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Infections in Confined Spaces: Cruise Ships, Military Barracks, and College Dormitories

Vivek Kak, MD

W.A. Foote Hospital, 1100 East Michigan Avenue, No. 305, Jackson, MI 49201, USA

Infections in humans involve an exposure of a susceptible host to an infecting organism in an appropriate environment. The conditions that favor the acquisition of an infecting organism include the behavior of the host, the underlying environment, and the host immune status. When focusing on high-risk individuals, traditionally the focus has often been placed on the underlying host's or the patient's immune status; however, the environment where the infection is acquired is often the risk factor that leads to the acquisition of the infection or the pathogenic organism. This is illustrated by airborne infections being easily transmitted in enclosed settings, such as dormitories, military barracks, prisons, and cruise ships.

This article focuses on infections that can be acquired by individuals based on their residence in dormitories in either the college or the military setting, and those acquired by individuals while traveling on cruise ships. Infections that are easily transmitted in these close settings often tend to have a high morbidity because a large number of individuals get exposed to the infecting organism and very often develop symptomatic infections. It is important that health care professionals have a familiarity with the common infections that can occur in these settings, and recommend appropriate precautions for individuals going to these venues.

Infections on cruise ships

The use of cruise ships is a rapidly growing method of travel, with the Passenger Shipping Association estimating that 10 million people traveled on cruise ships in 2000 and that this number will reach 20 million by 2010 [1]. The cruise ship industry has responded to the increasing number of

E-mail address: vivek.kak@gmail.com

travelers by increasing the size and capacity of cruise ships as exemplified by the recent launch of the liner *Queen Mary 2*, which has a guest capacity of over 3000 passengers. These modern behemoths are virtual traveling cities with common food and water supplies, shared sanitation and air-conditioning systems, and a large number of individuals traveling together. An infecting agent has the potential to enter either the food and water supply or the sanitation systems in these ships, be distributed widely across the ship, and cause significant morbidity. In addition, the close proximity between the passengers and the crewmembers in semiconfined spaces with interactions in the dining halls and recreational rooms increases the possibility of organisms being transmitted among them. The average cruise passenger is often an elderly individual and may have chronic illnesses, which can lead to them to being more susceptible to an infection and its complications. It is vital to the safety of passengers that any potential for transmission of an infecting agent be minimized on cruise ships.

The occurrence of typhoid fever and shigellosis on cruise liners in the early 1970s led to the establishment of the Vessel Sanitation Program by the Centers for Disease Control and Prevention [2,3]. The program does random unannounced inspections of cruise ships docking at United States ports. The ships are rated on various items that can impact on spread of infections, such as water sanitation, food handling, and general cleanliness. The ships are given a score, which is published and is also available on the Internet at www.cdc.gov/nceh/vsp/default.htm. The most common infections occurring on cruise ships tend to be respiratory and gastrointestinal infections.

Respiratory infections

The presence of an isolated environment, with close interaction between a vast cohort of individuals, increases the risk of a passenger being exposed to various respiratory secretions and potentially infectious respiratory viruses. The presentation of these infections is nonspecific and can vary from an upper respiratory tract infection to a life-threatening pneumonia. The elderly passengers often are at a higher risk of complications because of their underlying illnesses and physical conditions.

There have been well-documented reports of both influenza A and B outbreaks on cruise ships sailing [4–8]. These infections tend to have a high attack rate with a large number of individuals being infected before the epidemic is contained. These outbreaks can occur even in summertime, in regions where influenza is not in seasonal circulation. Either the passengers or the crewmembers can introduce the organism into the cruise ship population. It is recommended that passengers at high risk for complications of influenza (eg, persons aged ≥ 50 years, immunocompromised persons, and persons with chronic disorders of the pulmonary or cardiovascular systems) who were not vaccinated with influenza vaccine during the preceding fall or

