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Review of Singapore's dengue prevention and control programme

Introduction

Dengue haemorrhagic fever (DHF) appeared in Singapore in the 1960s and quickly became a major cause of childhood mortality. Public health response to dengue began in 1966, when DHF was made a notifiable disease, followed by the enactment of the Destruction of Disease Bearing Insects Act, 1968, a legislation to back the government's effort to reduce the vector population through source reduction and public education. The implementation of this vector control programme was completed in 1973, following which, Singapore experienced a prolonged period of low dengue incidence until the 1990s (*Fig. 1*). It appeared that vector control has worsened the dengue situation in Singapore as the rates of dengue since the 1990s and early 2000s are several folds higher than the 1960s.

Vector control

Disease prevention efforts launched in 1968 employing mainly environmental measures reduced the annual incidence of this disease from 43 to 1.3 per 100,000 population by 1976. Based on a large-scale study on *Aedes aegypti* and *Aedes albopictus* carried out in 1966-1968, this vector control programme involved reducing *Aedes* larval habitats, or larval source reduction, public education backed with law enforcement. The ethos of this entomological surveillance-based programme was that mosquito breeding precedes disease transmission and controlling the vector population before disease is detected would impact significantly on transmission. This programme resulted in a 15-year period of low incidence of both DF and DHF.

Lowered herd immunity

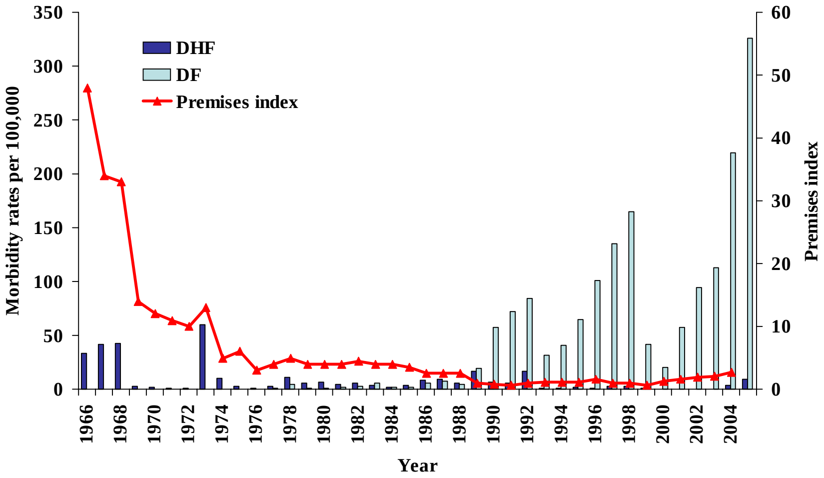
Several explanations have been put forth to explain the resurgence of dengue in Singapore despite the continued successful vector control program (*Fig 1*). Reduced dengue transmission in the 1970s and 1980s resulted in a concomitant reduction in herd immunity to dengue virus. Low levels of population immunity provide an ideal condition for dengue transmission despite low *Aedes* mosquito density. This hypothesis is supported by the observations made from a series of serological surveys conducted in 1982-1984, 1990-1991 and 1993, where a declining trend of seroprevalence among children was observed. Singapore has a very low dengue seroprevalence compared to other dengue endemic countries. The seropositive rate of 6.7% in primary school children and 42% in adults are in contrast to the rates reported in other endemic countries.

Transmission outside the home

Lowered herd immunity is, however, not the sole factor for the resurgence of dengue in Singapore. Dengue is predominantly a childhood disease, with more females than males among the adult cases. This disease pattern is expected as it fits with the behaviour of *Aedes aegypti*. This species of mosquito is highly domesticated, lives and breeds indoors, has a limited flight range and feeds almost exclusively on humans. Hence those that spend more time at home; ie. mothers and children, are more likely to be infected than those that go to work. In Singapore, however, the median age for reported DF and DHF cases is 25 years and there are 1.6 times more male than female cases. A serological study in 2001 found that school-aged children were 9 times more likely to have antibodies to dengue compared to pre-school children. This statistically significant difference suggests that the behaviour of the mosquito may have changed to where the risk of acquiring dengue in Singapore is greater when a person spends more time away from home.

There has also been a difference in the vector breeding habitats between the late 1960s and that in 1997. In the late 1960s, house indices (HI) were highest in slum houses (27.2%), shop houses (16.4%) and

Figure 1
Annual dengue incidence rates and *Aedes* house index, Singapore, 1966-2005



apartments (5.0%). In contrast, the HI data in 1997 showed that most of the breeding was in non-residential premises such as construction sites (8.3%), factories (7.8%) and vacant premises (14.6%). The residential properties in 1997 had very low HI: landed premises, 2.1% and apartments, 0.6%. Altogether, these findings suggest that disease transmission patterns in Singapore may have altered as a consequence of our vector control strategy.

