ORIGINAL RESEARCH

The Attack Rate of H1N1 in Various Berthing Configurations On Board an Aircraft Carrier

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ABSTRACT

Objective: We compared attack rates for novel H1N1 influenza A (H1N1) among various groups aboard an aircraft carrier as influenced by characteristics of their living arrangements.

Methods: During an outbreak of H1N1 on board the USS George Washington (GW), group affiliation (department or squadron membership) data were obtained on all patients who were placed in respiratory isolation based on their diagnosis with presumptive H1N1. Because berthing spaces are assigned by department and various characteristics of each department's berthing spaces are known, analysis of attack rates in comparison to these characteristics was possible. Attack rates were compared with the square feet of living space per sailor, occupancy rate of the berthing areas, and size of the berthing areas. These results were further correlated with the mission of the various departments or squadrons.

Results: The average attack rate was 3%, with the highest rates occurring in departments or squadrons whose mission required ongoing contact with civilian populations ashore. The attack rate among officers was 2.04 versus 3.19 among enlisted personnel; this difference was not significant ($P = .21$). The attack rate for women was 1.90 versus 3.09 for men, which was significant ($P = .05$). Although attack rates varied considerably based on organizational mission, no correlation was found between attack rate and square feet of living space per person or occupancy rate or size of berthing spaces.

Conclusions: The attack rate of the outbreak overall was limited to 3%. Smaller and more crowded berthing configurations did not contribute to higher attack rates, suggesting that transmission occurs most frequently elsewhere while engaged in other activities such as working, eating, or relaxing. Further studies are necessary to filter out potential correlations or variables not identified in this study, such as the difference between the number of men and women isolated. (*Disaster Med Public Health Preparedness.* 2013;7:131-135)

Key Words: H1N1, shipboard influenza, pandemic, isolation, outbreak, naval vessel, aircraft carrier, attack rate, berthing space

The 1918 influenza epidemic was a global disaster, resulting in approximately 50 million deaths worldwide. Its fast and deadly spread was aggravated by the logistics of World War I. In the United States, the disease was first observed in Fort Riley, Kansas. It ravaged many of the US Army camps, killing almost 30 000 soldiers even before they left the country and affecting more than a quarter of the entire Army before it ended.[1] Some have speculated that the epidemic helped tip the scales in favor of the Allied forces in the final days of World War I, with higher morbidity and mortality noted in Austria and Germany versus Britain and France.[2]

Today the potential for disease exposure and its operational impact is even more important. Indeed, the factors that were responsible for the global spread of the H1N1 virus in 1918 are even more prominent today. The most sophisticated military hardware is worthless if the soldiers, sailors, airman, and marines who run it have been incapacitated by disease. The US military spends enormous resources to protect personnel against many illnesses, including influenza.

Displacing 100 000 tons and carrying crews of approximately 5000 sailors, Nimitz-class aircraft carriers are designed to operate for extended periods of time at sea, leaving their crews in environmental (and consequently medical) "isolation." In the summer of 2009, one such aircraft carrier, the USS George Washington (GW), deployed from its home port of Yokosuka, Japan, on a patrol in the western Pacific. On July 2, 2009, the GW entered port in Perth, Australia, for a 5-day visit.

At the time, this part of the world was experiencing a World Health Organization (WHO) level 6 pandemic of novel H1N1 influenza A (H1N1). A level 6 pandemic is defined as an outbreak of an infectious agent affecting at least 2 WHO countries in at least 2 WHO regions.[3] The H1N1 outbreak was active throughout the western Pacific, and cases had been reported to WHO in Perth. Almost immediately after leaving port, the GW experienced an outbreak of a respiratory illness that was eventually confirmed to be H1N1. The outbreak on GW began 1 day before she left Perth and lasted 25 days (from July 5 to July 30); the number of sailors diagnosed with presumed H1N1 reached 142.

