

Application of the Ultraviolet Germicidal Irradiation system can reduce microbial surface contamination in ambulance compartments

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Research article for critique: William G. Lindsley, Tia L. McClelland, Dylan T. Neu, Stephen B. Martin Jr., Kenneth R. Mead, Robert E. Thewlis & John D. Noti (2018) Ambulance disinfection using Ultraviolet Germicidal Irradiation (UVGI): Effects of fixture location and surface reflectivity, *Journal of Occupational and Environmental Hygiene*, 15:1, 1-12, <http://doi: 10.1080/15459624.2017.1376067>

Study synopsis

Abstract

Emergency responders play a vital role in treating critically ill or injured patients, as they are often the first point of contact for the patient in the healthcare setting. Emergency medical services also play a vital role in the prevention and control of the transmission of communicable diseases and ensuring best practice infection control is enacted. Lindsley et al. (2018) recently examined the efficacy and impact of an ultraviolet germicidal irradiation (UVGI) system to disinfect the interior of an ambulance. A critique of this article is presented in the following.

Introduction

The risk of transmitting infections is of great concern to emergency healthcare professionals (HCP) (Jalili, 2020). COVID-19 has highlighted the significant global issue of

transferring critically ill pandemic patients to intensive care units, for which ambulances are routinely used to facilitate the transition of patients from home to hospital (National Health and Medical Research Council, 2019). However, ambulances may be a reservoir of multi-resistant microorganisms as patients' microbiotas may colonise healthcare personnel and the ambulances' physical environment, increasing the risk of transmission (Varona-Barquin et al., 2017). Thus, understanding how to adequately clean and disinfect an ambulance that has transferred a suspected/confirmed COVID19 patient is a contemporary practice issue. Environmental cleaning and disinfection principles in healthcare settings typically focus on the five moments of hand-hygiene (Laskar et al. 2018); cleaning frequently touched surfaces (e.g. blinds, railings); cleaning minimally touched surfaces (e.g. walls, floors, ceilings); and an infectious or terminal clean.

Terminal cleaning is a complete and enhanced cleaning procedure that decontaminates an area following the discharge or transfer of a patient with an infectious/communicable disease (National Health and Medical Research Council, 2019). Terminal cleaning efforts are tedious, time consuming, and several studies suggest that persistent contamination is common in patient areas after cleaning (Varona-Barquin et al., 2017; Rago et al., 2012). As existing cleaning practices only partly reduce contamination threats (Valdez, Sexton, Lutz & Reynolds, 2015), alternative approaches to reduce the risk of transmission in ambulances is needed.

Ultraviolet germicidal irradiation (UVGI) systems are employed in hospitals as a final disinfection step after the patient has been removed as they allow HCPs tasked with manual cleaning to focus on surfaces that are visibly contaminated, rather than attempt to clean every possible surface. A recent multi-site hospital clinical trial revealed that adding UVGI disinfection to routine cleaning practices decreased the incidence of methicillin-resistant *Staphylococcus aureus* (MRSA), vancomycin-resistant enterococci (VRE) and multi-resistant *Acinetobacter* in exposed patients (IRR=0.70, 95% CI=0.50-0.98; p =0.036) (Anderson et al. 2017). UVGI systems are easy to use, do not leave chemical residues and can be used while HCPs continue to work. However, UVGI systems have limited effect

against microorganisms on surfaces that are not in a direct line of sight of the system and are ineffective against organisms that are covered or inaccessible. The effectiveness of UVGI in ambulances is unclear; however, a study by Lindsley et al. (2018) may provide some emerging evidence and is the focus of this research critique.

Aim

The aims of this study were to: a) determine the ability of an UVGI system to disinfect the interior of an ambulance patient compartment; b) examine the variations in irradiance among different locations in the compartment; c) examine the effect of UV-reflective material on the efficacy of the UVGI system; and; d) examine the effect of UV-reflective paint on the efficacy of the UVGI system (Lindsley et al., 2018 p. 3).

Method

The researchers used a prospective observational design. A 2005 Wheeled Coach Type III ambulance was used in the study because it aligned to national construction standards (American Society for Testing and Materials, 2009). The UVGI light fixture was custom built for the study and consisted of 10 UV-C lamps (primary wave length 254 nm; UV per lamp 12, 4 watts). The lamps were mounted vertically in two circles (11.1 cm diameter aluminum post) and placed in three positions in the patient compartment (front,

middle and back). The windows of the ambulance were covered with aluminum foil, access was restricted and individuals inside the patient compartment wore a UV-C absorbing face shield and personal protective equipment (PPE) during data collection.

