Available online at www.sciencedirect.com
ScienceDirect
Vaccine 25 (2007) 2599–2609
Vaccine
www.elsevier.com/locate/vaccine

Private demand for cholera vaccines in Beira, Mozambique

Marcelino E.S. Lucas [a], Marc Jeuland [b,*], Jacqueline Deen [c], Nivalda Lazaro [d], Melissa MacMahon [b], Andrew Nyamete [c], Avertino Barreto [e], Lorenz von Seidlein [c], Arnaldo Cumbane [d], Francisco F. Songane [f], Dale Whittington [b]

[a] *Ministry of Science and Technology, Maputo, Mozambique*
[b] *University of North Carolina at Chapel Hill, USA*
[c] *The International Vaccine Institute, Seoul, South Korea*
[d] *Center for Environmental Hygiene and Medical Examination, Beira, Mozambique*
[e] *Ministry of Health, Maputo, Mozambique*
[f] *World Health Organization, Geneva, Switzerland*

Received 1 October 2006; received in revised form 28 November 2006; accepted 12 December 2006
Available online 21 December 2006

Abstract

In the summer of 2005, we interviewed 996 randomly selected respondents in Beira, Mozambique concerning their willingness and ability to pay for cholera vaccine for themselves and for other household members. Respondents were told that two doses of the vaccine would be required 2 weeks apart, and that the cholera vaccine would offer excellent protection against infection for the first year following vaccination, and some protection during the second and third year after a person is vaccinated. This research was carried out in order to learn more about private demand for vaccines in a cholera-endemic area. We asked two types of valuation questions: (1) a discrete-price offer for a vaccine that could be purchased for household members and (2) a payment card designed to assess uncertainty in the respondent's demand for a vaccine for self-protection. We estimate average household willingness to pay (WTP) for cholera vaccines in Beira to be 2005 US$ 8.45. This estimate of household WTP represents the perceived private economic benefits to a household – six persons on average – of giving all members free cholera vaccines.

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

1. Introduction

With recent advances in the development of effective new-generation vaccines, governments, health policy makers and international donors are increasingly considering the cost effectiveness of immunization programs against the diseases they target. Cost-effectiveness analyses typically judge the appropriateness of vaccination on the basis of ratios of vaccination program costs to (1) the number of illnesses and deaths averted, (2) reductions in disability-adjusted life-years (DALYs), or (3) savings in cost of illness (COI) both to individuals and to public health systems. From an economic perspective, comparison of total costs and benefits is an important additional test to judge whether a vaccination policy or program increases the general welfare of society. Our study analyzed data from interviews with respondents in 996 households in Beira, Mozambique, and assessed the private perceived benefits of cholera vaccines. We measured demand through respondents' estimates of what they would be willing to pay for a vaccine of 3-year duration, for themselves and for other household members.[1]

* Corresponding author. Department of Environmental Sciences and Engineering, CB#7431, School of Public Health, University of North Carolina at Chapel Hill, Chapel Hill, NC 27599, USA. Tel.: +1 919 360 9154.
E-mail address: jeuland@email.unc.edu (M. Jeuland).

[1] This study is one of several economic studies, sponsored by the International Vaccine Institute and the Bill and Melinda Gates Foundation (DOMI

0264-410X/$ – see front matter © 2007 Elsevier Ltd. All rights reserved.
doi:10.1016/j.vaccine.2006.12.027

The World Health Organization [1] reports that Mozambique had the highest number of cholera cases (20,080) worldwide in 2004. The city of Beira is situated in a region where the disease is endemic. Numerous conditions in Beira encourage the spread of cholera, including widespread flooding during the rainy season, defecation in open areas, use of poorly constructed pit latrines, and disposal of untreated wastewater in open drains and waterways [2]. Until major water and sanitation infrastructure improvements become financially feasible in Beira, vaccines against cholera may be an affordable and effective strategy for reducing the incidence of cholera.

A new-generation cholera vaccine (the oral recombinant toxin B subunit killed whole-cell rBS-WC type) was tested in Beira in 2003–2004. The trial was conducted in the *bairro* of Esturro, where approximately 57% of some 21,000 residents were vaccinated. Because of high public demand, the vaccination outposts used in the trial were opened to people from other *bairros* citywide; ultimately more than half of all persons vaccinated were from outside the original target area. First-year effectiveness was estimated at 78–84% [3], consistent with 6-month results from Peru [4] and similar to results after 4–6 months in Bangladesh [5,6].

We used the contingent valuation method (CVM) to measure the willingness and ability of Beira residents to pay for a cholera vaccine for themselves and for other household members. Our respondents were asked to indicate how many vaccines they would purchase if the vaccine were to be sold at a specified price. This report describes our sampling methods, research design, and statistical modeling, and presents results both for individual respondents and for households.

2. Methods

2.1. The contingent valuation method

The CVM was developed to value goods or services whose demand cannot be observed in ordinary markets; it has often been used for valuation of health and environmental goods and services [7,8]. The contingent valuation (CV) survey seemed particularly well suited for assessing demand for cholera vaccines in Beira because cholera vaccines had never been available to the city's residents until the trial launched in Esturro in 2003.[2] Our survey interview technique presented a hypothetical CV scenario and asked whether the respondent would purchase vaccines for the members of her household (including herself) at a specified price. Similar CV studies have been conducted to measure private demand for vaccines against diseases such as malaria [9] and HIV/AIDS [10] and to estimate the demand for cholera and typhoid vaccines in Hue, Vietnam [11,12]; Kolkata, India; Jakarta, Indonesia; and Matlab, Bangladesh.

