Available online at www.sciencedirect.com
ScienceDirect
Health Policy 85 (2008) 184–195
HEALTH POLICY
www.elsevier.com/locate/healthpol

Private demand for cholera vaccines in rural Matlab, Bangladesh

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Abstract

Objectives: To estimate household willingness to pay (WTP) for cholera vaccines in a rural area of Bangladesh, which had participated in a 1985 oral cholera vaccine trial.
Methods: A contingent valuation study was undertaken in Matlab, Bangladesh in summer 2005. All respondents ($N = 591$) received a description of a cholera vaccine that was 50% effective for 3 years and had negligible side effects. Respondents were asked how many vaccines they would purchase for their household at randomly pre-assigned prices. Negative binomial regression models were used to estimate the number of vaccines demanded and to calculate average WTP.
Results: On average, respondents were willing to pay about US$ 9.50 to purchase vaccines for all members of their household (i.e. US$ 1.70 per vaccine). Average WTP per person is US$ 2.40 for young children (1–4 years), US$ 1.20 for school-age children, and US$ 1.05 for adults. Median WTP estimates are significantly smaller: US$ 1.00 for young children, US$ 0.05 for schoolchildren, and US$ 0 for adults.
Conclusions: There is significant demand for cholera vaccines in Matlab at low prices. Recent herd protection research suggests that unvaccinated persons would also experience reduced incidence via indirect effects at low coverage rates associated with moderate vaccine prices.

Keywords: Vaccine demand; Willingness to pay; Contingent valuation; Cholera; Bangladesh

1. Introduction

In many less developed countries, cholera remains a serious public health problem. Most cases are concentrated in the “cholera belts” of coastal and delta areas in the tropics, of which Bangladesh is a classic example [1]. Incidence of cholera can be reduced through access to clean drinking water and proper disposal of sewage.

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0168-8510/$ – see front matter
doi:10.1016/j.healthpol.2007.07.009

However, infrastructure additions and improvements are expensive and progress has been slow, especially in rural areas. In Bangladesh oral rehydration solution (ORS) has successfully reduced the case fatality rate of cholera to less than 1% [2,3]. While the widespread use of ORS has limited the risk of death in areas with quality health care, it does not reduce the risk of contracting cholera upon exposure.

New-generation oral cholera vaccines were tested in Matlab, our research area, during 1985 and found to have protective efficacies of approximately 50% over 3 years [4,5]. Ali et al. [6,7] reanalyzed the data from the Matlab trial and found reduced disease incidence among unvaccinated individuals in localities with higher coverage (i.e. herd protection effects).

Despite evidence of vaccine effectiveness, policy makers in Bangladesh reported that they did not place a high priority on providing cholera vaccines, even in areas with high endemic incidence rates [8]. The reasons for the lack of interest include: (1) the success of ORS in reducing cholera mortality, (2) a desire to spend limited resources on other interventions, (3) the limited duration and effectiveness of cholera vaccines, (4) the higher cost of cholera vaccines relative to others included in World Health Organization's Expanded Program on Immunization (EPI), and (5) the inability to administer the cholera vaccine as part of the existing EPI schedule.

Given the lack of public sector support for a cholera vaccination program in Bangladesh, a key issue in developing a successful vaccination program is whether it can be financially sustainable. Our research attempts to quantify private willingness to pay for cholera vaccines in a highly endemic area, where free, high quality treatment facilities already exist. This study attempts to determine how much families are willing to pay for vaccines and how household decision makers would allocate vaccines among family members. Because residents of the Matlab area have previous experience with oral cholera vaccines, this area should offer useful evidence of the private value of the cholera vaccine.

Our research group surveyed a sample of 591 households in the Matlab area, where cholera is prevalent. In our in-home interview with the representative of each household, we presented a description of a hypothetical cholera vaccine that was 50% effective for 3 years and had negligible side effects; then, we asked if that individual would be willing and able to purchase the vaccine at a single specified price (preassigned from an array of six) for personal immunization and for immunization of other household members. This technique, known as the contingent valuation method, permits measurement of demand for goods that are not widely available or do not have markets; it has been used frequently to measure the demand for vaccines in developing countries [9–13], as well as for environmental goods and services [14–16].

1.1. Background

The Matlab Health Research Centre study area lies some 55 km southwest of Dhaka and has a population of approximately 224,000 [17]. The International Centre for Diarrhoeal Disease Research, Bangladesh (ICDDR,B) operates a hospital in Matlab sub-district whose services include free treatment to anyone with diarrhea. ICDDR,B also provides basic health services to approximately 111,000 people in Matlab town and 67 outlying villages. Once a month, ICDDR,B's Health and Demographic Surveillance System (HDSS) gathers information from each person in the ICDDR,B service area as well as from an additional 113,000 people in 75 other nearby villages who receive basic health care services from government facilities.[1] ICDDR,B has collected this information for more than 35 years, and the sample frame for the present study was generated from that database.