Irradiance measurements from the UV-C light fixture were made at 49 locations throughout the patient compartment and included both frequently touched surfaces (e.g., light switch), minimally touched surfaces (e.g., next to rear most seat buckle) and areas not in a direct line of sight of the system (e.g., on the back of an overhead hand rail, facing the ceiling). All measurements were repeated three times, sensors were rotated among locations, so that measurements were collected three times with different sensors at each location for each UVGI fixture position. This data collection approach generated 153 data points.

The efficacy of the UVGI system was also assessed under three different interior surface conditions. These were: 1) 'original' (i.e., as supplied by the manufacturer); 2) 'reflective' (i.e., vertical surfaces and floor covered with diamond-plate aluminum sheets); and 3) 'UV paint' (i.e., all white melamine interior surfaces painted with UV-C reflecting paint).

The researchers chose to assess the antimicrobial effect of the UVGI system using *Bacillus subtilis* spores (i.e. surrogate for

pathogenic microorganisms) because UVGI doses that inactivate 99.9% of *B.subtilis* spores on a solid surface would also inactivate at least 99.999% of many pathogens including *Staphylococcus aureus*, *Pseudomonas aeruginosa*, *Salmonella enteritidis*, *Serratia marcescens*, *Mycobacterium tuberculosis* (Lindsley et al., 2018). Spore loaded coupons were fastened next to the inlet domes of the UV light sensors. Ten coupons were placed in the locations in the ambulance with the lowest irradiance levels for each interior surface type and two control coupons were not exposed to UVGI. The tests were performed six times with original interior surfaces, three times with the reflective interior surfaces and three times with UV-paint surfaces.

Results

The UVGI systems can reduce microbial surface contamination in ambulance compartments. A UV-C dose of 52.6 mJ/cm² was required to inactivate 99.9% of the spores on a coupon (0.1% survival rate). Large variations in disinfection times were seen because locations further away from the UVGI fixture or in shadow received much lower UV-C doses compared to areas closer to the UV fixture. The overall disinfection time ranged from 16.5 hours for the poorest to 59 minutes for the best UV-C configuration. The overall disinfection time was reduced to 79 min by adding the reflective aluminium surfaces and to 59 min by painting the interior with UV-

reflective point. The Critical Appraisal Skills Programme (CASP; 2018) Qualitative research checklist guided the following critique.

Critique and application to practice

The findings of this study have relevance for emergency responders internationally who are required to transfer patients that have suspected/confirmed infections via ambulance (Williams-Claassen, 2013). This is a robust study with clear aims and a detailed description of research methods and measurement procedures. Optimising the UVGI fixture positions and increasing the interior ambulance surfaces UV reflectivity improved the efficacy and reduced the time required for disinfection. However, the considerable variation in disinfection time suggests that the effectiveness of the UVGI system is poor. Further, the feasibility and acceptability of the UVGI system in ambulances is unclear. The surfaces of the ambulance in this study were altered to improve the effectiveness of the UVGI system, and it is unclear if this would be feasible in practice. The Medical Research Council (MRC) Framework suggests that the UVGI system described by Lindsley et al. (2018) is a complex intervention, and researchers should explore the feasibility and acceptability, including barriers and facilitators to intervention uptake (Craig et al. 200). For instance, adding any amount of time to the cleaning process may further delay the availability of an ambulance (a crucial resource in rural settings) and despite

the benefit of enhanced decontamination, stakeholders may not see value in this new process. When new interventions are being designed, feasibility planning is recommended, and the Knowledge-to-Action Cycle can guide researchers (Graham & Tetroe, 2010).

The cost of implementing the UVGI system is unclear. As the UVGI system was custom built for this study, the 'actual' cost to purchase, maintain or train staff to operate a similar system is not yet known. Future researchers should report the cost of the UVGI system, and the Template for Intervention Description and Replication (TIDieR) checklist (Hoffman et al. 2014) can be used to inform this process. Further, the study by Lindsley et al. (2018) emphasises manual cleaning of visibly soiled areas instead of emphasising the pivotal role that manual disinfection/terminal cleaning plays before implementing the UVGI system. The researchers also based their conclusions on the longest disinfection times. Although sound for research purposes and to ensure complete confidence in spore inactivation, future research and policy discussions are required to balance the acceptance of irradiance times against the efficacy of alternate cleaning methods as well as human factors in current procedures. This would inform the benefits, effectiveness and economy, using the 'as low as reasonably practicable' (Miller, 2009) principles to determine if implementation of UV-C

disinfection is an improvement on current accepted standards.

