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A large outbreak of influenza A and B on a cruise ship causing widespread morbidity

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SUMMARY

In September 2000 an outbreak of influenza-like illness was reported on a cruise ship sailing between Sydney and Noumea with over 1100 passengers and 400 crew on board. Laboratory testing of passengers and crew indicated that both influenza A and B had been circulating on the ship. The cruise coincided with the peak influenza period in Sydney. Morbidity was high with 40 passengers hospitalized, two of whom died. A questionnaire was sent to passengers 3 weeks after the cruise and 836 of 1119 (75%) responded. A total of 310 passengers (37%) reported suffering from an influenza-like illness (defined as cough, fever, myalgia and weakness) and 528 (63%) had seen a doctor for illness related to the cruise. One-third of passengers reported receipt of influenza vaccination in 2000; however neither their rates of influenza-like illness nor hospitalization were significantly different from those in unvaccinated passengers. A case–control study also found no significant protective effect of influenza vaccination. With the increasing popularity of cruise vacations, such outbreaks are likely to affect increasing numbers of people. Whilst influenza vaccination of passengers and crew may afford some protection, uptake and effectiveness may not be sufficient to prevent outbreaks. Surveillance systems and early intervention measures, such as antiviral therapies, should be considered to detect and control such outbreaks.

INTRODUCTION

Cruise ship holidays are increasing in popularity worldwide with 10 million people cruising in 2000 [1]. With 49 new ships commissioned there is an anticipated 52% increase in worldwide capacity over the next 5 years [2]. Because of the relative ease with which communicable diseases can spread when introduced into confined, crowded environments, more frequent outbreaks of diseases such as influenza may accompany the expected increase in cruise holidays.

Influenza outbreaks have been previously documented on cruise ships in both hemispheres and have been reported when influenza is not in seasonal circulation in the general community [3–5]. The Centers for Disease Control and Prevention have issued

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guidelines to prevent and control influenza outbreaks on ships that include vaccination of crew and passengers, surveillance systems and response protocols [6].

Current Australian guidelines recommend influenza vaccination of at risk groups including those aged 65 years and over for whom annual vaccine is provided free [7]. Current uptake in NSW in those 65 years and over is approx. 74% [8]. In addition, the guidelines recommend that influenza vaccination should be considered by all persons travelling in large tourist groups.

In early September 2000, we were notified of the disembarkation and hospitalization in Noumea of five Australian passengers with respiratory illness from a cruise ship. The ship had sailed from Sydney to Noumea for a 2 week cruise in late August. The cruise carried over 1100 passengers, mostly Australian and New Zealand residents, and 400 crew. A diagnosis of Legionnaires' disease was reported by the doctors treating two of the passengers who disembarked in Noumea, on the basis of positive sputum direct fluorescent antigen (DFA) test results for legionella. Reports from the ship's doctor indicated that at least 38 other passengers had sought medical attention during the cruise for influenza-like illness. To detect the extent and cause of the outbreak and control any ongoing public health risk associated with the ship, we sent an investigation team onto the ship, while it was en route back to Sydney on day 13 of the cruise. Here we present the findings of our investigation.

METHODS

Descriptive epidemiology

The cruise ship had a five-bed hospital and medical clinic staffed by two doctors and nursing staff. On day 13 of the cruise we reviewed the clinic log and identified all passengers who had presented at the clinic with respiratory tract illness during the cruise. We defined suspected cases as patients with symptoms of an influenza-like illness plus a documented fever of $\geqslant 38$ °C and/or a diagnosis of pneumonia made by the ship's doctors. We asked suspected cases to complete a questionnaire and provide specimens of blood, urine and throat/nose swabs for serology, *Legionella pneumophila* urinary antigen and viral testing. The questionnaire included information on demographics, environmental exposures and activities before and during the cruise, symptoms, previous influenza vaccination, pre-existing medical problems, medications and smoking. Eleven passengers, who had presented to the clinic with onset of influenza symptoms within 48 h and were locatable by staff of the ship's clinic, were requested to provide a nose or throat swab for rapid influenza virus testing.

Relevant information on passengers hospitalized in Noumea was obtained by interview with close relatives or with the patients subsequently on their return to Australia. Sputum, urine and blood specimens from these passengers were obtained and tested for evidence of *Legionella pneumophila* infection.

