Hospital-Based Study of the Economic Burden Associated with Rotavirus Diarrhea in Hong Kong

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Background. Rotavirus infection is the most common cause of severe diarrhea in both developed and developing countries.

Methods. To estimate the economic burden associated with rotavirus infection in Hong Kong, we combined data on the disease burden of rotavirus-associated hospital admissions with detailed cost data for a subsample of 471 children with diarrhea admitted to hospitals.

Results. The annual total social cost and total direct medical cost for rotavirus-associated admissions were calculated as US $4.3 and US $4 million, respectively, by use of data collected during March 2001 to March 2003. The estimate of the direct medical costs was ~4-fold higher than a previous estimate; this difference largely reflects the greater disease burden identified through active disease surveillance conducted under the auspices of the Asian Rotavirus Surveillance Network. On average, families spent US $120 when their child’s admission was associated with rotavirus infection; this cost represents ~10% of the monthly salary of an unskilled or service worker.

Conclusions. These data emphasize the potential for a safe and effective rotavirus vaccine to reduce the economic burden associated with rotavirus disease.

In the United States, rotavirus infection has been reported to be responsible for 30%–50% of all diarrhea-related hospital admissions among children <5 years old and for >50% of diarrhea-related admissions during seasonal peaks [1]. It has been estimated that 1 in 78 children in the United States is hospitalized for rotavirus diarrhea, and recent estimates indicate that rotavirus diarrhea results in US $264 million in direct medical costs and US $1 billion in total costs to society each year [1]. As part of the Asian Rotavirus Surveillance Network (ARSN), active surveillance for rotavirus infection in Hong Kong showed that rotavirus was responsible for at least 24% of all diarrhea-associated hospital admissions (30% of all stool samples obtained from patients were positive for rotavirus). Results for 24% of stool samples sent for bacterial culture were positive, and salmonella was identified in 44% of stool samples. The results of a preliminary cost analysis using passive diarrheal disease surveillance and laboratory data from one hospital in Hong Kong suggested that rotavirus infection was responsible for US $1.2 million (HK $9.6 million) in direct medical costs [2]. This cost estimate from one university teaching hospital was extrapolated to the whole territory. The cost estimates were calculated solely on the basis of the average daily cost of hospitalization for general admissions of children to the pediatric wards of the hospital.

The present study aims to refine these estimates of economic burden by combining more-accurate information on the disease burden associated with rotavirus infection for the whole of Hong Kong (derived from the ARSN surveillance data [3] and as published else-
where in this supplement [4]), with more-detailed cost data collected from a sample of children hospitalized with diarrhea during the surveillance period. These data will be helpful to policy makers in deciding whether future safe and effective rotavirus vaccines should be made available routinely to all children in Hong Kong.

METHODS

Data on the disease burden associated with rotavirus infection, as reported elsewhere in this supplement [4], were estimated from combined active and passive surveillance data. The active surveillance data were collected by research staff visiting 4 of 12 publicly funded government (Hospital Authority [HA]) hospitals on at least a weekly basis, and the passive surveillance data were obtained from the Clinical Management System (CMS), which records discharge information on all patients admitted to HA hospitals. The economic burden study data were collected at the same 4 HA hospitals participating in the ARSN surveillance study during the surveillance period.

Ethics. The study was approved by the Clinical Research Ethics Committee of the Chinese University of Hong Kong and by the corresponding ethics committees of individual participating hospitals.

Sample. Children <5 years old were eligible for recruitment if they had been admitted to a participating hospital with a primary diagnosis of diarrhea within the previous 24 h and if their families could be contacted by telephone. Children were excluded if they subsequently did not pass any stool or were discharged within 48 h of admission without any bowel evacuation. After a pilot study was done to refine the questionnaires, participants were recruited from 1 March 2001 through 4 March 2003. The etiological organism responsible for the children’s diarrhea was not known at the time of recruitment, and, to ensure that there was a sufficient number of patients with rotavirus-positive diarrhea available for analysis, we increased patient recruitment during the peak season for rotavirus disease (November 2002 through March 2003).