2.2. Sampling and data collection

Because a comprehensive list of households in Beira was not available for use as a sample frame, we adopted a three-stage sampling procedure. Using *bairro*-level statistics from the 1997 census [13], we first determined what proportion of the total sample to select from each of four neighborhood types: (1) mostly cement housing, densely populated, with a few informal settlements, (2) older mixed cement housing and informal settlements on flooding land, (3) congested and flood-prone zones with mainly informal settlements, and (4) less densely populated, distant and sometimes planned neighborhoods. Two *bairros* were randomly selected from each neighborhood category and sample sizes assigned using population weights. In the second stage, smaller neighborhood units (*unidades*) were randomly selected from each chosen *bairro*. The third stage involved selection of households within the *unidades*. Project field staff scheduled interviews with every fifth house, though this task was difficult in some neighborhoods owing to narrow streets and houses without clear markers.

Project field staff selected households according to a set of inclusion criteria. A participating household was required to have at least one child age 18 or less, and the interview had to be conducted with the head of the household or his/her spouse. Interviews were conducted in Portuguese when possible or in Ndau or Sena (3%) if a respondent was insufficiently fluent in Portuguese to participate in the interview. Interview set-up staff and enumerators were trained according to guidelines for carrying out CV studies [14]. Only four respondents stopped the interview before it was completed. Informed consent was obtained from all sample respondents except one; that household was dropped from the sample.

2.3. The survey instrument

The survey questionnaire had eight sections. Section 1 gathered general demographic information, confirmed whether study inclusion criteria had been met, and obtained the respondent's informed consent. Section 2 dealt with the respondent's perceptions, attitudes, and experiences related to cholera. Section 3 assessed the respondent's knowledge of vaccines and cholera vaccination history and supplied information on the existing cholera vaccine, with a reminder about the Esturro vaccination trial, which had taken place about 18 months previously. For anyone in the household who had participated in the trial the enumerator recorded the number of doses received, vaccination outpost visited, and mode of transportation used.

program), of demand for vaccines against cholera, typhoid, and shigellosis in various developing countries, including India, Bangladesh, Vietnam, China, and Indonesia.

[2] Informal interviews with seven pharmacies and five government health posts confirmed that those locations had never sold or offered cholera vaccines. The government does not currently permit suppliers to bring cholera vaccines into the country for routine use.

Section 4 introduced our CV scenario, which assessed the respondent's willingness to pay (WTP) for cholera vaccines for household members and for individual (self) protection. The survey instrument presented both single-price and sliding-scale questions; some respondents were asked to reply during a single continuous interview, others were given overnight to consider their answers. The survey protocol was further varied such that some respondents received the single-price offer first and others received the sliding-scale exercise first. Section 5 assessed travel costs associated with going to a vaccine outpost to obtain vaccines, including mode of transportation, time spent in transit, and time spent queuing.

Section 6 of the survey recorded household socioeconomic characteristics. Section 7 recorded the interviewer's observations regarding visible conditions of the home and opinions on the quality of the interview. Section 8 probed the respondent's decision-making process in the CV experiment.

Analysis and discussion below center on details of the contingent valuation portion of the survey (section 4), including survey protocols, modeling, results, and implications.

2.4. Research design

The research design included three experimental treatments involving the sliding-scale and discrete-price offers for vaccines. Fig. 1 shows the combinations of questions developed for Section 4, the CV portion of the survey instrument, and the sample sizes associated with each.

Section 4 introduced CV scenarios that presented the respondent with both a single (discrete) fixed-price question and a sliding-scale exercise. In the fixed-price portion of the questionnaire, the enumerator asked how many cholera vaccines the respondent would purchase for household members (self included) if the two-dose regime were available at a specified price. The offer came after a reminder that respondents should carefully consider their household budget. Each respondent was offered a single price, randomly assigned from an array of five (5000, 20,000, 40,000, 70,000, and 100,000 meticals, about US$ 0.20, 0.82, 1.63, 2.86, and 4.08). All respondents received the same description of the cholera vaccine: oral ingestion in two doses given 2 weeks apart, with "excellent" effectiveness for the first year and diminishing effectiveness over the 2 following years.

The CV scenario included a series of questions designed to assess the degree of certainty in the respondent's reply to this first valuation question. Such questions have been found useful in reducing problems of hypothetical bias in CV studies [15]. Following these questions, respondents were debriefed about the reasons for being willing (or unwilling) to purchase the vaccines at the price offered. These questions were included to better understand the motivations behind respondents' answers. Respondents who were unwilling to purchase vaccines at the offered price were asked whether they would pay some nonzero price and, if not, whether they would accept vaccines if offered free of charge.