To estimate the extent of unreported illness and obtain control passengers, we generated 100 random numbers using SAS software and matched these numbers to the passenger list. Ship staff attempted to locate these 100 randomly selected passengers and invited them to attend the ship's clinic to assist in the investigation. Using this method we recruited 55 control passengers who were asked to complete a questionnaire and provide specimens (as above). These 55 passengers were recruited in the time available – some passengers could not be located and the number of refusals is unknown.

Diagnostic tests for crewmembers were ordered independently by the ship's doctor only as clinically indicated.

Case–control study

To identify independent risk factors for illness, we conducted a case–control study defining cases as suspected cases (see above) who had laboratory-confirmed influenza infection. We defined controls as passengers among the 55 sampled who had no laboratory evidence or symptoms of influenza. We asked those passengers who provided acute specimens to provide convalescent sera 4–6 weeks later, by means of a mailed request and referral form.

Cohort study

To determine the extent of disease and morbidity, we wrote to passengers 3 weeks after the cruise, asking them to complete a one-page questionnaire regarding illness experienced during and after the cruise. The questionnaire asked passengers about symptoms, influenza vaccination history (month and year), doctor visits, hospitalization, cabin location, symptom onset date and demographic details. Because the cohort questionnaire focussed upon illness occurrence rather than risk factors, it did not collect as much risk factor information as the case–control questionnaire did

(e.g. smoking status and previous medical problems not collected). In addition, with the passenger's consent, we contacted the doctors of those who had been hospitalized. We also contacted the doctors of a random sample of passengers, who had provided doctor contact details and consent, to confirm self-reported influenza vaccination status.

The cohort analysis was based on symptoms, rather than laboratory tests. In this analysis, we defined a case of 'possible influenza' as a passenger who reported fever and either cough or sore throat (CDC surveillance definition of influenza-like illness for triggering cruise ship alerts [6]), and a case of 'probable influenza' as a passenger who reported cough, myalgia, fever and weakness (consistent with the definition used for sentinel surveillance in NSW).

Environmental methods

We initially attempted to identify high-risk sources for Legionnaires disease on the ship. Two potential sources of legionella exposure identified were the air-conditioning system and showerheads (although both sources were considered to pose a relatively low risk). We assessed both potential sources, focusing on air-conditioning stations supplying, and showerheads within, cabins of symptomatic passengers. Water samples and swabs were collected for microbiological testing from 31 sites aboard the ship on day 13 of the cruise and from 10 cooling towers adjacent to the embarkation point in Sydney. Specimens were analysed, using standard methods, at the Legionella Reference Laboratory, ICPMR, Lidcombe, Sydney.

Laboratory methods

Specimen collection

Nose and throat swabs were collected from each subject using plain cotton swabs and placed together in viral transport medium and stored at 4 °C until delivered to the laboratory. Rapid antigen tests (Quickvue™, Quidel, San Diego, CA, USA) for influenza virus were performed according to the manufacturer's instructions.

L. pneumophila *serogroup 1 urinary antigen*

Urine specimens were tested, according to the manufacturer's instructions, using the Binax Legionella Urinary Antigen enzyme immunoassay (Binax Inc., Portland, Maine 04103) [9].

Direct fluorescent antigen (DFA) test for legionella *in sputum*

Concentrated sputum smears were heat- and formalin-fixed on Teflon-coated slides and stained with antibody–fluorescein conjugates: *L. pneumophila* (Monofluo™, Genetic Systems, Redmond, WA 98052), *L. pneumophila* groups 1–6, *Legionella* spp. b–j and *Legionella* spp. b–p (MarDX Diagnostics, Carlsbad, CA, USA). They were examined by fluorescence microscopy and recorded as positive if organisms with the appearance of legionellae were seen [10].

Legionella *serum indirect fluorescence antibody tests (IFAT)*

Convalescent sera were tested at a dilution of 1 in 128 using polyvalent *Legionella pneumophila* serogroups 1–6 and monovalent *L. longbeachae* serogroup 1 antigens (prepared in-house, using ATCC standard strains) [10]. Sera giving positive results were tested against individual antigens up to a titre of 1024. When both were available, acute and convalescent sera were tested in parallel.