Dengue in adults

The increase in the age of the cases in Singapore also has another implication for vector control. In the 1981 dengue outbreak in Cuba, DHF incidence was highest in those that were below 15 years old and those above 60 years old. Those whose ages were in between these two age groups did not develop DHF despite secondary infection with the same dengue serotype 2 virus. This observation suggests that age could be a susceptibility factor for DHF, an observation consistent with the trend of increasing DF and decreasing DHF cases in Singapore as the mean age of the cases increased over the years (*Fig 2*). This is reflected in the ratio of DHF to DF from 1977, when DF was also made legally notifiable besides DHF, to 2002. The exponential decrease in this ratio results from a fast growing denominator (DF incidence) along with a steadily reducing numerator (DHF incidence) over the years. Thus while the combined incidence of DF and DHF in Singapore may have increased, the burden of disease may now be less compared to the past or to other countries where DHF predominates.

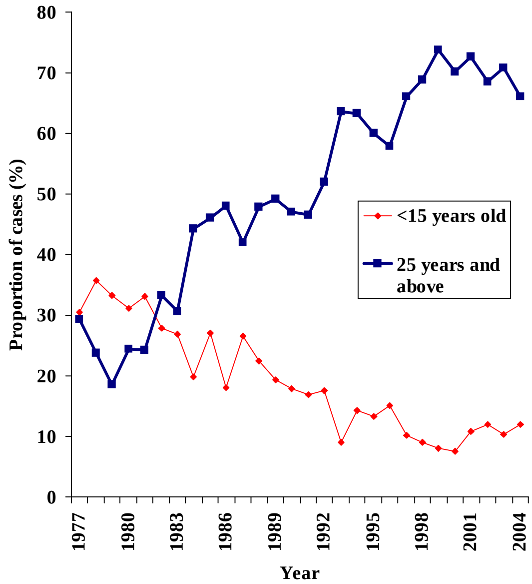
Shift in vector surveillance emphasis

Although the vector control programme was originally based on data from entomological surveillance, it became a more case-reactive system over time. The reason for this shift is not clear. We speculate that with vector control, dengue transmission became sporadic and isolated, thus initiating a policy of perifocal control in response to reported cases as a means of reducing cost. This is despite the lack of evidence that emergency control measures following the detection of cases are effective. Entomological surveillance-based vector control still exists but in limited "dengue sensitive areas". The overall result is that the ethos in which the original vector control programme was conceived has changed and this may be a significant contributor to the observed resurgence in dengue incidence.

Health education

Public education has been a linchpin of Singapore's vector control effort. It has thus far taken the

Figure 2
Proportion of dengue cases aged < 15 years and >25 years, Singapore, 1977-2004



form of national campaigns, such as the month long "Keep Singapore Clean and Mosquito Free" campaign in 1969 as well as educating school children to carry out source reduction in their homes. However, two community-based surveys in 1992 and 1995 showed that while the awareness of the Singapore population to dengue control is high, many of the respondents did not believe that there were mosquitoes in their homes and consequently did not carry out the necessary preventive measures. The survey population also reported that they checked their homes for mosquito breeding after having been fined under the Destruction of Disease-Bearing Insects Act, 1968, which has now been superceded by the Control of Vectors and Pesticide Act, 1998. The problem with responding only to a legal "stick" is that in the absence of checks by vector control officers, the public would not be motivated to preventing mosquito breeding. What may be necessary is a method of engaging the public through tools that provide regular positive feedback to the users. Singapore is currently trying out the use of larvicidal ovitraps by the public. The ovitrap, which was designed by Chan KL, consists of a black water-filled cylindrical container with a flotation device consisting of a wire mesh and two wooden paddles. The eggs laid by the mosquitoes on the wooden paddle would hatch and the larvae would develop in the water below the wire mesh. The resultant adult mosquitoes would be trapped under the wire mesh and drowned. Use of these traps may provide a positive stimulus to continue with their use, which in two previous instances, has reduced the mosquito population when used in sufficient numbers. Public volunteers were taught how to maintain the traps before being given a few traps to try at their residential areas. This trial is in its infancy so it is not known whether the large-scale use of such ovitraps may change the public's attitude to vector control and even reduce the vector population.

Regional collaboration

Singapore is located in a geographical region that is hyperendemic for dengue. A constant importation of dengue virus through travellers coming or returning to Singapore has likely contributed to the dengue resurgence observed. Each year, 8 million visitors arrive in Singapore through the air and sea ports. This does not include the local residents that travel abroad for work or leisure purposes, nor the thousands that commute across the causeway from the southern peninsula of Malaysia. The Singapore Changi Airport handles over 20 million passengers a year, a rate that might better illustrate the extent of human traffic in and out of Singapore. These figures suggest that symptomatic and asymptomatic individuals alike could easily enter Singapore and infect the vector mosquitoes. Epidemiologically, in the last 5 years, 5% to 10% of the total reported dengue cases in Singapore are imported. Most of these cases are from Indonesia, Thailand and Malaysia. This problem will likely continue to expand since both travel and trade in the region are likely to increase. Expanding resources and effort in achieving some levels of vector control in the Southeast Asian countries would likely reduce the importation of dengue and subsequently reduce the overall dengue incidence in Singapore.

