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**Hennings, Anthony J.** ***An Analysis of Company ABC's Ambulance Disinfection Procedures and Patient Compartment Cleanliness***

## Abstract

This study was conducted to determine overall quality of Company ABC's ambulance disinfection procedures. Company ABC's ambulances are used to transport patients between hospitals and are potential carriers for hospital acquired infections (HAIs). In order to carry out this study, four surfaces were tested within seven different ambulances. Adenosine triphosphate (ATP) bioluminescence testing was conducted to identify gross bacterial counts on selected surfaces to determine the effectiveness of the employees' cleaning and disinfection practices. The results of the ATP testing indicated that 39% of Company ABC's tested surfaces were above the standard hospital-based benchmark of 100 relative light units (RLUs). Along with ATP testing, the author of this paper created a checklist to assess the quality of Company ABC's disinfection policies / procedures. The results of the ambulance disinfection policy / procedure assessment process indicated that Company ABC did not have adequate measures in place to ensure the cleanliness of patient compartment surfaces in order prevent the spread of potentially infectious agents.

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This study could never have been possible without the support of my Fire Chiefs and the amazing help of local hospital staff. One of my greatest advocates, Dr. Finder, put forth a tremendous effort in ensuring my success throughout this project and its timely completion and his dedication allowed this work to be completed. My loving wife and two young children lived many days without my presence and without their love and support I would not have been able to succeed.

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## Chapter I: Introduction

Throughout the past five years, changes to infection control procedures appear to have led to higher quality procedures and optimized safety for hospital-based medical professionals and patients. Infection control in the prehospital setting, meaning patient care prior to admittance to a hospital, has lagged behind that of standard healthcare facilities and thus may necessitate action from patient transport providers to advance their pathogen control programs (Storm, Geibner, &Kolmos, 2018). In 2015, there were over 7.1 million hospital-acquired infections (HAIs) in the United States (Hensley & Monson, 2015). Hospital-acquired infection data collected by the Centers for Disease Control (CDC) involves various types of infections which involve the lungs (i.e. pneumonia), gastrointestinal and urinary tract, the bloodstream, and inpatient surgical sites (CDC, 2018). The CDC also identifies other types of diseases, encompassing a variety of infections which are transmitted within a healthcare facility. While there is no direct study outlining the spread of HAIs during patient conveyance inside an ambulance, it is the goal of prehospital care providers to ensure that the acquisition of HAI's does not take place during patient transport (McCallion, 2012).

With recent coverage changes within the Affordable Care Act (ACA), the occurrence of HAIs may be subject to a payment reduction by Medicare/Medicaid (NCBI, n.d.), as the infection may have been caused from within the hospital. Within the ACA, nursing homes may also be held financially responsible for the occurrence and subsequent treatment of HAIs. In light of the aforementioned ACA infection accountability approaches, ambulances may be a possible carrier of pathogens and therefore should be treated similarly to the guidelines that hospitals are subject to regarding the prevention of HAIs (NCBI n.d.). With ambulances serving as a direct link between both hospitals and nursing homes, it is conceivable that patients may be

exposed to pathogens from either facility, or through one or many intermediaries, such as ambulances.

As a prehospital care provider, Company ABC strives to deliver high-quality transport services as well as safe compartments for patients and employees. For example, Company ABC instituted the use of ultraviolet (UV) lights for enhanced disinfection of patient care compartments within Company ABC's ambulances in 2017. While this disinfection approach could be considered a positive move forward, the UV lights were delivered to company ABC with no protocol or time usage instructions. Company ABC strives to follow modernized infection control practices to ensure a biologically clean work area for employees and patients, however, this organization's ambulance disinfection policy was last updated in 1987. Given that a previous study indicated the presence of Clostridium Difficile (C. Diff) in a Company ABC ambulance, there is evidence of a potential issue with the organization's vehicle disinfection procedures (Yount, 2017). Along with the discovery of C. Diff in a Company ABC ambulance, it should be noted that both major hospitals in the region are experiencing C. Diff and HAI rates that are higher than the national standard. For example, both major hospitals experienced standardized infections rates (SIR) of C. Diff at 1.31 and 1.26 respectively, with the national benchmark being 1.0 (CMS, n.d.). SIR is calculated as a ration of the expected number of infections versus the actual number of infections (CMS, n.d.) Based on the aforementioned regional hospital infection rates as well as previous positive C. Diff testing results and potentially outdated procedures, there is a reasonable likelihood that the surfaces within Company ABC's patient transport vehicles contain microorganisms at levels which are greater than what is permitted within a hospital setting.

**Purpose of the Study**

The purpose of this study is to identify the extent that Company ABC's patient compartment disinfection procedures are effectively minimizing the risk of biological agents which may be transferred to transported patients as well as employees.

**Goals of the Study**

The following goals will be accomplished as a result of performing this study:

- Perform ATP bioluminescence testing in the patient compartments of Company ABC's transport ambulances.
- Identify gross bacterial counts to determine the effectiveness of current disinfection procedures.
- Assess current Company ABC vehicle surface disinfection procedures in relation to current published standards.

**Background and Significance**

Company ABC employs approximately 84 EMTs and paramedics who respond to over 8,000 Western Wisconsin-based emergency medical service (EMS) incidents per year. This EMS call volume has increased over 100 percent since the last revision of the company's infection control policy in 1987 and thus likely requires updating. These infection control policy changes are necessary to protect not only the company's employee assets, but also the patients who rely on Company ABC for EMS. Improved infection control practices will likely minimize Company ABC's legal liability as a result of a reduced spread of infectious agents and a decrease of medical malpractice allegations. The company will likely reduce its exposure to employee illness or death related worker compensation claims, as well as negative publicity associated with being associated with a disease outbreak. There are likely to be a plethora of different pathogens that

may be transmitted in an ambulance, however, this study is focused on measuring gross bacterial count as well as Company ABC's current disinfection policies/procedures in order to determine the overall disinfection effectiveness of patient compartment surfaces.

**Assumptions of the Study**

This study operates under the following assumption:

1. Substandard surface disinfection practices/procedures will cause bacteria to be present on patient compartment surfaces.
2. Bacteria will cause a bioluminescent reaction during testing.

**Limitations of the Study**

The study is limited by the following:

1. Only seven ambulances will be studied.
2. Positive bioluminescence results will indicate only that bacteria are present and do not discriminate between favorable and unfavorable microbes.

**Definition of Terms**

Following is a list of semi-technical terms which are used throughout the study:

**Ambulance.** A vehicle which transports injured or sick (Merriam-Webster, n.d.).

**Disinfect.** To free a surface from infection removing and/or by destroying harmful microorganisms (Merriam-Webster, n.d.).

**Emergency Medical Technician (EMT).** A person who is specially trained and certified to provide emergency medical before a patient reaches a healthcare facility (Websters, 2008).

**Paramedic.** A person who is trained to assist a physician or to give first aid or other health care in the absence of a physician and is often as part of a police, rescue or firefighting squad (Merriam-Webster, n.d.).

# Chapter II: Literature Review

The purpose of this study was to identify the extent that company ABC's patient compartment disinfection procedures are effectively minimizing the risk of biological agents which may be transferred to transported patients as well as employees. The literature review is set up in four basic categories, beginning with a description of hospital-acquired infections, various controls that are in place to prevent organism transmission, the quantitative testing methods which are available to evaluate the effectiveness of organism transmission controls, as well as surface cleaning techniques.