Laboratory confirmed legionellosis was defined by positive results in any of the following tests: *L. pneumophila* serogroup 1 urinary antigen; legionella DFA in sputum; or a fourfold or greater increase in antibody titre (seroconversion) in paired sera or a high titre (>512) against a single legionella antigen, in a single serum specimen.

Viral DFA and culture

Smears of deposits from nose and throat swabs were acetone-fixed and stained with fluorescein-conjugated monoclonal antibodies against influenza A and B haemagglutinin and nucleoprotein (Chemicon International, Temecula, CA, USA) directly, or after inoculation into shell-vial monolayers of MDCK cells, depending on the quality of specimens. The latter were examined for cytopathic effects (CPE), after 72 h incubation and stained by DFA for influenza viruses; positive vials were passaged in MCDK cells. There was insufficient of most specimens to perform DFA for other respiratory viruses, but all specimens were inoculated into tube cultures and observed for CPE for 3 weeks.

Typing and sequencing of influenza A virus isolate

The RNA sequence of a single influenza A virus isolate was determined in our laboratory by RT–PCR using

specific primers targeting the haemagglutinin (HA) genes of H3N2 and H1N1 [11]. The sequence was compared to existing influenza A virus sequences in the Influenza Database (Los Alamos National Laboratory) using BLASTN [12]. A single influenza A virus isolate recovered from the subjects in this study was serotyped at the WHO influenza collaborating laboratory, Melbourne, by haemagglutination inhibition [13].

Influenza A and B antibody tests

Sera were tested for antibodies against influenza A and B viruses by complement fixation using standard methods [14]. Laboratory-confirmed influenza cases were defined by positive tests as follows: influenza A or B virus antigen detected by IF or rapid antigen test; influenza virus A or B isolated; or a high serum antibody titre ($\geqslant 64$) against either influenza A or B viruses detected in a single specimen and/or seroconversion (fourfold or greater increase in antibody titre) in paired sera.

Statistical analysis

Statistical analyses were performed using Epi Info and SAS v6.12. A Yates corrected P value of $<0{\cdot}05$ was defined as statistically significant. To analyse risk factors in the case–control study, a multivariable logistic regression analysis was performed, using a backward method to eliminate non-significant, non-confounding variables. Age could not be modelled as a continuous variable as it did not meet linearity assumptions. This was checked by fitting age as a categorical variable and plotting the logit (P) for each group. Thus age was grouped into four quartiles.

RESULTS

Descriptive epidemiology

Of the 1159 passengers on the cruise, 366 (32%) sought medical attention at the ship's clinic between days 1 and 13. Of these, 203 (55%), or 18% of all passengers, presented with respiratory tract illness (Table 1). Five patients had a primary diagnosis of pneumonia. Of the 203 passengers presenting to the ship's clinic with respiratory tract illness, 60 were identified as suspected cases on medical record review by the ship's doctor. Of these, 56 completed questionnaires, 3 refused and 1 could not be located. Of 11 passengers identified aboard the ship with a recent onset of influenza symptoms, 2 had positive rapid influenza results.

Table 1. *Characteristics and experiences of cruise passengers* n = *1159*

	Number (%)
Characteristic/experience	
Consulted cruise doctor	366 (32)
Respiratory infection diagnosed	203 (18)
Tested for influenza* by	
Rapid test kit	11 (1)
Positive	2/11 (18)
Swab test	62 (5)
Positive	2/62 (3)
Acute serology	123 (11)
Influenza A positive	42/123 (34)
Influenza B positive	2/123 (2)
Convalescent serology	58 (5)
Influenza A seroconversion	11/58 (19)
Influenza B seroconversion	3/58 (5)
Completed follow up questionnaire	836 (72)
Age (years)	
Range, mean	2–90, 47 years
<25	133 (16)
25–39	125 (15)
40–64	410 (49)
65+	168 (20)
Sex	
Male	371 (44)
Female	465 (56)
Symptoms	
Cough	709 (85)
Sore throat	618 (74)
Phlegm	581 (70)
Headache	554 (66)
Weakness	505 (60)
Fever	472 (57)
Anorexia	444 (53)
Myalgia	413 (49)
None of the above symptoms	68 (8)
Possible influenza†	464 (56)
Probable influenza‡	310 (37)
Saw doctor post cruise	528 (63)
Hospitalized	40 (3·5)
Laboratory-confirmed influenza	8/40 (20)
Pneumonia	26/40 (65)
Exacerbation of heart/lung disease	10/40 (25)
Deaths	2/40 (5)

* Table inclusive of all reported laboratory results including those from outside of shipboard study.
† Fever and either cough or sore throat.
‡ Cough, fever, myalgia and weakness.

