Review Article

Influenza A (H1N1-2009) Pandemic in Singapore – Public Health Control Measures Implemented and Lessons Learnt

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Abstract

We describe the public health control measures implemented in Singapore to limit the spread of influenza A (H1N1-2009) and mitigate its social effects. We also discuss the key learning points from this experience. Singapore's public health control measures were broadly divided into 2 phases: containment and mitigation. Containment strategies included the triage of febrile patients at frontline healthcare settings, admission and isolation of confirmed cases, mandatory Quarantine Orders (QO) for close contacts, and temperature screening at border entry points. After sustained community transmission became established, containment shifted to mitigation. Hospitals only admitted H1N1-2009 cases based on clinical indications, not for isolation. Mild cases were managed in the community. Contact tracing and QOs tapered off, and border temperature screening ended. The 5 key lessons learnt were: (1) Be prepared, but retain flexibility in implementing control measures; (2) Surveillance, good scientific information and operational research can increase a system's ability to manage risk during a public health crisis; (3) Integrated systems-level responses are essential for a coherent public health response; (4) Effective handling of manpower surges requires creative strategies; and (5) Communication must be strategic, timely, concise and clear. Singapore's effective response to the H1N1-2009 pandemic, founded on experience in managing the 2003 SARS epidemic, was a whole-of-government approach towards pandemic preparedness planning. Documenting the measures taken and lessons learnt provides a learning opportunity for both doctors and policy makers, and can help fortify Singapore's ability to respond to future major disease outbreaks.

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Key words: Communications, Preparedness, Surge capacity

Introduction

The novel influenza A(H1N1) outbreak was officially declared a pandemic by the World Health Organization (WHO) on 11 June 2009.[1] We describe the public health control measures instituted in Singapore to limit the spread of H1N1-2009 and mitigate its effects on our society. We also discuss the key lessons learnt in managing the pandemic. Focus group discussions and interviews with key stakeholders from the Ministry of Health, Singapore (MOH) and the healthcare sector were conducted by the MOH H1N1 Taskforce Secretariat to review the management of the H1N1-2009 pandemic, and to elicit learning points. Important issues that surfaced were further debated in meetings in MOH to distil the key lessons learnt from the H1N1-2009 pandemic.

While many stakeholders contributed significantly to the latter, this paper contains the personal opinions of the authors and do not reflect the official views of MOH or its stakeholders.

Epidemiology of H1N1-2009 in Singapore

The first local imported case of H1N1-2009, a Singaporean who had returned from New York City, was detected on 26 May 2009. The first unlinked case (i.e. a case with no epidemiological links to previous cases) was detected on 18 June 2009 – the first indication that community transmission of H1N1-2009 had begun locally. By 9 July 2009 (Table 1), there were 1301 laboratory-confirmed cases of H1N1-2009 in Singapore.[2]

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Table 1. Chronology of Key Events and Control Measures in the H1N1-2009 Pandemic

Date	Events and Key Public Health Control Policies and Measures
25 Apr 2009	WHO declares "public health emergency of international concern".
Containment Phase in Singapore	
27 Apr 2009	WHO raised pandemic influenza alert from phase 3 to 4. Singapore begins thermal scanning of incoming passengers at airports, later extended to land and sea entry points. HANs were distributed. Passengers with elevated temperatures were asked to fill in HDCs.
28 Apr 2009	Singapore raised alert level to DORSCON Yellow. H1N1-2009 made a legally notifiable infectious disease in Singapore. Measures implemented included: • Full PPE in high-risk areas (e.g. ICU, ED, OT). • Triage in SOCs and EDs. • Isolation of confirmed, probable and suspect cases in RHs. • Inter-hospital movement of patients and HCWs restricted to medically indicated transfers and essential services. • HO and MO rotations suspended. • Contact tracing and issuance of QOs to contacts of confirmed and probable cases. • All suspect cases to be lab tested for H1N1-2009.
29 Apr 2009	WHO raises pandemic influenza alert from phase 4 to 5.
30 Apr 2009	Singapore's alert level raised to DORSCON Orange. Additional measures undertaken included: • Full PPE in all patient contact areas. • Patient transfers restricted to between linked RHs and NHs. • Clinical student training suspended. • Visitor restrictions in hospitals – 1 visitor per patient. • Contact tracing and QOs for contacts of confirmed and probable cases.
2 May 2009	Temporary visa requirements instituted for Mexican nationals.
4 May 2009	7-day QOs instituted for incoming travelers from Mexico.
7 May 2009	MOH initiates gradual transition in healthcare settings to DORSCON Yellow. Measures that were stepped down or relaxed included: • Full PPE only for HCWs in high-risk areas. • Hospitals could allow 2 visitors per patient instead of 1.
11 May 2009	Singapore's alert level formally returned to DORSCON Yellow. Measures that were stepped down included: • Lifting of restrictions on patient transfers between linked RHs and nursing homes. • Resumption of clinical student training. • Resumption of HO and MO rotations from 25 May 2009.
12 May 2009	Visa requirements for Mexican nationals lifted.
16 May 2009	QOs for incoming travelers from Mexico lifted.
26 May 2009	First imported case of H1N1-2009 detected in Singapore.
11 Jun 2009	WHO raises pandemic influenza alert from phase 5 to 6.
18 Jun 2009	First community case of H1N1-2009 detected in Singapore.
29 Jun 2009	Singapore commences transition to Mitigation Phase. Measures during this period included: • Cases still managed in RHs, but mild cases could be discharged home under QO. • No QOs for contacts of cases.
Mitigation Phase in Singapore	
9 Jul 2009	Singapore enters full Mitigation phase. Measures implemented included: • Mild cases to be managed in the community by PPCs. • Lab confirmation of H1N1-2009 required only when necessary for clinical management or for public health reasons.
11 Jul 2009	Thermal scanning at checkpoints and use of HDCs discontinued.
15 Jul 2009	Hospitals admitted H1N1-2009 cases based purely on clinical indications and not for isolation.
18 Jul 2009	First H1N1-2009-related death in Singapore.
26 Jul to 1 Aug 2009	Polyclinic attendances for ARI reached peak of 24,477. Proportion of ILI among ARI cases in polyclinics peaked at 22.9%.
2 to 8 Aug 2009	Proportion of H1N1-2009 among ILI cases in GP clinics and polyclinics peaked at 65.5%.
As at 30 Sep 2009	18 H1N1-2009-related deaths in total.