Data collection. Participating families signed informed consent forms. An initial questionnaire, which included demographic and clinical details, was completed at recruitment. Information regarding the clinical treatment of participants was obtained from hospital case notes by use of a structured questionnaire. Details of the costs related to each child’s diarrheal episode were obtained from the families, and families were given a symptom diary to complete during the 10 days after recruitment (while the child was hospitalized and after discharge). The research assistant demonstrated how to complete the symptom diary, which was intended to be a memory aid, to document all costs related to the child’s diarrheal episode. The families were encouraged to return the diary in a prestamped, preaddressed envelope after 10 days. Information recorded in the symptom diary included the length of the hospital stay, visits to other health care providers, extra travel costs, costs of additional diapers used, other miscellaneous costs (e.g., food supplements or nonprescription remedies), time off work required by family members responsible for the care of the child as a result of the child’s illness, and the respective estimated hourly, daily, weekly, or monthly salary lost. The families were telephoned 5 days after the date of admission if the child had been discharged from hospital and, then, again 10 days after the date of admission. At these contacts, the details of the various costs were recorded, together with other information related to the child’s illness. If the child still had diarrhea at the day-10 contact, a further contact would be made 5 days later.

Data analysis. Hong Kong has a dual, public, private health care system, but it has been estimated that 90% of inpatient care occurs within the public system at nominal cost to families [5]. The use of day care facilities for young children is relatively uncommon, because, even when both parents work, it is likely that the child will be cared for within the home by a maid or a member of the extended family. The cost analysis incorporated both monetary and time cost whenever applicable. Costs were estimated from 2 perspectives—social costs and private costs—as follows:

- Social costs = total direct costs + total indirect costs;
- Total direct costs = total HA costs + total family expenditure – family HA costs;
- Private cost = total indirect costs + total family expenditure.

Each of these aforementioned costs was calculated as follows:

- Total HA costs = HA inpatient cost + HA outpatient cost + HA ward follow-up cost;
- HA inpatient cost = (total number of days in HA hospital) × (cost of a general pediatric HA hospital bed/day);
- HA outpatient cost = (number of government outpatient department [GOPD] visits × official cost/GOPD visit) + (number of Maternal Child Health Clinic [MCH] visits × official cost/MCH visit) + (number of Accident & Emergency [A&E] visits × official cost/A&E visit), which includes all visits, occurring either before or after hospitalization, that were related to the same episode of gastroenteritis that required admission; and
- HA ward follow-up [WFU] cost = (number of WFU visits) × (official cost/WFU).

The HA calculates bed costs by using full cost estimates. Each hospital makes separate calculations for individual hospitals on an approximately yearly basis. For the Prince of Wales Hospital, the pediatric costs are calculated for 4 separate categories: neonatal intensive care unit bed, neonatal special care unit bed, pediatric oncology unit bed, and the remainder of
Total family costs were calculated as mother’s time cost + father’s time cost + other’s time cost, where mother’s time cost = \((\text{hours/day off work}) \times (\text{mother’s estimated hourly/daily salary})\); where father’s time cost = \((\text{hours/day off work}) \times (\text{father’s estimated hourly/daily salary})\); and where other’s time cost = \((\text{hours/day off work}) \times (\text{other’s estimated hourly/daily salary})\). Parents were asked to record in the symptom diary all time taken off from paid employment.

**Statistical analysis.** Cost data are presented as mean (SD), unless otherwise specified. The costs were calculated for the following etiological groups: any rotavirus positive, any rotavirus negative, any culture positive, any culture negative, only rotavirus positive, only culture positive, and confirmed rotavirus and culture negative. Average costs between these groups were compared using the bootstrap method, because the data were highly skewed. The method of calculation used involved the selection of a random sample (i.e., the bootstrap sample) from the original data set, with replacement. The process was stratified by etiological groups and was repeated 5000 times. The bootstrap mean cost differences were then calculated and compared on the basis of the 5000 bootstrap samples generated. The bootstrap BCa method was used to estimate the corresponding 95% confidence intervals of cost difference [6].

**RESULTS**

A total of 504 families of children who had diarrhea that had developed within the previous 24 h and who were admitted to the hospital within the previous 24 h were invited to participate in the study, and 471 (93.5%) of the families were recruited. Reasons for nonparticipation included the following: family...
refused to join the study, parents or guardian of the child was not available in the ward, family lived in mainland China and were unable to do the follow-up interview, or parents or guardian was unable to speak either English or Cantonese. Of the 471 children, 78 (17%) did not have a stool sample tested for rotavirus, and 65 (14%) did not have a stool sample cultured for bacteria. A total of 388 children had stool samples tested for the presence of both rotavirus and bacteria; 51% (200/393) of the samples were positive for rotavirus, and 16% (66/406) of the samples were positive for bacteria. Of the 200 rotavirus-positive samples, 185 were positive for rotavirus only, 14 were positive for both rotavirus and bacteria, and 1 was not cultured positive for bacteria. Three of the samples for which bacterial culture results were positive were not tested for rotavirus, leaving 49 positive samples, 185 were positive for rotavirus only, 14 were positive for both rotavirus and bacteria, and 1 was not cultured positive for bacteria. One hundred forty samples were negative for both rotavirus and bacteria.