Conclusion

In the absence of a safe and effective tetravalent vaccine for dengue viruses, vector control remains the only method to prevent this viral disease. The main lesson learned from Singapore's experience is that for a vector control programme to be effective, it must be based on carefully collected and analyzed entomological and epidemiological surveillance data. Reacting to cases, despite early and rapid diagnosis is unlikely to achieve significant impact on the reduction of incidence of dengue. The latter will require an increase in the expenditures on vector control, exploration of new strategies to lower and limit the *Aedes aegypti* population, and to reduce the extent of importation of dengue virus into Singapore.

(Based on Ooi EE, Goh KT, Gubler D J. Dengue prevention and 35 years of vector control in Singapore. Emerg Infect Dis 2006;12:887-93)

Influenza pandemic preparedness in Singapore

Introduction

Three influenza pandemics occurred in the 20th century – in 1918, 1957 and 1968. The ongoing epidemic of avian influenza A (H5N1) have prompted many countries to prepare for an influenza pandemic. As at 12 December 2006, a cumulative total of 258 human cases of avian influenza A (H5N1) with 154 fatalities (60%) have been reported from 10 countries. If the avian influenza (H5N1) virus acquires the ability to transmit efficiently between humans, there is a high probability that it will lead to the next influenza pandemic.

WHO pandemic phases

WHO's Global Influenza Preparedness Plan [1] describes six phases of increasing public health risk associated with the emergence of a new influenza virus subtype that may pose a pandemic threat. These are :

Interpandemic period

Phase 1. No new influenza virus subtypes have been detected in humans. An influenza virus subtype that has caused human infection may be present in animals. If present in animals, the risk of human infection or disease is considered to be low.

Phase 2. No new influenza virus subtypes have been detected in humans. However, a circulating animal influenza virus subtype poses a substantial risk of human disease.

Pandemic alert period

Phase 3. Human infection(s) with a new subtype, but no human-to-human spread, or at most rare instances of spread to a close contact.

Phase 4. Small cluster(s) with limited human-to-human transmission but spread is highly localized, suggesting that the virus is not well adapted to humans.

Phase 5. Larger cluster(s) but human-to-human spread still localized, suggesting that the virus is becoming increasingly better adapted to humans, but may not yet be fully transmissible (substantial pandemic risk).

Pandemic period

Phase 6. Pandemic: increased and sustained transmission in general population.

We are currently in phase 3.

Singapore's influenza pandemic readiness and response Plan

Singapore has developed a pandemic preparedness plan detailing actions to be taken before and during an influenza pandemic. Our Influenza Pandemic Readiness and Response Plan was first published in June 2005 and will be updated from time to time. The plan is accessible at the Ministry of Health (MOH)'s website at www.moh.gov.sg. The objectives of the plan are to:

- mitigate the socio-economic impact of a pandemic in Singapore, and
- reduce the morbidity and mortality associated with the pandemic.

Estimates of cases in an influenza pandemic in Singapore

Using the FluAID model produced by the US Centers for Disease Control and Prevention, an attack rate of 25% will result in 550,000 cases requiring outpatient care, 11,000 cases requiring inpatient care and 1,900 deaths.

Singapore's national strategy for pandemic preparedness

Domestically, the national strategy is threefold:

- establish an effective surveillance system to detect the importation of a novel influenza virus early;
- mitigate the consequences when the first pandemic wave hits and
- achieve national immunity as soon as possible.

During an outbreak, we will have to sustain the country through the first pandemic wave (expected to last 6 weeks) by minimizing mortality and morbidity through effective infection control, healthcare management, chemoprophylaxis and measures to increase social distancing. We will then vaccinate the entire population when a vaccine becomes available. Our pandemic response aims at achieving the following three outcomes:

a **Maintain essential services in Singapore to limit social and economic disruption.** To limit the impact on essential services; e.g. healthcare and utilities, certain segments of these services will be provided with antiviral prophylaxis (with Tamiflu).

b **Reduce morbidity and mortality through treatment.** We have stockpiled enough Tamiflu to treat all persons who require antiviral treatment.

c **Slow and limit the spread of influenza to reduce the surge on the healthcare system.** Additional measures will be taken to slow down the spread and reduce the surge requirements on our healthcare system, including:

(i) Community-wide social distancing. The key message to the public will be the importance of each individual's responsibility in preventing the spread of flu through personal hygiene and being socially responsible in their behaviour. It may be necessary to implement temporary closure of schools and childcare centres as well as limit public events to prevent people from congregating at public places.

(ii) Protection of healthcare institutions. They will be protected through infection control measures and personal protection practices developed during the SARS crisis. In addition, front-line healthcare workers will be given Tamiflu prophylaxis for 6 weeks (the estimated duration of the first wave of the pandemic).