Laboratory results

Of 104 acute sera collected from suspected cases and randomly selected passengers, 31 had influenza A, and 2 had influenza B complement fixing antibody titres

of 64 or higher. Convalescent sera were provided by 59 passengers among whom there were 8 influenza A and 3 influenza B seroconversions. Influenza B virus was demonstrated by DFA (see below) in the nose/throat swab of one passenger whose paired sera showed seroconversion for influenza A.

Viral DFA showed that 11 of 30 nose/throat swab specimens contained too few epithelial cells to give a reliable result. An influenza virus was detected in three specimens: influenza B virus antigen was detected by DFA but not cultured from one passenger with influenza-like illness and from one crewmember; influenza A virus was cultured from one randomly selected passenger. No other respiratory viruses were isolated from tube cultures.

The influenza A virus isolate was identified as influenza A/Moscow10/99-like, a variant of the influenza A/Sydney/5/97 strain (against which recipients should be protected by a similar strain in the year 2000 vaccine). DNA (1165 base pairs) was amplified by HA primers targeting H3 but not H1. Sequence analysis showed the closest similarity (99·4%) to the HA of Moscow/10/99-like H3N2 in the Influenza Database [15] and was also similar to that of other H3N2 influenza strains isolated in our laboratory at about the same time.

Thus there were 40 cases of laboratory-confirmed influenza A (31 with high antibody titres in acute sera, 8 seroconversions and 1 positive culture) and 7 influenza B cases (2 high antibody levels in acute sera, 3 seroconversions and 2 positive DFA tests). No tests for recent legionellosis were positive, including those from passengers who had been hospitalized in Noumea. All 113 urine samples tested were negative for *L. pneumophila* serogroup 1 urinary antigen.

Results from other laboratories

Thirteen additional laboratory diagnoses of influenza A infection were reported to NSW Health amongst passengers from the cruise who were tested by their own doctors, independently of our investigation (including four in hospitalized patients, see below). Eleven were based on single high antibody titres and two on seroconversion between paired sera. The total number of passengers tested independently is unknown.

Environmental findings

The engineering staff maintained records of all cleaning and sanitizing carried out on the ship. The showerheads were regularly sanitized and the ship's closed air-conditioning system was maintained in accordance with the manufacturer's instructions. The system was a low risk source of legionella bacteria. In addition, disinfection had been undertaken before our arrival on the ship. No other potential sources of legionella (such as spas, decorative fountains, potting mix or food humidifiers) were present on the ship and no *Legionella* species were isolated from any environmental samples collected.

Case–control study

We identified 31 cases and 34 controls. Of the 55 randomly selected passengers, 13 were excluded as controls with laboratory-confirmed symptomatic influenza and 8 were excluded with symptoms only. All 31 cases provided acute sera, 19 provided convalescent sera and 14 had viral throat/nose swabs taken. Of controls, 25 provided acute, and 12 convalescent, sera and 23 provided swabs.

Although cases tended to be older than controls (mean age 49·9 *vs.* 41·3 years), this was not statistically significant (*t* test; $P=0{\cdot}10$). Sex distribution was not significantly different ($P=0{\cdot}84$).

In univariate analyses, there was no association found between influenza infection and either sex, smoking, influenza vaccination or regular medication use. There was an association between influenza infection and both age group, those aged 40–64 years were most likely to have influenza ($P=0{\cdot}04$), and having previous medical problems ($P=0{\cdot}01$) (Table 2). In a multivariable logistic regression analysis, only previous medical problems was a significant independent risk factor for influenza [OR 8·0 (1·3–61); $P=0{\cdot}01$]. As this was the only significant risk factor obtained using a backward elimination method, other variables of *a priori* interest are presented, adjusted for medical problems only, in Table 2.