ARI: acute respiratory illness; ED: Emergency department; HAN: health alert notice; HCW: healthcare worker; HDC: health declaration card; HO: house officer; ICU: intensive care unit; ILI: influenza-like illness; MO: medical officer; NH: nursing home; OT: operating theatre; PPC: pandemic preparedness clinic; PPE: personal protective equipment; QO: quarantine order; RH: restructured hospital; SOC: specialist outpatient clinic; WHO: World Health Organization

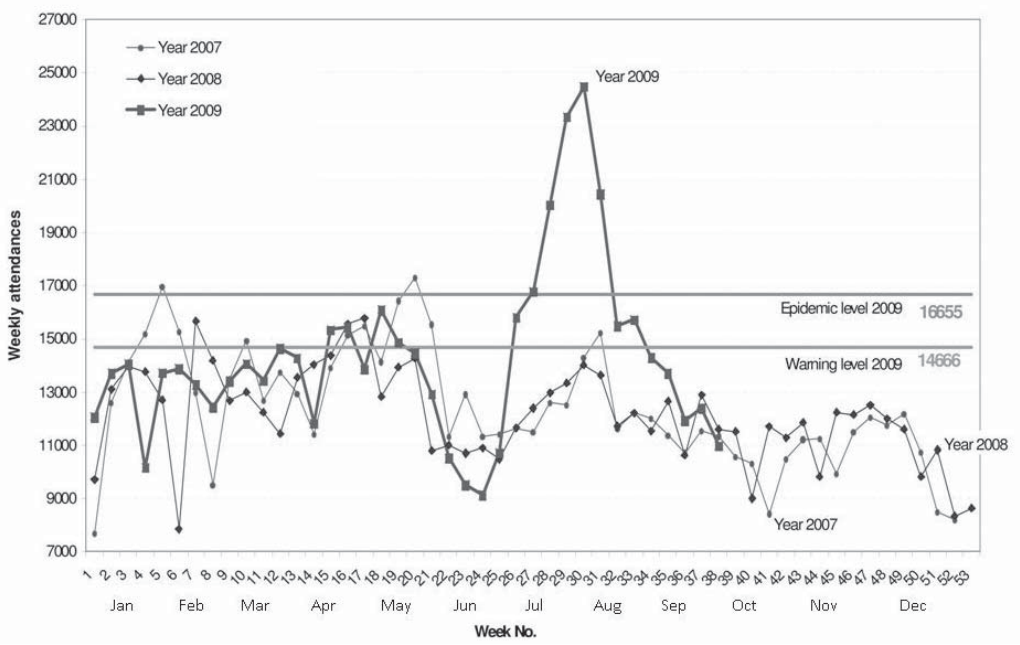

Fig. 1. Weekly polyclinic attendances of acute respiratory illness, 2007-2009.

At the height of the epidemic, polyclinic attendances for acute respiratory illness (ARI) reached a peak of 24,477 attendances in the week of 26 July to 1 August 2009 (Fig. 1). The proportion of H1N1-2009 among influenza-like illness (ILI) samples from general practitioner (GP) clinics and polyclinics peaked at 65.5% (95% CI, 62.0% to 68.8%) in the week of 2 to 8 August 2009.[2] During this week, all ILI samples which were positive for influenza A were laboratory-confirmed to have the H1N1-2009 strain, which had completely displaced the seasonal H1N1 and H3N2 strains.

Singapore's Influenza Pandemic Readiness and Response Plan

The Government of Singapore developed its National Influenza Pandemic Readiness and Response Plan (PRRP) in the aftermath of the severe acute respiratory syndrome (SARS) epidemic in 2003. It was therefore able to incorporate many of the lessons from that outbreak into the new pandemic preparedness framework. Although the PRRP had been exercised regularly over the years by government agencies and healthcare institutions, the H1N1-2009 pandemic was the first time the plans were tested in real life.

The national strategy for managing an influenza pandemic centred around establishing an effective surveillance system to detect the importation of a novel influenza virus, controlling the spread and mitigating the impact of the virus when the first pandemic wave hit, and then preparing the population for vaccination to achieve national immunity when the pandemic vaccine became available.

Overall, the plan aimed to: (a) Reduce morbidity and mortality through appropriate treatment of the influenza cases; (b) Slow the spread of influenza to reduce the surge on healthcare; and (c) Maintain essential services in Singapore to limit social and economic disruption.[3]

The Disease Outbreak Response System (DORS) was an integral part of the pandemic plan. The DORS was a colour-coded framework that served to guide the ramping up or scaling down of response measures (Fig. 2). It was premised on a virulent virus, and its different levels corresponded with WHO's Alert Phases 1-6. Progression through the levels correlated with increasing transmissibility of the virus. DORSCON Red and Black represented the levels at which the most exacting control measures had to be taken (Table 2).

Command and Control Structure in an Influenza Pandemic

The Homefront Crisis Management System (HCMS) in Singapore is the framework for coordinating the whole-of-government (WOG) response in times of a crisis. Under the HCMS, strategic and political guidance is provided by the Homefront Crisis Ministerial Committee for Influenza (HCMC-FLU), which is chaired by the Minister for Home Affairs. HCMC-FLU is supported by the Homefront Crisis Executive Committee (HCEG-FLU), chaired by the Permanent Secretary (Home Affairs) (Fig. 3). Ministries and agencies are functionally clustered into Crisis Management Groups (CMGs). Each CMG is an inter-agency group led by a Ministry that is the domain owner.

For example, CMGs were created for Border Control, Economic Sustainability, Safety and Security, Transport and Education. Each CMG was responsible for coordinating

DORSCON	WHO PHASE	Definition of DORSCON (based on transmissibility)
GREEN	1 to 3	Isolated animal-to- human spread
YELLOW	4	Inefficient human-to-human transmission
ORANGE	5	Larger cluster(s) but human-to-human spread is still localized
RED	6	The virus is fully transmissible. Community transmission occurs.
BLACK	6	Community transmission occurs and high rates of severe disease and deaths.

Fig. 2. Singapore's disease outbreak response system.