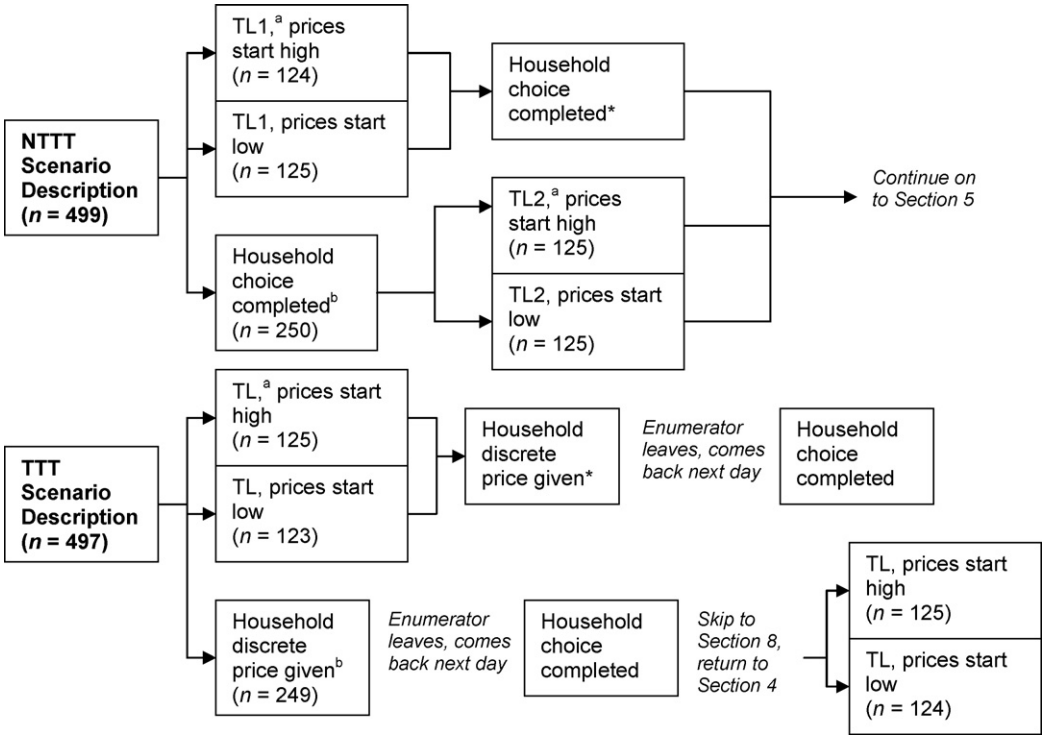

Fig. 1. Experimental research design for assessment of WTP. ([a]) Five single-offer prices were randomly assigned to respondents: Mts. 5000, 20,000, 40,000, 70,000, 100,000 (2005 US$ 0.20, 0.82, 1.63, 2.86, 4.08). ([b]) TL ("traffic light") sliding-scale exercise. TL1 = exercise presented before single-price offer; TL2 = exercise presented after single-price offer.

A further aspect of the single-price portion of the survey was that half of the respondents were given "time to think" (TTT) overnight before responding to the single vaccine price offered for household vaccinations. These respondents were allowed to consult with others; "no time to think" (NTTT) respondents, who gave their replies during a single-session interview, were not. Specifically, with TTT respondents the interviewer presented the randomly assigned single price for household vaccines during a first interview session and then returned the next day to ask whether the respondent would purchase the vaccines at that price and how many household members would receive it.[3] In a previous vaccine demand study, giving respondents time to think has been shown to reduce the stated demand for cholera and typhoid vaccines. There is also some evidence that it leads to more certain responses to price offers [12].

The second valuation question was designed to elicit the respondent's willingness to pay for a single cholera vaccine for self-protection only, and to estimate the degree of certainty in willingness (or unwillingness) to purchase the vaccine at various prices. Prices were presented in succession along a sliding scale ranging from 1000 to 100,000 meticals (US$ 0.04–4.08). Following the analogy of a traffic signal, the respondent indicated a "red light" (stop) at the point where the price rose to a point that was definitely unacceptable and, similarly, a "green light" (go) at the point where the price fell to a point where a purchase would definitely be made. If uncertain of willingness to pay a particular price on the scale, the respondent could indicate a "yellow light" (caution).

Half of our respondents were presented with these sliding-scale questions before they were given the other portion of the CV survey, the single-price offer for household vaccines. We called this protocol "traffic light first," or TL1; all such respondents (whether TTT or NTTT) completed this exercise during the first day. The remaining half of the respondents received the single-price household vaccine offer first, then the sliding-scale questions second (TL2). Thus, TTT respondents in the TL2 group only completed the sliding scale during the second interview. These arrangements were adopted because we speculated that hearing many price options when the sliding-scale questions was introduced first in the sequence first might prepare TL2 respondents to give more reliable answers to the single-price offer. On the other hand, TL2 respondents might instead "anchor" on prices heard in the sliding-scale exercise, allowing those values to influence replies to the single-price question, rather than stating actual personal preferences. To address that problem, we randomly assigned questionnaires such that half started the sliding-scale exercise with the highest price, and half started with the lowest price.

2.5. Modeling and analysis of demand

We assessed cholera vaccine demand with unitary household models of decision-making, using the number of vaccines each respondent had stated would be purchased at the single-price offer in the CV survey. The household decision maker is presumed to choose the number of two-dose treatments purchased for i household members so as to maximize their utility, which is a function of each family member's consumption and health, subject to the household budget constraint [9,11]. This yields household demand functions for i household members' immunizations A_i. The quantity of vaccines demanded depends on vectors of household members' health (H) and other characteristics (Z) (e.g., sex, birth order), as well as total income (y) and the prices for preventive (p_V) and mitigating (p_m) health goods:

$$A_i = g(y, p_V, p_m, Z, H). \tag{1}$$

Summing Eq. (1) over all members of the household yields the household demand function $A^* = \sum_{i=1}^{n} A_i$, where A^* is the total number of vaccines the decision maker purchases:

$$A^* = h(y, p_V, p_m, Z, H). \tag{2}$$

The decision maker's total WTP for cholera vaccines for household members is the area under this demand curve and to the left of household size (n):

$$\text{WTP} = \int_0^n h(y, p_V, p_m, Z, H)\,\mathrm{d}A. \tag{3}$$

We estimated the household demand function using a count regression model. The simplest count model assumes that the dependent variable (number of vaccines requested) is a random draw from a Poisson distribution with a mean λ_j, where j denotes the household. If n_j is household size, the model can be written as

$$P[A_j^* = n_j] = \frac{\mathrm{e}^{-\lambda_j}\lambda_j^{n_j}}{n_j!}, \tag{4}$$

where $n = 1, \ldots, n_j$, $\lambda_j = \mathrm{e}^{X_j\beta}$ and X_j is the vector of characteristics describing household j and research design aspects impacting the responses of household j (TTT-NTTT; "traffic light" sliding-scale ordering TL1, TL2; low or high sliding-scale starting point). Unfortunately, the basic Poisson model is restrictive in requiring that the conditional variance and mean of the dependent variable be equal, and because it does not eliminate the possibility of impossibly high counts, where $A_j^* > n_j$. When the conditional variance exceeds the conditional mean, as occurs in the demand data analyzed here, the data are "overdispersed" and the negative binomial probability distribution is preferred to avoid downward biasing of the standard errors of β [16]; λ_j is specified as $\mathrm{e}^{X_j\beta+\varepsilon_j}$, where ε_j is a error term with a gamma distribution.[4] The Poisson and

[3] Consecutive days were preferred, but in a few instances enumerators were unable to find the respondent at home for 2 or 3 days following the first half of the interview.