winter should consider receiving influenza vaccine before travel (1) with large organized tourist groups at any time of year; (2) to the tropics; or (3) to the Southern Hemisphere from April through September (the time of increased influenza activity in that hemisphere) [9]. It is also recommended that cruise lines should attempt to achieve at least an 80% vaccination rate among crew members on each ship each year [10]. These recommendations may be modified if the next pandemic influenza outbreak occurs initially outside the United States, to limit the potential of cruise ships to import the pathogenic organism to the United States. The other respiratory viruses that have caused outbreaks among cruise ships include cases of rubella, although the list is probably underrepresented [11]. A study of the epidemiology of injuries and illnesses among passengers on cruise ships revealed that respiratory tract infections were the most common cause of seeking medical attention by passengers and the crew members aboard the ship [12].

Among the bacterial pathogens causing respiratory infections on cruise ships, the most common infections reported have been caused by *Legionella* species. There have been over 50 different incidents of legionnaires' diseases associated with cruise ships [1,13]. The largest confirmed cluster involved 50 cases spread over nine different cruises in a single ship [14]. The factors involved in these outbreaks often involve contamination of the ship's water supply, the spas or pools, or its air-conditioning system. The prevention of *Legionella* infections on cruise ships involves treatment of contaminated water by using proper disinfection and filtration and properly cleaning and disinfecting spas and other devices that can disseminate the bacteria [15]. There have also been reported cases of vaccine-preventable infections, such as diphtheria and rubella, acquired on cruise ships [10,16]. The presence of individuals, especially crew members and passengers from different countries, with differing immunization status can lead to transmission of vaccine-preventable diseases, such as measles and rubella, on cruise ships. It is of utmost importance that before a cruise, passengers update their immunization status and get appropriate vaccination.

Gastrointestinal infections

There have been numerous outbreaks of gastroenteritis on cruise ships. A World Health Organization review listed over a hundred different outbreaks of gastroenteritis on cruise ships from 1970 to 2000 affecting over 16,000 individuals [1]. The Centers for Disease Control and Prevention's Vessel Sanitation Program Web site lists over 100 outbreaks of gastroenteritis since then, suggesting that this is a continuing problem [17]. The semiconfined setting of the ships with common source of food and water easily lends itself to outbreaks of diarrheal diseases. The presentation of the illness often involves sudden onset of diarrhea with persistent loose bowel movements accompanied with vomiting. There may be associated symptoms of abdominal

cramps, headache, myalgia, or fever. The patients may also complain of tenesmus or blood with their bowel movements, suggesting dysentery.

Most outbreaks of gastroenteritis acquired on cruise ships are caused by Noroviruses, formerly known as Norwalk-like virus. This group of viruses is notorious for causing diarrheal diseases in closed settings, such as in nursing homes [18]. There have been multiple outbreaks of these infections on multiple cruise ships over the past years [1,17,19]. These infections are often facilitated by the close living quarters, common food supplies, and intermingling of individuals that occur on cruise ships. Several routes including fecal-oral transmission, aerosolization while vomiting, food and water as vehicles, and environmental contamination by symptomatic patients or asymptomatic carriers can spread these viruses [13]. The reports in the literature have implicated water supplies, various food items, poor food handling techniques, along with person-to-person spread as methods of transmission of the virus to passengers on cruise ships [1]. The incubation period for noroviral gastroenteritis in humans is usually less than 2 days, although cases can occur within 12 hours after exposure. It presents as acute-onset vomiting, watery nonbloody diarrhea with abdominal cramps, and nausea. Children tend also to have vomiting more commonly but high-grade fever is usually not a feature of this condition and should suggest an alternative etiology. This is a self-limiting condition and usually only requires medical attention for dehydration. The widespread use of reverse transcriptase polymerase chain reaction techniques has led to an improvement in the diagnosis of this infection and an increased appreciation of the role of this virus in causing widespread epidemics of diarrhea on cruise ships [19]. The control of an outbreak is often very difficult and should involve aggressive infection control with active disinfection, isolation of sick individuals, and strict hand washing techniques with training of food handlers.