## Hospital Acquired Infection (HAI)

HAI is an infection that a patient acquires while in a hospital setting (Marcoitch, 2018). HAIs include central line-associated bloodstream infections (CLABSI), surgical site infections (SSI), catheter-associated urinary tract infection (CAUTI), and ventilator-assisted pneumonia (VAP) (CDC, 2018). A central line is a catheter placed into a large vein, such as in the groin, chest or neck (CDC, 2018). CLABSI is an infection, caused by bacteria or virus, which enters the body through an arterial venous catheter (CDC, 2018). SSI affects an area of the body where surgery has taken place and may range from a superficial colonization to takeover of an entire organ (CDC, 2018). This type of infection can be in any area of the body associated with surgery, including any organ. CAUTI may involve indwelling, external, or suprapubic catheters. An internal catheter is inserted into the bladder through the urethra, while an external catheter adheres to the genitalia without being inserted (CDC, 2018). A suprapubic catheter is a soft tube surgically implanted into the bladder above the pubis (CDC, 2018). VAP is an infection within the lung/lungs of a patient who is breathing with the assistance of a ventilator. A ventilator is a machine that essentially breaths for a patient through a tube placed in the neck, nose or mouth

(CDC, 2018). The infection is secondary to a pathogen introduced into the patient's lung/lungs, causing pneumonia (CDC, 2018). Working knowledge within the definitive areas of HAI would likely afford an individual the opportunity to understand and mitigate the risks involved.

Bacteria associated with HAI. Recently, much attention has been paid to hospital acquired infections, linking dirty hospitals to antibiotic resistant infections (Dancer, 2009). Dancer (2009) reviewed and examined through various literature, the links between antibiotic resistant infections and hospitals. The pathogens reviewed included methicillin-resistant Staphylococcus aureus (MRSA), vancomycin-resistant enterococci (VRE), norovirus, Clostridium difficile (C.dif) and Acinetobacter. These and other types of bacteria may be readily found in the hospital environment and are believed to be involved in HAI (Dancer, 2009).

The first antibiotic resistant infection for discussion is MRSA, a form of *Staphylococcus* bacteria, which is resistant to certain forms of antibiotics (CDC, 2016). Severe and life-threatening infections from MRSA can occur in healthcare settings (CDC, 2016). This form of infection is of interest because MRSA has the ability to survive up to one year in dust (Dancer, 2009). VRE is a drug resistant form of Enterococci bacteria which may be spread by the hands of healthcare workers after contact with a contaminated surface or contaminated patient, as well as directly from surfaces which have been contaminated (CDC, 2011). Nearly all VRE infections take place within a hospital and have the ability to colonize urinary catheters, wounds associated with surgical procedures or the bloodstream (CDC, 2011).

Norovirus is known to cause gastroenteritis or inflammation to the gastrointestinal tract which typically results in diarrhea and vomiting (CDC, 2013). Norovirus is found within vomit and feces of infected individuals and has the ability to spread rapidly within a healthcare facility due to the virus's ability to be propagate by airborne droplets (CDC, 2013). The germ *C. difficile*

is known to be the principle microbe which caused nearly 500,000 infections within the United States in 2011 and killed nearly 30,000 people (CDC, 2016). C. dif results in symptoms that include fever, nausea and watery diarrhea. Infections are often caused by the use of antibiotics which are responsible for wiping out the normal bacteria functioning within the gastrointestinal tract, allowing the C. dif to infect the area (CDC, 2015). C. dif is often transferred from the hands of healthcare workers who have come into contact with either an infected patient or surface (CDC, 2015). Acinetobacter are a form of bacteria that can cause infections primarily in intensive care units along with other healthcare settings. (CDC, 2010). The Acinetobacter bacteria has the ability to live in an environment for several days and can also survive on the skin of humans. It is spread through person-to-person and person-to-surface contact (CDC, 2010).

HAI prevalence/rates. In the United States, HAI rates are quantified using the standard infection ratio (SIR). The CDC uses standard infection ratios to determine the prevalence of HAIs within a healthcare system (e.g. hospital) (CDC, 2019). A SIR is used in place of a rate which could create an unfair comparison between two organizations with differing demographics. The SIR consists of the number of observed HAIs divided by the number of predicted hospital acquired infections. The use of a ratio also allows for a national benchmark of 1.0, with numbers higher than 1.0 being above the national standard and those below 1.0 falling under the national standard (CDC, 2019). The number of predicted HAIs is calculated using a logistic regression model (SSI), which is a statistical analysis which includes multiple variables. The model takes into account patient demographics and various risk factors which include body mass index, diabetes, as well as risk factors within a local hospital. Risk factors include a variety of situations from the size of the hospital performing a procedure to the length of time in which a

patient is admitted. The previous statistics create a number which determines the probability of a particular patient acquiring an HAI (CDC, 2019).

**Preventing HAI Transmission**

According to the World Health Organization (WHO) (2018), the prevention of HAI requires a program that includes limiting the transmission of organisms, controlling risk factors, protecting patients through prophylaxis, minimizing the use of invasive procedures, surveilling infections for spread, preventing infections among staff and strengthening patient care practices. (WHO, 2018). Risk factors include the use of personal protective equipment (PPE), hand washing and bed linen washing. The first step of the WHO organism transmission limiting process involves quality handwashing procedures which range from simple techniques to more elaborate methods that involve vigorous scrubbing prior to surgery. According to the CDC (2002), the transmission of pathogens from one patient to another via the hands of a healthcare worker typically follows a sequence of steps. The steps of the pathogen transmission process involve the organism's transfer to the hands of the health care worker, followed by inadequate handwashing and then contact with another patient (CDC, 2002). Pathogens associated with HAI can be found in areas of intact, normal skin, as well as draining and infected wounds (CDC, 2002), with the inguinal (groin) and perineal (between legs) areas the most commonly colonized. Other frequently colonized areas include the trunk, axillae (armpit), and upper extremities (CDC, 2002).

Another aspect of an infection control program involves quality personal hygiene which includes cleaning of the fingernails and hair. Masks should also be used in appropriate situations to protect patients and staff from airborne transmission of pathogens (CDC, 2002). A step towards a quality program, as outlined by the CDC, includes the common use of protective

gloves and safe injection practices. Safe injection practices include the use of disposable syringes and the elimination of unnecessary injections. WHO, 2018 also suggests that minimizing the transmission of pathogens from equipment to the environment requires adequate cleaning, disinfecting and sterilization methods be in place (WHO, 2018). Routine cleaning is necessary as up to ninety percent of microorganisms are present in visible dirt. WHO, 2018, also clearly defines zones and the level of cleaning that is necessary. In the case of ambulances, it would be reasonable to place these vehicles into what is considered zone B, which entails cleaning with procedures that do not raise dust and disinfecting areas that are contaminated with bodily fluids (WHO, 2018). WHO designates its best practices as a guideline for healthcare facilities to follow in order to slow the spread of any given disease.

