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Determining the risk of antibiotic-resistant bacterial contamination of emergency medical vehicles and paramedic personnel: Conclusions from a helicopter air ambulance case study

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Abstract

The presence of infectious disease-causing microorganisms in emergency medical vehicles presents potential public health risks in view of the multiple millions of ambulance calls that are made worldwide annually. This risk of infection is to the patients, to the patients' attendants who may also be transported, and to the paramedic personnel whose work involves pre-hospital transfer. This holds true especially for contamination with those pathogenic microorganisms that pose an increased threat due to their known resistance to front-line antimicrobial agents. Identifying the risks may lead to the development of best practices which could optimise infection control on a routine basis and during a large-scale emergency such as a bioterrorism event or pandemic. Our recent preliminary finding of methicillin-resistant *Staphylococcus aureus* in helicopter air ambulances in Queensland, Australia should provide impetus for a broader scope of investigation of antibiotic-resistant bacterial contamination on a range of emergency medical vehicles. This may warrant the preparation of amended guidelines for best practice in infection control in pre-hospital care cleaning and disinfection to target both a national and international audience among emergency service providers.

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Introduction

Emergency services personnel such as paramedics, police, firefighters, and specialized rescue and response teams perform important functions on a day-to-day basis but also provide critical life-saving assistance following a major incident. In this context, of profound concern is a growing body of research showing that emergency medical vehicles may act as carriers (so-called vectors) of pathogenic microorganisms and thereby facilitate infectious disease transmission [1]. Unless a broader screening process for pathogens is undertaken, and new policies, procedures and practices are developed to reduce transmission risks, emergency services personnel, equipment and vehicles may become unwitting infectious disease vectors, exacerbating the already serious health risks associated with disasters, pandemics and bioterrorism.

Recent studies have detected microbial and body fluid contamination of emergency service vehicles. We have found high numbers of potentially harmful bacteria in helicopter air ambulances in Queensland, Australia [2], as corroborated for different types of emergency medical vehicles and in various settings by other researchers worldwide [3-7]. Eibicht and Vogel tested for pathogens and found ambulances contaminated with the difficult-to-treat Gram-positive bacterium, methicillin-resistant *Staphylococcus aureus* (MRSA) [3], which is resistant to the commonly used class of penicillin-related antibiotics. Noh et al. tested 13 metropolitan ambulances and found that 49.9% of swab samples showed positive for bacteria; 0.9% were highly drug-resistant pathogenic strains: MRSA; methicillin-resistant coagulase-negative staphylococci (MRCoNS); and carbapenemase-producing *Klebsiella pneumoniae* (KPC) [4]. Roline et al. tested 21 ambulances and found 47.6% of surface swabbings were positive for MRSA [5]. Galtelli et al. tested helicopter ambulances and found "large numbers of microbes" [6]. Alves and Bissell tested microbiological cultures taken from four ambulances and found that "four of the seven species isolated were substantial nosocomial pathogens, and three of these four possess formidable antibiotic resistance patterns" [7]. Brown et al. reported that 49% of rural ambulances tested positive in at least one internal location for contamination with MRSA [8].

Furthermore, emergency care equipment has also been shown to have high rates of contamination. Kober et al. discovered enterococci and *S. aureus* on sphygmomanometer cuffs, stethoscopes and respirator masks in ambulances [9]. Lee et al. swabbed patient-ready trauma equipment at six hospitals and three regional ambulance services in the UK; they found that 57% tested positive for blood contamination [10]. Of 50 stethoscopes used by paramedics examined by Merlin et al. 32% tested positive for MRSA [11].

Assessment of bacterial contamination of emergency medical helicopters

Our proof-of-concept case study examined two emergency medical helicopters located in different towns in Central Queensland [2]. Helicopter air ambulances were chosen because of the paucity of research on these particular emergency service vehicles as vectors. Over a three-month study period, the two helicopters attended a total of 68 cases. These comprised of inter-facility transfers (66.2%), neonatal transfers (8.8%), primary responses (23.4%) (including road traffic incidents, cardiac arrest and medical cases), and one search and rescue case (1.5%). During this time each helicopter was sampled by taking swabs on six occasions on an approximately weekly basis. The helicopter's flight log (detailing for every response the distance, locations and number of patients carried) was made available. The presence or absence of bacteria was correlated with vehicle geographical location, intra-vehicle surfaces, flight and cleaning schedules, each over the course of the study.

At each sampling, the interior of the helicopter was swabbed in five areas that were considered to have a high frequency of contact by emergency personnel and patients, and therefore of increased risk of microbial contamination (Figure 1). The diagnostic procedures used were those approved by government regulatory bodies such as the US Food and Drug Administration, and involved routine microbiological culture-based methods. These included growing the samples in various types of selective media that differentiate possible positive bacterial colonies on the basis of colour. For instance, after 24 hours' incubation on chromogenic MRSA agar at 35°C MRSA colonies appear mauve-coloured whereas all other colonies range from blue to green or cream [12]. Further confirmation of their identity as either methicillin-resistant or multi-resistant was achieved using the disk diffusion (Kirby-Bauer) method on Mueller-Hinton agar [13].