The bacterial causes of diarrheal disease on cruise ships reported include enterotoxigenic *Escherichia coli*, *Salmonella* species including *Salmonella typhi*, *Shigella* species, *Vibrio* species, *Campylobacter jejuni*, and *Staphylococcus aureus* enteritis [1,3,13,20–26]. These infections often tend to be more severe than those caused by Noroviruses, and have led to sporadic deaths in cruise ship passengers. The parasitic causes of diarrhea reported on cruise ships include *Cyclospora* species, which were implicated in a large outbreak on a cruise ship where the passengers may have acquired the infection from eating raspberries [27]. There have been sporadic outbreaks of diarrhea on ships caused by *Cryptosporidium* species and *Trichinella spiralis* [1,28]. Most of these outbreaks involve a breakdown of the food and water sanitation chain. The factors implicated in various studies include use of contaminated food or water, inadequate food storage, cross-contamination of food, or infected food handlers [1]. The prevention of gastrointestinal infections on cruise ships involves controlling potential deficiencies in food and water handling as well as in cooking and catering, preventing sewage contamination of the water supply, and isolation of sick persons. In the

absence of effective vaccines for the prevention of infections by most of the previously mentioned organisms, with the exception of *S typhi*, these efforts are the primary preventive methods to decrease the burden of gastrointestinal illnesses on cruise ships.

Other infections

The cruise passenger can also often present with infections that they may acquire while on the land excursions that are part of the cruise. They can also become symptomatic with infections that may have been incubating before the start of the cruise. Infections that are endemic in the ports of call, such as malaria, may present on board the cruise ship itself. There have been isolated cases of meningitis acquired aboard cruise ships, although these are uncommon. The health care workers on board cruise ships need to be aware of infections that may be acquired on board or from the ports of call. The American College of Emergency Physicians has published guidelines for the health care facilities on cruise ships [29].

Infections in military barracks

The military barrack involves a unique living arrangement with a large number of military recruits living in close physical proximity. The recruit population generally consists of young and healthy individuals below 25 years of age. The recruits undergo a pre-entrance medical screening before qualifying for military service. They are generally very fit and have very few chronic illnesses. The recruits subsequently live in the barracks and train for combat within their own cohort. The close proximity of the individuals can lead to rapid transmission of certain infections in this setting. This section focuses on the most common infections seen in the military barracks.

Respiratory infections

Respiratory infections are widespread among the military recruits. The infections can range from nonspecific nasal discharge and congestion to pharyngitis with fevers to severe pneumonia. The close proximity of recruits leads to efficient transmission of respiratory pathogens among them. Early studies among military recruits showed that incidence of respiratory disease increased with an increase in the number of recruits in training [30]. Other studies demonstrated increased rates of respiratory infections during the winter months [31].

The major bacterial pathogens that have been implicated in epidemic respiratory infections in the military barracks include *Streptococcus pyogenes*, *Streptococcus pneumoniae*, *Bordetella pertussis*, *Mycoplasma pneumoniae*, and *Chlamydia pneumoniae*. The major viral pathogens include adenoviruses, influenza viruses, and the rhinoviruses.

Among the bacterial pathogens, *S pyogenes* is an endemic organism in many military settings. There have been outbreaks of group A streptococcal pneumonia [32] and outbreaks of acute rheumatic fever among recruits [33]. Based on the high morbidity of these infections, the military has frequently used mass prophylaxis of recruits using benzathine penicillin G to control group A streptococcal infections and its postinfectious sequelae [34].