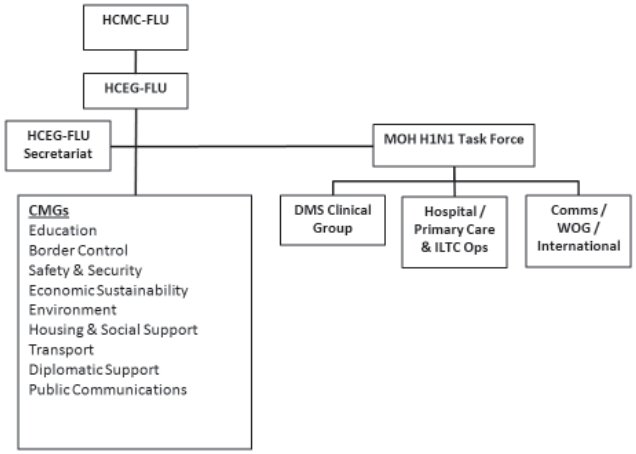

Fig. 3. Command and control structure for H1N1-2009 pandemic.

measures in its respective area, e.g. implementing public health control measures in schools, at the border checkpoints, and in the public transport system. Senior MOH representatives were assigned to CMGs to serve as resource persons.

During the H1N1-2009 pandemic, MOH set up an H1N1 Taskforce chaired by the Permanent Secretary (Health) to implement public health control measures and oversee the provision of medical services. The Taskforce comprised key policy makers, public health practitioners, senior clinicians, infectious disease physicians and other experts. MOH also set up the Director of Medical Services H1N1-2009 Clinical Group to advise on the clinical and public health aspects of the pandemic response.

Surveillance of H1N1-2009 in Singapore

The Infectious Diseases Regulations were amended to legally require all suspect and confirmed novel influenza A(H1N1) cases to be notified to MOH within 24 hours of diagnosis, with effect from 28 April 2009. From 30 June 2009, medical practitioners were only required to notify laboratory-confirmed H1N1-2009 cases as well as clinically suspected H1N1-2009 cases that were seriously ill. Medical practitioners were also required to inform MOH of H1N1-2009-related deaths within 24 hours of death, for both confirmed cases and deaths in which H1N1-2009 was strongly suspected.

Table 2. Main Control Measures in the Disease Outbreak Response System

1. Healthcare Measures	• Case management • Infection control in healthcare settings (including the use of personal protective equipment, triaging of febrile patients, screening and restriction of visitors to healthcare institutions, and restriction of inter-hospital movement of patients and healthcare workers) • Isolation of cases • Contact tracing and management of contacts (e.g. quarantine orders, prophylaxis) • Surveillance
2. Border Control Measures	• Health alert notice and health declaration cards for inbound travelers • Temperature/health screening for inbound travellers
3. Community Measures	• Public education on hygiene and social responsibility • Temperature screening at workplaces and on entry to buildings/events • Social distancing measures e.g. school closures, cancellation of events of mass gathering.

This policy was in line with WHO's recommendation that countries should monitor clusters of severe or fatal H1N1 infections.[4] In addition to case notification, MOH also worked with public sector restructured hospitals (RHs), polyclinics and GPs to ramp up the routine biosurveillance of patients with ILI. This provided MOH with data to estimate the prevalence of H1N1-2009 in the community.

H1N1-2009 Control Measures in Singapore

Singapore's strategies to control the H1N1-2009 pandemic were broadly grouped into 2 phases: Containment and Mitigation. In the Containment Phase, cases were either imported, or were local clusters linked to imported cases. Measures undertaken in this phase aimed to delay the spread of the disease in the community. In the Mitigation Phase, sustained community spread would have occurred; new cases would have no defined epidemiological links with existing cases. The Mitigation control measures aimed to minimise morbidity and mortality, and to slow the spread of the disease to avoid overwhelming the healthcare system.

In the early stages of the global outbreak, Singapore elevated its DORS alert levels in tandem with WHO's raising of its pandemic alert levels. Thus, Singapore's alert level was raised to DORSCON Yellow on 28 April 2009 and to DORSCON Orange on 30 April 2009.

When WHO first declared this outbreak a "public health emergency of international concern", there were as yet no confirmed cases of H1N1-2009 in Singapore. Although it was recognised that eventual importation of H1N1-2009 and local community spread was inevitable, MOH's decision from the outset was to apply rigorous containment measures

for as long as practicable, to slow the spread of the disease. The goal was to achieve a protracted "slow burn," rather than a "wild-fire" spread of the virus.

This decision was premised on 4 items of virus information available early during the pandemic:- (a) As this was a novel virus not previously seen in humans or animals,[5] it was anticipated that most individuals would not be immune to it; (b) Early data from Mexico appeared to indicate a high case fatality ratio (CFR), with 42 deaths and 949 laboratory-confirmed cases in Mexico on 5 May 2009.[6] However, it was recognised that these numbers may have been an overestimate of the true CFR, because surveillance may have focused on severe cases, with under-reporting of mild or asymptomatic cases. (c) Preliminary data suggested a secondary attack rate of 22% to 33%, compared to 5% to 15% for seasonal influenza,[6,7] meaning that the absolute numbers of persons with severe illness and death could be higher than in seasonal influenza, even if case fatality was eventually found to be equal to or lower than that of seasonal flu. (d) Unlike seasonal flu, young adults were disproportionately affected (severe illness occurring in healthy young adults), on top of the usual groups at risk for complications of seasonal influenza, i.e. the very young, pregnant women, and those with underlying medical conditions.[6]

When the US Centers for Disease Control and Prevention (CDC) later reported evidence suggesting that H1N1-2009 transmission was widespread and that uncomplicated illness was common,[8,9] the decision was made to de-link Singapore's DORSCON levels from WHO's pandemic phases. WHO's phases indicated transmissibility and geographic spread, whereas it was felt locally that responses should also be calibrated to the virulence of the virus. MOH initiated a gradual transition to DORSCON Yellow on 7 May 09, a week after the US CDC reports. In so doing, MOH deviated from its own original meaning of the DORSCON phases, placing emphasis on **severity** over **spread**. Healthcare institutions were also allowed to progressively step down various control measures based on the assessed risk in different healthcare settings. Singapore formally returned to DORSCON Yellow on 11 May 2009 and remained so, even after WHO raised the pandemic alert to phase 6 on 11 June 2009.