Cohort study

Address details were available for 1119 of 1159 (96·5%) passengers, of whom 836 (75%) returned the follow-up questionnaire. The most common symptom reported during or after the cruise was cough, which was reported by 85% of passengers (Table 1). Only 68 passengers (8%) were symptom free. Most symptomatic passengers [407 of 734 (55%) who reported an onset date] became ill during the first week of September (Fig. 1). Symptoms of possible and

Table 2. *Risk factors for laboratory confirmed influenza virus infection from case–control study: univariate analysis and variables of interest adjusted for a history of previous medical problems**

			Univariate		Adjusted for medical problems*	
Risk-factor	Case ($n=31$)	Control ($n=34$)	OR (95% CI)	*P* value	OR (95% CI)	*P* value
Previous medical problems	15 (50%) (−1)†	2 (11%) (−16)†	8·0 (1·3–61)	0·01	8·0 (1·3–61)	0·01
Influenza vaccination	12 (39%)	4 (18%) (−12)†	2·8 (0·7–13)	0·39	0·8 (0·2–4·3)	0·84
Smoking	3 (10%)	3 (17%) (−16)†	0·5 (0·07–4·0)	0·66	1·1 (0·2–6·4)	0·93
Age group (years)						
<25	5 (16%)	10 (29%)	Reference (1·0)	0·04	Reference (1·0)	0·16
25–39	3 (10%)	10 (29%)	0·6 (0·1–3·2)		0·4 (0·05–3·0)	
40–64	14 (45%)	7 (21%)	4·0 (0·98–16)		2·3 (0·3–17)	
65+	9 (29%)	7 (21%)	2·6 (0·6–11)		0·4 (0·04–3·8)	
Regular medication use	17 (59%) (−2)†	6 (35%) (−17)†	2·6 (0·6–11)	0·13	1·3 (0·3–5·5)	0·76
Sex (female)	19 (61%)	20 (59%)	1·1 (0·4–3·4)	0·84	1·5 (0·4–5·7)	0·55

* Only variable that was retained as significant in a multivariable logistic regression analysis using a backwards elimination method.

† Indicates number of missing patients.

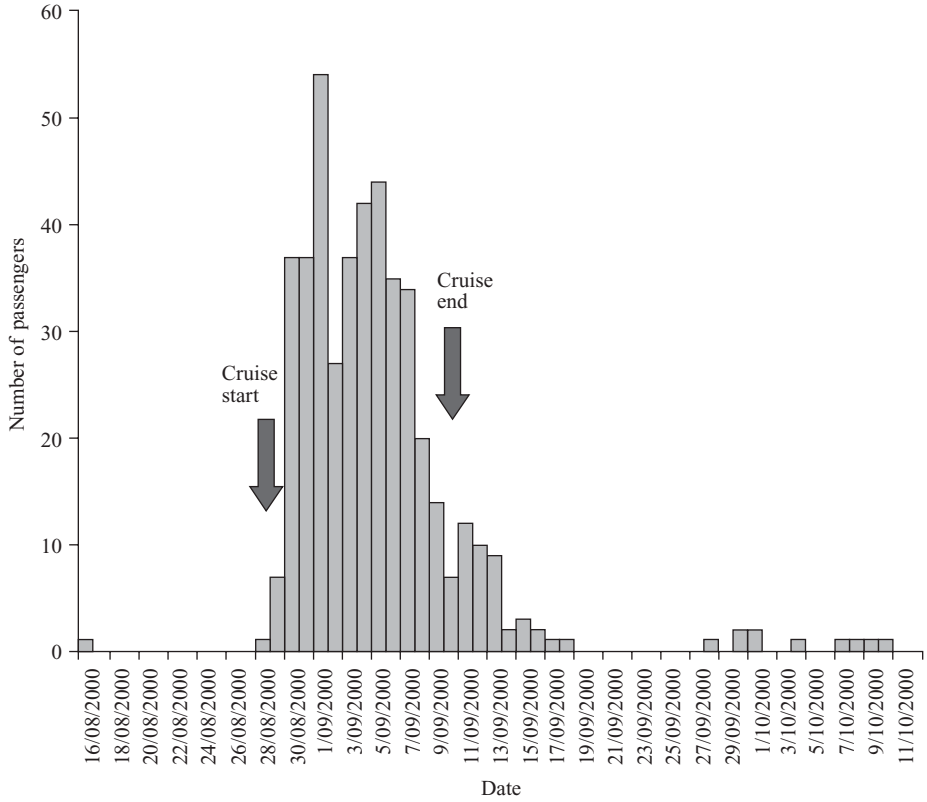

Fig. 1. Symptom onset date for passengers reporting possible influenza infection (fever and cough or sore throat) on follow-up questionnaire.