[4] To correct for the problem of high counts, we used a truncated count Poisson model to impose $A_j^* \leq n_j$, and compared to the results from the negative binomial specification.

the negative binomial distributions allow for realizations of zero counts.

WTP from either the Poisson or the negative binomial model is the area under the household demand curve and can be computed from the regression parameters as follows:

$$\mathrm{WTP}_j = \frac{-\mathrm{e}^{X_j\beta}}{\beta_\mathrm{p}}, \quad (5)$$

where β is the vector of parameter estimates excluding the price parameter, β_p.

In 36 cases where the respondent indicated in debriefing questions following the valuation scenario uncertainty regarding the number of vaccines that might be purchased, we adjusted the quantity of vaccines to be consistent with the maximum monetary amount the respondent was certain could be spent at the price offered, rather than recording the initial (uncertain) answer.

Because our respondents in Beira were reluctant to disclose household income (only 490 answered that question), we imputed income in all cases from household asset holdings, respondent education, and other socioeconomic factors. We then created dummy variables for each of four income quartiles for use in the econometric models described above.[5]

To observe how time to think (TTT) overnight about responses to the sliding-scale exercise had affected respondents' price choices and degree of uncertainty, we compared data from the TTT and NTTT subsamples in terms of length and midpoint of the uncertainty range. We limited this analysis to the TL2 (sliding-scale exercise given second) sample because all TL1 respondents completed the exercise on day 1. We also conducted standard ordinary least squares regressions analyzing length and midpoint of each respondent's choices in terms of the socioeconomic factors and research design variables investigated in the household models.

3. Results

3.1. Profile of sample respondents

More than 99% of respondents in the sample know about cholera. Nearly two-thirds (65%) reported that they know someone who has had cholera, and 19% said that it has affected someone in the household. These numbers may be inflated because some respondents may have confused cholera with other serious diarrheal diseases. Nearly 100% said they knew what vaccines are, and 97% had received a vaccine before. Almost as many (87%) correctly stated in response to an open-ended question that the purpose of vaccines was preventative, which suggests that most people understand how vaccines should be used. Only 21% reported that one or more family members had actually received a cholera vaccine; the great majority (951 of 971) had received the vaccine during the citywide vaccine trial in 2003. Of that group only 718 had received the required two doses.

Because (for logistical reasons) we drew our TTT and NTTT subsamples from different *unidades*, results shown for them in Table 1 do not compare exactly equivalent circumstances. A number of variables (income, electricity or private water connection, phone or refrigerator; respondents completing secondary school) are lower for the TTT sample, to a statistically significant degree. Two hygiene variables (soap in household on day of interview, household boils water) that we used as indicators of risk-aversion are significantly higher for the NTTT sample. We controlled for these differences in the multivariate count regression models. Overall, more than half of respondents had private (27%) or shared (27%) piped water connections; most of the rest purchased water from neighbors. About 40% of respondents had electricity. About half had simple pit latrines; 12% defecated in the open; 31% had in-home flush toilets, and 5% used shared flush toilets.

3.2. Households in and out of the market for cholera vaccines

From analysis of the debriefing questions, we found that only 2 of 991 respondents did not believe that the vaccine would be safe or that it could prevent the disease; they were dropped from the sample. All but 6 of the remaining 989 respondents said they would obtain the vaccine for household members if it were offered free of charge, but 71 respondents (7.1%) said they would not pay to receive vaccines. These 71 households were considered to be "out of the market."

During the 2003 cholera vaccination campaign about 57% of the population of Esturro, and roughly 9% of the city as a whole, received the two-dose vaccine regime offered in the trial. The sitting of the vaccine delivery outposts almost entirely within Esturro (the original target area) contributed to the lower citywide turnout during the campaign. Our survey respondents offered a variety of reasons for not traveling there to receive the vaccines: they were too busy at the time (98), or thought the vaccine clinics were too far away (72), or that the waiting lines were too long (42), or simply did not want the vaccine (38), were away (35), were poorly informed about the timing of the trial (32), saw the vaccine as "experimental" (20), were sick or pregnant at the time (12), or thought the vaccine was only for children (11).

Of the 983 respondents who said they would either pay the offered price or take a free vaccine, the majority (54%) said that avoiding the risk of death was their primary motivation for being vaccinated; another 28% reported primarily wanting to avoid the pain and suffering caused by the disease. Only 18% cited primary motives that could be captured by benefit estimates based on measures of avoided costs of illness such as avoided treatment expenses (15%) and avoided loss of wages (3%).

Over 90% of respondents who said they would buy one or more vaccines at the offer price said they would do so

[5] The model specification and results used to predict household income are available from the authors upon request.