From 1963 through 1996, ICDDR,B conducted a number of health intervention studies in the area, many of which included the free provision of products aimed at improving the health of participants. In addition to the 1985 cholera vaccine trial, residents of the government service area were included in 30–35 studies while residents of the ICDDR,B service area participated in 55–65 studies. These studies may have conditioned people in the area to believe that public health programs should be provided free of charge.

According to data from ICDDR,B's hospital surveillance records, the annual incidence of cholera ranges from one to five cases per 1000 persons. Because not all cases arrive at the hospital and some are misdiagnosed,

[1] The ICDDR,B hospital will provide free treatment for anyone that travels to the hospital, including people that reside outside of the MHRC.

the actual cholera incidence rate is unquestionably higher; epidemiological studies have estimated that the annual incidence rate could be 4–20 cases per 1000 persons in the Matlab area [18]. The most recent records, from 2003, show that 62 people among the HDSS population died from all diseases related to diarrhea, including cholera, corresponding to a mortality rate of 2.8 deaths per 10,000 persons [17]. Cholera transmission occurs year-round and peaks during April–May and September–October (i.e. just before and after the summer monsoon [19]).

Using the Matlab area as an example, Sack [18] compares the cost effectiveness of cholera treatment versus vaccination by performing break-even analyses of the cost per cholera death avoided using different incidence rates and vaccination costs. Sack estimated the treatment cost per death avoided at about US$ 350 (based on a 20% case fatality rate without treatment versus 0.5% with treatment). He reports that vaccines might be more cost effective per death avoided than the provision of free treatment if per capita vaccine cost is less than US$ 1 and if annual incidence exceeds 1 in 1000. However, this analysis ignores the disutility and financial costs of illness prevented through vaccination. Also, it may not be necessary to choose between vaccination and treatment. Instead, one can assess the marginal benefits of adding vaccination efforts to existing treatment programs.

Although cholera vaccines are not currently available, people in the Matlab area have had experience with the new-generation oral vaccine and a combined typhoid, paratyphoid A and B, and cholera (TABC) vaccine that was administered during the 1950s and 1960s. ICDDR,B's 1985 field trial administered two distinct oral cholera vaccines and a placebo. The vaccination program targeted children and mothers. More than 62,000 people took three doses, approximately 27,000 took one or two doses, and about 31,000 were absent or refused to participate [5].

Ali et al. [6] used a GPS database in combination with vaccine trial records to examine herd protection effects for the first year after the 1985 Matlab trial. They found a significant inverse monotonic relationship between local coverage rates and disease incidence in unvaccinated persons. The raw data showed that at target population coverage rates greater than 50%, disease incidence was about the same for vaccinated and unvaccinated persons and roughly 80% less than the incidence for placebo recipients in areas with low vaccination rates (i.e. less than 28% coverage). These results also suggest that researchers may have underestimated vaccine effectiveness in previous evaluations of the Matlab trial. In a separate study, Ali et al. [7] found significant herd protection effects for children less than 2 years of age who were not eligible for the Matlab trial. The local coverage rate for women greater than 15 years of age was a statistically significant correlate for incidence among children less than 2 years. However, the coverage rate for children age 2–15 years was not statistically significant.

People in the Matlab area also have access to vaccines from EPI, which are distributed by ICDDR,B's community health workers once per month [20]. The private market for vaccines in the area is minimal, with only a few pharmacies in Matlab town that sell and administer vaccines directly to individuals. The pharmacies' prices for providing tetanus vaccines vary considerably (US$ 0.30–1.34), possibly depending on the number of vaccines sold. The price for rabies vaccine was less variable (US$ 5.95–6.40). Note that these prices are based on an exchange rate of US$ 1 = 67.2 Bangladeshi Taka (1 August 2005). Unless otherwise noted, we present price information and results in 2005 US dollars using this exchange rate. These numbers are, however, unadjusted for purchasing power parity. Nationwide, Levin et al. [21] report that the private sector only accounts for about 2% of vaccines delivered in Bangladesh.

2. Materials and methods

2.1. Sampling procedure

The survey respondents were chosen via a two-stage cluster sample without replacement based on a household sample frame from ICDDR,B's HDSS database. The first stage selected a total of 3000 households, each with at least one child less than 18 years of age. Two-thirds of these households were located in the government service area, and one-third in the ICDDR,B service area. We over sampled the government service area because we believed that it might be slightly more representative of rural Bangladesh than the ICDDR,B service area. This also allowed us to test for differences in demand between service areas. The sample was then subdivided into 120 clusters of 22–28 households located within small geographic areas ranging about 1–4 km^2 depending on population density. This clustering reduced travel time between interviews.