Table 3. *Risk factors for self report of probable influenza (cough, fever, myalgia and weakness): univariate analysis of passenger cohort* (n = *836*)

Risk factor	Probable influenza ($n = 310$)	No probable influenza ($n = 526$)	RR (95% CI)	*P* value
Influenza vaccination	97 (31%)	158 (30%)	1·03 (0·9–1·2)	0·83
Age group (years)				
<25	43 (14%)	90 (17%)	0·8 (0·6–1·1)	0·18
25–39	50 (16%)	75 (14%)	1·0 (0·8–1·3)	0·97
40–64	161 (52%)	249 (47%)	Reference	—
65+	56 (18%)	112 (21%)	0·9 (0·7–1·1)	0·21
Sex (female)	182 (59%)	283 (54%)	1·1 (0·95–1·1)	0·19

probable influenza were reported by 464 (56%) and 310 passengers (37%), respectively.

Almost a third of passengers (255/836 = 31%) reported receiving an influenza vaccination in 2000. Of these, all but five (0·6%) had been vaccinated at least 2 weeks prior to the cruise. Peak time for vaccination was in March/April. Vaccination in 2000 was verified in 20 of 21 sampled passengers who had provided doctor contact details. For the remaining passenger the doctor's records did not document vaccination in 2000.

In a univariate analysis, there was no association between probable influenza and gender, age or influenza vaccination in 2000 (Table 3). This was not affected by adjusting for age group (RR influenza vaccination adjusted for age group 1·1; 0·9–1·4). Given this finding, and the limited number of predictor variables available (all of which were non-significant in univariate analysis), a formal multivariable analysis was not undertaken. An alternate analysis, censoring passengers reporting lesser symptomatology (i.e. probable influenza cases compared with entirely symptom free passengers), did not change the results.

Medical visits and hospitalization

Of the 836 responding passengers, 528 (63%) reported that they had seen a doctor for illness that they related to the cruise. Through either self-report or hospital/medical records, we identified 40 passengers who were admitted to hospital with a respiratory illness with onset during or in the 2 weeks following the cruise (3·5% of passengers). Their ages ranged from 19 to 82 years (median 74). Additional clinical information was available for 35 of the hospitalized passengers either from their doctors, laboratory results or self-report.

Most of those hospitalized had received influenza vaccination in 2000 [26/38 (68%), unknown for 2 patients]. Of 27 passengers aged 65 or over with reported vaccination status, 81% were vaccinated. In the cohort, influenza vaccination did not protect passengers against hospitalization. Amongst those aged 65 years and over, the relative risk of hospitalization for those vaccinated (18/124 = 14·5% hospitalized) compared to those unvaccinated (5/37 = 13·5% hospitalized) was 1·1 (0·4–2·7; $P = 0·91$).

Of the 40 hospitalized patients, 8 of the 21 tested had laboratory-confirmed influenza and 26 had pneumonia. Other investigations showed only *Haemophilus influenzae* isolated from 5 of 16 patients whose sputum was cultured. No other infections were identified by serological testing. The discharge diagnosis of 10 patients highlighted complications of pre-existing heart/lung disease exacerbated by respiratory infection. Two hospitalized men, aged 61 and 76 years, died from cardio-respiratory complications. The younger patient was not tested for influenza and the older patient had negative viral cultures of an endotracheal aspirate and negative acute serology for influenza. Neither had a *post mortem* examination. The younger man was unvaccinated and the vaccination status of the other man is unknown.