Table 1
Descriptive statistics

Variable name	NTTT ($n=498$)	TTT ($n=493$)	t-Statistic[a]
Respondent characteristics[b]			
% Male	48	47	0.20
Age (years)	38 (12)	37 (14)	0.98
Most common religion	Catholic (49%)	Catholic (39%)	3.18***
Median education (years)	6–7	6–7	1.40
Household characteristics[b]			
Number of young children	1.1 (1.1)	1.2 (1.0)	1.01
Number of school-age children	2.3 (1.4)	2.1 (1.5)	1.47
Number of adults	2.6 (1.4)	2.5 (1.3)	0.73
Predicted household income			
% Second quartile	23	29	2.25**
% Third quartile	28	26	0.88
% Fourth quartile	35	25	3.10***
Median reported monthly household income[c]	US$ 73	US$ 61	1.23
% With electricity	44	35	3.08***
% Owning telephone	48	40	2.47**
% Owning radio	82	82	0.13
% Owning refrigerator	30	23	2.47**
Primary source of drinking water			
% Private or shared connection	58	49	2.99***
% Buy from connected neighbors	34	32	0.97
% Other (communal source; bottled; well)	7	20	5.79***
Toilet			
% Public flush toilet or open pit latrine	51	52	0.44
% Flush toilet in home	33	29	1.46
% Shared flush toilet	5	6	0.70
Risk behavior, perceptions of disease, vaccination history			
% Soap in the house	83	78	1.78*
% Boil drinking water (sometimes or always)	47	41	1.79*
% Someone in household has had cholera	19	19	0.13
% Someone in household has died of cholera	3	2	1.00
% Knows someone (non-hh) who had cholera	68	61	2.17**
% At least one hh member vaccinated	30	22	3.08***

[a] $\text{Mean}_N - \text{mean}_T = 0$.
[b] Continuous variables reported as mean (with standard deviation) unless otherwise noted.
[c] Converted to 2005 US$ using an exchange rate of Mts 24,500 = 1 US$; to adjust for purchasing power parity (PPP) multiply by 4.58.
* Significant at 10% level.
** Significant at 5% level.
*** Significant at 1% level.

because the cholera vaccine was useful to them or household members for prevention and safety. Seven percent of such respondents said that they thought the price was reasonable, that they were worried about household members getting cholera, or that vaccination was recommended by health workers. Among respondents who did not want vaccines at the offer price, 95% said that the price was too high or that they did not have the money to pay for the vaccine. Less than 1% of respondents said they did not know why they would or would not pay the price offer or gave questionable responses to the debriefing questions. We conclude from this analysis of respondents' answers to debriefing questions suggests that respondents were thinking carefully about the CV scenario, agreeing to the offered price when they thought the cost was justified, and rejecting the vaccine when the price was too high.

3.3. Household demand estimation

In the single-price component of our CV scenario, as the offered vaccine price increased, the average percentage of household members for whom the respondent was willing to purchase vaccines decreased (Fig. 2). At all prices, giving respondents time to think about their decision overnight appears to have lowered the proportion of those willing to purchase the vaccine, although that effect can only be definitively seen in the multivariate models that control for differences in the NTTT and TTT samples. The TTT effect appears to be especially strong for the mid-range prices (US$ 0.82 and 1.64). Time to think also increased respondents' reported certainty about their answers. Twenty-seven (75%) of the 36 uncertain respondents were in the NTTT subsample.

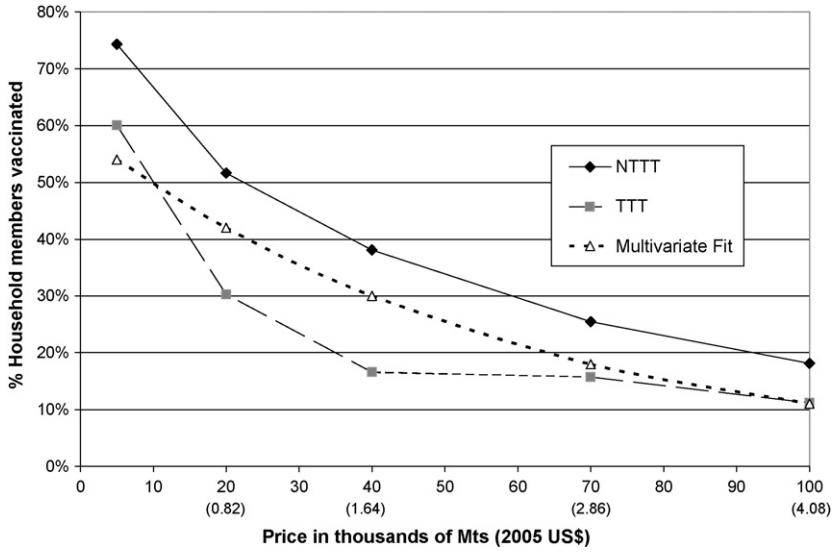

Fig. 2. Average percentage of household members who agreed to purchase vaccines at five offered prices with no time to think (NTTT) and time to think (TTT) and multivariate fit to complete sample, adjusting for time to think.

Our analysis of respondents' accounts of how they would allocate vaccines among their household members (Table 2) revealed that many made all-or-nothing decisions, saying they would buy no vaccines at all at the offered price or else that they would buy vaccines for everyone in the household. Of respondents who were offered the lowest price (US$ 0.20), 54% would have been willing to buy vaccines for all household members; 24% would have bought for none. As price increased, the proportion of respondents who would buy for all household members decreased, and the proportion who would buy for no one increased. At the highest price (US$ 4.08), 73% would buy for no one in the household, and only 12% would buy for all. A small number of respondents (15) expressed interest in purchasing vaccines for people who were not household members; these instances were excluded from the analysis of household demand. Our results might therefore slightly underestimate actual market demand.

Table 3 presents the results for three different multivariate specifications of the negative binomial household demand model. The parameter values and statistical significance are consistent across all three model specifications. We estimated a minimal model that includes only a few independent variables, then two more models with larger numbers of explanatory variables. The truncated Poisson specifications did not yield results that were substantially different. Respondents who were offered a higher vaccine price bought fewer vaccines for their households (1% level of significance). We present marginal effects of variable changes at three price levels (US$ 0.20, 1.00, and the mean offer price US$ 1.90) using the full model estimates in Table 4. These marginal effects are more easily understood in terms of an illustrative US$ 1.00 increase in vaccine price, which we estimate would lead to the purchase of 1.3, 1.0, and 0.7 fewer vaccines per household.