In the second stage we randomly selected two sets of 15 clusters of households and assigned one cluster from each set to each enumerator. We required enumerators to interview the mother or father of children in the household and to allot half their interviews to fathers.[2] Only two households refused to grant interviews. However, it proved difficult to interview male parents, because many reside and work outside the Matlab area. Nonetheless, we wanted to obtain a fairly even gender split between male and female parents. As a result, we chose not to interview 160 households where female parents or grandparents were available for interview, but males were not. This approach will bias our sample toward households for which males remain in the Matlab area, but allows us to better test for differences in preferences between mothers and fathers.

2.2. Survey instrument

The survey instrument was approved by the Institutional Review Boards at the University of North Carolina at Chapel Hill and at ICDDR,B. The instrument had six sections of questions and is available as an online Appendix. The first section recorded demographic information about the respondent and members of the household. The second section had questions regarding the respondent's perceptions of and experiences with cholera. The third section discussed how cholera was contracted, spread, prevented, and treated; it also included questions about the respondent's previous experience with the oral cholera and TABC vaccines. This section also introduced the cholera vaccine contingent valuation scenario, including descriptions of the vaccine's effectiveness and duration. Next, the respondents' understanding of the concept of vaccine effectiveness was tested. The fourth section contained the valuation questions that were used to estimate demand and willingness to pay (WTP) and is described in Section 2.3 below. The fifth section included questions to determine the value of a reduction in the risk of death for the respondent's youngest child [22]. The sixth section included socioeconomic questions about education, income, housing characteristics, assets, disease-averting behaviors, economic status, and access to credit.

Two sets of 60 pretest interviews helped us to adapt our survey to local conditions and to determine the appropriate bid (price) levels for the cholera vaccine. We employed 20 local enumerators to conduct the in-person interviews. These enumerators had experience working on other ICDDR,B public health studies, but had not administered contingent valuation surveys. They received 2 weeks of training according to the guidelines recommended in Whittington's review of CV practices in developing countries [16].

2.3. Research design

First, we explained that vaccine effectiveness was based on the joint probability of: (1) being exposed to illness and (2) being protected by the vaccine. The explanation used a picture with 50 blue and 50 red figures representing persons who would or would not be immune to disease after vaccination. Each respondent was then presented with a single price from an array of six randomly assigned prices (US$ 0.15, 0.37, 0.74, 1.12, 4.46, 8.93)[3] and asked if he or she would be willing to pay that price for a vaccine for personal immunization.[4] Then, respondents were asked how many vaccines they would purchase for family members and which family members would receive those vaccines. Prior to the first question about self-protection, respondents were instructed to consider their budget constraints and told that there were no right or wrong answers.

The interviews were staged such that respondents were divided into two groups. No time to think (NTTT) respondents received the entire questionnaire in one sitting. Time to think (TTT) respondents answered the

[2] We interviewed two respondents who were grandparents, because the parents had died.

[3] Equivalent prices in Bangladeshi taka are Tk 10, 25, 50, 75, 300, 600.

[4] Note that the oral cholera vaccine described in the scenario required two doses to be administered about 2 weeks apart. The hypothetical user fee represented the price per full vaccinated individual, not per dose. Throughout the paper, we refer to demand for two doses based on a single price.

first half of the survey, and then were given overnight to consider the prospective "purchase" of the cholera vaccines and to discuss the decision with other family members. An interviewer returned the next day to finish the survey.

2.4. Modeling strategy

Our household analysis is based on a model of vaccine decision making developed by Cropper et al. [11]. It is assumed that the decision maker maximizes the household utility function, which is a function of each family member's consumption and health, subject to a household budget constraint. Demand depends on non-wage income, the prices of vaccines and other preventive and mitigating health products, and a vector of individual and household characteristics.[5]

Count models are useful for examining household demand because they employ integer estimates for the number of vaccines purchased by each family. We used the negative binomial model, which is a variation of the Poisson regression model. The dependent variable (probability of buying vaccines for all family members) is a random draw from a negative binomial distribution with a mean λ_i, where i denotes the household. If V_i^* is the solution to the maximization problem and n_i is household size, the model can be written as

$$\Pr[V_i^* = n_i] = \left(\frac{e^{\lambda_i}\lambda_i^n}{n_i!}\right) \quad \text{where } n = 1 \text{ to } n_i, \qquad (1)$$

where $\lambda_i = e^{X_i\beta+\varepsilon_i}$ and X_i is a vector of characteristics describing household i and the vaccine price offered to that family. The term ε_i is an error with gamma distribution. The number of occurrences are distributed with mean λ_i and variance $\lambda_i + \alpha^{-1}\lambda_i^2$ where α is the common parameter of the gamma distribution.[6] The coefficient estimates are used to construct a demand curve for each respondent's household. The fraction covered can be estimated by dividing the estimated number of vaccines purchased by the population size. The area underneath the demand curve is the Marshallian consumer surplus, which we define as household willingness to pay.