Colour-coded alert phases

MOH has developed a colour-coded alert phase system to guide the various responses under the Pandemic Readiness and Response Plan according to the level of public health risk.

Alert GREEN 0. (corresponding to WHO phase 1 – 2). There is no circulating novel influenza subtype that has affected humans.

Alert GREEN 1. (~ WHO phase 3). Our current status. The public health threat to Singapore is minimal and the disease is an avian disease without any human-to-human transmission. The strategy is to step up our preparedness.

Alert YELLOW and ORANGE. (~ WHO phases 4 and 5). There is inefficient human-to-human transmission of influenza outside Singapore. In ORANGE, human-to-human transmission becomes more efficient compared to YELLOW and there is a larger cluster of cases outside Singapore, but it is still localized. The risk of importation of cases into Singapore is elevated. Where there are isolated imported cases, such cases have not resulted in sustained transmission locally. The strategy is to prevent further importation of cases and to ring-fence and isolate cases to prevent secondary transmission. The focus will be to provide targeted treatment of all cases and anti-viral prophylaxis to contacts including attending healthcare workers.

Alert RED. (WHO phase 6). The pandemic is underway and has spread to Singapore. There is significant risk of acquiring the disease from the community. The strategy is to minimize the spread of disease while preserving essential services and resources. Contact tracing and quarantine will be stopped once it is no longer operationally feasible.

Alert BLACK. (WHO phase 6). Morbidity and mortality rates are high, and emergency measures are needed to bring the situation under control. The focus is to contain the damage and regain control of the situation. Drastic measures like stopping all social events may be implemented.

Reorganizing the healthcare system in a pandemic

The healthcare system will have to be reorganized to deliver care as effectively as possible during a pandemic.

Outpatient care

Experience from previous influenza pandemics suggest that most patients will only require outpatient care. This will be provided at all polyclinics and participating private GP clinics. Tamiflu from the national stockpile will be supplied to participating clinics for dispensing to patients who require antiviral treatment. Outpatient clinics will also continue to provide care to non-flu patients.

Hospital care

In the pre-pandemic stage, all confirmed cases of avian influenza will be centralized in the Communicable Disease Centre, Tan Tock Seng Hospital to facilitate patient management. However, during a pandemic, all public sector acute hospitals will manage patients who need inpatient care. The public hospitals will also continue to manage non-flu patients who require hospital care. Intensive care beds in particular will quite likely be insufficient to meet demand. In a situation where the public sector hospitals are also overwhelmed, private hospitals may also need to manage influenza patients.

Antiviral drugs

A national stockpile of 1.05 million boxes (10 capsules per box) of oseltamivir (Tamiflu) for treatment and prophylaxis has been established. The efficacy of Tamiflu against human cases of avian influenza A (H5N1) has not been fully established and studies are ongoing. However, data from studies with seasonal influenza suggest that Tamiflu may be 50% effective in reducing the chance of developing complications following infection. This will help to reduce the surge on our hospitals. However, Tamiflu must be given early (within 48 hours) for it to be effective.

Vaccination

Vaccination is the key strategy in response to an influenza pandemic. In a pandemic, it is very likely that vaccines will only be available after 4-6 months. Initially, when vaccines are in short supply, vaccination will be provided to priority groups. As the vaccines become more readily available, vaccination will be expanded to include the rest of the population.

MOH has contracted a vaccine producer to manufacture sufficient pandemic vaccine for the entire population. The vaccine will be delivered only after the vaccine producer has fulfilled its obligations to supply its home country. MOH is also studying the possible stockpiling and use of prototype H5N1 vaccines. The main concern is whether such vaccines will be able to protect against a future pandemic strain.

(Reported by J Cutter, Deputy Director (Policy), Commmunicable Diseases Division, Ministry of Health)

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Outbreaks of norovirus gastroenteritis in two schools

Introduction

Noroviruses are a leading cause of gastroenteritis outbreaks in various settings, including restaurants, nursing homes, hospitals, schools, day care centres and cruise ships.[1, 2] Transmission usually occurs directly from person-to-person by faecal-oral spread, and indirectly through contaminated food and water, or environmental contact.[1, 3] The incubation period is 12-48 hours and symptoms may last 24-60 hours. Recovery is usually complete and there is no evidence of long-term health effects. Although norovirus gastroenteritis is self-limiting, susceptible persons (e.g. the young, the old and immuno-compromised persons) may be at a higher risk of dehydration which may need special medical attention.

On 27 Sep and 5 Oct 06, the Ministry of Health (MOH) received notifications of gastroenteritis outbreaks in a secondary and a primary school, respectively. Epidemiological investigations were immediately conducted to determine the extent of the outbreak, source of infection and mode of transmission. The findings of these investigations are summarised herein.