**HAI Prevention Regulations**

As a result of the 2009 omnibus bill which was passed by the United States government, any state that obtains preventive health and health services block grants is required to develop a plan to control HAIs (CDC, n.d.). The intention of this regulation is to substantially lower the recurrence of HAI by requiring each state to implement a five-year plan to lower infection rates. The CDC created a planning template for states to follow in the process of creating a plan and infrastructure. The first area discussed within the CDC's planning template involves the development of a state infrastructure plan for HAI surveillance, prevention, and control (CDC, n.d.). Included within the template are the basics for ensuring that healthcare facilities have the tools necessary to actually carry out an infection control plan, including a communication plan for different agencies to share data. The next section of the template involves surveillance, detection, reporting and response. This section includes local training guidelines for hospital staff as well as requiring hospitals to share HAI data with other health care systems. Another aspect

of the template addresses required collaborations within the state to ensure that large areas and possibly regions are communicating as well as developing plans for HAI prevention both in-hospital and in the community. The next area of the template includes the evaluation and communication of HAI data. This involves the development of a plan to measure progress towards HAI prevention goals, as well as a communication plan to share information with stakeholders. The last section specifically deals with Ebola and the development of a plan for a U.S.-based outbreak of this contagious pathogen (CDC, n.d.). While this template serves as a reasonable HAI control guide, there is minimal force to actually bind a given state to the various requirements.

**Biological Agent Testing Procedures**

The CDC offers a list of five methods for evaluating environmental hygiene (CDC, 2014). The methods serve as a guideline for hospital infection control professionals to use as they develop procedures for pathogen control. While patient transport (e.g. ambulance) service providers may not be required to follow such environmental hygiene evaluation methods, one could reasonably conclude that such would be in the public's best interest.

**Direct practice observation.** The first of the five methods involves direct practice observation. In this method, a qualified observer is used to watch the cleaning take place within a selected area. The process of using an observer is used to ensure the respective employees' adherence to established cleaning procedures and guidelines. Observation becomes a logistical difficulty as it requires one person to watch another individual clean and therefore this practice presents a potential cost prohibition by requiring an additional person to supervise cleaning (CDC, 2014). The cost of this observation process could be minimized by performing such on a periodic basis to ensure that standards and procedures are being followed.

**Swab culturing.** The next environmental hygiene evaluation approach includes the use of swab cultures. This method is used to identify a single pathogen, which could require numerous swab tests and thus increase the potential for significant cost. Swab culturing has the potential to be time-consuming due to the need to wait for sample growth. Swab cultures also require a level of pre-cleaning to ensure accurate assessments of a given disinfection practice (CDC, 2014).

**Agar slides.** Agar slide cultures serve as an additional assessment tool. Agar is a gelatin-based medium that allows the growth of bacteria and is used to visibly observe colonized pathogens. The agar coated slides can be used to quantify a gross bacterial count on a surface by counting the number of colonies that are formed. Similar to swab culturing, agar slide procedures require surface pre-cleaning to acquire a baseline for environmental cleanliness. Along with its challenges which include significant cost and time, agar slide cultures are regarded as a quality method for determining site surface contamination levels (CDC, 2014).

**Fluorescent marking.** Fluorescent markers are another option for evaluating the effectiveness of environmental hygiene practices. Fluorescent powders, gels and lotions were developed for the purpose of marking objects prior to the cleaning of a room (CDC, 2014). Lotions have proven to be difficult to clean from surfaces after use and the powders have noted challenges by the ease of disturbance. In contrast, the fluorescent gels have proven to demonstrate the accuracy of cleaning in the educational environment by clearly marking high touch areas and allowing students to see problem surfaces. Fluorescent gels and powders are deployed on high-touch areas prior to cleaning and are then assessed to determine if the gel or powder was properly removed from a particular surface during disinfection. Due to the difficulty of removing a fluorescent gel from a given surface, this approach typically fails to

indicate adherence to quality standards since the cleaned areas have been adequately disinfected (CDC, 2014).

**Adenosine triphosphate bioluminescence.** The fifth environmental hygiene surface evaluation method is adenosine triphosphate (ATP) bioluminescence, which measures the energy used by cells within living organisms. ATP is a chemical used by all living cells to create energy from sugar molecules. According to the CDC (2018), this surface cleanliness measurement tool uses a swab to sample a surface area. The swab is then analyzed using a luminometer which measures the total amount of microbial and non-microbial ATP in relative light units (RLU) (CDC, 2014). The readouts for relative light units are typically large in range and thus low readings are associated with decreased counts of aerobic organisms (CDC, 2014). High RLU readings may be associated with organic debris or a viable bioburden, which includes non-living cells that have accumulated. In certain cases, the surfaces tested could be viewed as failing to meet quality standards due to the surface not being visually clean and yet effectively disinfected from microorganisms (CDC, 2014). Another issue with ATP bioluminescence testing is the ability for the high concentrations of bleach (i.e., sodium hypochlorite) to oversaturate the reaction and result in less light reactivity. To minimize the potential for bleach interference, it is recommended that any surface which has been cleaned with a bleach-based disinfectant must be allowed to adequately dry before use of the ATP assessment tool (CDC, 2014). Despite limitations, ATP bioluminescence testing is used to document improvements daily cleaning as well as provide measurement for high touch surface cleanliness (CDC, 2014).

ATP bioluminescence testing has been used to assess cleanliness and disinfection in a variety of settings (Willis et al., 2007). Living organisms all contain adenosine triphosphate (ATP), and the presence of the molecule is an indication of microbial growth (Hola, 1999). With

that said, there is a positive correlation to the presence of high amounts of ATP and biological agent contamination. The technique first has a surface swab which is reacted with luciferin and luciferase enzymes with ATP, resulting in light emission. Light emission of one photon signals the presence of one ATP molecule (Willis et al., 2007) Within seconds, the result is provided by the handheld luminometer which makes this process beneficial for situations where immediate feedback is desired without the use of a laboratory and thus verify quality cleaning and disinfection practices (Douglas & Rothwell, 1991).

Emodio and Dino (2014) performed a meta-analysis of various studies regarding the use of ATP bioluminescence and surface cleanliness which have indicated a lack of international standardization of testing procedures regarding the presence of pathogens. Three significant observations were made by Emodio and Dino's research to support the lack of uniformity in ATP bioluminescence testing practices. The first is that the ATP measurement results can only be applied on a national scale, meaning that countries typically employ inconsistent testing methods (Emodio & Dino, 2014). Another area for concern is the fact that various studies occurred using different testing instrumentation with varying sensitivities as well as fluctuations which are caused by chemical contamination (i.e. sodium hypochlorite). Additionally, sensitivity issues have been caused by a lack of consensus on testing procedures (Emodio & Dino, 2014). The lack of uniform procedures arises due to inadequate cooperation between hospital systems which thus causes inconsistent testing practices. Despite the presence of various procedural and testing-based concerns, ATP bioluminescence testing is considered a quality method for rapid assessment of hospital surface disinfection practices (Emodio & Dino, 2014).

