Assessing the waterborne risk of a norovirus infection for military personnel in the Netherlands

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Summary

Norovirus (NoV) infection outbreaks are known to occur when people occupy limited space, often under poor hygienic conditions. These situations have been described for both civilians (e.g. cruise ships) or military personnel in operational situations. However, little is known regarding the NoV infection risk for military personnel during training, exercise or even recreational activities. This paper describes a quantitative analysis of the NoV infection risk potential, improving on the risk awareness of this disease under various conditions.

Introduction

Various reports and papers have been published over the years describing how deployed military personnel are at a particularly high risk of epidemic gastroenteritis. Especially crowded conditions that facilitate rapid person-to-person transmission of viral pathogens and poor hygienic conditions can be identified as important risk factors[1].

Between 1992 and 1997, four gastroenteritis outbreaks on board US aircraft carriers (crews ranging between 4200 - 5600 head) involving norovirus (NoV) have been described by McCarthy et al.[1] Up to 44% of the different crews had been affected, during outbreaks which have lasted between 13 days and 5 weeks, putting an enormous strain on day-to-day operations aboard these ships.

During Operation Enduring Freedom and Operation Iraqi Freedom, predominantly land-based operations, various NoV outbreaks also occurred, especially during the major combat phase of the conflict when hygiene was poor and access to potable water limited (Table 1)[2]. Although the US Marine Corps in Iraq had only 30 registered cases of NoV outbreaks in 2003, a conservative estimate would be that thousands of cases of NoV illness occurred in the First Marine Expeditionary Force in April through May 2003, as case registration was sparse and contact between units limited[2,3]. In 2003, during the first month of the British invasion in Iraq, 1340 cases were registered, from which 73% required hospital admission. 36% of these cases were hospital personnel and fresh local produce was identified as a likely source[2], underlining the contagious character of NoV and risks of uncontrolled foodstuffs.

NoV family, symptoms and infectivity

In their review, Donaldson et al.[4] describe how NoVs belong to the family of *Caliciviridae* and are small non-enveloped icosahedral viruses with a single-stranded RNA genome, making them more adaptable to specific circumstances than DNA viruses. The NoV genus contains more than 40 different strains, divided into five genogroups. Genogroup I (GI), GII and GIV are primarily human pathogens, whereas GIII and GV infect bovine and murine species respectively. The majority of outbreaks are linked to the GII.4 genocluster and a pandemic spread was first recognized in the mid-1990s. Different substrains have subsequently been confirmed in various countries and regions. Human immunity to NoV is limited by the fact that no long-term immunity occurs (re-infection after challenge with the same virus 27- 42 months later) and there is limited or no cross-strain immunity. In addition, humans are often exposed to other circulating NoV strains, making it very difficult to develop or implement specific preventive, immunological means.

The clinical symptoms usually last for 12-72 hours, with an incubation period of 24-48 hours. Symptoms include vomiting (69%), diarrhea (66%), nausea (79%), fever (37%) and cramps (30%). Virus shedding can continue for up to 3-5 weeks after original infection[3]. It is clear that the debilitating effect of a NoV infection and the strong reduction of combat readiness can have serious consequences for operational capabilities. In addition, it places a great strain on logistical resources and troop morale[1].

NoV outbreaks have also been recorded in civilian settings, ranging from outbreaks on board cruise ships (e.g. Celebrity Cruise Lines in April-May 2013 / www.cdc.gov), after Hurricane Katrina[5] in New Orleans or contaminated flood water affecting 77% of a tourist group of 64 people in Salzburg Germany, who were stranded in a flooded hotel. In addition, 6 out of 10 firemen who pumped water from the affected hotel fell ill to a NoV infection[6]. Overall it is estimated that NoVs cause up to half of all global outbreaks of gastroenteritis, making this the most common cause of sporadic diarrhea in community settings[7].

Apart from tactical situations, it is quite obvious that military personnel can also be exposed to potentially contaminated water or poor hygienic conditions during training and relaxation, deployment for humanitarian aid or evacuating people from flooded areas. In all scenarios a reduction in operational capability due to illness is undesired and should be avoided. However, tactical situations as described for the US aircraft carriers or Iraqi conflict are likely to carry a higher priority to obtain the mission's objective than to avoid a possible exposure to contaminated water. Nonetheless, improving risk awareness can always assist in preparing for a worst-case scenario, even when it is non-kinetic.

NoV presence in the Netherlands

In 2013 a quantitative risk assessment was published by de Man et al.[8] on the infection risk from exposure to waterborne pathogens in urban floodwater in the Netherlands. A critical factor was whether the water originated from combined sewers, storm sewers or rainfall generated surface runoff. The concentration of NoV was found to be similar to concentrations found in floodwater in Jakarta by Phanuwan et al.[9], ranging from 610-3300 pdu/ L (PCR detectable units) for NoV GI, to 530-40.000 pdu/ L for GII.