After more than 2 months of being in Containment, Singapore gradually transited to Mitigation in the week of 29 Jun 2009, when the daily number of epidemiologically unlinked newly diagnosed locally-acquired H1N1-2009 cases began to exceed the number of linked cases. During this transition, a more targeted and risk-stratified approach was adopted. Medical management of H1N1-2009 cases gradually shifted from hospitals to the community, so that hospitals could concentrate on treating the more severely ill. Certain containment measures such as contact tracing and the issuance of Quarantine Orders (QOs) were progressively scaled back. Containment measures finally converted to Mitigation measures on 9 July 2009.[2]

Control Measures in the Healthcare Sector

As opposed to the 2003 SARS epidemic in Singapore, where a key public health control measure involved centralising the management of all suspect and probable SARS cases in one designated hospital,[10] the plan for an influenza pandemic involved minimizing the risk of transmission in the community by isolating initial cases in hospitals during Containment, and then extending the care of patients to Pandemic Preparedness Clinics (PPCs) when there was widespread community transmission and large numbers of cases within the community.

(i) During Containment

Infection control measures were implemented in all healthcare settings, including hospitals, primary care clinics, intermediate and long-term care (ILTC) facilities, and community dialysis centres. Healthcare workers in high-risk areas such as intensive care units, isolation wards, operating theatres and emergency departments were required to use full personal protective equipment (PPE), including N95 masks, disposable gloves and gowns. Those working in other clinical care areas used appropriate PPE according to established protocols.

Triage systems to segregate febrile patients were instituted at all front-line settings, such as emergency departments (EDs) and outpatient clinics. Visitors to healthcare institutions were screened for fever and flu-like symptoms. Visitor numbers and visit times were restricted, and particulars of visitors were recorded to facilitate future contact tracing if necessary. Temperature monitoring of healthcare workers was carried out and clusters of ILI among staff were investigated. Inter-hospital movement of patients was limited to medically indicated transfers. ILTC facilities were also linked with RHs through a regional-zoning system to further reduce patient movement between healthcare facilities. Inter-hospital movement of doctors and healthcare workers was restricted to essential services. During DORSCON Orange, the rotation of house officers, medical officers and registrars to new postings was suspended, and the clinical training of all students in healthcare institutions stopped. The latter measures were lifted in DORSCON Yellow.

All patients confirmed to be positive for H1N1-2009 were admitted to RHs for isolation. Senior clinicians within RHs were designated as Health Officers under the Infectious Diseases Act and given the power to issue mandatory isolation orders to patients who refused to be admitted for isolation. Contact tracing was initiated for laboratory-confirmed cases of H1N1-2009.

Close contacts of index cases were served with mandatory QOs (for a period of 7 days from the date of last contact with the index case) and offered prophylaxis with oseltamivir. Local contacts were generally quarantined in their place of residence, whilst foreigners were quarantined in designated Government Quarantine Facilities. Contacts under quarantine were asked to monitor themselves for flu-like symptoms, and were transported to Tan Tock Seng Hospital for further management if they became symptomatic.

A dedicated "993" ambulance service was established to ferry suspect H1N1-2009 patients to RHs, so as to minimise the spread of infection within the community through the public transport system. As the patient load began to increase rapidly, taxis (MaxiCabs) were roped in to help ferry patients.

(ii) During Mitigation

During the transition to Mitigation Phase, all confirmed cases were still admitted to hospitals. However, mild cases were discharged with oseltamivir treatment and a QO if clinically stable, without significant comorbid conditions, if they had physically suitable local accommodation and a designated caregiver, and did not have vulnerable individuals at home (e.g. pregnant women, patients at extremes of age, and those with comorbidity).

From 15 July 2009, hospitals admitted H1N1-2009 cases based purely on clinical indications, rather than for isolation purposes. Patients with mild ILI symptoms were advised to visit PPCs, i.e. GP clinics activated during sustained community transmission of H1N1-2009 to manage ILI patients. PPCs were supported with oseltamivir and PPE from the national stockpile, and were given a special decal for easy identification. The list of PPCs was publicised in the media and provided to hotels. Members of the public could also send text messages to a specific mobile telephone number to locate a nearby PPC.

Laboratory tests to confirm the diagnosis of H1N1-2009 were no longer needed for every suspect case. They were only required in patients in whom the result was needed for clinical management (e.g. severely ill patients) or where testing had public health importance. Clinically mild patients with suspected H1N1-2009 were given medical leave to cover a self-quarantine period at home (7 days for adults, 10 days for children below 13 years, from symptom onset date). Oseltamivir treatment was recommended for high-risk patients with ILI when the surveillance prevalence of H1N1-2009 was about 30% in ILI cases.

Contact tracing and the issuance of QOs for contacts of confirmed cases were discontinued unless there was a specific public health need. Instead, close contacts were advised to monitor their own health and exercise social responsibility.

Border Control Measures

(i) During Containment

Thermal scanners screened all arriving passengers for fever at the airports from 27 April 2009. This was later extended to the land and sea entry points. Arriving passengers who were "flagged" by the thermal scanners were examined by healthcare workers and asked to fill in a Health Declaration Card (HDC). Those who were suspect cases of H1N1-2009 were referred to Tan Tock Seng Hospital for further evaluation. Health Alert Notices (HANs) were also given to arriving passengers, which advised them to monitor their temperature, look out for flu-like symptoms and to seek immediate medical attention if symptoms began.

It was recognised that thermal scanning was not foolproof, as cases could be asymptomatic. It was estimated that thermal scanning at the borders successfully detected about 25% of imported confirmed cases, mostly at the airport. Thermal scanners were less useful at land checkpoints as the many visitors and workers passing through at peak hours made it difficult to screen every individual. However, the aim of thermal scanning was to heighten the awareness of arriving passengers to the H1N1-2009 situation and raise the likelihood of self-monitoring.

As Mexico was the epicentre early in the pandemic, temporary visa requirements for Mexican Nationals were instituted on 2 May 2009. From 4 May 2009, all incoming travellers from Mexico were issued QOs for 7 days. These measures were lifted on 12 May 2009 and 16 May 2009 respectively, after the WHO Rapid Pandemic Assessment Collaboration estimated a lower CFR in Mexico of 0.4% (range, 0.3% to 1.8%).[11]

(ii) During Mitigation

Temperature screening and the use of HDC were discontinued at the border entry points on 11 July 2009.

Control Measures in the Community

(i) During Containment

A massive public education campaign was launched to inform the public about H1N1-2009, and to educate them about the importance of personal hygiene and social responsibility in slowing the spread of the disease. Ill persons were asked to stay away from school or work, avoid crowded public areas, and to seek immediate medical attention. These messages persisted throughout the entire H1N1-2009 pandemic.