Giving a respondent overnight to think about the WTP decision lowered stated demand strongly and significantly (1% level), even after the adjustment of uncertain responses. At the mean price, 0.6 fewer vaccines would be purchased for the household. The use of mosquito nets (65% of households had at least one person sleeping under a net at night) and having soap in the house (72%), both proxy measures of risk aversion, had positive and significant coefficients (10

Table 2
Percentage of respondents buying vaccines for household members

Price in Mts (US$)[a]	5000 (0.20)	20,000 (0.82)	40,000 (1.64)	70,000 (2.86)	100,000 (4.08)	All prices
No time to think (NTTT)						
Buying for all	61	41	38	21	13	35
Buying for some	22	27	10	18	19	19
Buying for none	17	32	52	61	68	46
n	99	100	100	100	100	499
Time to think (TTT)						
Buying for all	48	28	18	12	10	23
Buying for some	21	15	14	15	10	15
Buying for none	31	57	67	73	80	62
n	100	100	98	100	99	497

[a] Mts 24,500 = 2005 US$ 1; PPP-adjusted Mts 5345 = US$ 1.

Table 3
Multivariate model results[a]

Variable	Household negative binomial models			OLS models of sliding scale	
	Reduced model A	Reduced model B	Full model	Midpoint of uncertainty	Length of uncertainty
Price (thousands of Mts)	−0.016*** (0.002)	−0.017*** (0.002)	−0.017*** (0.002)		
Midpoint of sliding scale					0.41*** (0.04)
Time to think (TTT)	−0.38*** (0.09)	−0.37*** (0.09)	−0.37*** (0.09)	−4.25*** (0.94)	−1.33** (0.68)
TL1, start low[b]		−0.09 (0.11)	−0.07 (0.11)	−2.96** (1.25)	0.11 (0.87)
TL1, start high[b]		0.21* (0.11)	0.21* (0.11)	1.24 (1.34)	1.30 (1.00)
TL2, start high				1.01 (1.40)	0.17 (1.05)
Urban zone 2[b]		0.10 (0.14)	0.04 (0.14)	2.48 (1.69)	1.46 (1.14)
Urban zone 3[b]		−0.06 (0.17)	−0.10 (0.17)	−1.08 (1.82)	4.43*** (1.37)
Urban zone 4[b]		−0.04 (0.14)	−0.10 (0.14)	−0.01 (1.55)	1.21 (1.10)
Single[b]			−0.03 (0.20)		
Widow[b]			−0.42** (0.20)		
Divorced[b]			−0.10 (0.25)		
Male			0.10 (0.09)		
Muslim[b]			−0.01 (0.15)		
Protestant[b]			−0.12 (0.10)		
Household cholera death		−0.51 (0.42)	−0.48 (0.42)	−0.72 (3.18)	−1.63 (1.69)
Household cholera		0.01 (0.13)	− 0.04 (0.13)	0.86 (1.25)	1.04 (0.96)
Diarrheal incidence in *bairro*[c]		0.02 (0.02)	0.02 (0.02)	0.27 (0.24)	− 0.27 (0.17)
Count of household members	0.04** (0.02)	0.04* (0.02)		−0.79*** (0.24)	− 0.25 (0.16)
Count of young children			0.04 (0.05)		
Count of school children			0.05* (0.03)		
Count of adults			0.05 (0.04)		
Mosquito nets (yes/no)	0.18* (0.10)	0.19* (0.10)	0.22** (0.10)	−0.12 (1.05)	0.44 (0.69)
Soap in the house	0.30** (0.14)	0.29** (0.14)	0.25* (0.13)	3.14*** (1.04)	−1.40*** (0.79)
Asset 4 (motor vehicles)	0.54*** (0.14)	0.58*** (0.14)	0.57*** (0.15)	5.20* (2.88)	0.82 (2.37)
Income quartile 2[b]	0.42** (0.18)	0.40** (0.17)	0.35** (0.18)	1.86 (1.18)	0.60 (0.83)
Income quartile 3[b]	0.64*** (0.18)	0.63*** (0.17)	0.55*** (0.18)	4.86*** (1.30)	0.33 (0.96)
Income quartile 4[b]	0.82*** (0.20)	0.79*** (0.20)	0.71*** (0.21)	8.85*** (1.91)	0.16 (1.38)
Primary school only[b]	0.40* (0.23)	0.41* (0.22)	0.39* (0.22)	3.88*** (1.12)	2.09*** (0.77)
Secondary school[b]	0.48** (0.24)	0.45* (0.24)	0.41* (0.24)	5.11*** (1.74)	1.96* (1.17)
Post-secondary school[b]	0.76*** (0.27)	0.70** (0.28)	0.63** (0.29)	6.36 (4.28)	−2.80 (2.17)
Traveled to Esturro		0.07 (0.11)	0.11 (0.10)	0.94 (1.20)	0.72 (0.90)
Constant	−0.11 (0.28)	−0.34 (0.38)	−0.20 (0.38)	9.40*** (3.58)	4.87* (2.50)
n	956	956	951	827	827
Log-likelihood	−1713.8	−1709.1	−1694.5		
Pseudo-R^2/R^2 (OLS)	0.052	0.055	0.056	0.1881	0.3063
Wald Chi-sq ($p <$ Wald χ^2)	230.6 (0.000)	274.9 (0.000)	295.2 (0.000)		

[a] Excluded scenario rejecters. Standard errors in parentheses; robust standard errors.
[b] Excluded categories: no schooling, low income quartile, urban zone 1, married, traffic light 2, Catholic.
[c] Diarrheal incidence data taken from Cholera Treatment Center logbook.
* Significant at 10% level.
** Significant at 5% level.
*** Significant at 1% level.

and 5% level, respectively), suggesting that respondents who were more risk-averse were more likely to be willing to purchase larger numbers of vaccines. For the average household, using at least one mosquito net and having soap increased the number of vaccines that would be purchased, by 0.35 and 0.38 additional vaccines, respectively.

