Special Article

J Prev Med Public Health 2012;45;277-282 • http://dx.doi.org/10.3961/jpmph.2012.45.5.277

pISSN 1975-8375 eISSN 2233-4521

Journal of Preventive Medicine & Public Health

The Singapore Field Epidemiology Service: Insights Into Outbreak Management

Peng-Lim Ooi, Theresa Seetoh, Jeffery Cutter

Communicable Diseases Division, Ministry of Health, Singapore

Field epidemiology involves the implementation of quick and targeted public health interventions with the aid of epidemiological methods. In this article, we share our practical experiences in outbreak management and in safeguarding the population against novel diseases. Given that cities represent the financial nexuses of the global economy, global health security necessitates the safeguard of cities against epidemic diseases. Singapore's public health landscape has undergone a systemic and irreversible shift with global connectivity, rapid urbanization, ecological change, increased affluence, as well as shifting demographic patterns over the past two decades. Concomitantly, the threat of epidemics, ranging from severe acute respiratory syndrome and influenza A (H1N1) to the resurgence of vector-borne diseases as well as the rise of modern lifestyle-related outbreaks, have worsened difficulties in safeguarding public health amidst much elusiveness and unpredictability. One critical factor that has helped the country overcome these innate and man-made public health vulnerabilities is the development of a resilient field epidemiology service, which includes our enhancement of surveillance and response capacities for outbreak management, and investment in public health leadership. We offer herein the Singapore story as a case study in meeting the challenges of disease control in our modern built environment.

Key words: Disease outbreaks, Environment, Epidemiology, Leadership, Lifestyle

INTRODUCTION

Field epidemiology involves the application of epidemiological methods to often unexpected public health events where rapid on-site investigations and timely interventions are necessary. With global transformations in politics, economics and culture, the health of populations is increasingly more vulnerable to the threat of epidemics. From emerging and re-emerging diseases to the spread of antimicrobial drug-resistance, governments are faced with the challenge of improving surveillance and response capacities. With the support of the World Health Organization, 194 State Parties to the International Health Regulations (2005) have been implementing plans of action to enhance health security.

Certainly, the epidemic spread of diseases is not a novel phenomenon. But until the first International Sanitary Conference in 1851 and its serial meetings, there were few mechanisms that facilitated international cooperation among countries [1]. The long time span between the inaugural conference and the subsequent institutionalisation of a common framework suggest the difficulties and sensitivities involved in facilitating international cooperation on epidemic disease control [2]. Yet, that countries remain concerned with, and are willing to cooperate on the cross-border transmission of disease, indicates a rationale far surpassing historical continuity or obliga-

Received: February 1, 2012; Accepted: April 3, 2012

Corresponding author: Peng-Lim Ooi, MBBS, MSc, MPH, FAMS
College of Medicine Building, 16 College Road, Singapore 169854
Tel: +65-6325-8341, Fax: +65-6325-1168
E-mail: Ooi_Peng_Lim@moh.gov.sg

tory duty. A seemingly archaic and oft-overlooked reason is that disease epidemics have vast implications on national survival, and that the health of the domestic population provides countries with the assurance and freedom to pursue its vision and goals.

Located at the southern tip of the Malay Peninsula, Singapore is a relatively young country, having achieved its independence in 1965. For most part of its economic history, Singapore served as a major trading hub, providing a strategic and convenient port of call for sea and air cargo. Its advantageous geographical position was supported by good infrastructure and favourable government policy. This comparative advantage continues to be harnessed today. Singapore's Changi Airport is linked to approximately 200 cities in 60 countries, with about 5400 weekly flights [3]. In 2011, the airport handled a record 46.5 million passengers, a 10.7% increase over 2010's 42 million [4]. Adding to its global connectivity, Singapore has a heterogeneous, mobile population living in close proximity and restrained by an equatorial climate of high humidity levels and heavy rainfall, particularly during the months of November to January. In the course of 47 years of nation building, its total population has grown from a mere two million in 1970 to five million in 2010.