Costs were calculated for the different etiological groups: any rotavirus positive (n = 200), rotavirus negative (n = 193), any culture positive (n = 66), culture negative (n = 340), only rotavirus positive (n = 185), only culture positive (n = 49), and confirmed rotavirus and culture negative (n = 140) (detailed results are available from the authors on request). A summary of the main costs for the any rotavirus-positive, any culture-positive, and confirmed rotavirus- and culture-negative groups is shown in table 2. There was no difference in the various costs between the any rotavirus-positive group (n = 200) and the rotavirus-negative group (n = 193) (table 3). However, the total social, direct, and HA costs were statistically significantly higher for the any culture-positive group (n = 66) than for the culture-negative group (n = 340) (table 3).

For the patients with a positive rotavirus test result, the mean (SD) total social cost of a rotavirus-associated hospital admission was US $2037 ($1145), derived from the mean (SD) total direct cost of US $1951 ($1101) and the mean (SD) total indirect cost of US $87 ($204) (table 2). The mean (SD) total HA cost was US $1868 ($1083), and the mean total family expenditure was US $120 ($103).

We estimated that, during the 24-month period from 1 April 2001 through 31 March 2003, a total of 4.6% of all general pediatric admissions were associated with rotavirus infection and that the cumulative risk of hospitalization due to rotavirus infection by the age of 5 years was 1 in 24 children (reported elsewhere in this supplement [4]). The annual number of general pediatric admissions (<5 years old) to HA hospitals during this 24-month period was 95,211 admissions (47,605 admissions over a 12-month period). Under the assumption that 4.6% of these general pediatric admissions were associated with rotavirus infection, it is estimated that, for the HA, the annual cost related to rotavirus infection is US $4.09 million (mean total HA cost, US $1868 × 47,605 × 4.6%) or HK $31.9 million. A similar estimate is obtained using the estimate that 1 in 24 children in Hong Kong is admitted to the hospital with rotavirus diarrhea by the age of 5 years. With an average of 50,964 births occurring during the 5-year period of 1998–2002 (48,209 births in 2002, 48,219 births in 2001, 54,134 births in 2000, 54,039 births in 2000, and 54,039 births in 2000).

### Table 2. Social and private costs of rotavirus diarrhea and bacterial culture–positive and –negative diarrhea in Hong Kong.

<table>
<thead>
<tr>
<th>Cost</th>
<th>Rotavirus diarrheaa (n = 200)</th>
<th>Bacterial culture–positive diarrheaa (n = 66)</th>
<th>Rotavirus- and bacterial culture–negative diarrheaa (n = 340)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total social costb</td>
<td>2037 (1146)</td>
<td>2299 (1253)</td>
<td>1902 (1346)</td>
</tr>
<tr>
<td>Total private costc</td>
<td>207 (235)</td>
<td>187 (141)</td>
<td>190 (238)</td>
</tr>
<tr>
<td>Total direct costd</td>
<td>1951 (1101)</td>
<td>2229 (1243)</td>
<td>1832 (1321)</td>
</tr>
<tr>
<td>Total indirect cost</td>
<td>87 (204)</td>
<td>60 (97)</td>
<td>70 (154)</td>
</tr>
<tr>
<td>Total HA cost</td>
<td>1868 (1083)</td>
<td>2145 (1230)</td>
<td>1748 (1223)</td>
</tr>
<tr>
<td>Inpatient cost</td>
<td>1773 (1077)</td>
<td>2032 (1238)</td>
<td>1646 (1215)</td>
</tr>
<tr>
<td>Outpatient cost</td>
<td>90 (23)</td>
<td>96 (40)</td>
<td>92 (23)</td>
</tr>
<tr>
<td>Follow-up cost</td>
<td>10 (22)</td>
<td>16 (35)</td>
<td>10 (28)</td>
</tr>
<tr>
<td>Total family expenditure</td>
<td>120 (103)</td>
<td>127 (112)</td>
<td>120 (173)</td>
</tr>
<tr>
<td>Family cost paid to HA and government</td>
<td>37 (15)</td>
<td>42 (15)</td>
<td>36 (16)</td>
</tr>
<tr>
<td>Total other family costs</td>
<td>83 (100)</td>
<td>84 (110)</td>
<td>84 (165)</td>
</tr>
<tr>
<td>Length of stay, mean (SD), days</td>
<td>3 (2)</td>
<td>4 (2)</td>
<td>3 (2)</td>
</tr>
</tbody>
</table>