DISCUSSION

Our investigation indicates that this was a large outbreak of influenza that caused considerable morbidity; at least one-third of passengers were unwell and many were hospitalized. Cruise ships often have large numbers of passengers in older age groups, who may be more vulnerable to infections, and who may in fact choose to take cruises for 'health reasons'. However, on this occasion the passenger list did not have an excessive number of individuals of extreme age. There was evidence of both influenza A and B viruses

circulating on the ship, but laboratory results indicated that influenza A virus caused the greater burden of illness. Crew-members were also affected, although to a lesser extent; 37 of the 400 crew (9 %) presented to the clinic during the cruise, with a respiratory tract illness. We could not confirm the presence of Legionnaires' disease, which is a notifiable disease in Australia. All tests were negative and there were no notifications of the disease among cruise passengers. To our knowledge, this is the first report of a cruise ship outbreak implicating both influenza A and B viruses.

The cruise coincided with the influenza season in Sydney in 2000, with September the peak month for the circulation of influenza as detected by routine surveillance systems [16]. Some passengers reported onset of symptoms on or before the first day of the cruise. It is likely that they introduced the virus onto the ship and that it was then rapidly disseminated to others.

Outbreak studies have limitations in their ability to assess vaccine efficacy without bias (such as that possibly introduced by self report and incomplete follow-up) and with sufficient power. Previous studies demonstrate that influenza vaccine effectiveness varies greatly, dependent upon the age and immunocompetence of the recipients and upon the match between the vaccine strains and circulating strains [17–21]. Assuming that the isolated influenza A strain was the predominant cause of influenza on the ship, our data suggest that the vaccine did not protect those on board who had received it. This apparent lack of efficacy may have been due to undetected influenza strains or other viruses, such as respiratory syncytial virus, causing illness compatible with our definition of influenza. The vaccine may have had low efficacy in the elderly targeted population (although vaccination of this population has been shown to be effective in other studies [22,23]). We found that the peak time for vaccination had been 4–5 months before the cruise and it is possible that vaccination induced immunity was waning by the time of the outbreak. A history of vaccination may also correspond with underlying medical problems, explaining the finding that amongst those with probable influenza in the cohort, those vaccinated were more likely to be hospitalized.

We believe that the use of antibody titres to diagnose influenza in the context of an acute clinically compatible illness is appropriate, although we recognize the possibility that high titres could theoretically be observed in persons recently vaccinated. Most serologically confirmed cases occurred in those who had not been vaccinated (19 of the 31 cases were unvaccinated).

The case–control study determined that only a history of pre-existing medical problems was a significant predictor of laboratory-confirmed influenza. This may be due to the methodology used to recruit cases, all of whom had attended the private medical clinic on the ship. Passengers with pre-existing medical problems may be more likely to use medical services when unwell and this may have caused selection bias. In addition, incomplete laboratory testing in all subjects, the small number of healthy controls recruited and the fact that controls were more likely to leave unanswered questions about risk factors, limited the power of the case–control study to evaluate risk factors.

The investigation highlighted difficulties with surveillance of respiratory illness on cruise ships. Despite many presentations with consistent illnesses, definitive diagnosis was difficult. It is likely that the two sputum DFA tests that were positive for legionella antigen were false positive results. *Legionella* species were not isolated from these specimens, no other evidence of recent legionellosis was found in any other passengers and no environmental source of legionellae was identified. Influenza rapid test kits and legionella urinary antigen screening were of assistance in this investigation as early indicators of the likely cause. The availability of point of care testing for influenza or other pathogens (despite their modest sensitivity) means that such assays could be used in similar future situations, thus allowing appropriate cohorting or rational use of antivirals and antibiotics.

Influenza vaccination is not a panacea; uptake, effectiveness and strain matching are potential variables. Therefore, whilst vaccination is a useful prevention strategy, effective surveillance and early control measures, such as rapid diagnosis, isolation protocols and antiviral therapy may be required. Such actions have been instigated in outbreaks, where back to back cruises were being undertaken, with apparent efficacy [24]. No antivirals were used during or after this outbreak. The ship was cleaned with chemical disinfectants in port, and enhanced surveillance systems detected no illness in those who subsequently utilized the ship as a floating hotel during the Olympic games.

In conclusion, we recommend that cruise ship passengers are made aware of the potential for influenza outbreaks and are appropriately vaccinated; that rapid testing facilities for influenza be available aboard ships; and that ships report suspected outbreaks triggered by routine surveillance rapidly so that public health agencies can assist, utilizing antiviral treatments where appropriate.

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