Outbreak in a secondary school

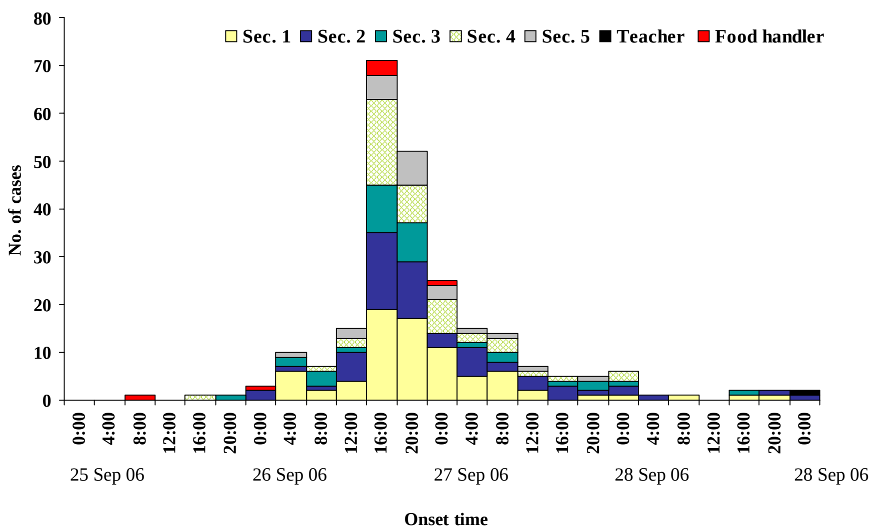
Findings

This is a single session school with a total enrolment of 1,501 students from Secondary 1-5, supported by 81 teaching and 21 non-teaching staff. The school is served by a canteen, which has a total capacity of eight stalls (A-H) operating from 0900 hr to 1500 hr under a staggered recess time schedule.

A total of 246 gastroenteritis cases comprising 239 students, one teacher and six food handlers were identified. The index case was a food handler who developed onset of symptoms in the morning of 25 Sep 06 (*Fig. 3*). Affected students were distributed across all levels (Secondary 1-5) with attack rates ranging from 9.2%-32.2%. Among the ethnic groups, cases involved mainly the Chinese (99.2%) and a few Indians (0.8%), but no Malays were affected. The clinical symptoms were vomiting (91.5%), abdominal pain (77.2%), diarrhoea (77.1%), nausea (70.3%), fever (69.5%), and headache (65.4%). Majority (84.1%) received outpatient treatment, one was hospitalised for observation while the rest (15.4%) self-medicated.

Analyses of food-specific attack rates based on the food items consumed 24-48 hours prior to onset of illness implicated three food stalls selling sev-

Figure 3
Time distribution of 246 cases of gastroenteritis in a secondary school, 25-28 Sep 06



eral food items on 25 and 26 Sep 06 (*Table 1*). However, no one specific food item was established as the vehicle of transmission.

All eight food stalls were found to be satisfactorily maintained. However, the ice-making machine in stall A and the seal of the refrigerator in stall G were defective, and the dedicated toilets for the foodhandlers did not have toilet paper and soap for handwashing.

A total of 13 food samples, 12 water samples, and nine environmental swabs were collected for microbial analyses. Four water samples from water coolers and a swab from the ice making machine at Stall A showed high total bacterial counts while samples of sausages and boiled fish cakes from Stall G and ice cubes from Stall H showed contamination by enteropathogens such as *E. coli* and *S. aureus.*

A stool sample from a symptomatic student was tested negative for enteropathogens. Six of 12 foodhandlers referred to the Communicable Disease Centre on 28 and 29 Sep were found to be positive for norovirus genogroup 2. The infected foodhandlers were tested again on 16 Oct and found to be negative for norovirus.

Actions taken

The principal of the school was advised to undertake the following disease control measures to break the chain of transmission by :

- Maintaining closure of school canteen until the food handlers were certified free from infection;
- Educating and re-emphasising to food handlers to refrain from handling food when they are unwell;
- ensuring that the canteen, including appliances, was thoroughly cleaned and the two faulty installations (ice-making machine and refrigerator) rectified;
- working with the National Environmental Agency to improve the food and personal hygiene of food handlers and spruce up the environmental sanitation;
- working with the Public Utilities Board to address bacterial contamination of a water cooler, which was an incidental finding;

Table 1

Analysis of attack rates in an outbreak of gastroenteritis in a secondary school, Sep 2006

Date food consumed	Stall	Case (n=134)			Control (n=184)			p value	Odds ratio	95% CI
		Ate	Did not eat	% ate	Ate	Did not eat	% ate			
25-Sep	A	94	40	70.1	53	131	28.8	<0.0001	5.8	3.6-9.5
	C	30	104	22.4	16	168	8.7	0.001	3.0	1.6-5.8
26-Sep	A	74	60	55.2	42	142	22.8	<0.0001	4.2	2.6-6.8
	C	23	111	17.2	14	170	7.6	0.009	2.5	1.2-5.1
	F	31	103	23.1	20	164	10.9	0.003	2.5	1.3-4.6

- ensuring that the toilets were thoroughly cleaned and adequately equipped with soap and toilet paper;
- promoting strict hygiene and handwashing by students and staff, especially after using the toilet and before meals; and
- identifying students and staff who developed symptoms, isolating them early and referring them for medical treatment.