**NOTE:** Data are total mean (SD) costs in US dollars, except where noted. One US dollar equals 7.8 Hong Kong dollars. HA, Hospital Authority.

* Groups are not mutually exclusive.
* Total direct cost + total indirect cost.
* Total indirect cost + total family expenditure.
* Total HA cost + total family expenditure—family cost paid to HA and government.
* Total costs paid by family for outpatient care, other health care providers, travel costs, and miscellaneous costs, such as extra diapers and medications.
51,281 births in 1999, and 52,977 births in 1998), the annual cost to the HA for rotavirus diarrhea would be US $3.97 million. The corresponding estimates for the annual social cost and the annual family expenditure are US $4.3 million (50,964/24 × US $2037) and US $0.25 million (50,964/24 × US $120), respectively.

**DISCUSSION**

We have estimated that the annual HA costs or direct medical costs for admissions associated with rotavirus infection are US $3.97–$4.09 million. This estimate is nearly 4 times greater than our previous estimate of US $1.2 million (HK $9.6 million) [2]. The previous estimate assumed that 5.3% of Hong Kong’s population of 6.3 million individuals was <5 years old, that the annual incidence of rotavirus diarrhea was 1.97 cases/1000 children <5 years old, that the hospital bed cost was HK $3096, and that the mean length of stay was 4.7 days. The higher estimate in the present study is largely the result of a higher estimate of disease burden (risk of admission by age 5 years, 1 in 24; annual incidence, 8.1–8.8 cases/1000 population). The catchment population of the study hospital used to calculate the previous incidence of rotavirus diarrhea appears to have been an underestimate. The CMS data used in the present study made it possible to obtain accurate data on the total number of admissions to all HA hospitals in Hong Kong, which could then be related to the total number of births. The hospital bed cost was also higher (HK $4152), although the duration of stay was shorter (3 days).

In the present study, we have also estimated total social costs, indirect costs, and family expenditure costs that have not previously been estimated for episodes of diarrhea requiring a hospital admission. These cost estimates indicate that most costs associated with rotavirus infection are reflected by the direct medical costs, which, in turn, are mainly determined by the cost of a general pediatric bed and the length of the hospital stay. It could, therefore, be argued that the costs associated with rotavirus infection could be significantly reduced by reducing hospital admission rates. One option for reducing the number of hospital admissions is to promote outpatient care for diarrheal illness. Clinical data collected during the present study (not reported here) showed that most patients admitted for diarrhea were not considered to be dehydrated at admission. This phenomenon may be a reflection of the fact that, in our population, diarrheal disease treated in the hospital is relatively mild, or, alternatively, it could be a reflection of the fact that most children have received early and effective treatment, thereby preventing dehydration. Although attempts can be made to modify admission practices, accomplishing this goal may be difficult, because admission practices also reflect local cultural perceptions and expectations. Therefore, a second option for reducing the number of hospital admissions for rotavirus diarrhea is also needed, such as use of a safe and effective rotavirus vaccine. Because rotavirus vaccines are more effective against severe disease than mild disease [7] and if the proportion patients with mild diarrhea admitted to our hospitals is large, then it is possible that the introduction of a rotavirus vaccine in Hong Kong may not result in as dramatic a reduction in admission rates as might be expected. Nonetheless, even if a rotavirus vaccine could reduce admission rates by only 50%, direct medical costs in the longer term could still be reduced by US $2 million.