**Cleaning and Disinfection Techniques**

To prevent the spread of infection, a systematic program is needed to prevent disease spread through cleaning/disinfection. In order to strengthen its HAI practices, a hospital system in Connecticut created task force to initiate the revision of its policies regarding infection control. This task force approached the policy revision process by creating a multidisciplinary team (Dumigan et al., 2009). There is an importance to include not only infection control managers and administrators in policy development-related efforts, but also to involve workers that have surface cleaning/disinfection experience. An option for a process improvement strategy involves the use of Deming's plan-do-check-act model (Dumigan et al., 2009). Since it is not possible to write one blanket policy to protect all aspects of disinfection throughout a hospital setting, each location must be considered from a policy/procedure development standpoint (Dumigan et al., 2009). The process starts by making a list of tasks that must be completed and then assigning the functions to various entities for completion. These tasks may include cleaning during daily activities, hospital discharge and changeover of patient compartments. For this hospital's policy review process, the employees were questioned on whose role it was to clean since they were not correctly conducting their duties due to being instructed by others to either skip an activity or were never told to perform the procedure (Dumigan et al., 2009). A two-phase surface disinfection system was used where the surfaces in 105 patient rooms were first cleaned using the protocol in place and then were checked for adherence to existing procedures (Dumigan et al., 2009). The check portion of the study was completed using ATP bioluminescence (Dumigan et al., 2009). In all, the task force concluded that the formation of a multidisciplinary team was necessary in order to create policies/procedure for the performance of routine cleaning (Dumigan et al., 2009).

The CDC has various recommendations for the disinfection and sterilization of hospital surfaces, but this governmental agency has not produced any literature on ambulance cleaning with the exception of a procedure to be used during an Ebola outbreak. Specific step-by-step decontamination instructions have not been developed by a governing agency in reference to ambulance cleaning and disinfection, however, guidelines have been published for precautions within a hospital setting. It should be noted that the CDC does provide guidance for surface disinfection procedures on medical equipment and environmental surfaces, including all five of the surfaces covered within this research (CDC, 2009). Hospital setting disinfection activities must be completed using a low to intermediate-level agent and the applicable surfaces require a regularly scheduled cleaning program (CDC, 2009). Following are five main areas of concern with regard to the disinfection of surfaces outlined by the CDC (2009).

- Floor surfaces may be contaminated by bed wheels, shoes, spills and airborne particles. These areas should be routinely disinfected as part of a quality HAI prevention program.
- The contamination of detergents which are used during hospital disinfection-related activities. In particular, the CDC guideline calls for scheduled changing of mop water.
- Cleaning of surfaces that have been contaminated with bodily fluids. This guideline also recommends the disinfection of environmental surfaces including door handles and bedrails.
- The disinfection of any surface which has potentially become contaminated by an infectious material or bodily fluid should align with the Occupational Safety and

Health Administration (OSHA) 1910.1030(d)(4)(ii)(A) workplace housekeeping requirements.

- A single cleaning product be used throughout a facility for simplicity and training as the fifth aspect for surface disinfection (CDC, 2009).

The CDC (2007) provides a list of standard precautions which are to be used near any patient that has the potential of carrying an infectious disease. The list of standard precautions includes hand hygiene and personal protective equipment, which includes handwashing, wearing gloves and wearing protective clothing when there is a likelihood of bodily fluid splashes (CDC, 2007). Another area outlined in standard precautions is care of the environment. This area includes the establishment of policies and procedures for cleaning surfaces around patients that could be exposed to pathogens (CDC, 2007). The standard precautions include a recommendation to use an EPA-registered disinfectant to kill pathogens. Along with this recommendation is a guideline to review the efficacy of the disinfectant to the pathogen being targeted (CDC, 2007). Even within the hospital setting, no rigid procedure has been produced and thus only recommendations and guidelines exist. These guidelines will be utilized during the review of Company ABC's ambulance procedures for patient compartment decontamination/disinfection.

**Chemicals Used for Disinfection**

The CDC (2008) outlines various chemicals which are used for the disinfection and sterilization within healthcare facilities. The chemicals chosen for review are those which are typically associated with the pre-hospital patient conveyance. While no particular chemical is considered a 'catch-all' from a surface disinfection standpoint, each agent has a cleaning-related application within a hospital setting.

**Alcohol compounds.** Alcohols are typically isopropyl or ethyl alcohol which has been diluted with water. Alcohols lose efficacy when such are diluted to a concentration of less than 50 percent, with optimal levels ranging between 60 and 90 percent (CDC, 2008). Ethyl alcohol is a viricidal agent that is effective at inactivating multiple viruses, including the human immunodeficiency virus (HIV) and Tuberculosis when used in a concentration between 60 and 80 percent (CDC, 2008). Alcohols also have certain disadvantages such as an inability to completely sterilize a surface and have been linked to the transfer of bloodstream infections, such as postoperative Clostridium, due to inadequate disinfection capabilities. Another drawback to the use of alcohols is the solvents' level of flammability and volatility. The National Institute of Occupational Safety and Health (NIOSH) lists recommended exposure limits (RELs) of 400 parts per million (ppm) and 1000 ppm for isopropyl and ethyl alcohols respectively (CDC, 2018). Alcohols have a place in hospital disinfection as such compounds are readily available and have been proven effective as a virucide. Alcohols have a place in ambulance disinfection situations as such compounds are readily available and are also used for decontamination of skin prior to intravenous line placement. With alcohol's primary use within prehospital medicine during patient conveyance, employees are wearing nitrile gloves as a standard precaution in order to minimize dermal-related exposures.

**Chlorine compounds.** Chlorine and chlorine compounds are used for disinfection in concentrations that are similar to household bleach (CDC, 2008). Bleach has displayed a capability to kill Tuberculosis and C. dif. A 1:10 – 1:1000 dilution of sodium hypochlorite, or an EPA-registered Tuberculocide, has been recommended for blood spill cleanup (CDC, 2008). Household bleach is used in the healthcare setting for countertops and floors (CDC, 2008). The drawbacks to chlorine and chlorine compounds include possible corrosion of metals, bleaching

of fabrics and irritation to human eyes, mouths and throats (CDC, 2008). Chlorine compounds vary in exposure limits, however, chlorine itself has an REL of less than 1 ppm and varying concentrations are typically noted on the manufacturer's safety data sheet (SDS) for the respective material (CDC, 2018). Chlorine compounds are recommended by the CDC for certain types of cleanup, however, the drawback of equipment discoloration and the effects on human health make it useful in limited circumstances where chemical resistant surfaces and adequate ventilation are present. Thus, this group of chemical substances would be useful on surfaces within an open-door ambulance. Chlorine compounds do require a level of glove-based skin protection for hands during use and such apparel is generally available within an ambulance (CDC, 2018).

**Formaldehyde compounds.** Formaldehyde is used as a sterilant and disinfectant that is typically in a solution known as formalin. This compound is a high-level disinfectant and is used to kill viruses, Tuberculosis, bacteria, spores, and fungus (CDC, 2008). Formaldehyde's use in healthcare is limited as it has a REL of less than 1 ppm (CDC, 2018). The low REL is in place to limit human exposure as formaldehyde is considered a carcinogen as well as an irritant to the eyes, nose, and throat (OSHA, 2011). Formaldehyde compounds are a potent disinfecting agent, however, the health concerns associated with use have limited its capabilities in the healthcare setting due to its toxicity and carcinogenic tendencies which would require high level respiratory protection for safe use. Thus, it is likely that the use of Formaldehyde for ambulance disinfection would require extensive procedures from a personal protective equipment as well as compartment ventilation standpoint.