Discussion

Based on the clinical and epidemiological features of this outbreak, norovirus was one of the aetiological agents considered. The aetiology was confirmed by the detection of norovirus genogroup 2 from the stools of all the six symptomatic foodhandlers.

This was a foodborne outbreak traced to an infected food handler from Stall A who was ill in the morning of 25 Sep, but continued to prepare drinks in the canteen. Infection then spread rapidly to other foodhandlers through close contact at work and sharing of common toilet facilities. Contamination of food items and environmental surfaces in the canteen could occur by direct contact with the soiled hands, stool or vomitus of the infected foodhandlers. The finding of bacterial contaminants in food and environmental samples was incidental but indicative of poor personal and food hygiene and sanitary practices. Additional evidence that the canteen was the reservoir of infection was corroborated by the finding that the Malay students who had been fasting (Ramadhan) were unaffected in this outbreak.

This outbreak highlighted the importance of prohibiting sick food handlers from preparing food, particularly in settings involving large numbers of people as institutional outbreaks of norovirus gastroenteritis implicating sick food handlers have been documented[4].

Outbreak in a primary school

Findings

The school has a single session with a total enrolment of 899 students from Primary 1-6, supported by 61 staff (teaching and non-teaching staff). The school is served by a canteen comprising six stalls operating under a staggered recess time schedule.

A total of 154 gastroenteritis cases (145 students, eight staff and one food handler) were identified. The first two cases developed symptoms in the morning of 3 Oct 06 (*Fig.4*). Affected students were distributed across all classes and comprised Chinese (68.8%), Malays (13.6%), Indians (12.3%) and others (5.2%). The clinical symptoms were vomiting (92.9%), abdominal pain (56.5%), diarrhoea (48.1%), fever (47.4%), headache (18.2%) and nausea (16.9%). Majority (68.8%) sought outpatient medical treatment; five (3.2%) were warded in hospital for observation, while 43 (27.9%) self medicated.

Contaminated food items from the canteen were ruled out as the vehicle of transmission in this outbreak because the canteen had been closed for the weekend and Children's Day holiday from 30 Sep–2 Oct 06.

One significant finding was the school's cleaning and disinfection procedures. The school had two groups of cleaners; one group was employed by the school whereas the other was from a contract company. Workload was divided by locality. The in-house cleaners were in-charge of classrooms while the contact cleaners took charge of the corridors, toilets and basketball courts. There were no proper procedures for cleaning up vomitus and cleaners would mop the contaminated area without using bleach disinfectant (sodium hypochlorite). The pails and mops were then brought to the washing area located near the basketball court/ canteen. After rinsing or cleaning, the mops were then hung near the canteen to dry.

A total of five clinical samples (four vomitus and one stool samples) were obtained from affected students and staff, and tested for bacterial enteropathogens, norovirus and rotavirus (not done for vomitus samples). One stool and one vomitus sample were tested positive for norovirus genogroup 2 at the Molecular Laboratory, Singapore General Hospital. No food samples were available for testing, while seven environmental swabs taken during inspection of the premises tested negative for norovirus.

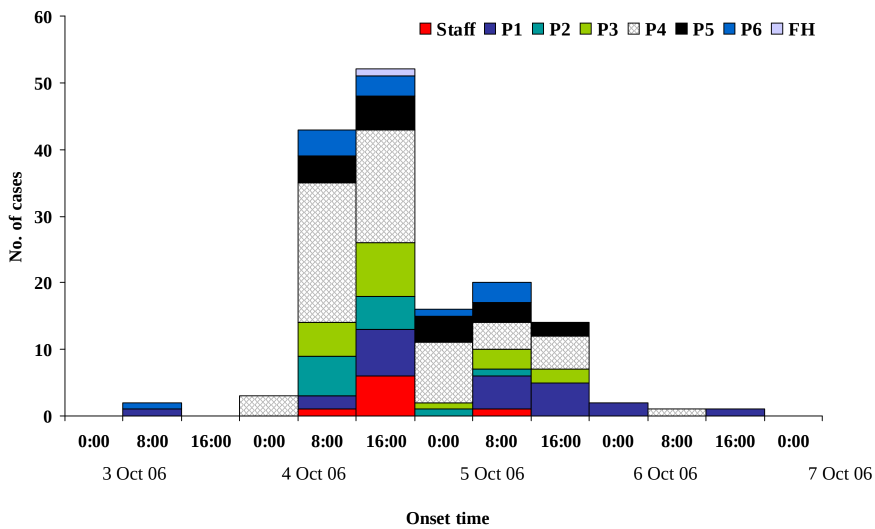
All the 12 food handlers were sent for stool screening and three tested positive for norovirus genogroup 2. Two of them were asymptomatic while one had onset of symptoms on the evening of 4 Oct 06.