In this article, we share an epidemiological perspective to Singapore's experience in safeguarding its population against the onslaught of novel diseases. We suggest the circumstances that condition its set of disease control measures may not be entirely unique, namely, the features of global connectivity and cosmopolitanism witnessed in many cities today. We also describe our local characteristics so that the reader may more aptly draw conclusions from where we differ.

GLOBAL HEALTH SECURITY

Singapore's international connectivity places it at an increased risk of disease outbreaks, with global air travel playing a pivotal role in the dissemination of emerging infections. In February 2003, an outbreak of severe acute respiratory syndrome (SARS) was introduced into Singapore with the return of three unsuspecting young travellers from Hong Kong [5]. SARS transmission from symptomatic patients to other passengers and crew was subsequently documented in at least three flights flying outbound from Hong Kong [5].

In order to stem the spread of SARS, a contact tracing centre was established at the Ministry of Health Singapore. The centre catered for 200 officers who sought to identify all contacts of SARS cases and observation cases in whom SARS could not be ruled out [6]. Legal provisions were strengthened to endow the Director of Medical Services with the legal authority to order the quarantine of persons, and confer an offence for persons who disobeyed [6]. When the disease threatened to establish itself within hospitals, mandatory protection gear and infection control procedures were set in place, along with close monitoring of healthcare workers for SARS symptoms as well as movement restrictions on all staff, patients, and visitors in hospitals [6]. In mounting large-scale quarantine operations alone, it cost the government approximately US$5.2 million [6]. 238 cases with 33 deaths were reported [7], yielding a 14% case fatality rate. Compared to the economic recession in 1997-1998 and 2001, the SARS crisis had the deepest, albeit short-lived impact on visitor arrivals with many airlines drastically reducing flight numbers to Singapore [8,9]. By April 2003, visitor arrivals dropped 67% and caused a ripple effect on business activities as companies delayed or cancelled trade and investment missions and travels [10].

Similarly, the widespread dissemination of the novel influenza A (H1N1) in 2009 was thought to be related to the high number of flights out of early major centres of the epidemic. Investigations into a cluster of six cases confirmed transmission of the H1N1 on board a commercial aircraft [11]. These events illustrate the capability of diseases to transmit rapidly across borders, facilitated by convenient air travel [12,13].

Fear and uncertainty over an unknown disease could ignite widespread panic, with adverse repercussions on the economy and social fabric. Hence, in the aftermath of SARS, Singapore invested heavily into pandemic preparedness [14,15]. Our national strategy is premised on a well established surveillance and response system that forewarns, detects, and contains the importation of a novel agent, and on mitigation measures when community spread is sustained (i.e., showing no epidemiological link to imported source cases). A national pandemic readiness and response plan was developed with the Disease Outbreak Response System Condition framework as its risk management centre-piece [16]. This framework helps calibrate outbreak response according to the nature and transmissibility of the agent.

Our pandemic experiences have shown that disease control cannot be the sole purview of the health authority [17]. In order to facilitate a strong command and control centre where knowledge is effectively cascaded to stakeholders and efforts

coordinated across various government bodies and agencies, Singapore adopts a "whole-of-government" approach through its Homefront Crisis Management System. Our *modus operandi* gathers relevant ministries and inter-agency groups that either lead or support a sector (e.g., health, foreign affairs, trade and industry) to mitigate the consequences of an outbreak. Since Singapore is highly dependent on international trade and food supplies from overseas, total border closure is not feasible. The aim, therefore, is for the country to maintain continuity of essential services and supplies. In the meanwhile, morbidity and mortality can be reduced through early isolation and treatment of cases, quarantine of close contacts, mass vaccination once a pandemic vaccine becomes available, and the stepping up of infection control in different settings [18,19]. Clear communication at the national level is also needed at all stages during an outbreak. This helps ensure public confidence and strengthen social morale, which are likely to run deficit. As illustrated during SARS [20], the timely provision of information, advocacy for social responsibility, and promotion of good hygiene practices helped build trust between the people and the government.