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Date	Setting	Number of cases	Description	Reference
2002	British Army, field hospital, Bagram, Afghanistan	29	Cases primarily among hospital staff; 10 cases evacuated to hospitals in the U.K.;1 case treated in Germany; nosocomial cases required field hospital to be closed	16
2002	U.S. Navy, USS Theodore Roosevelt, aircraft carrier	520	Outbreak occurred after leaving Norfolk, VA; lab confirmed	22
2002	U.S. Navy, USS Constellation, aircraft carrier	747	Outbreak occurred after leaving Singapore; lab confirmed	22
2003	British troops, Iraq	1,340	First month of British invasion in Iraq; 73% of cases required hospital admission; 36% of cases were hospital personnel; fresh local produce was likely source	3
2003	U.S. Marine Corps, Iraq	30	30 lab confirmed cases; first confirmation of norovirus gastroenteritis in theater using field lab	21
2003	U.S. Navy, USS Enterprise, aircraft carrier	96	Outbreak occurrred after leaving Norfolk, VA; lab confirmed	22
2003	U.S. Navy, USS Vinson, aircraft carrier	107	Outbreak occurred after leaving Hawaii; lab confirmed	22
2003	British Navy, RFA Argus, Casualty Receiving Ship	37	Norovirus and other enteric viruses detected; salad considered source of outbreak	19
2003-2006	British troops, multiple outbreaks, Shaibah, Iraq	Unknown; 43 positive samples	Multiple norovirus strains detected in 5 of 8 outbreaks	19
2007	British troops, multiple outbreaks, Basra, Iraq	Unknown; 29 positive samples	Multiple norovirus strains detected in 1 of 2 outbreaks	19

Table 1: Reported NoV outbreaks in military forces during Operation Enduring Freedom and Operation Iraqi Freedom[2].

In 2005 Lodder and De Roda Husman[10] published a study on the presence of NoV in sewage and surface water in the Netherlands. Concentrations of NoV found ranged from 4900 pdu/L for river water samples to $8.5x10^5$ pdu/L for sewage samples. Schets et al.[11] reported in 2008 on the presence of waterborne pathogens in surface waters in Amsterdam. Samples taken from the IJmeer, Amstel, Herengracht and Prinsengracht contained amounts of NoV ranging between 10^3-10^4 pdu/L. A clear relation was found between increased NoV concentrations and high intensity rainfall, when dirt from the streets is washed into the canal, sewage systems overflow and discharged water from nearby polders containing runoff from agricultural land is transported into the canals. These studies clearly showed that even exposure to river and surface waters in the Netherlands during training or recreation is not without risk of a NoV infection, let alone when military personnel is deployed in flooded areas when river water and sewage can become mixed. Based on the above mentioned concentrations and given the fact that already 10 NoV PCR detectable units[10] may lead to infection, a volume of 0.1 mL to 1.0 mL contaminated water is already sufficient to cause a disease outbreak[4,8].

NoV contaminated water ingestion

Parallel to the actual virus concentrations, the importance of the amount of water ingested has become apparent. Studies done by Schijven and De Roda Husman in 2006[12] and Schets et al. in 2011[13] focused on quantifying these ingested amounts. They surveyed both occupational & sport divers, swimmers and surfers, taking into account, i.e. diving equipment used, marine or recreational water, age and time spent in water. Quantities varied between ~10 mL per dive for divers up towards 170 mL per day for surfers. Recently de Man et al.[8] added to these parameters, by presenting data on water ingestion via hand-mouth exposure became available, indicating a range between 0.02 mL (adults - hands wet when clearing floodwater) and 1.7 mL (children - swallowing droplets / mouthful).

In addition, the actual mean infection risk after exposure was calculated by de Man et al[8]. These calculations took into account various other pathogens that are present in contaminated floodwater (e.g. *Campylobacter jejuni* and *Giardia* spp.). However, the contribution of NoV to the overall risk was relatively high (> 50%), allowing for a mean NoV infection risk based on the overall risk. The mean risk of infection when exposed to floodwater originating from combined sewers was 3.9%, storm sewers, 0.58% and from rainfall generated surface runoff 0.039%. Although these risk percentages seem relatively low, they are calculated using the average water volume ingested via hand-mouth exposure (0.02 mL). When a more plausible range of water volume ingestion is used (1-10 mL) as described when swallowing droplets or swimming / diving, the actual mean infection risks increase dramatically: ingestion of 1 mL water originating from combined sewer leads to a 100% infection risk; 1 mL water from storm sewers leads to a 29% infection risk; 1 mL water originating from rainfall runoff leads to a 2% infection risk. As NoV concentrations found by de Man et al.[8] in water from storm sewers(~3300 pdu/L) are comparable to those found by Lodder and De Roda Husman[10] for river water samples (~4900 pdu/L), an infection

Afb. 1 en 2: Voorbeelden van risico op besmetting door water.

risk of approximately 20% (> 50% contribution of NoV to the overall infection risk, being 29%), or 1 every 5 persons, can be estimated.