Non-healthcare establishments were advised to do temperature- and symptom-screening of visitors and staff, and to record particulars of visitors. The public were also advised to postpone non-essential travel to affected countries.

The precautions taken in schools included twice-daily temperature checks, granting 7-day Leave of Absence to students with recent travel history to affected countries, home-based learning programmes for affected students, suspension of school assembly, and scaling down extra-curricular activities to minimise congregation.

To break any potential chain of transmission within schools, a set of triggers for class closures was developed. Classes would be closed for 7 days, if the class had 3 or more known confirmed cases or 5 or more cases who had been given a 7-day Medical Certificate (MC) within 5 days. Pre-school classes would be closed for 7 days if the lower threshold of 2 or more known confirmed cases or 3 or more cases issued 7-day MC within 5 days was breached. Between 28 June and 31 August 2009, there were 66 class closures at the primary and secondary schools, junior colleges and centralised institutes, and 82 class closures in kindergartens and special education schools (unpublished data, 2009 – Ministry of Education, Singapore).

(ii) During Mitigation

To boost continuity, businesses were advised to institute social distancing measures wherever practicable, e.g. allowing staff to telecommute and using split-team arrangements. They were also advised to display prominent signs at building entrances to remind staff and visitors to be socially responsible. Organisations could screen staff's and visitors' temperature, based on their own risk assessment. Organisations were also advised, wherever possible, to deploy staff that were at higher risk of complications from H1N1-2009 infection (e.g. pregnant women) from front-line work to lower risk areas. Temperature checks in schools were progressively scaled down, and assemblies and extra-curricular activities gradually resumed.

Public Communications

During the H1N1-2009 pandemic, the government worked closely with the media to provide regular updates so that the public were continually apprised of the latest H1N1-2009 situation globally and in Singapore. The public were consistently reminded of steps they could take to reduce their risk of acquiring and spreading the disease. A dedicated government website on influenza also facilitated the public's easy access to information.

Evaluating the Effects of Control Measures

As noted during SARS, an assessment of the relative effectiveness of the different control measures is critical in preparing for future outbreaks of a similar nature.[12] During the H1N1-2009 pandemic, MOH took the initiative to conduct public health operational research to strengthen its ongoing response strategies and control measures. For example, a study to estimate infection rates of H1N1-2009 and to assess the efficacy of various preventive measures (e.g. pre-exposure antiviral prophylaxis, seasonal influenza vaccination, and PPE use) was rapidly approved and funded by MOH. However, given the many constraints during a pandemic, it was difficult to ensure that operational research was completed in a timely way to influence the ongoing responses and control measures.

This paper does not analyse the effectiveness of the response strategies and control measures during H1N1-2009, or their success in mitigating the impact of the pandemic. Further targeted research will be required to address those issues. Some areas worthy of study include the cost-effectiveness of the scale of public health control response undertaken in Singapore versus other countries, whether control measures were overly focused on RHs, and whether the slow burn strategy really helped to decrease the peak of cases later seen. However, we propose 5 key lessons from the pandemic.

Key Lessons Learnt in the Management of the H1N1-2009 Pandemic

Lesson 1: Be Prepared, but be Flexible

As a nation and as a healthcare system, Singapore was arguably better prepared for a large-scale infectious disease outbreak than during SARS in 2003. Nonetheless, several aspects of our pandemic influenza plans could not be fully applied to the H1N1-2009 pandemic. Therefore, existing plans had to be adapted, and pre-determined public health control measures modified to better suit the H1N1-2009 situation, as the pandemic evolved.

Disease outbreak response system

The aims of the DORS framework (see above) were to assist MOH in infectious disease outbreak threat assessment, and to recommend appropriate control measures. Before H1N1-2009, H5N1 was assessed to be the most likely cause for an influenza pandemic. Accordingly, DORS was designed to respond to an influenza pandemic with the high morbidity and mortality associated with H5N1, considering the current and perceived future evolution of the transmission characteristics of the H5N1 virus. Pandemic planning had therefore assumed that influenza cases would be imported into Singapore shortly after it emerged in our region, and that the first wave would last about 6 weeks. In other words, prior preparation and exercises failed to fully anticipate a virus that was highly transmissible but caused low morbidity and mortality and had a different demand on health services; and a pandemic first wave lasting more than 6 weeks.

Further, under the high morbidity and mortality of an H5N1 scenario, linking the escalation of alert levels in the DORS to escalation of WHO Pandemic Alert Phases[13] seemed

reasonable, as this would allow us to progressively scale up control measures according to rising virus transmissibility and disease spread across human populations worldwide. However, after WHO revised its pandemic alert system to one based on transmissibility and geographic spread alone, escalation within the DORS had to be de-linked from WHO's pandemic alert phases because it was no longer meaningful.

Leaving behind the DORS framework midway through a pandemic was a tremendous challenge. Under the DORS, specific public health control measures were tied to colour-coded alert levels. People in the healthcare sector and other government agencies were familiar with the colour code system and its associated control measures, after intense pre-pandemic planning and exercises. The DORS was used as a "plug-and-play" operational tool, each colour code automatically triggering specific responses. A deep understanding of the rationale behind the specific measures was not the priority of such a tool. Thus, when it became evident during the H1N1-2009 pandemic that the control measures and colour codes in the previous DORS framework were not completely applicable to a virus like H1N1-2009, both MOH and its stakeholders had to reframe and relearn the context of public health control measures during the pandemic. Communicating a new set of public health measures under the new system was particularly difficult, producing some variability in the implementation of appropriate measures by different stakeholders.

Scenario planning

H1N1-2009 confirmed that being prepared was critical to implementing public health control measures rapidly and efficiently; it also highlighted the need to retain flexibility in control measures, especially so since reality can differ significantly from the original planning model.

Better scenario planning should guide future enhancements of the DORS framework and the PRRP, including planning for a range of potential known and unknown threats with varying degrees of severity. Tactical responses and appropriate control measures are required for each scenario, and planning should include actual processes, as only then will the effects of each scenario on manpower, resources and stockpile requirements be fully appreciated at different stakeholder levels. Based on our experience with H1N1-2009, appropriate control measures must not be hardwired.

Instead, it will be more expedient and effective for MOH and its stakeholders to be familiar with different suites of measures, which can be implemented in a modular fashion as needed. Secondly, when the need arises, stakeholders ought to have flexibility to assess and take appropriate measures locally. This will ensure that there is built-in flexibility within the DORS framework for a more nuanced and customised set of control measures to be adopted when responding to specific threats.