BUILT ENVIRONMENT AND ECOLOGY

Singapore's population density has more than doubled from 3.5 thousand population per square km in 1970 to 7.1 thousand population per square km in 2010 [21]. This is notwithstanding its position as one of the most cosmopolitan societies in Southeast Asia-for every three Singaporean residents, there is now one non-Singaporean resident [21]. In ecological terms, Singapore's rapid urbanization has resulted in an increasingly built environment with new dynamic interactions between niches that are natural (biosphere) and man-made (technosphere). This in turn leads to emerging health concerns peculiar to an urbanized built environment [22,23].

As for elaborations on our flora and fauna, we shall state what is most obvious to infectious disease: the presence of vectors. Singapore's tropical climate gave over to the prevalence of mosquito vectors such as the *Aedes* spp. and *Anopheles* spp., whose populations were ruthlessly abated through a range of stringent control measures and the removal of marshlands and forested areas, though not entire, as the country rapidly urbanized [24]. It was with some degree of concern then that epidemic chikungunya, a mosquito-borne viral disease, surfaced in 2008 [25,26]. Genetic analysis showed that the first three local episodes were most likely the result of independent importations of the virus from neighbouring Asian countries while locally acquired cases that occurred around July in the same year were largely due to a single strain which was closely related to the strain detected in cases imported from Malaysia [26]. In a similar measure, although Singapore was certified malaria-free by the World Health Organization in 1982 and the *Anopheles* spp. vector population was reduced to low levels, the country remains vulnerable to outbreaks involving foreign workers with relapsing malaria who, due to socio-behavioural and economic reasons, did not seek early medical treatment [27,28]. The first locally acquired human *Plasmodium knowlesi* infection, an emerging malaria parasite, was also reported in 2007, with four additionally detected human cases within the same year, and one in 2008. All cases involved military personnel who had undergone training in restricted-access forested areas in Singapore [29]. The quintessential vector-borne disease, dengue, continues to be endemic in Singapore with cyclical outbreaks observed. In 2005, a switch in denguevirus (DEN) serotype predominance from DEN-2 to DEN-1 unleashed an unprecedented epidemic in both size and geographical distribution of cases [30]. Low herd immunity against the DEN-1 serotype due to the introduction of immunologically naive non-residents from non-dengue endemic countries, as well as the cunning of the *Aedes aegypti* in exploiting difficult-to-reach habitats were factors that contributed to the outbreak.

While Singapore has been exemplary in its effective implementation of environmental health programmes, and that the connection between the environment and the health of its people was recognized early in its development, leading to major clearance works of putrid, polluted areas of living and the establishment of a systematic drainage and sewerage system to ensure good standards of public sanitation and hygiene [24], the battle against emerging and re-emerging diseases is one that requires continued vigilance. A new variable that may amplify disease transmission is climate change as evident by extreme weather events, particularly the unprecedented flash flooding witnessed in parts of the country from 2010 to 2011. Our national environment agency has acknowledged the difficulties in rainfall prediction, which may augur unfavourably for mid- to long-term infrastructural planning. Extreme weather events are indicatory of an upset ecological system that remains poorly understood and addressed even as the country grapples with the new realities of climate change. Moving for-

ward, our disease control programmes require periodic review as the epidemiological triad of host, environment, and agent rebalances dynamically.

LIFESTYLE AND OUTBREAK EPIDEMIOLOGY

Singapore, by and large, has seen extraordinary growth in its average national income since its humble beginnings as a colonial outpost. In attaining its vision to become a "distinctive global city" [31], its relatively affluent, well-educated, and upwardly mobile population have increased access to environments, goods, and services that are not previously experienced and their risks to individual health uncertain. Besides unusual outbreaks [32,33] and stress-related disorders [34], other curious aetiologies [35,36] have occurred from time to time. In addition, changes in lifestyle by an ageing population-about 400 000 baby boomers will turn 65 years old between now and 2020-is a major force re-shaping our society.