3. Results

Generally, respondents understood the cholera vaccine scenario and provided reasoned answers to our valuation questions. Only 9 of the 591 respondents rejected our hypothetical description of vaccines or vaccine effectiveness either because they believed that the vaccine would not be effective or would have negative side effects. These respondents were dropped from further analysis.[7]

3.1. Sample socio-demographic characteristics

The socio-demographic characteristics of the sample households are summarized in Table 1. About 37% of respondents are from the ICDDR,B service area, and their average age is about 40 years. Average household size is 5.8 persons, including 0.1 infants less than 1 year old, 0.7 young children (1–5 years), 1.7 school-age children (6–17 years), 3.0 adults (18–65 years), and 0.2 elderly adults (66 years and up). The average respondent had 3.6 years of eduation, with 35% of the sample reporting that they never attended school. The average monthly household income was about US$ 75, which corresponds to an average monthly per capita income of US$ 13. About 39% of respondents received electricity directly from a grid. A few other respondents had installed solar panels or used large batteries.

3.2. Water and sanitation behaviors

The primary source (85%) of drinking water for most respondents was hand pumps; most (60%) shared pumps with their neighbors. Hand pumps have proved problematic because of extensive, naturally occurring arsenic contamination in the local groundwater

[5] Note that we also analyzed data for individual respondent demand for self-protection; the results are available upon request from the authors.

[6] A truncated Poisson model was also estimated for these data. This model avoids demand predictions that exceed the number of household members for each respondent. Because WTP estimates are similar for truncated Poisson and standard negative binomial models, we concluded that the negative binomial model should be employed because it allows for overdispersion.

[7] Overall, 90% of respondents reported that they would be "primarily involved" in the cholera vaccine purchase decision. By gender, 85% of female respondents and 95% of male respondents would be involved. Thus, our sample should be representative of household decision makers.

Table 1
Variable definitions and descriptive statistics (respondent and household (hh) characteristics)

Variable name	Description	Mean (S.D.) ($N = 591$)
Respondent characteristics		
Male	Gender = 1 if male, =0 if female	0.49 (0.50)
Age	Age (years), continuous	40 (9.7)
Practice Hinduism	Religion = 1 if Hindu, =0 else	0.06 (0.25)
Education 1–5 years	=1 if respondent completed 1–5 years of school	0.36 (0.48)
Education 5–10 years, vocational	=1 if respondent completed 5–10 years of school, vocational school, or madrassa	0.18 (0.38)
Education more than 10 years	=1 if respondent completed university, postgraduate or professional course	0.12 (0.32)
Unable to read	=1 if respondent is not able to read a newspaper	0.53 (0.50)
Household characteristics		
Infants	Number of infants (<1 year), continuous	0.12 (0.34)
Young children	Number of children age 1–5, continuous	0.7 (0.72)
School-aged children	Number of children 6–17, continuous	1.7 (1.11)
Adults	Number of adults age 18–65, continuous	3.0 (1.45)
Elderly adults	Number of elderly adults age >65, continuous	0.20 (0.43)
Monthly income per capita	HH income divided by number of hh members (US$ per month), continuous	13.7 (11.5)[a]
Log income per capita	Natural log of hh income divided by number of hh members, continuous	6.8 (0.7)

[a] The average household monthly income was US$ 75 (Tk 5000).

aquifers. Only 8% of surveyed households reported boiling their drinking water, though some did treat water with bleach (5%), via sedimentation with alum (4%) or with filters made of cloth, ceramics, sand, or composite material (7%).[8] The respondents primarily used improved pit, unimproved pit, and hanging latrines[9] for feces disposal.

3.3. Previous experience with oral cholera or TABC vaccines

In our survey 182 of 591 respondents reported that they had received the oral cholera vaccine during the 1985 trial. From respondents' accounts of their household members' experience with vaccines, it appears that about 10% of respondents and their household members had received vaccines. (This is likely an underestimate, because respondents may not have been aware of vaccines received by others.) Most respondents (90%) reported that they were satisfied with the vaccines received by themselves and their family members. They thought (incorrectly) that most of the vaccinated persons in their households (72%, including themselves and other members) were still protected by the vaccine.