Lesson 2: Good Surveillance Systems and Access to Information is Critical for Evidence-Based Risk Management and Decision-making

To detect early signals indicative of infectious disease outbreaks of epidemic/pandemic importance, Singapore relies on routine local disease surveillance as well as the monitoring of reports scoured from different parts of the world.

External surveillance

Monitoring diverse sources of information from around the world is resource intensive and often challenging, not just because of the inherent difficulty of interpreting early "weak" signals, but also because skilled people are needed to interpret reports made in foreign languages. MOH's external surveillance systems did not play a significant role in providing early warning in H1N1-2009. Fortunately, however, Singapore was plugged into an informal global network of public health professionals and organisations. The interaction and information exchange with our counterparts proved valuable in keeping MOH abreast of the rapidly changing world situation.

Local surveillance

Local disease surveillance systems were critically important in informing us about the pandemic situation within our own borders, after H1N1-2009 arrived in Singapore. For example, surveillance among polyclinic attendances for ARI provided data on the proportion of ILI cases among ARI cases, plus the prevalence of H1N1-2009 amongst ILI cases. This information was of great value in monitoring the progression of the pandemic in the community, identifying the start of sustained community transmission, and guiding the step-down of containment measures such as contact tracing and the issuance of QOs. Local surveillance also guided the development of treatment policies, e.g. when to prescribe antiviral drugs to high-risk patients with ILI, without the need for confirmatory laboratory testing.

Evidence-based decision-making

Throughout the H1N1-2009 pandemic, it was extremely useful to have a core group of clinicians, comprising public health, infectious disease, microbiology and respiratory medicine specialists, meet regularly to review epidemiological and clinical information as it flowed from international and local sources. Frequent information reviews guided local decisions on the implementation of public health control measures. For example, data on healthcare utilisation patterns in other jurisdictions, in particular New York City and Victoria, Australia, helped the MOH to estimate the potential effect of H1N1-2009 on our own healthcare system. The local clinical and scientific community also contributed significantly to making

decisions in their respective areas of expertise, such as writing clinical management guidelines for particular risk groups, developing and validating diagnostic tests for H1N1-2009, and conducting genomic analysis to characterise the virus and detect possible mutations.

It was acknowledged, however, that good scientific evidence was lacking for a number of control measures. For instance, there were questions about the type of PPE needed in different healthcare settings (e.g. low-risk patient areas such as outpatient clinics, versus higher risk areas such as emergency departments and operating theatres). Such matters highlighted the need for real-time, targeted, public health "operational" research to determine the effectiveness of specific public health policies and control measures. To obtain such knowledge, we need to plan ahead so that the research manpower and resources may be activated during an outbreak. As public health "operational" research is contextually different from clinical research, and the issues tend to be very local, the research agenda needs to be driven by appropriate local public health groups and professionals.

In the absence of complete information, good risk management requires that control measures err on the side of caution. Singapore's alert level was raised to DORSCON Yellow on 28 April 2009 and subsequently to DORSCON Orange on 30 April 2009, even when there were no local cases. This action occurred because, in contrast to seasonal influenza, which predominantly affects the very old and very young, the initial reports on H1N1-2009 had shown an apparently high CFR in Mexico, a higher secondary attack rate than seasonal influenza, and a disproportionate number of young adults being affected.[6] Although H1N1-2009 later proved milder than feared, the initial strategy of raising the DORSCON levels proved valuable not just as a risk management strategy, but also as a public health risk communication strategy. The rapid escalation of the DORSON levels was widely reported in the local media, raising public awareness of the unfolding situation. The action bought time to make community-wide preparations to handle the first H1N1-2009 cases.

Lesson 3: Integrated Responses at the Systems Level are Essential for a Coherent Public Health Response

Integrated responses at the systems level, whether in the healthcare system or at the WOG level, and the clear demarcation of roles and responsibilities, are essential for a coherent response. Trust between stakeholders and a degree of system discipline are critical for success, and must be developed and built up in "peacetime".

Integrated healthcare system response

Healthcare in Singapore is delivered by a variety of providers in the public, private and voluntary welfare organisation (VWO) sectors. Public health control measures taken by each sector significantly influences the overall outcomes of control measures at the national level. The different parts of the whole healthcare system should ideally work as a coordinated, integrated system.

During an influenza pandemic, primary care doctors in the community (GPs and Family Physicians) will be at the frontline seeing patients with ILI. An effective primary care response can prevent the overloading of EDs in our RHs. As part of the PRRP, private GP clinics were roped in to serve as PPCs during the H1N1-2009 pandemic. PPCs functioned as part of the front line in national pandemic preparedness by treating patients with ILI during sustained community transmission, and serving as sites for vaccination, once the pandemic vaccine was available. They were supported with antiviral drugs, vaccines, and PPE from the national stockpile.

However, participation in the PPC scheme was entirely voluntary, and in a pandemic there may potentially be insufficient clinics to meet the needs of the population. In the H1N1-2009 pandemic, infrastructural constraints made it difficult for several primary care clinics to meet heightened infection control requirements in an outbreak setting, e.g. the need for triage of patients, and physical separation of febrile and non-febrile patients. And although the original plan was to link ILTCs with RHs through a regional-zoning system to reduce patient movement, the diverse service types and the different abilities of step-down care providers meant that all patient care needs could not be fully met within a zone.

The role of private hospitals had also not been fully developed in local pandemic planning. Although private hospitals were involved in pre-pandemic preparedness exercises, had the need arisen they might not have been able to share in the load of influenza cases with the public sector, because the numbers of isolation rooms in private hospitals were only sufficient for their own use.

During the H1N1-2009 pandemic, the response across the entire healthcare sector was coordinated by MOH through the MOH H1N1-2009 Taskforce. As the pandemic evolved, all sectors were quickly brought together to implement a national-level healthcare system response. However, Singapore's pandemic planning had been primarily sector-based, and largely focused on public sector institutions. Looking ahead, better planning and coordination between providers at different points along the care continuum (primary, secondary, step-down care), and exercising providers down to the level of response processes, will likely be important for an integrated system response, to ensure optimum patient care.

