Review Article

Medical evacuations in biosecurity conditions

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ABSTRACT

The possibility of airborne or vector/fomite transmission of infectious diseases renders necessary the institution of cleaning/decontamination and desinfection protocols for medicalised transport vehicles. This causes health care resources and implements to be inoperative for variable periods of time depending on the procedures used. The possibility of transmission increases in the case of emergent or re-emergent diseases, and becomes critical when transport of presumably or confirmedly NBC (Nuclear - Biological - Chemical) agent-affected individuals is contemplated. Hence the necessity to use more or less complex isolation systems and means which may even allow performing a number of medical procedures. The advantages of such protocols or systems range from the reduction and shortening of the in situ health care / medical assistance times where the ABC incident has occurred, through the optimisation of resources through the reduction of the non-operative periods of medicalised transport means, down to reducing the stress levels of the health-care personnel by not having to use personal protection devices and equipment in order to feel personally safe.

Key Words: *Ambulance decontamination/disinfection. Airborne disease transmission. Portable isolators. NBC (Nuclear-Biological-Chemical). Bioterrorism.*

RESUMEN

Evacuación sanitaria en condiciones de bioseguridad

La posibilidad de transmisión de enfermedades infecciosas por vía aerógena o por fomites, hace necesario la instauración de protocolos de limpieza y desinfección en los vehículos de transporte sanitario, y provoca que los recursos sanitarios estén inoperativos durante más o menos tiempo de acuerdo a los procedimientos empleados. Esta posibilidad de transmisión es mayor si cabe cuando nos referimos a enfermedades emergentes o reemergentes, y se hace crítica cuando debamos realizar transporte sanitario de personas que hayan resultado afectadas por agentes NBQ. Y de aquí surge la necesidad de utilizar sistemas de aislamiento más o menos complejos, que permitan incluso realizar ciertos actos médicos. Las ventajas de su uso irán desde reducirse los tiempos de asistencia sanitaria en la zona donde se haya producido un incidente NBQ, pasando por una optimización de recursos al disminuir los tiempos de inoperatividad de los transportes sanitarios, hasta reducir los niveles de estrés del personal sanitario al no tener que utilizar equipos de protección individual para sentirse seguros.

Palabras clave: *Desinfección de ambulancias. Transmisión aerógena. Equipos de aislamiento portátiles. NBQ. Bioterrorismo.*

INTRODUCTION

The risk of airborne contagion in confined spaces such as modes of transport is something that cannot be ignored[1-3]. Therefore, hypothetically, if we know that a patient is infected with an airborne disease before transportation, we can take infection control measures and carry out specific disinfection procedures to combat the infecting agent. This would eliminate the risk of contamination for health care personnel and patients who might later be transported in the medical transport vehicle and would avoid excessive preventive measures being taken. It would also reduce the psychological stress caused by the risk of infection[4-9].

So then how long would an ambulance be inoperative for after transporting an infected individual? Which techniques or who could guarantee that the procedures and/or products used would eliminate any risk of infection? And more importantly, what risks would health care personnel be exposed to if a product or products for disinfecting the resting area of a medical transport vehicle were not used correctly because of lack of knowledge about the product or for other reasons?[10,11]

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With regard to the second question about cleaning procedures, the strict and rigorous implementation of these procedures is very important because if is not done correctly and thoroughly we cannot guarantee that we have eliminated the risk of infection. *Shigella sonnei* is an example of a bacterium that can remain on a glass or metal surface for up to 10 days at temperatures of 15°C. *Staphylococcus aureus* sticks to hospital cleaning equipment such as mops for over 56 days. This illustrates the inefficiency of poor hygiene procedures[12] and the significance of these bad practices with regard to the risk of spreading infections by the faecal oral or droplet route or by aerosols containing faecal materials because of the high environmental resistance (up to three months) for some enteric viruses such as hepatitis A or rotaviruses. This is the case even when using disinfection procedures with sodium hypochlorite, 70% ethanol or chlorhexidine which all work very well as bactericides but not as virucides[13].

The following factors are important from a public health point of view: risk prevention in the workplace, resource management, complying with current regulations (Royal Decrees 1211/1990, 664/1997, 619/1998 and the Ministerial Order of 3rd September 1998 which expands on the law on land transport planning) and following the codes and recommendations linked to good hygiene practice[14-18]. However, what happens when we talk about emergent or re-emergent diseases such as severe acute respiratory syndrome (SARS) or a possible mutation of the avian flu virus which could trigger an epidemic among human beings?[19,20] This brings up even more issues given that potential scenarios involving epidemics could affect national and even international security[21-23].