Potential NoV infection risk

For calculation purposes, several assumptions had to be made, including the assumption that each host (person ingesting a sufficient quantity) would be equally susceptible to a waterborne infection[8]. Although the mean value used to define this parameter is based on various studies using test subjects, it does not account for the specific host factors linked to each individual, determining whether a person actually falls ill after infection. However, the survey done by Schijven and De Roda Husman[12] differentiated between occupational and sport divers and listed specific health complaints (nausea, vomiting, diarrhea), which can be contributed to a gastroenteritis. Assuming the level of physical fitness of an occupational diver is comparable to that of the average military professional, 30 to 60% of the people interviewed reported one or more of these complaints during a one year period. In all, it becomes clear that there is a potential risk for a NoV infection when military personnel is training, exercising or operating in water, even in the Netherlands. Therefore, the information provided in this report can be used to create an improved risk awareness of uncontrolled water and select appropriate measures to reduce the impact of a potential NoV outbreak. Preferably, these measures should be taken into account in the planning stage of an operation or exercise in order to avoid an unforeseen reduction of operational capacity. Taking the different scenarios (tactical / aid / evac / training & recreation) under which military personnel can be deployed, the focus should lie on maintaining high hygiene standards, access to sufficient potable water and controlled food supplies, available medical treatment and quarantine capacity in case of an outbreak, (personal) equipment decontamination and having sufficient operational capacity in reserve to complete the mission if required.

SAMENVATTING

RISICOBEOORDELING OP EEN DOOR WATER OVERGEBRACHTE NOROVIRUSBESMETTING VOOR MILITAIREN IN NEDERLAND

Norovirus (NoV)-uitbraken zijn berucht wanneer er veel mensen op een klein oppervlak verkeren, vaak onder slechte hygiënische omstandigheden. Deze situaties zijn beschreven in zowel civiele omstandigheden (bijv. aan boord van cruiseschepen) alsook voor militairen tijdens operaties. Echter, er is weinig bekend over het mogelijke NoV-infectierisico voor militairen tijdens training, oefeningen of zelfs recreatie. Dit rapport beschrijft een kwantitatieve analyse van het NoV-uitbraakpotentieel en draagt daarmee bij aan het risicobesef van deze aandoening onder verschillende omstandigheden.

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MEDEDELING

25 korte verhalen - 25 short stories

Dr. L(eo) van Bergen heeft als medisch historicus, werkzaam bij het Koninklijk Instituut voor Taal-, Land- en Volkenkunde (KITLV) te Leiden, vele publicaties en boeken op zijn naam staan over tussen oorlog en geneeskunde zoals: Zacht en Eervol - Lijden en sterven in een Grote Oorlog. Voor het Nederlands Militair Geneeskundig Tijdschrift (NMGT) heeft hij diverse artikelen geschreven en boekbesprekingen verzorgd.
In de afgelopen jaren heeft dr. Van Bergen 25 korte fictieve, doch zeer realistische verhalen geschreven over de Eerste Wereldoorlog met als titel "Onder stervenden". De onderwerpen variëren van soldaat tot generaal, van brancardier tot chirurg, van een soldaat met shell shock tot een gezichtsmismaakte en van een kind van een soldaat tot zijn vader. Deze verhalen zullen bij voldoende voorinschrijvingen worden gepubliceerd in een tweetalige editie, Nederlands en Engels, geïllustreerd door de Amsterdamse kunstenaar Henk Fakkeldij.
Het boek zal ongeveer twintig (€ 20,-) euro gaan kosten, exclusief de verzendkosten.

Geïnteresseerde lezers kunnen voor de voorinschrijving contact opnemen met dr. Van Bergen via zijn e-mailaccount: l.vanbergen@kpnmail.nl

Medical historian Dr L(eo) van Bergen, working at the Royal Netherlands Institute of South East Asian and Caribbean Studies, Leiden, has published many articles and books on war and medicine, such as: Before My Helpless Sight. Suffering, Dying and Military Medicine on the Western Front 1914-1918. He also has regularly published articles and reviews in the Netherlands Military Medical Review.
In the last few years Van Bergen has written 25 short fictional, but very realistic stories on World War I, titled: ‘Among the Dying’. The themes vary from common soldier to general, from stretcher-bearer tot surgeon, from a shell-shocked soldier to a facially disfigured, from the child of a soldier to his father. In the case of a sufficient number of prescriptions, these stories will be published in a two-language edition (Dutch and English), illustrated by the Amsterdam artist Henk Fakkeldij.
The costs will be around €20 (excl. postage costs).

Those who are interested can contact Dr Van Bergen by e-mail: l.vanbergen@kpnmail.nl