Integrated, whole-of-government response

Previous reviewers noted that the effective implementation

of public control measures in an outbreak requires a coordinated, cross-sector inter-ministerial collaboration.[12] Our H1N1-2009 experience underlined this fact. Non-health government sectors involved in mounting a WOG response to the H1N1-2009 pandemic included Education (control measures in schools), Border control (temperature screening, HDCs and HANs for travelers), Trade and Industry, and Foreign Affairs (to manage foreigner cases or contacts who were isolated or issued QOs).

The Homefront Crisis Management System allowed for effective coordination of control measures at the WOG level through the CMG structure. From our experience, crisis organisational structures and crisis appointments should ideally map as closely as possible to peacetime structures and appointments. This step will ensure that crisis appointment holders fully grasp the relevant ground issues in their domain that may affect the control measures during an actual crisis. Crisis organisational structures and appointments need to be assigned in peacetime and rehearsed. Exercises provide the opportunity for WOG stakeholders to deepen their understanding of crisis issues on the ground, clarify ownership of crisis policies and processes, and minimise overlap and "plug the gaps".

The familiarity and trust built up during exercises also allows for some degree of decentralisation, autonomy and faster decision-making during an actual crisis. However, while crisis organisational structures and appointments should be assigned and exercised, they must not be hard-wired. Again, flexibility is often needed to optimise public health responses, and it is important to be able to use the strengths and capabilities of available organisations and individuals.

Lesson 4: Creative Manpower Strategies are Needed to Build and Maintain Healthcare Surge Capacity in Peacetime

Demand for healthcare services will rise rapidly during a pandemic and may overwhelm existing resources in the healthcare system. Surge capacity is needed to respond to such potential demand. The ability to manage surge effectively is critical, since bottlenecks anywhere may have knock-on effects elsewhere, greatly amplifying its impact on the healthcare system. For example, during the containment phase locally, all cases of suspected H1N1-2009 were required to undergo confirmatory laboratory testing so that positive cases could be isolated. Bottlenecks in laboratory testing would have resulted in suspect cases being kept in isolation facilities of RHs while awaiting test results. A longer turnaround time for isolation beds, in turn, increases the waiting time for admission of new H1N1-2009 cases.

The reserve number of beds and other infrastructure that hospitals need for surge purposes has to be pre-determined through scenario planning and modelling. Cancellation of electives and non-urgent admissions can increase surge capacity and decrease the reserve beds needed. The trade-off is in hospital revenue and unmet elective demand, which might not be acceptable, depending on the duration and severity of the crisis. Further, a deep understanding of the crisis scenarios and the actual skill sets and manpower required is necessary for surge capacity planning.

Pre-pandemic, MOH had convened clinical expert committees to advise on the likely surge requirements. For example, isolation and intensive care capabilities were progressively expanded to improve isolation and intensive care surge capacities. These efforts were based on the predicted attack rate of an influenza pandemic, as well as peacetime operational demands. However, appropriate surge capacity planning also depends largely on the crisis scenario, e.g. a pandemic affecting mainly children would cause a surge in demand for paediatric and not adult intensive care units.

The most severe constraint facing surge capacity planning tends to be shortages in trained professionals rather than in infrastructure or equipment. "Hardware" can be ramped up quickly, whereas the training of health professionals typically requires years. Nevertheless, both are equally important, and surge capacity for infrastructure and equipment can reasonably grow in step with manpower surge capacity.

Although trained professionals often work longer hours during a crisis, manpower surge planning is not about staff working longer – such a reaction is not sustainable in a prolonged crisis. Creative manpower surge capacity could consist of a concurrent peacetime-and-crisis appointment system, e.g. hiring more clinicians for clinical research or postgraduate training in "peacetime"; and redeploying them for fulltime clinical work during a crisis. The clinicians will need to be involved in some clinical work in peacetime so they can function effectively during crises. To attain this goal without raising the manpower cost of providing care in peacetime, the existing clinical workload has to be shared amongst the expanded headcount, without having more established positions for peacetime clinical services.

Manpower surge strategies relying on concurrent peacetime-and-crisis appointments may require that during a crisis, "peacetime" duties be suspended and people redeployed for crisis work. However, this may not always be so, and H1N1-2009 was a case in point. Because the outbreak was milder than feared, the arguably fair expectation was for important "peacetime" work to continue. However, despite being milder, at the peak of the pandemic, community polyclinics were seeing about twice as many patients as usual. The EDs of RHs faced similar demands. Funding the added clinicians through crisis budgets and parking them in research, training and

quality, ensures that the additional persons can be readily redeployed during a crisis like H1N1-2009.

Lesson 5: Strategic, Timely and Clear Communications Should Occur within an Environment of Trust

Communication is central to coordinating an effective public health response in a pandemic. The 2003 SARS experience taught us the importance of the timely and transparent provision of updated information to ease anxiety, and to engage citizens successfully in measures to curb the spread of the disease.[12] The H1N1-2009 experience also showed the importance of a defined communications strategy. Its elements are knowing what, when and how to communicate, keeping information clear and concise, and finally maintaining the public trust.

Communications with Public

Early in the pandemic, proactive public messaging, education, and managing public expectations raised the general awareness of public health issues like personal hygiene and social responsibility, and probably averted panic over deaths occurring due to H1N1-2009. This strategy relied on prominent announcements on DORSCON elevations and frequent press releases and updates. MOH's strong working relationship with the media, built up over time, coupled with the high levels of public trust and confidence in the Singapore Government, were critical factors for effective public health communications.

For example, surveys conducted by the Ministry of Information, Communications and the Arts (MICA) and the Health Promotion Board (HPB) consistently indicated that citizens felt that they were adequately updated on the H1N1-2009 situation; the majority (>84%) considered that the information provided by the government and media coverage were "just right" (unpublished data, 2009 – Ministry of Information, Communications and the Arts, Singapore; and Health Promotion Board, Singapore). The attack rate of H1N1-2009 in Singapore as at end-September 2009 was estimated[14] to be 10%, a significantly lower rate than early estimations of 20% to 30%. It is postulated that the practice of good hygiene and socially responsible actions by the population may have contributed to the lower-than-expected attack rate.

As part of risk communication and management, it was decided during the pandemic that major policy changes, such as downgrades in DORSCON alert levels, or the shift from Containment to Mitigation, would be gradual over days or weeks, rather than an abrupt change. The gradation enabled the public to adapt to new measures steadily. The strategy also allowed MOH to selectively enforce more stringent control measures in response to the assessed risk of specific settings e.g. hospitals or the Asian Youth Games Village, even as other control measures were relaxed elsewhere. While this strategy fortified public communications during H1N1-2009, it might have produced confusion in hospitals and other healthcare settings (see discussion below).