The diagnostic screening described was conducted on each sample to test for the presence or absence of both MRSA and multi-resistant *S. aureus*, vancomycin-resistant enterococci (VRE) and Carbapenem-Resistant Enterobacteria (CRE), all of which are recognised as significant contributors to healthcare-associated infections [14,15]. In addition, we tested for the equivalent antibiotic-susceptible organisms as an indicator of the potential of the above antibiotic-resistant bacteria to be carried by these vehicles.

Both presumptive MRSA and other colonies were recovered from each helicopter at all sampling periods, with one exception when presumptive colonies were not recovered. Excluding those instances when bacteria on the selective media plates were too numerous to count the total number of colonies recovered was similar for both helicopters (15,069 versus 14,399 colony forming units). Overall, of the presumptive colonies tested 18.7% were identified as *S. aureus*, 76.0% were typed as other staphylococci (such as *S. epidermidis* and *S. haemolyticus*), and 5.3% were determined to be other genera of bacteria [2].

Since 94.7% of the colonies tested were identified as *Staphylococcus* spp. the potential for the existence of MRSA in emergency medical helicopters is very real. This is especially likely as the prevalence of MRSA among emergency services personnel is reported to be over four times that of the general population [16]. The large numbers of microorganisms recovered in this and a previous study [6] increases the risk of pathogen transfer between the vehicle, emergency services personnel, patients and their attendants. This reaffirms the necessity for standardized cleaning protocols as well as appropriate staff training for their implementation.

The risk presented to patients and emergency medical providers

Previous studies have found MRSA in ambulances in both metropolitan (47.6%) [5] and rural areas (49%) [8]. A range of equipment used by emergency services personnel has also been shown to have high rates of contamination [9-11]. Furthermore, by performing nasal swabbing Amiry et al. demonstrated an alarmingly high prevalence of MRSA among emergency services personnel, 6.4%, much greater than the 1.5% MRSA colonization recorded for the general population [16]. Also, on the theme of work-related stress Smith et al. found that “paramedics ranked outbreaks of new and highly infectious disasters highest for fear and unfamiliarity” [17].

The presence of MRSA and multi-resistant *S. aureus* in emergency medical vehicles could create a risk to patients during and after the 4.4 million and 32 million emergency ambulance responses each year in, respectively, Australia and the US [18,19], as well as for the attendant family members and friends of the patients and for the paramedic personnel who work in these vehicles. This type and level of threat applies equally to emergency service responders in other countries around the world.

If emergency medical helicopters are spreading potentially deadly pathogens among the many thousands of patients that they transfer to hospital each year, scaling up the frequency of use of vehicles it would imply that road-based ambulances may also act as vectors of transmission of potentially deadly pathogens among the millions of patients they transport annually. Moreover, inadequate infection control in emergency medical vehicles could exacerbate the effects of a bioterrorism or pandemic event.

Cleaning and disinfection practices for emergency medical vehicles

It is axiomatic that items or surfaces that have been exposed to a patient’s skin, blood or body fluids should be considered as potentially contaminated. As pathogenic microorganisms are able to survive outside the body for an extended time infection can spread by handling contaminated objects [20]. The most common means of infection transmission occurs when gloved or ungloved hands touch a contaminated surface and/or there is patient contact with contaminated surfaces or medical equipment [21]. It is therefore essential that items of patient care equipment (such as blood pressure cuffs, monitors, stethoscopes and stretchers) that come into contact with skin and/or mucous membranes are subjected to a two-step process of cleaning and disinfection after each response [22]. Defined as the simple removal of foreign and organic materials from a surface or object, cleaning using water, detergents and a scrubbing action physically removes but does not kill microorganisms. This is distinct from disinfection, the process used to kill and prevent the growth of microorganisms on objects and surfaces, which is typically accomplished with regulated chemical products [23].

The inadequacy of execution of conventional manual infection control methods has been linked to operator errors, especially regarding selection, formulation, distribution and contact time of the disinfectant [20,21,23]. Approaches to improve effectiveness include staff training programmes, continuing education, feedback on cleaning and disinfecting performance, routine microbiological analysis of surface hygiene, and the use of fluorescent markers or assays to assess the thoroughness of the procedure [23]. While these measures can improve the efficiency of traditional ways to decontaminate, their sustainability has not yet been investigated. The use of non-manual vehicle disinfection reduces the chances of operator errors associated with traditional cleaning methods and offers the potential for more effective eradication of pathogens to reduce transmission of infections [24]. However, to date there is no definitive evidence to indicate the clinical effectiveness of non-touch or automated disinfection procedures, such as those based on steam cleaning, the use of hydrogen peroxide or ultraviolet light irradiation to prevent or reduce infection rates in ambulances [25,26].

