreover, households face substantial loss of income as opportunity cost while providing care to the patient. For the purpose of evaluation, the study will consider the vaccination and the treatment as two different economic activities. The cost of vaccination negates the cost on the treatment of the disease.

Study design and conceptual framework

This study is an economic evaluation of health interventions and tries to compare social costs and benefits of the programme using standard economic methods. This is a prospective study which estimates the future costs and benefits using cross-sectional data from various sources after triangulation under a set of strong assumptions. The interventions constitute an economic activity

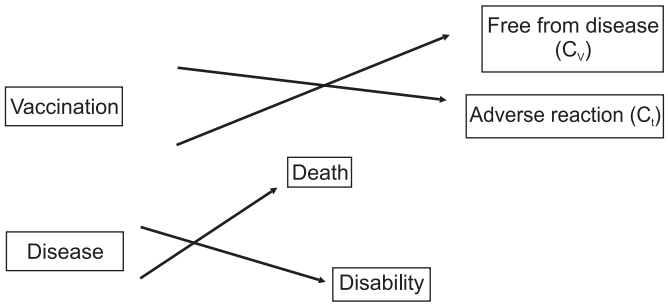

Fig. 1: Conceptual framework.

and a typical production function can be used as a conceptual framework for the study (Fig. 1).

Social cost of the intervention

For the purpose of evaluation we only calculate the cost of introducing the vaccine in the routine service and to maintain it. We will not include the cost of one time mass campaign in the beginning of the programme to avoid the huge escalation of cost for the five years project under study. We also assume that the vaccine will not invite any significant capital expenditure under present system. However, recurrent expenditure at regular interval will be required mostly for the personnel, storage, transportation and distribution, monitoring and administrative cost. The data pertaining to such costs were collected from the government health system through the appropriate method like interview, observation and departmental records. Wherever possible items and consumables were valued at market prices else shadow pricing was used. The overhead costs were allocated as per units consumed. Thus, standard methods of economics were used to collect cost data as suggested by standard literature[5]. Due to adverse reaction of the vaccine in certain cases the society bears some additional cost of treatment which is also added to the cost of vaccination. For the purpose of study, the cost of treatment of a adverse reaction is considered to be equal to the cost of treatment of JE case as data for treatment of adverse reaction was difficult to calculate.

The cost of treatment per case of JE was calculated by interviewing a key respondent from the households of the patients undergoing treatment at B.R. Ambedkar Hospital, Gorakhpur, Uttar Pradesh. For provider side-cost estimation appropriate method as in the case of estimation of vaccination was used. All important capital costs were utilised and appropriate valuation methods were also employed[6].

Social benefit of the intervention

Principle effect of vaccination is protection from the disease and its severe consequences. Thus, vaccine prevents death, disability and discomfort. Thus, benefits from the vaccine are multiple, however, in this study we only quantify the benefits in the form of cost saved on treatment of the disease. We calculate total cost saved on treatment of the disease avoided due to vaccination. Net value is thus, determined by properly discounting the costs to the base year of 2011.

Method of analysis

The data were entered in a spread sheet (MS excel) calculator and analyses were run to calculate the annual cost of vaccination (unit cost of vaccine applied to the total numbers of vaccinations done). The number of vaccine vials required is calculated as per the method given in the Government of India's operational guideline on JE vaccination. The successive annual costs were discounted using social discount rate of 10% to get the total discounted cost of vaccination. Similarly, the total benefit was estimated by estimating the total number of cases avoided for the future year. For this purpose, we used the effectiveness ratio of the vaccine at 98% and vaccination coverage equal to that of DPT vaccine as on implementation vaccine will be administered along with DPT. This way we can understand the total number of JE cases in the presence of a JE vaccine in a given year. Next using a time series analysis we can get a rough estimate of number of JE cases that would occur in future years without JE vaccination. The difference of cases without vaccine and that with vaccine gives the estimate of number of JE cases avoided. This number multiplied with the total cost of treatment of JE gives the value of resources saved.

RESULTS

Demographic and socioeconomic profile of the respondents

A total of 120 cases of JE were included in the study for the purpose of estimation of household cost for treatment of JE. Average age of patients was 6 yr (range 2–22 yr). About 62% of cases were males and >67% belonged to households with gross monthly income < ₹ 5000 per month, 26% between ₹ 5000 and 10000, and only 7% reported monthly income above ₹ 10000. The median monthly household income was ₹ 3200 (range 2400–50,000 per month). Almost 33% of the households sourced their expenditure from loan and 50% relied on their earnings or savings. Around 10% cases were financed by close relatives or friends (not loan but as a gesture of solidarity). Rest refused to disclose their source of expenditure. The median duration of hospitalisation was 12–13 days. Only 24% of cases directly visited the government hospital without visiting anywhere else.