3.4. Attitudes about cholera and vaccines

The variables thought to influence demand for cholera vaccines are summarized in Table 2. About 37% of respondents reported that at least one member of their household had suffered from cholera in the past; 6% reported a death in the family. Another 27% of respondents knew of someone other than a household member who had suffered from cholera. The proportion of households that had experienced a cholera death was more than twice as high in the government service area, possibly because ICDDR,B's provision of health care and previous research studies have reduced cholera-related deaths. More respondents believed that cholera is serious or very serious for children (84%) than for adults (64%). Also, more respondents believed that their children would be likely to contract cholera in the

[8] An unrelated arsenic health intervention promoted the use of filters and sedimentation to reduce arsenic exposure.

[9] The improved pit latrines had cement floors and solid walls, providing better privacy than unimproved pit latrines. Unimproved pit latrines generally consisted of a hole in the ground surrounded by walls made of poor materials.

Table 2
Variable definitions and descriptive statistics (perceptions of disease, vaccine history and characteristics of research design)

Variable name	Description	Mean (S.D.)
Risk behavior, perceptions of disease, vaccination history		
Treat drinking water	=1 if household treats water for drinking;	0.15 (0.36)
Someone in household has had cholera	=1 if someone in household has had cholera	0.37 (0.48)
Know person who has had cholera (outside hh)	=1 if knows someone outside hh who has had cholera, but not someone in hh	0.27 (0.50)
Cholera is very serious for adults	=1 if respondent believes cholera is (very) serious for adults	0.64 (0.48)
Cholera is serious for children	=1 if cholera (very) serious for children	0.84 (0.50)
Cholera likely for respondent	=1 if respondent believes he or she is likely or very likely to contract cholera in next 5 years	0.20 (0.40)
Cholera likely for respondent's child	=1 if respondent believes his or her child will likely contract cholera in next 5 years	0.40 (0.49)
Believes cholera is common in community	=1 if respondent believes cholera is common in his or her community	0.20 (0.40)
Respondent believes vaccine is still working	=1 if respondent had oral cholera vaccine and believes that it is still effective	0.24 (0.43)
Respondent had cholera vaccine satisfied, not working	=1 if respondent had oral cholera vaccine was satisfied, but does not think vaccine still works	0.06 (0.25)
Respondent unsatisfied with vaccine	=1 if respondent was not satisfied with previous vaccine for self or family member	0.03 (0.16)
Characteristics of research design		
Time to think	=1 if given time to think overnight	0.47 (0.50)
ICDDR,B	Health service area; =1 if ICDDR,B, =0 if government	0.37 (0.48)
Price	Referendum price (Bangladeshi Tk), continuous	157 (198)

next 5 years (40%) than believed that they themselves (20%) were at risk. Thus, it appears that respondents consider cholera to be dangerous, especially for children; they also believe the risk of their household members contracting the disease is higher than would be expected based on reported incidence rates.

Most respondents understood our description of vaccine effectiveness. About 75% correctly answered four questions designed to test understanding. With those who did not answer correctly, we repeated the vaccine effectiveness description, then repeated the test questions. After this second round, the overall suc-

Table 3
Household demand for vaccines (raw data)

Price US$ (Tk)	US$ 0.15 (10)	US$ 0.37 (25)	US$ 0.74 (50)	US$ 1.10(75)	US$ 4.50 (300)	US$ 9.0 (600)
Household demand[a]						
NTTT sample size	54	54	57	52	54	39[b]
Average number of vaccines per family	4.4	4.4	3.2	2.8	0.8	0.2
TTT sample size	51	48	47	46	46	38[b]
Average number of vaccines per family	4.1	3.1	1.8	1.6	0.3	0.5
NTTT						
% Family members vaccinated	76	75	60	53	16	4
TTT						
% Family members vaccinated	63	53	31	27	4	10

[a] Number of vaccines purchased divided by number of persons in household.
[b] Sample size was smaller for the highest price, because it was only used to choke off demand.

cess rate rose to about 93%: only some 7% of all respondents were unable to answer the test questions correctly.

A majority (68%) believed that the most important benefit of a cholera vaccine is to prevent pain and suffering. Others (24%) cited avoiding the risk of death from cholera as most important. Very few (8%) cited avoided treatment costs or lost wages as the primary benefit of a cholera vaccine. These answers suggest that economic analyses that rely primarily on cost-illness estimates would underestimate the private economic benefits of the vaccine.

3.5. Household demand

Table 3 shows the raw data for the average fraction of household members that the respondents reported would be vaccinated at each price. The average fraction of household members vaccinated decreases as the price increases and for respondents given time to think. We found that many respondents (74%) either decided to purchase vaccines for all family members or for none of their family members. Relatively fewer respondents (26%) chose to purchase vaccines for some, but not all of their family members.