Actions taken

The principal of the school was advised to undertake the following measures to break the chain of transmission and prevent a recurrence of the outbreak by:

- identifying sick students and staff, isolating them early and seeking medical treatment if necessary;
- promoting frequent hand washing by students and staff, especially after using the toilet and before each meal;
- observing hygiene etiquette, e.g., cover mouth when coughing /sneezing followed by hand washing;
- proper cleaning and disinfecting areas contaminated by stool/vomitus with household bleach in a ratio of one unit to 50 units of water;

Figure 4
Time distribution of 154 cases of gastroenteritis in a primary school, 3 - 6 Oct 06



- Ensuring that the school premises, including canteen and installations (e.g., water coolers) were cleaned and well maintained;
- ensuring toilets were in a sanitary condition and adequately equipped with soap and toilet paper;
- ensuring adequate ventilation and avoiding overcrowding in areas where there was congregation of students;.
- reminding food handlers to observe food and personal hygiene, and refrain from handling food if unwell; and
- making sure that foods were cooked thoroughly before serving and there was no cross-contamination between raw and cooked foods.

Discussion

Unlike the secondary school outbreak, an association with canteen food was excluded because Malay students who were fasting were affected, and no food handlers were ill on 3 Oct. Hence, it was likely that spread of the infection occurred through close contact with infected students and contaminated fomites. This outbreak involved a very young population which posed unique challenges in obtaining reliable epidemiological information. How the first two cases acquired the infection is not known but once the virus was introduced into the susceptible school population, rapid spread of infection occurred. Inadequate disinfection of the surfaces contaminated with vomitus was a contributing factor to the outbreak.

Comments

The two school outbreaks coincided with the final examinations and were a major cause of public concern. Strict control measures had to be introduced even before confirmatory results of the aetiological agent were established. Further, because prolonged viral shedding in the stools following recovery was typical of norovirus infection and could further propagate the outbreaks, good hygiene practices had to be emphasized to all students and staff. Implicated food handlers were also barred from handling food for a fortnight until they tested negative for the norovirus. Closure of the two school canteens in the meantime resulted in outsourcing of food catering to companies which had to ensure food safety procedures were in place throughout the logistics chain.

Although the two outbreaks were attributed to the same aetiological agent, their main modes of transmission differed. The first outbreak involved food-borne spread through a symptomatic food handler while in the second outbreak, inadequate disinfection of contaminated premises probably resulted in the generation of multiple cases. The latter also showed that rapid transmission of infection needs not occur only in closed or confined spaces.

Three factors contributed to the explosive nature of both outbreaks. Firstly, there was a high proportion of cases (>90%) with vomiting. Infected vomitus contains up to 10 million infectious particles/ml and incidents of projectile vomiting can give rise to infectious droplet aerosols and widespread contamination. Secondly, the virus has a low infectious dose of 10-100 particles and could remain viable in the environment for up to 5 days as a consequence of inadequate environmental cleaning[4]. Thirdly, the densely populated school environments facilitate spread to many susceptibles.

Two important lessons learnt from the outbreaks were that symptomatic individuals should refrain from handling food, and areas contaminated by stool/vomitus should be properly cleaned and disinfected. Following these episodes, MOH worked closely with the Ministry of Education and other agencies to develop disease control advisories for the schools to prevent recurrence of norovirus gastroenteritis outbreaks.

(Contributed by Low C, Nur Rasidah, Lim S, Ooi PL, Disease Control Branch, Communicable Diseases Division, Ministry of Health)

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Rotavirus infection and vaccination

Introduction

Rotavirus is a common cause of severe diarrhoea and vomiting in infants and young children. A global review estimated that nearly every child will experience at least one episode of rotavirus gastroenteritis by the age of five years [1]. Rotavirus is predominantly transmitted by the fecal-oral route from person to person. It can cause severe diarrhoea, vomiting and fever leading to rapid dehydration. Repeat rotavirus infections tend to be less severe and there is a lower risk of developing severe disease. The occurrence of two rotavirus infections, whether symptomatic or asymptomatic, can result in complete protection against moderate-to-severe illness [1].

Rotavirus is reported in both developing and industrialized countries. However, rotavirus infections are more commonly reported in developing countries. Every year, rotavirus causes approximately 111 million episodes of gastroenteritis requiring only home care, 25 million clinic visits and 2 million hospitalizations in children aged under 5 years over the world [2]. Based on a review of studies between 1986 and 1999, rotavirus is estimated to be responsible for 440,000 deaths among children aged under 5 years each year and 82% of all such deaths occurred in developing countries [2]. A more recent review of studies between 2000 and 2004 estimated that the number of rotavirus associated childhood deaths has increased to 611,000 [3].