Outbreaks of pneumococcal pneumonia among recruits have also been reported [35]. The use of mass administration of pneumococcal vaccination and mass chemoprophylaxis using azithromycin led to a termination of an outbreak involving Marine Corps recruits [36]. A placebo-controlled trial, however, to see if the use of pneumococcal vaccination among recruits leads to a decrease in pneumonias did not show any difference between the two arms [37]. The other causes of pneumonia in the recruit setting include the atypical bacteria *M pneumoniae* and *C pneumoniae* [38]. There are also scattered reports of pertussis cases among recruits living in barracks. A study implicated *B pertussis* as a possible cause of prolonged cough among trainees in up to 17% individuals [39]. This may be an underappreciated pathogen, especially because it is highly infectious with easy transmissibility among cohorted residents, as seen in the barracks.

Adenoviruses are probably among the most common viral pathogens found in military barracks. They are responsible for a large number of respiratory infection epidemics among military recruits. Adenoviruses tend to be endemic to the various military barracks and training facilities, with recruits acquiring infections early in their training. The presentation of these infections had a wide spectrum, from asymptomatic infection to severe pneumonia leading to death [40]. The large morbidity caused by the annual adenoviral epidemics led to the development of live oral adenoviral vaccine against adenovirus serotypes 4 and 7. This was followed by a dramatic decrease in the cases of adenoviral infections [41]. Unfortunately, the sole manufacturer ceased production of the vaccine in 1996 leading to a resurgence of the disease and associated fatalities [42]. There are hopes that the vaccine will be available again for use in 2008.

The other virus that causes epidemics among military barracks is the influenza virus. The first documented influenza outbreak during the 1918 influenza pandemic was among recruits at Fort Riley, Kansas, with its subsequent spread across the United States. This infection has been mitigated by the mandatory annual influenza vaccination in the military trainees. There have, however, been small outbreaks of influenza despite the vaccinations [43]. The 1976 outbreak of swine influenza A H1N1 at Fort Dix, New Jersey, which led to illness among 13 soldiers and 1 death [44], illustrated the potential of the next pandemic influenza strain to cause devastating morbidity and mortality among military barracks in the absence of an effective vaccine.

Other viruses that have been noted to cause disease in military barracks include rhinoviruses, coronaviruses, Coxsackie A21 virus, and respiratory

syncytial virus [45–49]. These viruses do not seem to cause a significant burden of disease, however, based on the published reports. There have also been epidemics of varicella among military recruits living in open barracks, with high attack rates among susceptible adults. These have occurred before the licensure and widespread use of the varicella vaccine [50].

The barrack setting can also lead to an increased transmission of tuberculosis among recruits. Accordingly, military recruits are considered to have latent tuberculosis with only greater than or equal to 10 mm of induration from purified protein derivative (tuberculin). Before starting active training all recruits are screened by tuberculin skin testing followed by chest radiography, if the initial test is positive. This approach is probably responsible for prevention of most cases of active tuberculosis among the military barracks, although major outbreaks of tuberculosis in the military have been reported aboard naval ships [51].

Meningococcal infections

In the 1960s, meningococcal epidemics occurred frequently in military barracks. Initially, an attempt was made to control the frequent epidemics using mass chemoprophylaxis, which led to the organism becoming increasingly drug resistant. This led to the development of the first meningococcal vaccine in the military, and since 1971, widespread use of the meningococcal vaccine along with reducing crowding and limiting class size has led to reduction of this fatal disease in the military setting [52].

Skin infections

The close proximity of individuals in the barracks during training can lead to the spread of skin infections among the residents of military barracks. There have been outbreaks of community-acquired methicillin-resistant *S aureus* infections among recruits [53]. There was also a report of cutaneous *Bacillus cereus* infections on the scalps of military cadets where acquisition of a short haircut increased the risk of infection [54]. The control of skin infections often involves implementation of a good hand hygiene program and using separate personal hygiene items.