This leads us back to our initial hypothetical case and thus, if we acknowledge that the patient that is being transported has a highly contagious airborne disease which puts everyone at risk, guarding the patient's airways alone would probably not be enough to prevent contagion among medical personnel (it might be enough in cases involving viral haemorrhagic fevers, the plague, smallpox and the flu)[24,25]. Whereas, by using Individual Protection Equipment (IPE), medical personnel can increase their level of protection as a preventive measure against the risk of infection[26-29]. However, we must bear in mind that the correct (and necessary) level of individual protection is completely ineffective against contagion if there is no training on how to use IPE[30-32]. This also does not answer our initial question about how much time an ambulance would be inoperative after transporting an infected individual.

Figure 1. An ambulance which has been contaminated after transporting a patient infected with NBC agents.

MEDICAL TRANSPORT VEHICLES FOR THOSE AFFECTED IN NBC INCIDENTS

This issue becomes even more complicated if we consider a scenario in which NBC (nuclear, biological, chemical) agents have been disseminated either accidentally or intentionally with criminal or terrorist motives given that in this kind of situation there is a much greater need to disinfect the area and transport the affected individuals in isolation (Figure 1). Different NBC agents need to be handled differently[33]. If we compare the risk of contamination of radionuclides compared to that of biological or chemical agents, the possibility of contamination is much smaller in the nuclear scenario than in the others and for that reason decontamination treatment for the infected individuals is a priority[34]. This does not mean that the intervening personnel and the infected individuals should not take the necessary barrier measures against contamination to prevent the spread of infection to other medical staff they come into contact with.

Furthermore, if we add to this a lack of knowledge about the clinical symptoms of highly contagious infectious diseases such as SARS, smallpox and other infections related to bioterrorism[35-38] we could be facing a situation in which dissemination is greater since the surge cannot be identified by medical centres[38]. This is coupled with the risk of contagion via a minimal dose of an airborne virus which highlights the importance of preventive measures and infection control while transporting patients to or between medical centres[39,40]. The compulsory use of medical

transportation vehicles with a dividing panel that separates the driver and patient area stands out among the measures that should be taken[41] and for greater protection vehicles should have High Efficiency Particulate Air Filtration (HEPA) to prevent infections spreading from the vehicle to the outside[42]. Moreover, the amount of medical material used should be kept to a minimum and any equipment that generates aerosols as well as humidifiers should be avoided. The inside surfaces should be protected with single use, waterproof, plastic covers because of the risk of infectious particles that could be deposited there on or that might cling to the different horizontal and vertical wall sufaces[43,44].

In terms of chemical incidents, the attack in Tokyo in March 1995 showed how contamination from a chemical warfare agent spread between infected individuals and the rescue team when some members of the emergency teams and hospital personnel were affected by the contamination[45]. The greater the amount of contact with the affected individual. The more likely this become therefore, medical professionals should be aware of the need to prevent secondary contamination from the affected individuals of a NBC incident by using the correct level of individual protection and establishing decontamination procedures and contamination control with contamination detectors for those who are affected. The aim of this would be to reduce the level of contamination and prove that there has been a decrease or that it has been eliminated altogether. As a result the prognosis for affected individuals would improve once the substance that is causing their condition has been eliminated and medical staff would no longer have to use protective equipment which would improve the quality of patient care for those affected[46-48].

However, if we do not consider the aforementioned case particularly significant because it is so unlikely to occur, we may view things differently if we analyse the accident at Bhopal. This accident caused 3,500 direct deaths and the same number of people were in a critical condition. Furthermore, 150,000 people required medical treatment and the long term consequences for those affected have included problems with sight, mental disorders, liver and kidney damage etc.[49]. However, in terms of what interests us, the accident and its consequences are not the most important aspects of this case. Our interest lays in the fact that one of the evacuation routes used passed through the toxic cloud which meant that people who were being evacuated were once again exposed to the toxic effects of the disseminated chemical substance[50].

ISOLATION DEVICES

This type of device was designed to isolate the affected individual who needed to use it from external elements in two types of scenarios. In the first scenario, the individual affected by contamination is contaminated or infected/unwell and the use of this device prevents contamination or contagion of the surrounding environment. This device is used until it is decontaminated in a decontamination station or taken to a medical facility and submitted to an infection control test. The second scenario arises when the person who needs the device can not use the protective equipment because of an injury or disease, yet must cross a contaminated area. Irrespective of the use, it is necessary to establish decontamination procedures for the isolation devices when they have been placed on the user to prevent any risk of contamination and when they have been used they should be decontaminated so that they can be re-used or destroyed as hazardous waste in the case of single use devices.

Isolation devices may or may not have a NBC filter for the incoming and outgoing airflow because in most cases it is the person inside who has the NBC filter (as well as a mask). The main advantage of using this is that it impedes contamination of the surrounding area from the NBC infected individual (for that reason they have air filters in the openings) or contamination of the individual who cannot wear protective equipment from the surrounding area. These devices have not been well received by the people that use them because of the feeling of claustrophobia they produce when they isolate the user from their surroundings. This means that the user has no contact with the outside world because the device acts as a barrier (Figure 2).