Table 4
Household negative binomial regression results and WTP estimates

Model	Household model	
	1	2
Price (Tk)	−0.005*** (−6.5)	−0.005*** (−13)
Time to think	−0.38*** (−3.85)	−0.44*** (−4.3)
Male	0.27*** (2.64)	0.27** (2.4)
Resident from ICDDR,B service area	−0.18* (−1.78)	−0.25** (−2.1)
Age	−0.008 (−1.40)	−0.009 (−1.4)
Education 1–5 years	0.18 (1.48)	0.16 (1.3)
Education 6–10 years	0.28* (1.92)	0.22 (1.5)
Education >10 years	0.12 (0.83)	0.14 (0.81)
Log income per capita	0.37*** (4.43)	0.39*** (4.5)
Number of hh members		
Number of infants < age 1	0.041 (0.29)	−0.020 (−0.14)
Number of children age 1–5	0.19*** (2.59)	0.21*** (2.8)
Number of children age 6–17	0.13*** (2.75)	0.13*** (2.7)
Number of adults age >18	0.17*** (5.32)	0.17*** (5.2)
Practice Hinduism	0.30 (0.17)	0.034 (0.17)
Serious or very serious for children		−0.26** (−1.9)
Serious or very serious for adults		0.32*** (3.0)
Cholera likely for respondent		0.30** (2.2)
Cholera likely for children		0.079 (0.72)
Someone in hh has had cholera		0.023 (0.20)
Know someone other than hh member that has had cholera		−0.13 (−1.0)
Respondents had prior vaccine; was satisfied and thinks vaccine still works		0.050 (0.42)
Respondent had prior vaccine; was satisfied but thinks vaccine no longer works		0.33* (1.7)
Respondent had prior vaccine; not satisfied		−0.38 (−0.97)
Treats water		0.23* (1.8)
Constant	−1.8*** (−2.9)	−1.9*** (−2.8)
R^2	0.09	0.11
Estimated average WTP, NTTT government service area (US$)	14.30	14.30
Estimated average WTP, NTTT ICDDR,B service area (US$)	12.30	12.30
Estimated average WTP, TTT government service area (US$)	10.00	10.00
Estimated average WTP, TTT ICDDR,B service area (US$)	9.00	9.00

T-statistic in parentheses.
* Significance at the 10% level.
** Significance at the 5% level.
*** Significance at the 1% level.

Negative binomial regression results for the household demand model are summarized in Table 4. Model 2 includes all possible covariates, while Model 1 only considers variables that are unrelated to cholera and vaccine experience. Coefficient standard errors are empirically corrected for the cluster sampling procedure. Average marginal effects, which reflect the change in average household demand for a unit change in a single variable, are summarized in Table 5. Vaccine price is highly significant, and there is an average marginal decrease in stated demand of 0.58 vaccines per family for a price increase from US$ 0.50 to 1. Respondents residing in the ICDDR,B service area and TTT respondents state that they would purchase fewer vaccines for their families; average marginal decreases are about 1.3 vaccines if given TTT and 0.7 for the ICDDR,B service area. Male respondents and respondents from wealthier families purchase significantly more vaccines; average marginal demand increases by 0.05 vaccines per US$ 1 increase in monthly per capita income. Average marginal demand decreases by 0.04 vaccines as respondent age increases by 1 year. As expected, respondents with larger families report that they would purchase more vaccines. This is true for all age groups, although the coefficients for the number of school-age children are smaller than those for young children or adults.

Interestingly, we find that the number of vaccines that respondents say they would purchase increases significantly for respondents who believe that cholera is a serious disease for adults or who believe that adults are likely to contract cholera. However, the coefficients for these beliefs for children are smaller and less significant. The average marginal increase in demand if respondents believed that cholera is likely for adults is 1.2 compared to only 0.25 for the same belief for children. This may occur if parents are more risk averse about their children's health than their own (i.e. they will purchase vaccines for children even if they do not think the disease is serious). Respondents that previously received a cholera vaccine said they would purchase more vaccines for their families, unless they were not satisfied with the first vaccine. We also find that respondents who treat their drinking water generally report that they would purchase significantly more vaccines (average marginal effect is one vaccine), indicating common preferences for risk averting behaviors.