### Table 3. Differences in costs between rotavirus-negative group (n = 193) and rotavirus-positive group (n = 200) and bacterial culture–negative group (n = 340) and bacterial culture–positive group (n = 66), in US dollars.

| Group comparison, cost variable | Mean cost difference | Mean cost difference for bootstrap samplea | 95% CI | P
|-------------------------------|---------------------|------------------------------------------|-------|---
| Rotavirus-negative vs. rotavirus-positive | | | |
| Social cost | −40 | −38 (−266 to 228) | .4 | |
| Private cost | −18 | −17 (−65 to 23) | .2 | |
| Direct cost | −24 | −23 (−244 to 234) | .4 | |
| HA cost | −22 | −21 (−244 to 214) | .4 | |
| Family expenditure | −2 | −2 (−25 to 27) | .5 | |
| Culture-negative vs. culture-positive | | | |
| Social cost | −323 | −321 (−657 to −4) | .03 | |
| Private cost | 14 | 14 (−29 to 55) | .4 | |
| Direct cost | −345 | −344 (−682 to −35) | .02 | |
| HA cost | −342 | −340 (−673 to −39) | .02 | |
| Family expenditure | −9 | −9 (−40 to 19) | .2 | |

**NOTE.** One US dollar equals 7.8 Hong Kong dollars. 95% CI, 95% confidence interval; HA, Hospital Authority.

a Bootstrap estimation using 5000 repetitions.

b Bias corrected.
In Hong Kong, routine immunizations of children are government funded through a public system of MCH Centres, and only a relatively small percentage of children receive their routine vaccines privately. Conversely, nonroutine vaccines, such as those for varicella and Haemophilus influenzae type B, are only available through the private health care system. The rationale for approaching the present study mainly from the HA perspective was that, if the cost to the HA (and, hence, to the Hong Kong government) could be shown to be substantial, there would be a greater likelihood that the government would consider introducing a future rotavirus vaccine into the routine immunization schedule. However, by documenting costs incurred by the family during their child’s illness (i.e., the total family expenditure; table 2), we were also able to provide some indication of the additional costs incurred by families with children infected by rotavirus, who use the highly subsidized HA public hospital system. However, the present study was not able to determine costs associated with rotavirus infection treated entirely within the private health care system. It is estimated that, at present, ~10% of inpatient care in Hong Kong occurs within the private system [5]. The 10% of the population who use the private sector for inpatient care may be particularly likely to consider purchasing a rotavirus vaccine through the private system. A study focusing on this sector would be useful if the primary market for a rotavirus vaccine is anticipated to be the private sector. However, even without such information, our data indicate that families incur costs of US $120 when their child’s admission to an HA hospital is associated with rotavirus infection. Approximate average salaries of unskilled and service workers in Hong Kong are US $1000/month; this suggests that a rotavirus-associated hospital admission could incur costs equivalent to ~10% of a monthly salary. It should also be emphasized that the present study has only assessed costs of episodes of rotavirus diarrhea that require hospital admission and does not include costs associated with diarrheal episodes that are treated in the community.

A US study concluded that a rotavirus immunization program would be cost effective from the perspectives of society and the health care system [8]. The study noted that the cost of the program would be offset by the reduction in the health care cost of rotavirus diarrhea if the price of the vaccine were US $9/dose. On the basis of a birth cohort of 3.9 million infants, the annual cost associated with rotavirus diarrhea to the health care system was estimated to be US $264 million, of which two-thirds was related to the cost of hospitalization. The social costs in the present study were US $1001 million. For a birth cohort of 50,000 infants, the equivalent health care system costs, hospitalization costs, and social costs would equal US $3.4, US $2.2, and US $12.8 million, respectively. Our social costs were much lower than these estimates, mainly because they reflect differences in the calculations of the loss of earnings of caregivers. Because hospitalization accounts for the largest proportion of costs of rotavirus-associated illness to the health care system, it will be important to assess the effect of a rotavirus vaccine on rates of hospitalization when more data become available [9].

In the present study, we have also examined the costs of admissions related to nonrotavirus diarrhea. Although some minor differences were noted, only the social, direct, and HA costs for patients whose stool samples were bacterial culture positive were significantly greater than costs for patients whose stool samples were culture negative (table 3). This phenomenon likely reflects the longer hospital stay for the culture-positive group, compared with the culture-negative group. The costs related to the rotavirus-positive group were not different from those related to the rotavirus-negative group. The significant costs associated with these nonrotavirus causes of diarrhea reflect the need to also examine ways to prevent these other causes of childhood diarrhea.

Rotavirus infection imposes a significant economic burden on Hong Kong, particularly to the government, which provides for most inpatient care through a subsidized public health system. Although the introduction of a safe and effective rotavirus vaccine may not prevent all rotavirus-associated hospital admissions, it could result in significant cost savings to the Hong Kong government.

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