**Glutaraldehyde compounds.** Glutaraldehyde is another high-level disinfectant and sterilant which is used in the hospital setting on medical instruments such as respiratory therapy

and hemodialysis equipment (CDC, 2008). The chemical is a high-level disinfectant and is suitable for killing spores, Tuberculosis and viruses, however, is not appropriate for cleaning non-surgical surfaces due to its toxicity and ability to cause various human health reactions, including asthma (OSHA, 2006). Another concern is that the REL of this class of compounds is less than 1 ppm (CDC, 2018). Glutaraldehyde is a disinfectant that is appropriate for specific medical equipment that requires a high level of disinfection, however, it is not appropriate for walls, counters, and non-invasive equipment due to its toxicity. It is unlikely that glutaraldehyde would be appropriate for use in ambulances as its inhalation and toxicity risks are considerable for employee's who could be located in a confined area without high level respiratory protection.

**Hydrogen peroxide compounds.** Hydrogen peroxide is used as a high-level disinfectant and has bactericidal, viricidal, sporicidal, and fungicidal properties (CDC, 2008). It is used for the disinfection of hard surfaces as well as certain forms of hospital instrumentation. Hydrogen peroxide has a drawback due to having a NIOSH REL of 1.4 ppm (CDC, 2018). Hydrogen peroxide has been used in urinary catheter bags, however, this chemical is not known to reduce the incidence of catheter associated urinary tract infection (CAUTI) (CDC, 2008). While hydrogen peroxide does hold a place in healthcare disinfection, it is not typically used on the surfaces within an ambulance due to its inhalation risks within the confined areas of a patient compartment.

**Quaternary ammonium compounds.** Quaternary ammonium compounds are cleaning and surface disinfectants which are used throughout the healthcare setting. Based on literature from the CDC (2008), quaternary ammonium compounds are not sporicidal or Tuberculocidal, but do effectively eliminate fungus, bacteria and viruses (CDC, 2008). Quaternary ammonium compounds are used primarily in surface disinfection of equipment that may contact the skin as

well as surfaces and walls. Quaternary ammonium compounds do carry a NIOSH REL of 10 ppm, along with a designation of being a skin irritant (CDC, 2018). Thus, it appears as though quaternary ammonium compounds are acceptable for ambulance surface disinfection as the inhalation-based risks for employees are low and the substance's ability to disinfect is adequate.

**No-Touch Surface Disinfection**

New technologies are available for surface disinfection that do not require any interface between the surface and staff. The most commonly utilized technology involves a pulsed ultraviolet (UV) light system which includes a small portable lightbulb on a pedestal stand that can be placed within an area and then removed after use. The pulsed UV light is most commonly run for approximately 20 minutes to disinfect an enclosed space (Hosein et al., 2016). Pulsed disinfection systems emit UV light at a range which is germicidal whereby cells are damaged by the intensity of the light emitted and are rendered unable to replicate (Knudson, 2013). The prevalence of dangerous antibiotic resistant disease such as C.diff and MRSA in healthcare settings call for advanced efforts in infection control (Knudson, 2013). These dangerous bacteria are associated with HAI and this form of no-touch disinfection is being explored in conjunction with other room cleaning processes. The application of pulsed UV light after the use of surface chemical decontamination practices has been shown to decrease MRSA colonies, however, pulsed UV light has not been used in the absence of manual disinfection practices (Jinadatha et al., 2015). Manual disinfection is necessary since pulsed UV light achieves higher levels of disinfection when there is less organic material present. Pulsed UV light is also useful as it serves as a safety net for areas that may have been missed during standard cleaning procedures (Jinadatha et al., 2015). A drawback to UV light disinfection is the effects on workers' skin and eyes. OSHA does not currently enforce a UV light regulation while

NIOSH has published a time exposure limit is less than one minute (Akbar & Ruback, 2005). Such time-related exposure limitations require signage to deter employees from entering an area where UV light emissions are present. UV light units may utilize a remote control to turn the light on and off which therefore limits the need for an employee to manually power up a unit within a given area. The remote control would be necessary in ambulance operations for an employee to turn the unit off from a distance, as an ambulance may be needed during the time in which it is being disinfected due to an emergency call. As the previously discussed space and worker proximity limitations have the ability to be controlled, the use of pulsed UV light would appear to be a practical means of augmenting chemical disinfection practices in an ambulance setting.

**Summary**

Various aspects of hospital and prehospital infection control were covered in this chapter. It is necessary to understand what a HAI is and the bacteria that initiates the infection as well as how these dangerous infections are tracked and monitored. The science behind understanding the manner in which HAI bacteria spread appears to be sound, however, the systems in place for tracking HAI has indicated the possibility of inadequacy due to a lack of consistent practices among healthcare systems. Another area discussed are the regulations in place regarding HAI prevention, which may be flawed as the laws in place hold little power over states to comply. Various testing procedures were explored, with the ATP bioluminescence technique emerging as a preferred tool for ambulance disinfection testing to quantify the amount of living organisms present on surfaces through relative light units. Cleaning techniques and chemicals as well as no touch surface disinfection were explored. Organizational infection control techniques include forming a multi-disciplinary team for the purpose of creating effective protocols to combat HAI.

Surface cleaning techniques were studied as well as standards and procedure to reduce the spread of dangerous pathogens. Various chemicals have a wide array of uses within the medical field, with quaternary ammonium and bleach compounds possessing the greatest potential for use in ambulance surface disinfection activities. While quaternary ammonium compounds have great potential, they possess a drawback in an inability to kill spores, such as C. Dif, which require a sodium hypochlorite solution for disinfection. Other chemicals possess higher efficiency in killing bacteria and viruses than quaternary ammonium compounds, however, the same chemicals retain high levels of toxicity and/or are known carcinogens. Pulsed UV light radiation disinfection methods have recently emerged to supplement manual chemical disinfection techniques. This new radiation procedure should not be taken as a one-stop disinfection approach, but rather, as a backup to other chemical-based cleaning techniques.

Infection control is a difficult topic and it requires a large knowledge base, however, it is plausible that SIR rates may decrease through worker education activities and the use of appropriate disinfection procedures. Upon consideration of all areas, a quality ambulance patient compartment surface disinfection program needs be formed to protect patients, employees and the general public. It is believed that ATP bioluminescent testing will provide a baseline on the effectiveness of Company ABC's current ambulance surface disinfection practices.

# Chapter III: Methodology

The purpose of this study was to identify the extent that Company ABC's patient compartment disinfection procedures are effectively minimizing the risk of biological agents which may be transferred to transported patient as well as employees. This research will measure the gross ATP count on various surfaces located within the patient compartment of seven ambulances from Company ABC. The gross ATP count is used as a benchmark for general cleanliness and bacterial load on tested surfaces. The areas of concern are surfaces that are contacted during nearly every patient interaction and were chosen due to the probability of neglect during cleaning procedures. The ATP bioluminescence tool used is a luminometer (make/model), used to detect gross ATP counts on the tested surfaces. The effectiveness of Company ABC's current disinfection control policy will be evaluated through a checklist research tool which was developed by the author as a result of information that was gathered in the literature review portion of this study.

## Subject Selection and Description

No human subjects were used during this data collection procedure. Company ABC administration is aware of the planned ATP testing procedure and written consent was provided from Company ABC management personnel to perform testing. No specific identifiers, including the company name or actual ambulance unit numbers, will be shared within this research. ATP testing procedure data was collected from each ambulance during a typical day within the service. Company ABC understands that there will be no forewarning of ATP testing process to identify the effectiveness of the organization's current disinfection activities. The surfaces selected are areas that will likely be touched during nearly every patient interaction. These surfaces have been determined through subject matter experts within the field and are

chosen as the areas may not always be adequately cleaned and disinfected. The following four areas were selected for ATP bioluminescence testing.