Other challenges in communicating with the public during H1N1-2009 included capacity overload of the MOH website and hotlines, which experienced downtimes when overwhelmed by heavy traffic. MOH hotline operators also had to ensure that they did not give ambiguous or inconsistent advice to callers as the pandemic evolved. Public education messages also had to be translated into 4 major languages, and these had to be technically accurate, reader friendly, and culturally sensitive. Although the H1N1-2009 pandemic provided an opportunity for MOH to experiment with new media tools such as blogs and mobile text messaging, our experience showed that such tools appeared to have a limited reach. Traditional print, television and radio remained the most effective communication channels in disseminating pandemic information. Nevertheless, new media may have a greater role in crisis communications in the future.

Communications within the Healthcare Sector

As the bulk of public health control measures occurred in healthcare settings, communications within the healthcare sector posed one of the biggest challenges during the H1N1-2009 pandemic. The rapidly evolving situation required communications to be fast and effective. All members of the healthcare family, whether public or private, required regular and timely updates to respond as an integrated system. Feedback channels were also needed so that healthcare groups could update MOH on the ground situation.

Many modes of communication were used. For example, face-to-face meetings, email and snail-mail circulars and directives, mobile text messages, and the Internet were concurrently deployed. Similarly, multiple staff-level channels of communication were maintained to speed up the information flow. For instance, the MOH Operations Centre liaised directly with the operations departments in RHs, while the Director of Medical Services would liaise directly with the senior clinical leaders of hospitals. The difficulty lay in ensuring that messages and information were consistent, and viewed as official. There was also a potential for messages to be unclear or incomplete, which would lead to confusion on the ground and a variable implementation of control measures.

The decision to make both the downgrades in DORSCON alert levels and the shift from Containment to Mitigation gradual transitions may have worked well in conveying risks to the public. However, this might have confused healthcare professionals, who might have expected specifically timed changes in alert levels and clearly prescribed measures. Communication strategies for the healthcare sector should therefore take into account the possible difference in expectations, and explain clearly the rationale for the

decision. The measures to be taken during transitions should be as simple as possible, to avoid misunderstanding.

Public perception of the quality and credibility of decisions behind control measures and policies was important in determining buy-in from healthcare sector stakeholders and professionals, in particular for policies that were difficult or burdensome to implement. Having a sound and rational scientific and epidemiological basis for control measures is important. Clearly, trust between members of the healthcare family greatly improves communication, but trust cannot grow overnight when a crisis is underway. Regular engagement during peacetime can forge a stronger communication substrate to support the coordinated implementation of public health control measures during a crisis.

Conclusion

Singapore's ability to respond to public health threats has improved significantly, because of its experience in managing the SARS epidemic, and its WOG approach in preparing for a pandemic over the past 5 years. The coordinated and collaborative efforts of government agencies, the healthcare sector, businesses, and members of the public were essential in ensuring that the measures to control the spread of H1N1-2009 were implemented efficiently and effectively so as to minimise morbidity and mortality from the disease and its impact on the society and economy. The 5 key lessons gleaned from managing the H1N1-2009 pandemic guide efforts to further strengthen Singapore's capacity to respond to future major disease outbreaks.

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REFERENCES

1. World Health Organization. Statement to the press by WHO Director-General Dr Margaret Chan, 11 June 2009. Available at: http://www.who.int/mediacentre/news/statements/2009/h1n1_pandemic_phase6_20090611/en/index.html. Accessed 10 October 2009.
2. Ministry of Health, Singapore. Outbreak of pandemic influenza A (H1N1-2009) in Singapore, May-September 2009. Epidemiol News Bull 2009;35:39-48.
3. Cutter J. Preparing for an influenza pandemic in Singapore. Ann Acad Med Singapore 2008;37:497-503.
4. World Health Organization. Changes in reporting requirements for pandemic (H1N1) 2009 virus infection, 16 July 2009. Available at: http://www.who.int/csr/disease/swineflu/notes/h1n1_surveillance_20090710/en/index.html. Accessed 10 October 2009.
5. United States Centers for Disease Control and Prevention. Swine influenza A (H1N1) infection in two children - Southern California. March-April 2009. MMWR 2009;58:400-2.
6. World Health Organization. Technical Consultation on the severity of disease caused by the new influenza A (H1N1) virus infection, 5 May 2009. Available at: http://www.who.int/csr/resources/publications/swineflu/Report_20_05MayTeleconferencex.pdf. Accessed 10 October 2009.
7. World Health Organization. Assessing the severity of an influenza pandemic, 11 May 2009. Available at: http://www.who.int/csr/disease/swineflu/assess/disease_swineflu_assess_20090511/en/index.html Accessed 10 October 2009.
8. United States Centers for Disease Control and Prevention. Outbreak of Swine-Origin Influenza A (H1N1) Virus Infection — Mexico, March-April 2009. MMWR Dispatch 2009;58. Available at: http://www.cdc.gov/mmwr/pdf/wk/mm58d0430a2.pdf. Accessed 9 December 2009.
9. United States Centers for Disease Control and Prevention. Swine-Origin Influenza A (H1N1) Virus Infections in a School — New York City, April 2009. MMWR Dispatch 2009;58:1-3. Available at: http://www.cdc.gov/mmwr/preview/mmwrhtml/mm58d0430a1.htm. Accessed 9 December 2009.
10. James L, Shindo N, Cutter J, Ma S, Chew SK. Public health measures implemented during the SARS outbreak in Singapore, 2003. Public Health 2006;120:20-6.
11. Fraser C, Donnelly CA, Cauchemez S, Hanage WP, Van Kerkhove MD, Hollingsworth TD, et al. Pandemic potential of a strain of influenza A(H1N1): early findings. Science 2009;324:1557-61.
12. Tan CC. SARS in Singapore – key lessons from an epidemic. Ann Acad Med Singapore 2006;35:345-9.
13. World Health Organization. WHO Pandemic Alert Levels. Available at: http://www.who.int/csr/disease/avian_influenza/phase/en/index.html. Accessed 14 October 2009.
14. Cutter JL, Ang LW, Lai FYL, Subramony H, Ma S, James L. Outbreak of pandemic influenza A (H1N1-2009) in Singapore, May to September 2009. Ann Acad Med Singapore 2010;39:273-82.