Developing and implementing best practice guidelines for infection control

In the context described above, there is a pressing public health need for the widespread implementation of standardized, improved infection control procedures [1]. Compliance with best practices for cleaning and disinfecting the interior of emergency medical vehicles is an important factor in preventing the spread of antibiotic-resistant bacteria in pre-hospital care settings. Emergency services personnel, their patients and attendants have an increased risk of contracting infection without there being in place clear guidelines and an understanding of, and adherence to, these procedures by ambulance personnel [1,22].

The collective findings of studies of bacterial contamination of pre-hospital care vehicles and contents [2-11] may help to promote best practices for disinfecting emergency medical vehicle fleets, equipment and supplies. This may also lead to the broader development of new or improved policies and procedures that could reduce the day-to-day transmission of deadly pathogens and mitigate the spread of bioterrorism or pandemic microorganisms.

Some efforts have been made to reduce infectious disease transmission through the use of new, supposedly antimicrobial types of fabric; these fabrics have been used to manufacture uniforms for emergency medical service personnel. However, Groß et al. tested one such fabric designed to reduce contamination risks and found no significant difference in microbial contamination compared to standard materials [27].

Future research should aim to sample a breadth of emergency service vehicles in a variety of locations in order to describe and quantify the risk to the paramedic profession and to patients. In turn, this will assist in defining what (if any) mitigation strategies are required to ensure best practice on a daily basis and in case of possible bioterrorism, natural disasters or pandemic outbreaks [28]. A key provision should be future professional development training arrangements for paramedic personnel in air ambulance helicopters and other emergency medical vehicles in awareness of infectious diseases and best practice in infection control.

Discussion

Antibiotic-resistant bacteria are recognised as a major and growing threat to human health, and routinely cause a substantial proportion of healthcare-associated infections, as acknowledged by the medical, nursing and paramedic professions [29,30]. Despite this recognition, there is very little information on the significance of antimicrobial resistance in pre-hospital emergency care [1], which is typically the primary point of patient contact.

Although preliminary research to date from ourselves [2] and others [3-8] has identified possible hazards, each of these studies was limited to only one type of vehicle. The gap in knowledge is the relative contributions to potential infectious disease transmission of a broad range of emergency service providers. Our long-term objective is to determine the extent of contamination currently existing on or in emergency service vehicles across Australia, targeting police cars and fire trucks as well as emergency medical vehicles. These include standard road-based ambulances, first response cars, motorcycle ambulances and helicopter air ambulances, as well as the type of light aircraft used by the Royal Flying Doctor Service to reach patients in remote locations throughout Australia. The data generated would be used to assess the potential for unwanted disease spread and thus to develop recommendations to minimize transmission risks for personnel and for the community.

Conclusion

Globally, all civilised societies are reliant upon the services of paramedics and other emergency medical professionals. Yet, paradoxically given the importance of the role that this sector fulfils, little is known of the risks of infectious disease transmission from contamination by microbial pathogens of vehicles, equipment or personnel. Evaluation of potential risks to paramedics, patients and to the general population should be considered as an imperative in order to develop effective risk reduction interventions. Recent research has established that helicopter air ambulances and other emergency medical vehicles can be vectors for infectious microorganisms. Items of equipment that are handled frequently by paramedics may be at particular risk of contamination.

Mitigating the risk of antibiotic-resistant bacterial contamination of the interior of emergency medical vehicles is a pre-hospital care issue that is encountered daily but one which also has major implications in disaster management scenarios. Preventative strategies intended to reduce the threat of pathogenic bacterial transmission to ambulance staff, patients and their attendants through ensuring a cleaner, safer medical environment demonstrate paramedic industry best practice. Further in-depth research is needed to determine the potential risk of infectious disease transmission among different vehicle types and which may inform the development and implementation of new or revised policies and procedures for cleaning schedules. This affirmative action should strengthen the paramedic sector's mission to save lives, speed recovery and serve the community by helping to provide the highest standards of rapid response critical care.

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Authors' contributions

AWTR conceptualized the paper, which was developed further in discussion with SM. Both authors wrote and critically reviewed various drafts, contributed to preparation of the final version and provided consent for submission.

Figures

Figure 1: Sites for microbiological swab sampling for detection of bacterial contamination inside a helicopter air ambulance. Following discussions with paramedic staff and pilots five areas of the aircraft (A) were considered to have a high frequency of contact by emergency personnel and patients. These locations were: (B) the floor surface between the emergency personnel seats and patient stretcher; (C) the seat belt buckle on the emergency personnel seats; (D) the hand piece of the Citizens' Band radio; (E) the buttons on the display panel of the cardiac monitor/defibrillator; and (F) the blood pressure cuff storage bag.

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