The role of lifestyle was evident in an outbreak of *Fusarium* keratitis associated with contact lens wear (ReNu with Moisture Lock, manufactured by Bausch and Lomb) which we investigated in 2006 [37]. Of the 66 patients diagnosed, close to 82% reported poor contact lens hygiene practices [38]. This illustrated a lack of patient knowledge of the potential harm of novel products if not used properly. More recently, during the *Escherichia coli* food poisoning outbreak in Germany and the Fukushima nuclear incident in Japan, the agri-food and veterinary authority had to increase its surveillance of food imports to ensure consumption safety. Our high dependency on food imports, a lack of good local substitutes, and the proclivity for international food items made available through a global food production and supply-chain network place Singapore at increased risk of food-borne incidents [39,40]. This is compounded by the flagrant use of antibiotics and pesticides, mass production of processed food items, high ambient temperatures, and an extensive farm-to-fork process, providing many opportunities for contamination of food items [41]. With such risk factors, the national pastime of exotic dining outside the home needs only small mentioning.

For outbreak management, investment needs to be wisely directed towards capability enhancement and Singapore has learnt that dealing with unknowns requires sufficient bandwidth in both infrastructure (i.e., hardware) and expertise (i.e., software). Recognising the importance of epidemic intelligence, a public health intelligence unit was set up in 2011 to monitor and analyse changes in local and overseas disease landscapes. Intelligence that is acquired from this process is used to track potential threats, trigger public health response, and facilitate risk communication to relevant stakeholders as necessary.

PUBLIC HEALTH LEADERSHIP

In our global village where many potential threats loom ominously over the horizon, we need public health leadership. Singapore is continuously on the look-out to improve its capability and capacities in the detection of, and response to health threats, whether known or unknown. To achieve this resilience, the Singapore Field Epidemiology Training Programme was institutionalized in 2010. Administered by the Communicable Diseases Division of the Ministry of Health and modelled after the US Centers for Disease Control and Prevention's Epidemic Intelligence Service, courses are conducted biannually. In addition to didactics and rigorous fieldwork, novel training methods such as multimedia gaming are being introduced. The first cohort comprising ten trainees will be graduating in July 2012. This programme aims to build a cadre of field specialists who can lead and support the public health mission. For its professional contributions, it has successfully gained recognition into the global Training Programs in Epidemiology and Public Health Interventions Network and is a founding member of the regional ASEAN+3 Field Epidemiology Training Network.

To cultivate public health leadership on a broader front, the Saw Swee Hock School of Public Health at the National University of Singapore was elevated to a full faculty in 2011. The School aims to produce future public health leaders and fulfil a unique niche in utilising new technologies to provide local solutions to some of today's most pressing public health challenges, including infectious disease control. It has recently signed a memorandum of understanding with the London School of Hygiene and Tropical Medicine, to advance research and education in areas of infectious disease control, health systems, and chronic diseases with an Asian focus [42]. In addition to public health manpower, the country's Communicable Disease Centre which has steadfastly served the nation in the clinical management of outbreaks for the past hundred years, will soon be integrated into a new purpose-built state-of-the-art facility for the isolation and management of patients with infectious diseases [43]. Further, the number of infectious disease specialists has increased from 16 in 2003 to 39 in 2010.

CONCLUSION

The experience of Singapore offers a case study for field epidemiology and disease control in a globally-connected city. Its territorial compactness, population heterogeneity, and relative affluence mirror the characteristics of many cities today. The presence of a stable government and efficient civil service is a strong contributing factor in its ability to implement policies and regulate human behaviour. That the city-state can be an anomaly, beating the odds of its natural landscape of tropical diseases showed that good public health can be sustainably practised with the right policies that evolve with the dynamics of modern living and its impact on disease transmission.

CONFLICT OF INTEREST

The authors have no conflicts of interest with the material presented in this paper.