Purchaser side cost of treatment of JE

The purchaser side cost was calculated as direct and indirect cost[7] and it has a varying range from ₹ 5800–1,46,378. This huge variation was due to the large number of patients who went for private health care treatment before coming to the government hospital. One more reason in rising price of this treatment can be attributed to

Table 1. Total purchaser side costs for JE

Cost category	Median (₹)	Range (₹)	%
Direct cost			
Total medical cost	6638		50
Transportation and accommodation	4430		33
Food	1520		11.5
Loan	624		4.7
Sub total	13212	3781–74876	37
Indirect cost			
Wage loss to patient	8170	1289–94381	36
Wage loss to attendants/relatives, cost of attending the dependents back home	14257	2400–29000	64
Sub total	22427		63
Total	35639		100

the duration it affects the respondent as larger the duration larger is the purchaser side expenses.

Average (median) of total direct cost (both medical and non-medical) as borne by the patients was around ₹ 13212 (range ₹ 3781 to ₹ 74876) and indirect cost was averaged (median) around ₹ 22,427. Direct cost constituted almost 37% of the total purchaser side cost. The largest share of direct cost was constituted by medical cost (50%). Table 1 summarises the total purchaser side cost.

This value of total indirect cost incorporates the product of total number of workdays lost (due to illness and during recovery phase) multiplied by prevailing wage rate as per to patient's occupation. For unskilled and unemployed patients in the productive age group the wage rate of unskilled labourers as decided by the district administration was used. On an average (mean) a case of JE lost 587 h of work per episode of the disease. Value of loss of income (opportunity cost) to the patient's relative and household was arrived at ₹ 14,257 (range ₹ 2400–29000) which is inclusive of cost to one-to-two full time attendant with the patients, cost to those who regularly visited the patients and the perceived cost to the households in which some dependants were left unattended back home because person who looked after them was visiting this patient in hospital. These indirect costs constitute almost 63% of the total cost borne by the household. On an average 212 days of school/instructional days (nearly 848 h of learning time) were lost for the patients in the age group of 5–15 yr of age.

Provider side cost

Provider side cost was collected from the B.R. Ambedkar Medical College, Gorakhpur. Here a special ward is provided for the treatment of JE cases. Unit cost of treatment of per case was calculated using step down approach as done in standard health economics study[8]. Unit cost of treatment of a JE patient was found to be nearly ₹ 16900. Table 2 represents the break-up of provider side-cost of treatment.

Table 2. Unit cost of treatment of JE case

Items	Total expenditure for 2008–09 (in ₹)	Per diam per capita	Per patient cost of curative treatment (in ₹)
Salary	14040107.2	230.7714	6421.6
Allowances	4910728.66	46.06179	1309.73
Travel and daily allowances	11737.68	1.037143	25.04
Laundry	45446.26	4.018929	82.53
Utilities	260517.08	25.66929	518.74
Fuel	183405.5	16.20536	259.75
Maintenance	808455.46	32.43321	1567.13
Stationary and others	242095.9	21.39107	421.95
Printing	9977.28	8.815714	246.84
Miscellaneous	106576.04	9.593571	168.62
Drug	1650227.34	211.1882	3913.27
Overhead	5707586.94	23.43107	812.07
Annualised capital	7556751.4	44.48929	1141.7
Total cost	35533612.74	675.106037	16888.97

Unit cost of vaccination

According to the data from international organisation People for Assessment of Technology in Health (PATH) which procured the vaccine from China the price of one vaccine from provider perspective will be around ₹ 11.70. For ease of calculation we can keep other costs at zero as we know that vaccine will be administered at 18 month along with booster dose of DPT. Thus, we keep the charges of logistics and other expenses inclusive in the price of ₹ 11.70 (Table 3).