The unique environment aboard naval vessels presents particular epidemiological advantages and challenges. On board US Navy ships, the majority of crews live in open- bay berthing, sleeping in 2- or 3-stack bunk beds, with no ability to isolate one living/sleeping space from another. These berthing spaces are usually assigned by squadron or department.

Medical facilities have a similar configuration, with 40 of 51 inpatient "beds" configured as 2-stack bunks in an open bay ward. There are 2 rooms designated as isolation rooms, each containing 4 beds in the same open configuration. Three intensive care beds are single beds, but are also in an open area.

Similar, but much smaller populations have been discussed previously.[4,5] We analyzed the attack rates on board the GW according to department or squadron as correlated with various aspects of the living accommodations on the ship. Squadrons and departments are sections of the larger commands that are usually large enough to have their own mission and leadership structure. They are logical units to compare and contrast. There were 9 affected squadrons (as part of the Air Wing command) and 11 departments (as part of the GW command) that were affected and present on board the GW at the time of the outbreak.

METHODS

Following the visit to Perth, Australia, medical personnel on board GW screened all sailors presenting to sick call for upper respiratory complaints. All active duty personnel serving aboard GW had received the annual seasonal trivalent influenza vaccinations (FluMist® influenza vaccine live, 2009-2010 formula, MedImmune, LLC; Fluzone influenza virus vaccine, suspension for intramuscular injection, 2009-2010 formula, Sanofi Pasteur Inc) in the fall of 2008. The sentinel case of novel H1N1 (later confirmed by polymerase chain reaction) aboard GW presented on July 6 (day 1), 1 day before the ship left Perth. By day 11, new cases of presumed H1N1 were prevalent throughout the ship. The peak number of cases occurred on day 14, with 21 new cases identified and 55 patients in isolation. On July 30 (day 25), the last patient was diagnosed with presumed H1N1. A presumptive diagnosis of H1N1 was assigned if the patient demonstrated a core body temperature of 37.8°C or greater and 2 or more of the following symptoms: rhinorrhea, nasal congestion, pharyngitis, myalgias, chills, or cough. As guidance was still being formulated at WHO and the Centers for Disease Control and Prevention (CDC), no formal case definition was available; this definition was deliberately designed to maximize sensitivity, even at the expense of specificity.

Once diagnosed, a patient's demographics were recorded. Vital signs (temperature, pulse, respiratory rate, blood pressure) were obtained, symptoms were reviewed, and a focused clinical examination was completed by 1 of the ship's 9 health care providers. All patients diagnosed with presumptive H1N1 were placed in respiratory isolation. Initially, respiratory isolation was accomplished by quarantining patients in the medical ward, but the numbers eventually overwhelmed the available space. When this occurred, the medical department worked with the engineering department to derive a solution. A berthing area was identified that was vented directly outside the ship (most berthings are vented in series on board US Navy ships). This area was cleared and became the quarantine space for men, while female patients remained in the medical ward. All patients received symptomatic treatment including decongestants, antipyretics (acetaminophen), and anti-inflammatories (ibuprofen), as indicated. Initially, all patients received a 5-day course of Tamiflu® (oseltamivir phosphate, Roche Laboratories Inc), 150 mg daily for 5 days.

Included in the demographic data (Table 1) was information on the patient's department or squadron assignment for a calculation of attack rates. Because berthing spaces on board GW are assigned by department or squadron, the demographic data also provided information on the characteristics of the living accommodations for each affected individual. The attack rates for the various departments and squadrons were compared according to their berthing spaces, including size of the berthing space (ie, total number of people living in the open-bay berthing area); the square feet of living area (total square feet in a berthing space divided by the number of people living in the space); and occupancy rate

TABLE 1

Demographics of the USS George Washington With Relevant H1N1 Attack Rates

	Ship's Population	Isolated (Presumed H1N1)	Attack Rate, %	*P*
Total	4596	142	3.09	–
Gender				
Male	3910	129	3.3	.05
Female	686	13	1.9	
Rank				
Enlisted	4204	134	3.19	.21
Officer	392	8	2.04	

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(percentage of available beds occupied in a given berthing space). The attack rate was defined as the number of people affected as a percentage of the total number of people in a given command. Some consideration was given to attack rates among different age groups, but these data were not readily available and were thought to be beyond the scope of this study.