REFERENCES

1. Fidler DP. From international sanitary conventions to global health security: the new International Health Regulations. Chin J Int Law 2005;4(2):325-392.
2. Hoffman SJ. The evolution, etiology and eventualities of the global health security regime. Health Policy Plan 2010;25(6): 510-522.
3. Singapore Economic Development Board. Unparalleled connectivity & infrastructure; 2011 [cited 2012 Jan 16]. Available from: http://www.edb.gov.sg/edb/sg/en_uk/index/why_singapore/connected.html.
4. Streenivasan V. Changi Airport sets fresh records in traffic. The Business Times; 2012 Jan 24 [cited 2012 Jan 26]. Available from: http://www.asiaone.com/News/Latest%2BNews/Singapore/Story/A1Story20120123-323527.html.
5. Olsen SJ, Chang HL, Cheung TY, Tang AF, Fisk TL, Ooi SP, et al. Transmission of the severe acute respiratory syndrome on aircraft. N Engl J Med 2003;349(25):2416-2422.
6. Ooi PL, Lim S, Chew SK. Use of quarantine in the control of SARS in Singapore. Am J Infect Control 2005;33(5):252-257.
7. Leong HN, Earnest A, Lim HH, Chin CF, Tan CS, Puhaindran ME, et al. Tan SARS in Singapore: predictors of disease severity. Ann Acad Med Singapore 2006;35(5):326-331.
8. Singapore Ministry of Trade and Industry. Economic survey of Singapore 2009: Singapore's tourism sector [cited 2012 Jan 17]. Available from: http://www.mti.gov.sg/ResearchRoom/Documents/app.mti.gov.sg/data/article/21265/doc/Box_8.4__AES2009.pdf.
9. Singapore Department of Statistics. Seasonal adjustment of economic time series; 2006 [cited 2012 Jan 17]. Available from: http://www.singstat.gov.sg/pubn/papers/economy/ip-e32.pdf.
10. Singapore Ministry of Trade and Industry. Impact of severe acute respiratory syndrome (SARS) on the Singapore economy; 2003 [cited 2012 Jan 17]. Available from: http://app-stg.mti.gov.sg/data/article/21/doc/NWS_2003Q1_SARS.pdf.
11. Ooi PL, Lai FY, Low CL, Lin R, Wong C, Hibberd M, et al. Clinical and molecular evidence for transmission of novel influenza A(H1N1/2009) on a commercial airplane. Arch Intern Med 2010; 170(10):913-915.
12. Ooi PL. Application of international health regulations in the Singapore pandemic influenza experience. Int J Infect Dis 2010;14(S1):e426.
13. Low CL, Chan PP, Cutter JL, Foong BH, James L, Ooi PL. International health regulations: lessons from the influenza pandemic in Singapore. Ann Acad Med Singapore 2010;39(4): 325-323.
14. Ooi PL, Lim S, Tham KW. Lessons from SARS in an age of emerging infections. Med Lav 2006;97(2):369-375.
15. Ooi PL. Outbreak surveillance and response: what you need to know. J Singap Fam Physician 2008;34(2S):16-17.
16. Cutter J. Preparing for an influenza pandemic in Singapore. Ann Acad Med Singapore 2008;37(6):497-503.
17. Ooi PL, James L. Managing outbreaks in Singapore: a case study of SARS. In: Kamnuan U, Yin MA, editors. Good practices in responding to emerging infectious diseases: experiences from the ASEAN plus three countries. Bangkok: Bureau of Epidemiology; 2010, p. 71-77.
18. Ooi PL. Hospital acquired SARS: wake up call in a brave new age of epidemics. In: Wagenaar C, Davids J, editors. Architecture of hospitals. Groningen: University Medical Centre Groningen; 2005, p.166-173.
19. Chan PP, Subramony H, Lai FY, Tien WS, Tan BH, Solhan S, et al. Outbreak of novel influenza A (H1N1-2009) linked to a dance club. Ann Acad Med Singapore 2010;39(4):299-304.
20. Landard J, Sandman PM. SARS communication: what Singapore is doing right; 2003 [cited 2012 Jan 17]. Available from: http://www.psandman.com/articles/sars-2.htm.
21. Singapore Department of Statistics. Key demographic indicators, 1970-2011 [cited 2012 Jan 16]. Available from: http://

www.singstat.gov.sg/stats/themes/people/popnindicators.pdf.