Table 5
Average marginal effects for household negative binomial regression

Variable (change in variable)	Household model	
	Price = US$ 0.50	Price = US$ 1.00
Price (US$; 1 unit US$ 0.50)	−0.58 (0.000)	−0.45 (0.000)
Time to think	−1.3 (0.000)	−1.1 (0.000)
Male	0.84 (.005)	0.71 (0.005)
Resident from ICDDR,B service area	−0.73 (0.068)	−0.62 (0.068)
Age (yrs)	−0.037 (0.048)	−0.031 (0.050)
Education (category- 0, 1–5, 6–10, >10)[a]	0.29 (0.098)	0.25 (0.10)
Monthly income per capita (US$ 1 per cap)	0.045 (0.000)	0.032 (0.000)
Number of infants < age 1	−0.12 (0.79)	−0.10 (0.79)
Number of children age 1–5	0.58 (0.018)	0.49 (0.19)
Number of children age 6–17	0.39 (0.012)	0.33 (0.11)
Number of adults age >18	0.55 (0.000)	0.47 (0.000)
Practice Hinduism	−0.07 (0.91)	−0.06 (0.91)
Cholera likely for respondent	1.2 (0.023)	1.0 (0.025)
Cholera likely for children	0.16 (0.66)	0.13 (0.66)
Someone in household has had cholera	0.25 (0.49)	0.22 (0.49)
Unsatisfied with previous vaccine	−1.2 (0.15)	−1.0 (0.15)
Treats water	0.99 (0.09)	0.84 (0.092)

p-Value in parentheses.

[a] As opposed to the educational dummy variables used in the negative binomial regression, an education categorical variable is necessary for average marginal effect analysis. The same educational levels are used to differentiate the category variable, which increases from lower to higher education (i.e. 1 = no formal education, 2 = 1–5 years, 3 = 6–10 years, 4 = greater than 10 years).

Each model's estimated average WTP for vaccinating all household members including the respondent is shown at the bottom of Table 4. The estimates of household WTP are stable among both model specifications and vary from US$ 9.00 for TTT respondents in the ICDDR,B service area to US$ 14.30 for NTTT respondents in the government service area. Considering the average household has 5.7 members, the average household WTP per person varies from US$ 1.60 to 2.50 depending on location and method of survey administration.

We can also use separate negative binomial models to estimate vaccine demand for discrete age groups. The dependent variable is redefined to represent the demand for each age group and separate models are estimated. The estimated average WTP per person for young children age 1–5 years (US$ 2.40) is higher than for school-age children age 5–17 years (US$ 1.20) and adults (US$ 1.05). The predicted coverage as a function of price for young children, school-age children and adults is plotted in Fig. 1 (based on time to think results). Fig. 1 shows that the predicted fraction of young children vaccinated is higher than that for the other age groups at any price. These findings suggest that respondents place more value on vaccinating young children than older children and adults.

It is also useful to compare mean WTP estimates to median WTP estimates. The median WTP by age group corresponds to the price in Fig. 1 at which 50% of an age group population is vaccinated. The median WTP is about US$ 1.00 for young children, US$ 0.05 for school-age children, and US$ 0 for adults. The fairly large differences between mean and median WTP estimates indicate that there is great heterogeneity in

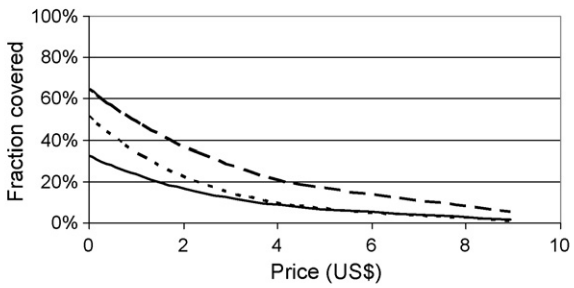

Fig. 1. Predicted coverage rates as a function of price by age group. (– –) Young children (1–4 years), (- -) school age children (5–17 years), (—) adults (>18 years).

WTP for cholera vaccines among households. In other words, there is a large portion of the population that is only willing to pay small amounts of money if any for cholera vaccines, while there is also a small fraction of the population with high WTP. Specifically, although the estimated average adult WTP is US$ 1.05, we predict that only about 25% of the adult population would choose to buy vaccines at a price of US$ 1.

4. Discussion

The contingent valuation study reported here provides estimates of private demand for cholera vaccines in Matlab, an impoverished rural area of Bangladesh where cholera is endemic. Factors associated with vaccine demand include age, income, gender, and opinions about the severity and likelihood of contracting cholera. Consistent with prior research in other developing countries, we found that hypothetical demand estimates were dependent on whether respondents received time to think about and discuss the purchasing decision with other household members [23,24]. The provision of the time-to-think-treatment reduced average household WTP by about 30%, resulting in a best estimate of average household WTP of about US$ 9–10. We prefer the TTT estimates because we believe the extra time and discussion is more consistent with actual purchasing decisions and reduces enumerator bias.

According to our model estimates, there is considerable heterogeneity in cholera vaccine demand by age group. The fraction of young children (age 1–5) vaccinated would be higher than that of school-age children or adults at any price. In addition, the mean WTP per person is much higher than the median for all age groups. This indicates that some households are willing to purchase vaccines at high prices, while many have little demand even at very low prices.