Diagrams of the ship allowed calculation of the square footage in each berthing area. Berthing assignment rosters provided information on the numbers of beds in each space and the number of sailors assigned to each. Using these 3 data sets, the square feet of living space per sailor and the occupancy rate of each berthing space were identified or calculated. These values were chosen because, while other studies have looked at square feet per sailor or soldier, the occupancy rate was seen as another indicator of crowdedness.

The study was found to be exempt from an institutional review board due to its retrospective nature and lack of any identifiable data.

RESULTS

The sentinel case of novel H1N1 (later confirmed by polymerase chain reaction) onboard GW presented on July 6 (day 1). On July 7, a close contact of the sentinel case patient within the same berthing and workspace developed symptoms. This department was screened, but no additional cases were immediately identified. Close contacts of both patients began a prophylactic regimen of Tamiflu® on day 2 (75 mg daily for 10 days). Only 1 additional patient was diagnosed in this department (on day 6).

On day 3, the first case in a second department was diagnosed. The same approach, using aggressive screening and prophylaxis of close contacts was tried, but 8 sailors were ultimately affected.

Two cases appeared in a third department on day 6. Within the next 48 hours, 4 additional cases were diagnosed in this department. The 6 patients had contact within their workspaces, but lived in different berthing areas. This department received screening and prophylaxis, and no additional cases were reported.

By day 11, new cases of presumed H1N1 were prevalent throughout the ship. The epidemic eventually spread to 20 of 27 departments or squadrons on board. The peak number of cases occurred on day 14, with 21 new cases identified and 55 patients in isolation. On July 30 (day 25), the last patient was diagnosed with presumed H1N1. No further cases of presumed H1N1 were identified for the balance of the deployment, despite of port visits to Singapore and Manila in August.

Officer staterooms accommodate between 1 and 6 officers per room. Enlisted berthings accommodate between 9 and 188 people, with between 300 and 9450 square feet per living space (Table 2).

TABLE 2

H1N1 Attack Rate by Command[a]

Department/Squadron	Total Personnel	Sq ft/person	Occupancy Rate, %	Attack Rate, %
WEPS	267	25.01	83.18	0.37
ENG	268	18.10	91.47	0.75
AIR	595	25.04	93.98	1.51
VFA-192	184	18.34	81.77	2.17
SUP	297	20.85	76.55	2.36
REA	343	20.15	81.86	2.62
VFA-195	186	13.68	87.08	2.69
OPS	239	29.03	89.51	2.93
HSL-51	33	16.71	100.00	3.03
AIMD	301	31.40	74.27	3.32
VFA-27	192	12.15	100.00	4.17
VFA-102	207	15.48	98.36	4.83
VAQ-136	156	11.44	80.90	5.13
ADMIN	51	8.82	85.19	5.88
VAW-115	131	17.70	92.44	6.11
HS	32	39.06	84.21	6.25
DECK	130	19.28	81.76	6.92
CSD	172	29.83	65.90	9.30
HS-14	178	16.78	60.13	9.55
VRC-30	12	25.00	61.11	41.67

[a] Of the 20 affected departments/commands on board, 11 were ship departments and 9 were carrier Air Wing FIVE squadrons. The total number of personnel and the number isolated were used to calculate the attack rate for each respective command. Obtained were each command's allotted enlisted berthing space, the total number of racks, and the number occupied to compute occupancy and square feet per sailor.