Over time NBC isolation bags have evolved in terms of their design characteristics and technical specifications. Since they were first used their only purpose has been to protect the uncontaminated surroundings from contamination or the uncontaminated person inside from contaminated surroundings. The devices have developed and evolved in response to the challenges of infection control procedures and techniques in public health without forgetting their military origins. They have gone from being known as “NBC isolation bags” to “NBC evacuation stretchers for casualties” or “NBC evacuation pods”.

This evolution basically has taken place because of the need to facilitate medical care for infected individuals who are being transported. In principle, the “NBC isolation bag” is literally a bag made of a material that is NBC contamination resistant and has a small transparent window (Figure 3). Today, with the development of new materials and de-

Figure 2. A NBC body bag (Ground Army).

Figure 4. Isolation stretcher (pressurised/ depressurised).

Figure 3. A NBC body bag with internal structure.

Figure 5. A NBC evacuation pod (pressurised).

signs a variety of different equipment is available which offers improved comfort for those who have to use it and for professionals who have to handle it. Some have even integrated NBC filters to filter the outgoing airflow (Figure 3).

We have single or multi-use decontamination devices which are capable of working in normal atmospheric pressure conditions, excessive pressure and low pressure conditions according to the necessary requirements. The latter conditions are obtained using motorized devices which impel or extract air from the inside (Figures 4, 5 and 6). The main difference between the excessive and low pressure devices is that the low pressure ones should have a rigid structure which can prevent an inward collapse of the structure (Figures 4 and 6).

Both systems (excessive and low pressure) are more comfortable than those that have been previously described because they have more space inside and because the user does not need to wear a mask which lowers the individual's stress levels. The use of excessive or low pressure systems with motorised devices depends on the existing risks, although in all systems the air that is expelled from the inside is filtered and, therefore, not contaminated. Excessive pressure systems are used when the aim is to prevent contamination getting inside the device and in this case the incoming airflow should be filtered. If there are small tears in the covering material the excessive pressure will prevent contamination reaching the outside because the air will pass through the excessive pressure inside (Figure 5). In contrast, low pressure systems are used when we want to prevent air from inside escaping without being filtered (Figure 6). There are versatile systems available on the market which allow us to work with excessive or low pressure depending on how the filters are positioned inside or outside the device (Figure 4).

If isolated transport conditions in medical transport

Figure 6. Biological isolation chamber (low pressure).

Figure 7. The Italian air evacuation team's isolation stretcher.

vehicles on land are an important requirement, they must be considered essential in the medical air evacuations of infected individuals who need a higher level of biosecurity[51]. An example of this is the isolation equipment for aeromedical evacuation that the American and Italian armies use (Figure 7)[52]. This equipment can be used for the limited transportation (not mass transportation) of patients with unidentified, lethal or highly contagious conditions. It can also be used in cases of suspected biological attacks that demand specialised medical care for the affected individuals[53,54]. Infected individuals who are considered "suspicious cases" or "confirmed cases" and are being transported back home or those affected by a NBC incident need to be taken to hospital in secure, isolated conditions (biosecurity conditions). However, we also need to develop isolation systems for airports and ports of entry which can provide collective protection, in other words, facilities with incoming and out going air flow filtration systems (with excessive and/or low pressure).

Therefore, if we have protected transport systems and facilities in transit areas, we should also have medical facilities with biosecurity conditions and collective protection that can be used until the agent that has caused the need for isolation has been dealt with.

What benefits are there in using these devices? Firstly, the time spent attending those affected by a NBC incident will be reduced since their transfer from the area where the incident took place to the medical centre where they will be decontaminated (as long as they have decontamination stations) not delayed. This allows resources to be managed more effectively given that medical transport vehicles will not have to be decontaminated after each use because they will not have been contaminated in the first place. Furthermore, the unclean circuits of contaminated ambulances are prevented since contamination from the inside to the outside and vice versa cannot take place. These devices also make the safe transportation of those affected by NBC contamination or highly contagious diseases possible without putting them or the surrounding area at risk thanks to the appropriate biosecurity conditions. Secondly, modern transportation devices allow varying degrees of medical care for those who are using them given that they have interior glove systems and other systems ranging in complexity for introducing and taking out built in medical materials and equipment. Thirdly, they allow medical professionals who are attending those who are unwell/contaminated to work without any kind of individual protection equipment, to improve patient care and to optimise medical transport resources by reducing the decontamination/disinfection times of the medical transportation vehicles or eliminating the decontamination process altogether because they never become contaminated.

CONCLUSION

The use of isolation in the medical transportation of individuals affected by a contagious infection in a scenario involving a given epidemic or who have been contaminated in a technological or NBC incident, creates distinct advantages for the patients and medical staff (and the rescue team). Patients experience a reduction in the time spent on patient care and thus, the available medical resources are managed more effectively and medical care on the whole improves.

For medical staff, the most important benefit would be a decrease in stress levels that are linked to these circumstances because their perception of the risks that they are exposed to would change and that would improve their level of care since they would not have to use any kind of individual protection.

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