1. The “on” button, located on the cardiac monitor located in the patient compartment.
2. The surface directly behind the bench seat in the patient compartment.
3. The surface directly under the cardiac monitor mount in the patient compartment.
4. The countertop surface between the cab of the ambulance and the patient compartment.

**The cardiac monitor “on” button.** A cardiac monitor is a tool used in both pre-hospital and in-hospital care which provides automatic blood pressure, pulse oximetry, cardiac rhythm monitoring and electrotherapy. This machine is used in nearly every patient interaction, therefore is touched multiple times through each patient experience. Typically, this surface is touched with gloved hands that have already been in contact with a patient and potentially infectious diseases.

**Surface behind the bench seat.** The small horizontal surface area located directly between the bench seat and the wall of the patient compartment is an area that is often neglected during decontamination activities. The is an area that could be exposed to infectious material, including blood. It is difficult to see direct contamination within this area and it is more difficult than other surfaces to access. With its likelihood to be neglected during routine cleaning, it is an appropriate are for bioluminescence testing.

**The surface under the cardiac monitor.** The cardiac monitor in all of Company ABC’s patient transport vehicles is mounted on a countertop within the patient compartment. The monitor never leaves its mount during certain patient interactions. With that being the case, the monitor is not typically removed during routine cleaning and may be overlooked.

**Countertop between the cab and patient compartment.** Company ABC's ambulances employ a truck style chassis with a patient compartment which is mounted toward the rear of each vehicle's frame. The interaction between the driver of the vehicle and the employee who is providing patient care is necessary and thus necessitates an open area between the personnel. The open area is often referred to as a "pass-through". This pass-through is open to the contaminants within the patient compartment, however, the size and location of the pass-through may cause this area to be overlooked from a surface disinfection standpoint. While large contaminants are not likely to contact the pass-through surfaces, there is the potential for microbes to be deposited within this area.

**Instrumentation**

A luminometer, (make/model), will be employed and will measure the amount of light in photons produced from a chemical reaction. The reaction will take place between the ATP present in the sample and the chemicals luciferin as well as luciferase. The output from the reaction is measured in relative light units (RLUs). The number of RLU's creates a direct correlation to the number of ATP molecules located within the sample.

The third goal of this study was to analyze Company ABC's current ambulance disinfection procedures. The ambulance disinfection procedures will be analyzed using a checklist created by the author using various aspects of surface disinfection which are included within Chapter II. No human subjects were used during this portion of the research, however, Company ABC administration was used to attain the organization's current disinfection practices. The developed checklist is located within Appendix A and primarily consists of best-practice statements with yes/no answers that relate to information that was gleaned from Chapter II of this study. The author of this research is an employee who has intricate knowledge of

current practices, however, members of Company ABC administration were used to attain the organization's current disinfection practices. A checklist will be employed to analyze Company ABC's current disinfection procedures. The checklist is located as Table 2 within Appendix A.

**Data Collection Procedures for ATP Bioluminescence Testing**

Data will be collected using a swab which will be processed through the use of a Hygiena SureTrend luminometer. Each of the four areas in question will be swabbed, using a Hygiena Ultrasnap swabs which are compatible with the Hygiena SureTrend luminometer. Each swab will be taken consistently and accurately in accordance with the following procedure.

- Ambulances will be tested within the garage of each ambulance's respective station.
- The doors of the garage will remain closed during testing.
- The researcher will enter each ambulance from the side door located within the patient compartment.
- The researcher will be wearing Company ABC uniform clothing and will follow current practices to avoid contaminating the patient compartment's surfaces.
- During testing, all doors to the ambulance will remain closed.
- Only the researcher will be present during testing.
- The selected areas will be swabbed in order of numbers 1 through 4 as indicated within the form used for data collection. (see Appendix A)
- All swab collections will be completed in accordance with the manufacturer's recommendations listed as follows.
    - Turn on luminometer
    - Select the location to be tested
    - Remove swab tip from tube

  - Swab an area four inches by four inches while rotating the swab tip ensuring that the swab is not touched by the researcher during the process
  - Replace the swab into the tube
  - Break the snap bulb on the top of the tube
  - Squeeze any liquid from the bulb into the tube
  - Shake the tube in an up and down motion for five seconds
  - Insert the tube into the chamber of the luminometer
  - Press the “OK” button on the luminometer
  - Dispose of swab tube after reading is presented
- ATP bioluminescence data was recorded immediately within a form that is located in Appendix B.

**Data Analysis**

The ATP bioluminescence data was collected and quantified using a form which consisted of the area of the ambulance swabbed, the unit number of the ambulance being tested and the RLU’s produced from each sample. The data was eventually provided in the results section within Table 1. To assess the overall cleanliness of these ambulances, the measured results were compared against hospital benchmarks of 100 relative light units (RLU's), with any reading over 100 RLU being considered failing. Using hospital-level benchmarks will identify whether or not Company ABC is adhering to national standards and appropriately disinfecting its ambulances (Amodio & Dino, 2015).

**Limitations of the Study**

Throughout this research there were areas of limitation encountered, as follows.

- The number of ambulances tested is a limiting factor as a larger sample size would be appropriate, however, ABC ambulance service has only seven ambulances.
- Each of the ambulances is swabbed in four locations which were selected as possible areas of inadequate surface disinfection. The four locations were selected as more than one type of patient compartment configuration is used within the seven ambulances. Ambulance patient compartment setup was a factor, as each of the four tested areas should be consistent in all of the compartment layouts.
- The data collected will be used as a benchmark for surface disinfection which provides evidence as to the cleanliness of the surface tested.

**Summary**

With the data collected, a baseline will be established regarding the extent of Company ABC's ambulance disinfection as well as the efficacy of the organization's current disinfection practices. The data can be compared against acceptable limits of RLU's in other facilities that have a program for measuring. With the data from both the policy/procedure analysis and ATP testing, it is likely that Company ABC's current disinfection practices will be reasonably assessed for potential deficiencies.

# Chapter IV: Results

The purpose of this study was to identify the extent that company ABC's patient compartment disinfection procedures are effectively minimizing the risk of biological agents which may be transferred to transported patients as well as employees. The methodology included the sampling of frequently touched areas that are prone to the collection of infectious material. This chapter discusses the results of ATP bioluminescence testing as well as an assessment of the disinfection procedures in place for Company ABC.

## Presentation of Collected Data

The first two goals of this study were to perform ATP bioluminescence testing within the patient compartments in Company ABC's ambulances to identify gross bacterial count. The ATP bioluminescence testing quantified the presence of bacteria and thus the effectiveness of current disinfection practices used by Company ABC within ambulance patient compartments.

In total, 28 surfaces were tested within seven ambulances operated by Company ABC. Each ambulance was given a number of one through seven while four areas were tested within each ambulance. Each area tested displayed the number of relative light units (RLUs) present in that particular sample. The amount of RLU directly correlates to the gross amount of ATP present within each sample. The data within Table 1 indicates that of 28 surfaces tested, 11 areas (39%) were above the hospital-based benchmark of 100 RLU. During informal discussions with local hospital staff, the benchmark used within one local hospital system is 50 RLU which is significantly less than the published standards. Ambulances are a less controlled environment than that of the hospital setting due to the mobile nature of emergency medical services and thus the benchmark of 100 RLU's was selected.