Specimens from 32 patients on board the GW were submitted for polymerase chain reaction analysis. Of the 32 samples sent, 16 (50.0%) were confirmed positive for H1N1. Samples were not obtained from all affected patients for several reasons. Early in the outbreak no uniform protocol was available for obtaining samples. Once those protocols were established, sample storage place was in short supply. Because we were under way on deployment, transport of the samples to the nearest country had to be coordinated by airplane or helicopter while we were at sea or shipped from a port when pier side. The samples were then shipped to San Diego, where they were analyzed. Because of these logistics, samples and results were only obtained on a proportion of those affected. The overall attack rate was 3%. The attack rate among officers was 2.04 versus 3.19 among enlisted personnel, but this difference was not significant ($P = .21$ by χ^2). The attack rate for women was 1.90 versus 3.09 for men; this was significant ($P = .05$). Attack rates for each individual department and squadron are presented in Table 2. The attack rates versus square feet per sailor are shown in Figure 1. Of note, squadrons HS-14 and VRC-30 experienced relatively high attack rates in spite of low occupancy rates (Figure 2).

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No statistically significant positive correlation was noted between attack rate and any of the variables that were examined (Table 3).

DISCUSSION

During a normal patrol, 11 departments and 9 squadrons (roughly department sized) would be embarked on board the GW. Personnel are assigned to berthing spaces according to department or squadron, which provided a useful method for comparing the attack rates in different living situations. We found a significant variation among the attack rates of the different departments and squadrons and a great deal of variation in the size and occupancy rate of these berthing spaces. The square feet per sailor and occupancy rate examined the crowdedness of a particular berthing space.

The initial hypothesis was that smaller berthing spaces or those that were more crowded would have higher attack rates. However, no significant correlations between any of these characteristics and attack rate were noted. Based on our knowledge, we believe that this study represents one of the largest collections of H1N1 patients living in a virtually isolated setting, suggesting that the lack of correlation was a real finding. The isolation allowed for an assessment of the spread of the outbreak from a point of exposure, with little risk of additional cases being introduced from outside contact. The lack of correlation between attack rates and living conditions would suggest that transmission likely is occurring during activities such as working, eating, or relaxing. This finding would not be surprising, as most people on the ship spend the majority of their days (18 hours per day) awake versus sleeping in berthing. Future studies may benefit from more stringent or detailed demographic data collection for patients who are isolated to allow for a more detailed analysis and gauge real-time containment measures.

Two squadrons demonstrated attack rates that were distinctly outside of the standard range. Both squadrons had unique characteristics that set them aside from the rest of the crew of the GW and likely explained the noticeably different attack rates. Both HS-14 and VRC-30 operated shore-based detachments in Darwin, Australia, during the outbreak. A sizeable number of personnel in these squadrons were ashore and experiencing ongoing exposure to H1N1 from the local population. Meanwhile the rest of GW's crew was exposed to H1N1 for a comparatively short time. For this reason, the attack rates of HS-14 and VRC-30 were viewed as outliers.

FIGURE 1

Attack Rate vs Square Foot per Sailor With Correlation Graph. The attack rate is compared by command according to the square feet per sailor provided in the allotted berthing space.

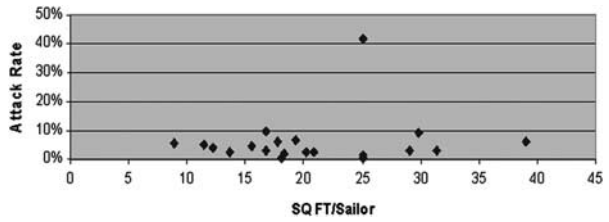

FIGURE 2

Attack Rate vs Occupancy With Correlation Graph. The attack rate is compared to the occupancy of each command's enlisted berthing spaces. This measure indicates how crowded the allotted spaces are.