Sexually transmitted infections

The military recruits living in the barracks are at a higher risk of sexually transmitted diseases. This risk is caused by the age of the individual rather than their residence in the barracks. The use of paid sex workers and sexually transmitted diseases has historically flourished alongside military establishments from time immemorial, leading to sexually transmitted disease transmission between the barracks and surrounding communities. In the United States, the most commonly reported communicable infections in the military are sexually transmitted diseases, with *Chlamydia* infections

being the highest followed by gonorrhea [55]. The military recruits tend to have higher rates of sexually transmitted diseases than the general population. In one study up to 10% of female recruits had *Chlamydia* infections [56]. The large disease burden caused by the sexually transmitted diseases and potential for complications from asymptomatic infections has led to recommendations of annual screening of all sexually active females less than 25 years old [57].

Prevention of infections in barracks

In view of the high burden of a potential epidemic in the barracks, the military actively vaccinates all recruits in barracks to minimize the spread of vaccine-preventable infections. The vaccines currently given to the trainees include diphtheria, acellular pertussis, tetanus; hepatitis A; hepatitis B; measles, mumps, rubella; meningococcal conjugate vaccine; influenza vaccine; polio vaccine; and based on need, varicella and yellow fever vaccine. These vaccines are further supplemented, based on occupational and deployment circumstances of the recruits [58]. The widespread use of these vaccines by the military has been successful in preventing the epidemics that occurred in the past. The adenovirus vaccine is expected to be reintroduced by 2008.

Infections in college dormitories

The college dormitory is similar to the military barrack in its living structure. The inhabitants are often young individuals from different regions of the United States and different countries, with varying and often incomplete immunization status. The proximity of individuals in this setting can lead to infections by a vast array of organisms, especially those transmitted by the aerosol route. The most commonly reported and feared infection is caused by *Neisseria meningitidis*. In the 1990s, the death of students across various college campuses from meningococcal meningitis made national headlines [59]. The presence of a single case on campus is often followed by widespread media attention and panic [60].

The freshmen living in college dormitories are at a higher risk of meningococcal disease compared with the general student population because they may be exposed to colonized students more often than other college students [61]. Those asymptomatic students who become carriers develop protective immunity, leading to lower risk of the disease in subsequent college years. The presentation of these infections can range from a meningitis picture to fulminant meningococcemia with septic shock. This has led to recommendations for college freshman to consider being immunized against meningococcal infections [62].

Other infections that have an increased incidence in the dormitories include influenza and influenza-like illness [63]. These infections present

with upper respiratory signs and can range from very mild disease to severe pneumonia. There have also been numerous outbreaks of vaccine-preventable diseases in dormitories including mumps and measles [64,65]. Other pathogens that have a higher risk of spreading in the dormitories include varicella and rubella viruses. A significant number of these outbreaks can, and have, originated from students who have had none or incomplete vaccinations. The use of vaccines against these pathogens should be vigorously encouraged to minimize the spread of these diseases in college dormitories. The American College Health Association currently recommends the following immunizations as part of the prematriculation immunization requirement for college students: measles, mumps, rubella, influenza, meningococcal disease, hepatitis A, hepatitis B, polio, varicella, diphtheria, pertussis, tetanus, and the human papilloma virus [66].

The prevention of these respiratory infections can also be aided by improving personal and hand hygiene practices. A study demonstrated that use of a hand sanitizer along with a hand hygiene campaign led to a decrease in upper respiratory illnesses in a college dormitory [67]. The prevention of infections in this setting involves a robust education campaign that can increase awareness among students about the various infections to which young college students are susceptible.

Sexually transmitted diseases are a major concern in the college student population. The incidence of sexually transmitted diseases among college students living in dormitories is similar, however, to the national rates in individuals of the same age group [68]. The close proximity of individuals in college dormitories is not a risk factor for sexually transmitted diseases.

Summary

The presence of a vast cohort of individuals in semiconfined settings as is present on cruise ships, military barracks, and college dormitories is often accompanied by an increase in the risk of particular infections. These are often gastrointestinal infections among cruise ships and respiratory pathogens that are easily transmitted in the barrack and dormitory setting. The control of these infections involves attention to good personal hygiene, safe food and water handling, and use of vaccines to prevent vaccine-preventable diseases.

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