22. Ooi PL, Lim S. SARS and the city: emerging health concerns in the built environment. In: Tham KW, Sekhar C, Cheong D, editors. Healthy buildings 2003. Singapore: National University of Singapore; 2003, p. 73-80.
23. Lau G, Ooi PL, Phoon B. Fatal falls from a height: the use of mathematical models to estimate the height of fall from the injuries sustained. Forensic Sci Int 1998;93(1):33-44.
24. Bhaskar AR, Chia MC, Chua YP, Chung D, Danani SM, Ho CH, et al. Singapore: my clean & green home. Singapore: Singapore Ministry of the Environment; 1997, p. 39-43.
25. Ooi PL. Transmission of chikungunya in Singapore, 2008. Int J Infect Dis 2010;14(S1):e374.
26. Ng LC, Tan LK, Tan CH, Tan SS, Hapuarachchi HC, Pok KY, et al. Entomologic and virologic investigation of Chikungunya, Singapore. Emerg Infect Dis 2009;15(8):1243-1249.
27. Lee YC, Tang CS, Ang LW, Han HK, James L, Goh KT. Epidemiological characteristics of imported and locally-acquired malaria in Singapore. Ann Acad Med Singapore 2009;38(10):840-849.
28. Ooi PL, Goh KT, Lee KM. Local transmission of Plasmodium vivax malaria in Singapore. Ann Acad Med Singapore 1997;26(5):588-592.
29. Jeslyn WP, Huat TC, Vernon L, Irene LM, Sung LK, Jarrod LP, et al. Molecular epidemiological investigation of Plasmodium knowlesi in humans and macaques in Singapore. Vector Borne Zoonotic Dis 2011;11(2):131-135.
30. Koh BK, Ng LC, Kita Y, Tang CS, Ang LW, Wong KY, et al. The 2005 dengue epidemic in Singapore: epidemiology, prevention and control. Ann Acad Med Singapore 2008;37(7):538-545.
31. Singapore Ministry of National Development. An endearing home, a distinctive global city, Singapore. Singapore: Singapore Ministry of National Development; 2008, p. 2-5.
32. Ooi PL, Goh KT, Lee HS, Goh CL. Tussockosis: an outbreak of dermatitis caused by tussock moths in Singapore. Contact Dermatitis 1991;24(3):197-200.
33. Ooi PL, Goh KT, Heng BH, Toh YH. Epidemiological investigations into an outbreak of building-associated illness in Singapore. Asia Pac J Public Health 1994;7(4):201-205.
34. Ooi PL, Goh KT. Sick building syndrome: an emerging stress-related disorder? Int J Epidemiol 1997;26(6):1243-1249.
35. Ooi PL, Goh KT. Sick-building syndrome in a tropical city. Lancet 1996;347(9004):841-842.
36. Ooi PL, Goh KT, Phoon MH, Foo SC, Yap HM. Epidemiology of sick building syndrome and its associated risk factors in Singapore. Occup Environ Med 1998;55(3):188-193.
37. Saw SM, Ooi PL, Tan DT, Khor WB, Fong CW, Lim J, et al. Risk factors for contact lens-related fusarium keratitis: a case-control study in Singapore. Arch Ophthalmol 2007;125(5):611-617.
38. Khor WB, Aung T, Saw SM, Wong TY, Tambyah PA, Tan AL, et al. An outbreak of Fusarium keratitis associated with contact lens wear in Singapore. JAMA 2006;295(24):2867-2873.
39. Solhan S, Chan PP, Kurupatham L, Foong BH, Ooi PL, James L, et al. An outbreak of gastroenteritis caused by Salmonella enterica serotype Enteritidis traced to cream cakes. West Pac Surveill Response J 2011;2(1):1-8.
40. Ooi PL, Goh KT, Neo KS, Ngan CC. A shipyard outbreak of salmonellosis traced to contaminated fruits and vegetables. Ann Acad Med Singapore 1997;26(5):539-543.
41. Saker L, Lee K, Cannito B. Infectious disease in the age of globalization. In: Kawachi I, Wamala SP, editors. Globalization and health. Oxford: Oxford University Press; 2007, p.19-38.
42. National University of Singapore. Partnering one of the world's leading institutions in global and public health; 2011 [cited 2012 Jan 17]. Available from: http://newshub.nus.edu.sg/headlines/1111/partnering_01Nov11.php.
43. Pang M. No need for panic over bird flu: experts; 2012 [cited 2012 Jan 26]. Available from: http://www.ttsh.com.sg/about-us/newsroom/news/article.aspx?id=2909.