Another goal of this study was to analyze the current disinfection procedures in place for Company ABC. The disinfection procedures were analyzed using a checklist created by the author with various components of effective surface disinfection policies/procedures that were presented within Chapter II. The completed checklist which contains information based on an assessment of Company ABC's current policies/procedures is located below in Table 2.

Table 1

*Patient Compartment Surfaces RLU Count*

| Ambulance | Cardiac Monitor "on" Button (1) | Surface Behind Bench Seat (2) | Surface Under Cardiac Monitor (3) | Surface Behind Cab (4) |
|---|---|---|---|---|
| 1 | 70 RLU | 209 RLU | 72 RLU | 80 RLU |
| 2 | 45 RLU | 107 RLU | 225 RLU | 175 RLU |
| 3 | 56 RLU | 62 RLU | 90 RLU | 268 RLU |
| 4 | 41 RLU | 99 RLU | 21 RLU | 290 RLU |
| 5 | 59 RLU | 43 RLU | 67 RLU | 340 RLU |
| 6 | 166 RLU | 48 RLU | 130 RLU | 1051 RLU |
| 7 | 21 RLU | 97 RLU | 58 RLU | 206 RLU |

Table 2

*Ambulance Disinfection Procedure Checklist*

| Area of Concern | YES | NO |
|---|---|---|
| Does the organization have a specific procedure to prevent the spread of HAI? | | NO |
| Comments: There is a policy that discusses decontamination, but it does not mention HAI. | | |
| Does the organization have a personal hygiene procedure? | | NO |
| Comments: There is no formal personal hygiene procedure in place. | | |
| Does the organization have a PPE procedure for normal patient care activities? | YES | |
| Comments: There is a PPE procedure in place of reasonable quality. | | |
| Does the organization have a PPE procedure for patients with a known communicable disease? | YES | |
| Comments: There is a procedure in place, however, it is in need of updating, as it does not include appropriate PPE for cleaning procedures. | | |
| Does the organization have any procedures in place to test/monitor compliance with cleaning and disinfection practices? | | NO |
| Comments: There is no specific monitoring procedure. | | |
| Does the organization collaborate with local health systems (hospitals) in relation to HAI prevention? | YES | |
| Comments: The organization does work with local health systems, however, no formal policy is in place. | | |
| Does the organization have a procedure for the cleaning and disinfection of ambulance floors and cot wheels? | | NO |
| Comments: | | |

| | | |
|---|---|---|
| Does the organization typically employ the use of mop buckets to clean facility and ambulance floors? | | NO |
| Comments: | | |
| If mop buckets are employed, is a procedure in place for routinely changing the mopping detergent? If so, how often is the detergent changed? | | NO |
| Comments: | | |
| Does the organization have procedures for the cleaning of surfaces with the ambulance patient compartment? | | NO |
| Comments: No particular policy has a procedure, however, cleaning is mentioned. | | |
| Does the organization adhere to OSHA standards, particularly 1910.1030(d)(4)(ii)(A) with regards to the cleanup of potentially infectious material? | YES | |
| Comments: There is a reasonable adherence to the OSHA 1910.1030(d)(4)(ii)(A) regulations. | | |
| Does the organization use quaternary ammonium compounds for the cleaning of surfaces within ambulance patient compartments? | YES | |
| Comments: The organization uses quaternary ammonium compounds but the policy doesn't specifically state the use of such. | | |
| Has documented training been completed with the use of quaternary ammonium compounds and proper cleaning technique? | | NO |
| Comments: | | |
| Does the organization use chlorine solutions for the cleaning of surfaces within ambulance patient compartments? | YES | |
| Comments: | | |
| Has documented training been completed with the use of chlorine solutions and proper cleaning techniques? | | NO |
| Comments: | | |

| | |
|---|---|
| Does the organization use UV light technology for ambulance disinfection? | YES |
| Comments: | |
| If UV light is used, is a procedure in place for employees to follow on the time use of the light? | NO |
| Comments: There are instructions located on the device itself, however, no procedure in place. | |
| If UV light is used, is a procedure in place for employees to follow with regards to personal protective equipment and safety? | NO |
| Comments: The device was provided with UV protective glasses, however, no formal procedure exists on when or how such protective glasses should be utilized. | |
| Does the organization employ a driver's compartment cleaning/disinfection procedure? | NO |
| Comments: | |
| Does the organization provide periodic employee training with regards to chemical and UV light-based cleaning/disinfection practices? | |
| Comments:<br>Additional sheets will be added for comments as needed. | |

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**Discussion of ATP Bioluminescence Testing and Disinfection Checklist Results**

The first area discussed within the literature review was that of HAI and the organisms that cause these infections. As noted within the review, ATP bioluminescence testing does not identify specific pathogens, but rather, only the amount of bacteria that are present. The results indicate that within each Company ABC ambulance, there are bacteria present on various surfaces in amounts that exceed the levels deemed acceptable within a hospital setting. The hospital-setting benchmark of 100 RLU was used as no ambulance-based standards for ATP bioluminescence testing exist.

Various pathogens that were discussed in Chapter II include C. dif, MRSA, Norovirus, and Acinetobacter which could potentially be present in areas within Company ABC ambulances. Previous research indicated that one of Company ABC's ambulances was potentially positive for C.dif (Yount, 2017). The likelihood that one of these dangerous pathogens is present in Company ABC's ambulances could potentially be higher due to the measured bacterial load levels being above the hospital-based standard of 100 RLU. It should be noted that two major area hospitals have also displayed standardized infection rates (SIR) above the national standard which therefore create a higher likelihood that Company ABC's ambulances are harboring HAI-based pathogens(CMS, n.d.).

The second area of discussion involves the organization's internal controls to prevent the spread of HAIs. Company ABC has only minimal controls in place which have not been recently updated. Effective controls which are outlined within this research indicate the potential for ineffective surface disinfection policies/practices that are currently being followed by Company ABC. While employee training with regard to OSHA standard 1910.1030(d)(4)(ii)(A) has been conducted, there is no formal written program in place. Company ABC does have a procedure in place with regard to the use of personal protective equipment which includes the use of gloves with all patients as well as handwashing and needle safety procedures. Cleaning and decontamination of spills containing potentially infectious material is located with Company ABC's procedures which call for the use of a household bleach at a 1:10 dilution. Within the current disinfection guideline, there is no mention of using quaternary ammonium compounds which are the standard used within Company ABC for ambulance surface disinfection. The parameters for use within the organization's disinfection guideline state that any contaminated area should be cleaned, although no procedure indicates the cleaning approach that is to be

employed. Under Company ABC's guideline, surfaces would only be required to be cleaned if such area is noted as being contaminated. With Company ABC employing minimal patient transport vehicle disinfection standards, the data indicates that Company ABC ambulances generally have more bacterial load than what is acceptable by hospital standards.

The third area discussed within Chapter II relates to quantitative bacterial load testing methods. ATP bioluminescence testing was performed on each of Company ABC's ambulances to determine the gross bacterial count on each of the four surfaces tested within each ambulance. ATP bioluminescence testing indicates the background for general cleanliness, but does not produce results of specific microbes that are discovered. Company ABC does not routinely utilize a quantitative testing method in place to ensure worker compliance to cleaning procedures.