Demand for vaccines also tended to be higher in larger households (5–10% significance, depending on the model), and in those with more school-aged children (10% significance). Finally, as expected, demand for vaccines was lowest among households in the low income quartile and highest in the high-income quartile: the dummy variables are statistically significant at the 1 and 5% levels. Demand also increased with ownership of motor vehicles (an asset held by 28% of households in the highest income quartile). Households with higher levels of education also had significantly higher vaccine demand (at the 5–10% level, depending on the education level) with post-secondary schooling having the stronger effect.[6]

The marginal effects of the income and education variables are of similar magnitude. The average respondent in the second-lowest income quartile would buy 0.6 more vaccines

[6] There is significant correlation between the education-level variables and other variables used in the model. This partially explains the high standard errors for the education-level coefficients. Note that because education levels were also part of the predictive model for income, income quartiles may partly reflect the effect of education as well.

Table 4
Change in the number of vaccines purchased with a one-unit increase in levels of explanatory variables using the full negative binomial model[a]

Variable	Price = US$ 0.20[b]	Price = US$ 0.82[b]	Mean price = US$ 1.90[b]
Price (thousands of Mts)	−0.05	−0.04	−0.03
Time to think (TTT)	−1.1	−0.85	−0.60
TL1, starting high	0.69	0.53	0.36
Count of young children	0.11	0.09	0.06
Count of school children	0.15	0.11	0.09
Count of adults	0.13	0.10	0.08
Mosquito nets (yes/no)	0.68	0.52	0.35
Soap in the house	0.73	0.56	0.38
Asset 4 (Motor vehicles)	2.3	1.8	1.2
Income quartile 2[c]	1.2	0.91	0.62
Income quartile 3[c]	0.82	0.64	0.41
Income quartile 4[c]	0.76	0.59	0.38
Primary school[d]	1.2	0.89	0.61
Secondary school[d]	0.24	0.18	0.11
Post-secondary school[d]	1.3	0.99	0.68

[a] Marginal effects evaluated at the mean of variables (except for price) and correspond to a 0–1 discrete change for dummy variables.
[b] Unadjusted for purchasing power parity: Mts 24,500 = US$ 1.
[c] The marginal effect is the change in number of vaccines purchased moving from the preceding quartile to the listed quartile (i.e., income quartile 2 marginal effect refers to the effect of moving from quartile 1 to 2). To see the effect of moving from quartile 1 to 4, simply add the three marginal effects.
[d] Similarly, the marginal effect of education levels is the change in number of vaccines purchased moving from the preceding education level to the listed education level.

than would an average respondent in the lowest quartile—an effect similar in magnitude to the effect of having a full primary, rather than subprimary, level of education. The marginal effect of owning a motor vehicle is 1.2 more vaccines per household.

Diarrheal incidence rates and prior experience with cholera in the household were not significant predictors of vaccine demand. Participation in the 2003 Esturro vaccine trial (ignoring the possible endogeneity issues associated with this variable) was not a statistically significant explanatory variable for demand. There does not appear to be much spatial influence on demand; households farther away from the city center (urban category 4) and away from flood-prone zones had negative model coefficients, but the effect was not statistically significant.

Interestingly, TL1 respondents – those who received the single-price offer second, after the sliding-scale exercise – did not respond differently than those who received the single-price offer first, as long as the enumerator began the sliding-scale exercise with the lowest price. This result suggests that respondents did not generally have trouble with discrete-price (single-price) offers. Where the starting point had been at the high end of the scale, we found evidence of anchoring: respondents were more likely to buy larger numbers of vaccines (10% significance level). The marginal effect of this anchoring was to raise the number of vaccines that a household would buy by 0.4.

Average WTP for cholera vaccines for all household members was about US$ 7.70 for TTT respondents and US$ 13.30 for NTTT respondents. Average WTP can be interpreted as the perceived private economic benefits to a household of having everyone in the household receive cholera vaccines free of charge. Because we believe that giving respondents time to think provides more realistic demand estimates, and because of the inherent (locational and socioeconomic) differences in the two subsamples, we adjusted all responses to reflect the effect of time to think, using the full model specification. These results indicate that if all respondents had been given time to think, average WTP for cholera vaccines for households of six family members would be US$ 8.45, which yields an average per capita WTP estimate of about US$ 1.40 for the two-dose regime. Using bootstrapping techniques, the standard deviation of this per capita estimate in the sample was found to be US$ 0.95, and the median US$ 1.25. Adjusting for purchasing power parity (PPP), the average willingness to pay for a household of six is US$ 38.80, or roughly US$ 6.50 per capita.

3.4. Uncertainty in respondent demand: evidence from the sliding-scale exercise

Consistent with evidence from the multivariate household models, respondents given time to think overnight expressed lower demand for the vaccine when completing the sliding-scale exercise. This effect can be seen in the upper (lowest "red light" price) and lower (highest "green light" price) bounds of the uncertain range of WTP, as well as at its midpoint. TTT respondents show significantly lower values on all three of these measures (Table 5). For instance, the midpoint of the range drops from US$ 0.93 to 0.65. TTT respondents also appear more certain about how much they would pay: having time to think reduces the range of uncertainty (calculated as the difference between the upper and lower bounds) from US$ 0.87 to 0.64, a highly significant difference ($t = 4.35$).