Benefits of intervention

We assume the benefit to be limited to the cost saved on treatment due to vaccination. This is a very crude approach yet we can argue that if without considering the other benefits the net value is positive then we need not bother about those benefits. Total estimation of JE cases in the absence of vaccination is done by a time series analysis using previous year incidence data from

Table 3. Total unit cost of vaccine on treatment of JE (in ₹)

Year	No. of persons vaccinated	Unit cost of one vaccine	Total cost of vaccination	Discount price
2011	1084761	11.70	12691704	12691704
2012	1199000	11.70	14028300	12753000
2013	1220745	11.70	14282716	11803897
2014	1330876	11.70	15571249	11698909
2015	1403408	11.70	16419873	11214994
Total				6016250

Table 4. Total cost saved on treatment of JE due to vaccination (in ₹)

Year	Estimated number of JE cases	Cost avoided by the provider	Cost avoided by the purchaser	Total cost saved due to vaccination	Discount value @ 10%
2012	3722	62860746.34	132648358	195509104.3	177735549.4
2013	3954	66778987.38	140916606	207695593.4	171649250.7
2014	4186	70697228.42	149184854	219882082.4	165200663
2015	4418	74615469.46	157453102	232068571.5	144096324.4
Total					658681787

NVBDCP. Total benefit from the intervention is presented in Table 4.

Cost benefit analysis

Total discounted cost is ₹ 6,01,62,504 while total discounted benefit is ₹ 6,58,681,787. This gives a net discounted value of ₹ 598.52 million. The cost benefit ratio is equal to almost 11 which means that for every rupee invested in vaccination we are getting a return of ₹ 11 over the period of five years. The IRR is surprisingly high over the study period and is equal to 291%. Cost of vaccination is almost constant over the project period while benefit from the resources saved is falling more sharply (Fig. 2).

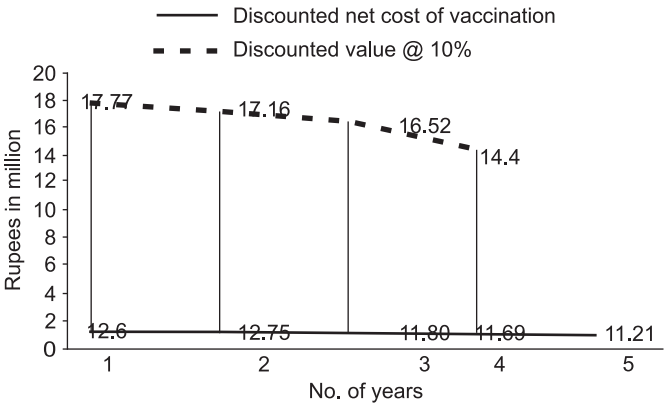

Fig. 2: Graphical representation of annual discounted cost and benefits. (all costs are in million Rupees)

DISCUSSION

The result showed that the benefit of vaccination was much higher than the cost of it. The return on investment is surprisingly high and it is rarely a return from any other such projects. Together these two values make the intervention highly recommended. Although this finding is based on various assumptions but still various benefits were not taken into consideration which are definitely much more than present return. Uttar Pradesh has a large population and incidence rate of JE is ₹ 15 per 10,000 for allover India but owing to its high population number of children at risk is more in Uttar Pradesh than anywhere else in the country, thus the gain of benefit will be more in Uttar Pradesh.

There is clear indication that the cost burden by purchaser in respect to availing curative care is more than the burden by the provider side, thus, in the case of cost of provider for vaccination is one sided but it still gives a huge benefit to the purchaser. Almost all the respondents had catastrophic expenditure due to JE (>90%). It could be attributed due to high cost of travelling and duration of the disease. Around 65% respondents had additional cost of private health care which on adding will increase the costing on treatment side very high but in general even though they were given free service at the government hospital still they bear various expenses.

This study can serve as an ex-ante evaluation of vac-

cination project. However, certain operational issues are worth discussing which were not accounted properly in our model. First with all vaccinations there is a huge cost associated with storage, distribution, monitoring and disposal of waste safely. Our model does not take into account these because we assume that introduction of JE vaccine will not add extra burden of delivery as it is administered along with booster dose of DPT. However, this is not so and substantial cost can be involved which can bring down the expected value of net benefits. Second routine coverage of booster dose of DPT is very low, only 19% in UP[9]. This means that even JE vaccine will also be delivered poorly through routine system. If routine method is chosen then again high chances are there that benefits will be low as number of JE cases may remain high. If a special drive is designed every year then the cost may be very high still the intervention may remain reasonable.

CONCLUSION

This study is important because it is based on a very simple model which does away with the need to perform complex quantification of many health benefits as in a cost benefit studies of measles vaccination in Japan[10]. Only one component itself is giving so high returns that even in worst scenarios intervention is worth undertaking. However, we can conclude that operational issues must be addressed correctly so that maximum number of cases can be avoided albeit at a higher cost of vaccination so that poorest of the poor can be benefited most.

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