Rotavirus infection in Asia

The Asian Rotavirus Surveillance Network (ARSN) was formed in 2001 to define the epidemiology and prevalence of rotavirus disease in Asia and to use these data to make informed decisions regarding the possible future use of rotavirus vaccines. Data collected by ARSN suggested that 45% of all diarrhoea-related hospitalizations among children under 5 years old in Asia were attributable to rotavirus infection, ranging from 30% in Hong Kong, 44% in Taiwan, 46% in China, 49% in Malaysia, 54% in Indonesia and 73% in Korea [4].

Children aged between 4 months and 3 years are at greatest risk for rotavirus infection. Rotavirus disease-associated hospitalization occurs more in younger ages in countries with the lower income level. For example, about 80% of hospitalization occurred among children during the first year of life in India and Myanmar while only about 30% of hospitalizations occurred among children in the same age group in Korea and Hong Kong [5].

Rotavirus infection in Singapore

In Singapore, acute gastroenteritis is the most common gastrointestinal disorder in children and rotavirus was the most common viral agent. Each year, about 600 children are seen in Kandang Kerbau Hospital (KKH) for treatment of rotavirus infection. It accounted for 10% of admissions to general paediatric units and 5% of admissions to government hospitals in Singapore [6]. A study conducted in 2003 and 2004 on hospitalization cases under the age of 15 years at KKH reported 1,226 cases of acute gastroenteritis. As for the aetiology of these cases, 81.4% was viral and 17.9% was bacterial. More than two thirds were under 5 years of age (56.9% was aged 1 to 4 years). Rotavirus accounted for 12.2% and 19.5% of all gastroenteritis caused by viral infections in 2003 and 2004, respectively [7]. There has been no deaths from rotavirus infection in Singapore so far, probably due to the easy access to medical treatment.

Prevention and management

There is no specific treatment available for rotavirus infection. Rotavirus diarrhea is treated by oral or intravenous re-hydration therapy to maintain hydration. Most children will recover in 5 to 10 days [8]. As the virus is transmitted by the fecal-oral route and it survives for long periods on hard surfaces, in contaminated water and on hands, improved sanitation and hygiene measures may not be effective in preventing the spread of rotavirus [9]. As such, vaccination against rotavirus is the most effective method of reducing severe diarrhoea caused by rotavirus infection.

Rotavirus vaccines

The first rotavirus vaccine licensed was RotaShield, which is a live oral tetravalent vaccine. It was licensed and recommended by the US Centers for Disease Control and Prevention (US CDC) for universal immunization of United States infants in 1998 but was withdrawn from the US market in 1999 due to its reported association with intussusception [10].

Recently, two new rotavirus vaccines have become available in the market. They are Rotateq, marketed by Merck, and Rotarix, marketed by GlaxoSmithKline. Both are live, attenuated vaccines, administered orally in the first few months of life. Rotarix is a live attenuated human monovalent G1P{8} strain RIX4414 rotavirus vaccine. Rotateq is a pentavalent (G1, G2, G3, G5 and P1) human-bovine reassortant rotavirus vaccine. Large multicentre trials (over 60,000 children in each) were conducted to study the safety and efficacy of these two new rotavirus vaccines. Rotarix was studied in Asia, Europe, Latin America, and South Africa and Rotateq was studied mainly in Finland and the United States.

The use of Rotateq vaccine was recommended by the Advisory Committee on Immunization Practices (ACIP) of the US CDC for protection against rotavirus infection in infants and young children in February 2006. Rotateq is the only vaccine approved in the United Stated for prevention of rotavirus gastroenteritis at present [11].

Vaccination against rotavirus infection in Singapore

The approved rotavirus vaccine in Singapore is Rotarix, which has been registered since October 2005. The vaccine is to be administered in two oral doses one to two months apart concomitantly with routine infant vaccinations. It has a reported 85% efficacy against both severe rotavirus gastroenteritis and rotavirus-associated hospitalization. Hospitalisations for diarrhoea of any cause were reported to decline by 42% among immunized children under 1 year of age. The use of Rotarix has not been associated with an increased risk of intussception [12]. Results from clinical trials suggested that Rotarix was well tolerated and highly immunogenic in Singaporean infants [13].

There are many strains of rotavirus with the most common serotypes being G1 to 4 and G9. Rotarix is protective against G1, 3, 4 and 9 but not the other strains, including G2. The vaccine also does not prevent gastroenteritis and severe diarrhea due to other causes.

The Expert Committee on Immunization (ECI) in Singapore reviewed the need of incorporating rotavirus vaccine into the national childhood immunization programme in 2006. In view of the low incidence and low disease burden (especially, the low likelihood of complications) from rotavirus-associated infections in Singapore, the Committee did not recommend the inclusion of the vaccine into the programme.

(Reported by Chan F, Communicable Diseases Division, Ministry of Health)

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Any comments or questions should be addressed to:

The Editor
Epidemiological News Bulletin
Communicable Diseases Division, Ministry of Health
College of Medicine Building, 16 College Road,
Singapore169854
E-mail : Goh_Kee_Tai@moh.gov.sg
Lyn_James@moh.gov.sg