Table 5
Uncertainty in WTP derived from sliding-scale exercise (US$)

Subsample and variable	NTTT	TTT	*t*-Statistic
TL2, sliding-scale exercise after single-price question (436 observations)			
Midpoint[c]	0.93	0.65	4.92***
Upper bound[a]	1.36	0.97	5.06***
Lower bound[b]	0.49	0.32	3.90***
Length of range[c]	0.87	0.64	4.35***
TL1, sliding-scale exercise before single-price question (441 observations)			
Midpoint[c]	0.85	0.75	1.81*
Upper bound[a]	1.29	1.11	2.20**
Lower bound[b]	0.42	0.39	0.77
Length of range[c]	0.87	0.73	2.65***

[a] Excludes respondents without a true upper bound (green at all prices).
[b] Excludes respondents without a lower bound (green at all prices, or red at all prices).
[c] Excludes respondents with an undefined upper or lower bound.
* Significant at 10% level.
** Significant at 5% level.
*** Significant at 1% level.

4. Discussion

The primary conclusion of the research reported here is that the vast majority of people in Beira want cholera vaccines for themselves and for members of their households—but they are too poor to pay very much for them. Our best estimate of household WTP for cholera vaccines (a two-dose regime per recipient) in Beira is about 2005 US$ 8 (US$ 38, PPP-adjusted), or US$ 1.40 per capita (US$ 6.50, PPP). Some economists fear that respondents will answer contingent valuation questions strategically. For example, respondents might overstate their demand for vaccines if they thought this would encourage government or donors to initiate free vaccination campaigns. Alternatively, respondents might understate their demand for vaccines in hopes that this would induce donors to provide vaccines at low or no prices. It is thus difficult to know how a respondent would answer if she wanted to act strategically. Our analysis of respondents' answers to the debriefing questions did not suggest that strategic behavior was a problem in this survey. Rather, we believe that respondents were seriously considering the CV scenario and trying to give accurate, honest answers.

We found that giving respondents time to think about the CV price offer significantly lowered stated demand and decreased the uncertainty of their responses. This effect was significant even when coupled with the conventional approach of adjusting the valuation data using responses to a follow-up question about uncertainty.

Our analyses show that the most significant factors that increased private demand for cholera vaccines were lower price, higher income, increased asset ownership, more education, and higher household risk aversion (as inferred from evidence of attention to hygiene). Larger households had higher demand, and when faced with a single-price offer, respondents often, though not always, said that they would purchase vaccines for all members or for none. Households that had experienced illness or death from cholera did not show higher demand for vaccines than other households.

In summary, the results of this contingent valuation study suggest that the majority of citizens of Beira are willing to pay at least a small amount (e.g., US$ 0.25) toward the cost of the vaccination program. We suggest that a well-targeted vaccination campaign need not depend solely upon funds from international donors or the Government of Mozambique, but could be partially financed by the recipients of the vaccine.

Acknowledgments

This research is part of the Diseases of the Most Impoverished Program (DOMI), administered by the International Vaccine Institute with support from the Bill and Melinda Gates Foundation. 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.

References

[1] WHO. Cholera, 2004. Wkly Epidemiol Rec 2005;80(31):261–8.
[2] Ansaruzzaman M, Lucas M, Deen JL, Bhuiyan NA, Wang X-Y, Safa A, et al. Pandemic Serovars (O3:K6 and O4:K68) of *Vibrio parahaemolyticus* associated with diarrhea in Mozambique: spread of the pandemic into the African continent. J Clin Microbiol 2005;43(6):2559–62.
[3] Lucas MES, Deen JL, Von Seidlein L, Wang X-Y, Ampuero J, Puri M, et al. Effectiveness of mass oral cholera vaccination in Beira, Mozambique. N Engl J Med 2005;352(8):757–67.
[4] Sanchez JL, Vasquez B. Protective efficacy of oral whole-cell/recombinant-B-subunit cholera vaccine in Peruvian military. Lancet 1994;344(8932):1273–5.
[5] Clemens J, Sack D, Harris J, Chakraborty J, Khan M, Stanton B, et al. Field trial of oral cholera vaccines in Bangladesh. Lancet 1986;2(8499):124–7.
[6] Clemens JD, Sack DA. Field trial of oral cholera vaccines in Bangladesh: results from three-year follow-up. Lancet 1990;335(8684):270–2.
[7] Hanemann WM. Valuing the environment through contingent valuation. J Econ Perspect 1994;8(4):19–43.
[8] Carson RT. Contingent valuation: a user's guide. Environ Sci Technol 2000;34(8):1413–8.
[9] Cropper ML, Haile M, Lampietti J, Poulos C, Whittington D. The demand for a malaria vaccine: evidence from Ethiopia. J Dev Econ 2004;75(1):303–18.
[10] Whittington D, Matsui-Santana O, Freiberger JJ, Van Houtven G, Pattanayak S. Private demand for a HIV/AIDS vaccine: evidence from Guadalajara, Mexico. Vaccine 2002;20(19/20):2585–91.
[11] Canh DG, Whittington D, Thoa LTK, Utomo N, Hoa NT, Poulos C. Household demand for typhoid fever vaccines in Hue City, Vietnam: implications for immunization programs. Health Policy Plann 2006;21(3):241–55.

[12] Cook J, Whittington D, Canh DG, Johnson FR, Nyamete A. Reliability of stated preferences for cholera and typhoid vaccines with time to think in Hue, Vietnam. Econ Inq 2007;45(1):100–14.
[13] INE. Second National Census. Maputo, Mozambique, 1998.
[14] Whittington D. Improving the performance of contingent valuation studies in developing countries. Environ Resour Econ 2002;22(1–2): 323–67.
[15] Blumenschein K, Johannesson M, Yokoyama KK, Freeman PR. Hypothetical versus real willingness to pay in the health care sector: results from a field experiment. J Health Econ 2001;20(3):441–57.
[16] Cameron AC, Trivedi PK. Econometric models based on count data: comparisons and applications of some estimators and tests. J Appl Econometr 1986;1(1):29–53.