The appropriate and prompt application of infection prevention and control measures is essential for preventing transmission of infection in the prehospital environment. The recent COVID19 outbreak has demonstrated the need for a primary strategy in the prehospital field to reduce the risk of infection for both the healthcare providers and patients being transported by ambulance. The Centers for Disease Control and Prevention (CDC) (2020) has recently released interim recommendations for the Emergency Medical Services (EMS) during the COVID-19 pandemic. These recommendations have highlighted the need for EMS staff to be trained and educated in the prevention of the transmission of infectious diseases, the appropriate use of personal protective equipment, including respiratory protection, and trained in practices

to clean and disinfect ambulances in-line with services' own standard operating procedures. The CDC further outlined how to decontaminate and clean an ambulance that has transported a person under Investigation or patient with confirmed Ebola, which may inform practices as they relate to other viruses such as SARSCOV2/COVID19 (CDC, 2016). The decontamination process is designed for a three-person team, while the UVGI system in the study by Lindsley et al. (2009) only required one person to use, position and operate the treatment. The full decontamination procedure is summarised in Table 1. This procedure is time and labour intensive, as well as being procedurally reliant. Having different control mechanisms in the cleaning process that are less subject to human error, such as UV-C disinfection, can be seen as beneficial and merits further research towards practical implementation.

Table 1

<p>Before Decontamination</p> <ul style="list-style-type: none"> • Limit the number of people exposed to potentially contaminated materials • All waste, including PPE, drapes, and wipes, should be considered Category A infectious substance and should be packaged appropriately for disposal. PPE should be donned and doffed according to organisational protocols. • PPE selection should consider worker protection for biological exposures and potential chemical exposures based on the disinfectant used.
<p>During Decontamination</p>

- Disinfect the outside of any prepositioned but unused medical equipment (still inside the protective bags they were placed in) and pass it to the warm zone. If the equipment was removed from a protective bag in transit, assess the equipment to determine if it can be properly decontaminated and disinfected, or disposed of.
- Any areas that are visibly contaminated with the patient's body fluids should be decontaminated first with an approved EPA-registered disinfectant for the appropriate contact time before soaking up the fluid with absorbent materials.
- If the interior of the ambulance was draped prior to transport, remove the draping by rolling the drapes down outside in, from the ceiling to the floor of the unit starting at the front of the compartment and moving to the rear.
- Roll flooring drapes from the front to rear of the compartment, rolling drapes outside in.
- To facilitate packaging and transport, drapes can be gently cut into segments. It is important that all drape materials are in sections that are small enough to facilitate the insertion of the biohazard bags into an autoclave or pre-determined Category A infectious substance packaging for disposal.
- Two people in PPE should manually disinfect the interior of the patient care compartment with particular detail for high-touch surfaces such as door handles and steps using care to limit mechanically generated aerosols and using the surface wipe method to disinfect.
- Disinfect the interior as a team so that the team members can talk to each other through the process and expedite the decontamination process. Once the manual interior wipes down has been completed, collect and package all waste as Category A waste.
- Manually wipe down the ambulance's exterior patient loading doors and handles, and any areas that may have been contaminated, with disinfectant. The exterior of the ambulance does not require a full disinfectant wipe down.
- Once the outside of all surfaces (including waste bags) have been wiped with disinfectant, then doffing can occur.

After Decontamination

- A third person who has been in the cold zone should supervise doffing, which should be performed according to organisation doffing protocols. Dispose of all waste according to organisation protocols as well as local and federal regulations for Category A infectious substances.
- Additional cleaning methods can also be used. While not required, this may provide additional assurance to personnel and public prior to returning the vehicle to service. Ultraviolet germicidal irradiation, chlorine dioxide gas, or hydrogen peroxide vapour can be used for an additional disinfection step. However, these should not replace the manual disinfection, as their efficacy against organisms in body fluids has not been fully established and these methods may require specialised equipment and PPE.
- The ambulance can then be returned to service.

Table 1. SOP for Decontamination of an Ambulance that has transported a person under Investigation or patient with confirmed Ebola (CDC, 2016)

Note: The following key assumptions are being made in the above SOP: All healthcare workers (hospital and out-of-hospital) who are involved will have received education and training and demonstrated the necessary competencies for management of patients with serious communicable diseases. Healthcare facilities and transporting ambulance agencies have procedures for the management of patients with serious communicable diseases. Facilities and transporting ambulance agencies are conducting tabletop and operational exercises that test and refine procedures for the transfer of patients. This guidance complements other CDC guidance for management of patients with serious communicable diseases. PPE = Personal Protective Equipment.

Conclusion

This study is the first paper to report UVGI system to disinfect an ambulance and provides emerging evidence for the application of UVGI as a decontamination approach. Emergency responders using ambulances at the front line of public health are at risk of exposure to patients with known or unknown infectious diseases. The study examined in this research critique demonstrates that UVGI systems have the potential to reduce the transmission of infectious diseases in ambulances and could be incorporated into terminal ambulance disinfection. Implementation of this system would require further economic evaluation, engineering, and design testing in various ambulance configurations and the training of EMS staff in its use described.

Competing Interest

None declared

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