This research has indicated that no cleaning technique guidelines for Company ABC's ambulances have been developed. Within the cleaning techniques discussion, various chemicals for disinfection were explored and quaternary ammonium compounds as well as chlorine solutions emerged as the most acceptable disinfecting agents. Company ABC does use quaternary ammonium and chlorine compounds, however, no formal training has been conducted on specifically when to use such disinfection-based chemicals. Along with cleaning techniques, the use of UV light disinfection was explored. Company ABC does employ UV light disinfection, however, there is no procedure in place on how to utilize secondary disinfection equipment. Company ABC does not have a procedure in place for the amount of time that UV light must be present, or a policy for worker safety regarding the use of protective eyewear. The lack of procedure for UV light system use may relate to why bacterial counts within Company ABC's ambulances exceed the standards set forth by hospital disinfection standards.

**Summary**

The data provided within this research indicates that many surfaces located with Company ABC's ambulances contain bacterial load levels that exceed hospital standards. In total, 36% of surfaces tested were considered above the hospital-based benchmark of 100 RLU's, with each ambulance testing above hospital standards in at least one location. Thus, an assessment of Company ABC's current disinfection procedures indicates potential inconsistencies and a lack of formalized standards.

# Chapter V: Conclusions and Recommendations

The purpose of this study was to identify the extent which Company ABC's patient compartment disinfection procedures are effectively minimizing the risk of biological agents which could potentially be transferred to transported patients as well as employees. The goals of this research were to perform ATP testing on patient compartment surfaces to identify gross bacterial counts as well as to analyze Company ABC's current ambulance disinfection procedure. ATP bioluminescence testing was completed on four areas located within the patient compartment of seven Company ABC ambulances. The results of the ATP bioluminescence testing indicated that the gross bacterial load on surfaces within the patient compartment of Company ABC's ambulances is above hospital-based standards. Company ABC's current disinfection control policy was assessed using a checklist tool which was created by the author of this research to scientifically identify areas of potential deficiency.

## Conclusions

As a result of the analysis of ambulance patient compartment ATP bioluminescence testing as well as Company ABC's vehicle policy / procedure review, the following conclusions were developed:

- ATP bioluminescent testing results indicate that Company ABC's bacterial load levels on ambulance patient compartment surfaces exceed that of hospital standards.
- Company ABC has shown deficiency within its patient compartment disinfection procedures, which could potentially contribute to the spread of HAI.
- Company ABC's lack of uniform procedure for ambulance compartment disinfection likely caused the bacterial load to be elevated.

**Recommendations**

As detailed throughout this study, Company ABC is likely to be utilizing flawed patient compartment disinfection procedures. This study's results indicate that Company ABC employs an inadequate and outdated ambulance patient compartment disinfection procedure which therefore should be updated. The results of this study also indicate that the gross ATP counts which exceed recommended levels for hospitals are likely due to a lack of an adequate patient compartment surface disinfection procedure. Following are recommendations for Company ABC in order to minimize the potential for infectious pathogens to be transferred to patients as well as employees:

- Develop a new patient compartment disinfection procedure to ensure that Company ABC's ambulance interior surfaces are reasonably disinfected following patient transport activities.
- Develop a procedure for the use of UV light disinfection with instructions for use and provisions for ambulance personnel safety.
- Properly train employees on any new ambulance disinfection procedures and cleaning techniques.
- Develop a testing procedure to ensure compliance with disinfection policies/procedures.
- Develop an annual procedure review along with department-wide training on current disinfection procedures.
- Work with area hospitals to maintain up-to-date ambulance disinfection procedures and thus prevent the spread of HAI throughout the community.

**Areas of Further Research**

Areas of further research may be necessary and appropriate to ensure the safety of patients as well as employees in the prehospital setting and include the following:

- Company ABC has a need to develop a new ambulance patient compartment disinfection procedure. Following the implementation, ATP bioluminescence testing should be employed to determine the effectiveness of the new procedure(s).
- As a limitation of this study, only seven of Company ABC's ambulances were tested and therefore larger-scale research with multiple ambulance services would be appropriate.
- The areas of the ambulance patient compartment test were selected due to high use and the potential for neglect during cleaning procedures. Thus, additional ATP-based testing of additional areas throughout ambulance interior surfaces would be appropriate in future studies.

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## Appendix A: Ambulance Disinfection Procedure Checklist

| Area of Concern | YES | NO |
|---|---|---|
| Does the organization have a specific procedure to prevent the spread of HAI?<br><br>Comments: | YES | NO |
| Does the organization have a personal hygiene procedure?<br><br>Comments: | YES | NO |
| Does the organization have a PPE procedure for normal patient care activities?<br><br>Comments: | YES | NO |
| Does the organization have a PPE procedure for patients with a known communicable disease?<br><br>Comments: | YES | NO |
| Does the organization have any procedures in place to test/monitor compliance with cleaning and disinfection practices?<br><br>Comments: | YES | NO |
| Does the organization collaborate with local health systems (hospitals) in relation to HAI prevention?<br><br>Comments: | YES | NO |
| Does the organization have a procedure for the cleaning and disinfection of ambulance floors and cot wheels?<br><br>Comments: | YES | NO |
| Does the organization typically employ the use of mop buckets to clean facility and ambulance floors?<br><br>Comments: | YES | NO |

| | | |
|---|---|---|
| If mop buckets are employed, is a procedure in place for routinely changing the mopping detergent? If so, how often is the detergent changed? | YES | NO |
| Comments: | | |
| Does the organization have procedures for the cleaning of surfaces with the ambulance patient compartment? | YES | NO |
| Comments: | | |
| Does the organization adhere to OSHA standards, particularly 1910.1030(d)(4)(ii)(A) with regards to the cleanup of potentially infectious material? | YES | NO |
| Comments: | | |
| Does the organization use quaternary ammonium compounds for the cleaning of surfaces within ambulance patient compartments? | YES | NO |
| Comments: | | |
| Has documented training been completed with the use of quaternary ammonium compounds and proper cleaning technique? | YES | NO |
| Comments: | | |
| Does the organization use chlorine solutions for the cleaning of surfaces within ambulance patient compartments? | YES | NO |
| Comments: | | |
| Has documented training been completed with the use of chlorine solutions and proper cleaning technique? | YES | NO |
| Comments: | | |
| Does the organization use UV light technology for ambulance disinfection? | YES | NO |
| Comments: | | |

| | | |
|---|---|---|
| If UV light is used, is a procedure in place for employees to follow on the time use of the light? | YES | NO |
| Comments: | | |
| If UV light is used, is a procedure in place for employees to follow with regards to personal protective equipment and safety? | YES | NO |
| Comments: | | |
| Does the organization employ a driver's compartment cleaning/disinfection procedure? | YES | NO |
| Comments: | | |
| Does the organization provide periodic employee training with regards to chemical and UV light-based cleaning/disinfection practices? | YES | NO |
| Comments: | | |
| Additional sheets will be added for comments as needed. | | |

## Appendix B: ATP Bioluminescence Test Results Form

| Ambulance | Cardiac Monitor "on" button (1) RLU | Surface Behind Bench Seat (2) RLU | Surface Under Cardiac Monitor (3) RLU | Surface Behind Cab (4) RLU |
|---|---|---|---|---|
| 1 | | | | |
| 2 | | | | |
| 3 | | | | |
| 4 | | | | |
| 5 | | | | |
| 6 | | | | |
| 7 | | | | |