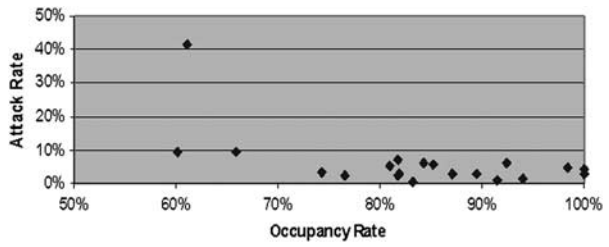

TABLE 3

Comparison of H1N1 Attack Rate to Berthing Statistics[a]

Measurement	R	R^2	*P* (1- tailed)
Attack rate vs sq ft/person	0.131	0.017	.290
Attack rate vs occupancy rate	-0.562	0.316	.005
Attack rate vs maximum No. of racks occupied	-0.418	0.174	.034
Attack rate vs mean No. of racks occupied	-0.449	0.202	.024
Attack rate vs median No. of racks occupied	-0.382	0.146	.048
Attack rate vs total space	-0.362	0.131	.059
Attack rate vs command size	-0.456	0.208	.022

[a] R, correlation coefficient; R^2, coefficient of determination; and racks, individual bunk beds.

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Most of the patients isolated on board were enlisted personnel (134 of 142; 94%). However, most of the crew on the GW is enlisted, and no statistical difference was noted between the attack rates for enlisted personnel and those for officers (3.2% vs 2.0%, $P = .21$ by χ^2). The difference between the attack rates for men and women on board GW was statistically significant. Possible explanations include variations in social habits, hygiene, work patterns, or an as yet unidentified characteristic, but this study was not designed to investigate these parameters.

The overall attack rate in this study was lower than those reported by Vera et al[4] (22%) and Dill et al[5] (12%) on smaller naval vessels. Although the larger size and crew of the GW meant more crowded berthing spaces, it also meant that sailors were separated to a much greater degree than in the smaller ships. This potentially limited the outbreak by protecting some portion of the crew (8 of 28 organizations aboard the ship reported no cases). Of note, this protocol of dividing living space by organization was what enabled the analysis described in this article.

During the 1918 epidemic, the US Army determined that the square feet of living space per soldier was inversely proportional to the incidence (attack rate) of H1N1. In barracks that allowed 45 square feet per soldier, the influenza incidence was up to 10 times more than barracks afforded 78 square feet per person.[6] While the GW is much larger than naval ships discussed in previous articles, the ship also carries a much larger number of personnel, which means larger and more crowded berthings are present. Even the most lavish berthing spaces on the GW did not reach the threshold of the austere barracks described in the US Army's study, which may explain why the correlation between square feet of living space and attack rates were not observed in this study. It may be that a minimum threshold in square feet of living space must be reached to establish a benefit of increasing the living space even more.

This study examined variables involved in disease spread on an aircraft carrier, one of the most isolated populations extant. However, it is conceivable that the observations could be equally applicable to other "isolated" populations, such as in prisons. To our knowledge, no standard operating procedures existed for this particular scenario of an onboard H1N1 outbreak. The ship has a fully operating medical ward with some intensive care and surgical capability. When these capabilities are strained, sailors can be evacuated to larger land-based civilian and military hospitals.

The study has several limitations, including the fact that the attack rates and patterns observed might have been an inaccurate representation, as persons can be infectious before the onset of symptoms. Most of the isolated patients were never tested for H1N1 influenza. Given the chronology of events and a background incidence of upper respiratory illnesses near zero, it was assumed that at least half of those isolated were in fact positive for H1N1, as was the case with those sampled. Although attack rates by age were not considered in this study, it may be worth examining in future studies to add additional insight.

CONCLUSIONS

The attack rate of our outbreak overall was limited to 3%, and was not significantly different between enlisted personnel and officers. The significant differences found among various departments and squadrons were likely multifactorial. No correlation was demonstrated between the different configurations of berthing spaces and the attack rate. Smaller and more crowded berthings did not contribute to higher attack rates, suggesting that transmission occurs most frequently elsewhere, while engaged in other activities such as working, eating, or relaxing. More detailed data collection in a similar outbreak in the future could potentially provide the additional sensitivity needed to discern more subtle correlations or variables, if they exist. The difference between the numbers of male and female personnel isolated is another finding to consider with closer analyses.

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