The stated preference technique is limited by the inability to validate that respondents would follow through with their stated responses if faced with a real purchasing decision. While we acknowledge this limitation, we believe that this sample is uniquely suited in some respects for using a stated preference method to value a cholera vaccine. Because many respondents or their family members participated in the 1985 cholera vaccine trial, they should be familiar with the vaccine's benefits. They should also be aware that the vaccine was not 100% effective. In addition, these respondents have had experience in participating in other health surveys and should be less prone to enumerator bias and yea-saying.

The ICDDR,B diarrhea hospital located at the center of our study site is nationally renowned for excellence in providing free treatment for cholera and other diarrheal disease. This may result in lower demand for cholera vaccines relative to other areas in rural Bangladesh. In fact, we found that, on average, people in the ICDDR,B service area expressed less demand for cholera vaccines than those in the government service area. But our interviewees in the government service area reside within only a moderate distance (within 2.5 hours by traditional methods of transportation) of the ICDDR,B hospital, and many had participated in prior ICDDR,B studies (though they probably participated in fewer studies than those residing inside the ICDDR,B service area). As a result, our estimates from the government service area are also likely affected by ICDDR,B's imprint. Other communities in Bangladesh that experience high incidences in the absence of ICDDR,B services might have higher willingness to pay for cholera vaccines.

While beyond the scope of this paper, our cholera vaccine demand models can be used in combination with recent herd protection findings to aid policy development. At present, cholera vaccine herd protection models are not well defined. Ali et al. [6,7] provide only five data points to show the coverage-incidence relationships based on population clusters that are either 0.5 [6] or 2 km [7] in radius. In addition, the 1985 campaign targeted women and children only; we do not know how adult male coverage rates would impact herd protection results. We are not aware of more comprehensive cholera herd protection modeling efforts, which might examine how vaccination rates within subgroups (e.g. age groups, gender, water and sanitation behaviors) effect herd protection.

Ali et al. [7] found that cholera vaccine coverage rates for women over 15 years were more important than coverage rates among children for effecting herd protection in children less than 2 years (who were not eligible for the Matlab campaign). As epidemiological models for cholera vaccine herd protection become available, the demand relationships (e.g. demand by age and gender) presented in this paper could aid vaccine pricing policy if government and non-profit groups choose not to fully subsidize campaigns. Demand, incidence and herd protection data could be used to examine tradeoffs between the number of cases avoided, public investment, and the vaccine price charged. In addition, one could also examine the potential for cross-subsidies to enhance herd protection effects. Our findings suggest that households would place precedence on vaccinating young children; however, the total cases avoided in the community might be increased by providing incentives to vaccinate women over 15 years based on herd protection evidence [7]. We also need to caution that our results are relevant for estimating demand for the initial period of a cholera vaccination campaign. It is likely that vaccine demand would decline in following periods as the community becomes familiar with herd protection effects and the incidence of disease declines for both vaccinated and unvaccinated persons.

With these reservations, we suggest that a cholera vaccination program in the Matlab area could charge a small fee for cholera vaccines and still achieve some herd protection. Ali et al. [6] observed herd protection effects at coverage rates as low as 30% of the target population and very large effects at coverage rates greater than 50%. We estimate that a cholera vaccination program could achieve a 30% coverage rate with a user fee of US$ 1.50 per fully vaccinated individual and a 50% coverage rate with a US$ 0.50 user fee. (Note that these coverage predictions are for the whole population rather than the targeted subpopulation as presented in [6,7].) If poorer households are co-located with wealthier ones, there is potential for these poorer households to experience a reduction in cholera incidence when wealthier households purchase vaccines even if the poor households do not purchase vaccines themselves. However, if the wealthy households that purchase vaccines are geographically distant from poor, high incidence neighborhoods, herd protection effects accruing to poor households will be less significant. Thus, it is necessary to consider the spatial patterns of demand to fully understand the potential for herd protection.

Acknowledgments

This research was funded by the International Vaccine Institute (IVI) with support from the Bill and

Melinda Gates Foundation as part of the Diseases of the Most Impoverished Program (DOMI), under project number DOMI C-SE-3. The DOMI program works to accelerate the development and introduction of New-generation vaccines against cholera, typhoid fever, and shigellosis. The Program involves a number of parallel activities including epidemiological studies, social science studies, and vaccine technology transfer. The results will support public decision-making regarding immunization programs for cholera and typhoid fever. ICDDR,B acknowledges with gratitude the commitment of IVI and Bill & Melinda Gates Foundation to the Centre's research effort.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.healthpol.2007.07.009.

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