

Detection of potentially pathogenic bacteria on emergency care personnel's safety protective footwear and evaluation of infection, prevention, and control procedures in the uMgungundlovu district of KwaZulu-Natal

A dissertation submitted in fulfilment of the requirements for the degree of Master of Health Sciences in Emergency Medical Care in the Faculty of Health Sciences at the Durban University of Technology

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DECLARATION OF ORIGINALITY

This is to certify that this work is entirely my own and not that of any other person, unless explicitly acknowledged (including citation of published and unpublished sources). The work has not previously been submitted in any form to the Durban University of Technology or to any other institution for assessment or for any other purpose.

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Date 16/10/2025

ETHICAL CLEARANCE

This is to certify that the research studies conducted for the purposes of this dissertation have the approval of the Institutional Research Ethics Committee (IREC) of the Durban University of Technology (DUT) in KwaZulu-Natal.

Institutional Research Ethics Clearance Number: IREC 128/21

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ABSTRACT

Emergency Care Personnel (ECP) within KwaZulu-Natal Emergency Medical Services (KZN EMS) consistently respond to medical, trauma, and disaster emergencies. Emergency care personnel often serve as primary responders responsible for providing specialised care and life-saving interventions, which may increase their risk of exposure to healthcare-associated infections. Emergency care personnel are equipped with official attire and Safety Protective Footwear (SPF), which are part of their Personal Protective Equipment (PPE) for duty. Working in the pre-hospital setting presents challenges due to the lack of patient history provided to ECPs' upon initial contact, increasing the risk of Healthcare-Associated Infections (HAIs). Emergency care personnel may unintentionally facilitate transmission of diseases. In the pre-hospital setting, there is a scarcity of information regarding disease transmission. Emergency care personnel are restricted in their ability to sanitise and disinfect their vehicles and SPF because of high-priority cases and limited turnaround times. In the absence of an Infection Prevention and Control (IPC) policy regarding cleaning procedures for EMS personnel, there is a potential risk of HAIs. KZN EMS does not possess an adequate IPC system, in contrast to hospitals.

The purpose of this study was to evaluate ECPs' SPF for the presence of microorganisms related to bacterial infections and to determine whether EMS KwaZulu-Natal uMgungundlovu district has any infection prevention and control procedures or policies. This study employed a prospective cross-sectional quantitative approach and was conducted in two phases. The initial phase involved swabbing of 53 selected ECPs' SPF at the EMS Grey's Hospital base to identify bacterial contamination. This was followed by data collection using a questionnaire distributed to all EMS bases in the uMgungundlovu District, aimed at assessing ECP's IPC awareness and practices among 165 staff members. After distributing the questionnaire to all bases in the uMgungundlovu district, a total of 303 participants were surveyed, with 165 (54%) responding.

A considerable proportion of participants were uninformed of EMS policies and practices due to the absence of an EMS IPC policy. Inadequate IPC awareness, insufficient disinfection practices, unavailable PPE, and inaccessible cleaning supplies were all prevalent issues. The study employed an aerobic culture-based method consisting of 53 samples. The bacterial analysis revealed six pathogens (11.3%) in seven (13.2%) SPF samples. *Pasteurella canis*, *Enterococcus faecium*, *Enterococcus casseliflavus*, *Escherichia coli*, *Pantoea agglomerans*, and *Acinetobacter radioresistens* were all identified as potential pathogenic organisms.

This study demonstrated the prevalence of microbial contamination on ECPs' SPF, which may act as a reservoir for transmitting potential infections to patients and healthcare personnel. Emergency medical service personnel showed significant non-compliance in cleaning and disinfecting practices. KwaZulu-Natal EMS uMgungundlovu District lacks an effective cleaning protocol for decontaminating SPF. Further research is necessary to determine whether contaminated SPF contributes to the transmission of infectious pathogens in pre-hospital settings. Additionally, KZN EMS must address the insufficient supply of cleaning materials, inadequate IPC training, and poor procedural guidelines.

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DEDICATION

This dissertation is dedicated to all the emergency care personnel who serve with tenacity and compassion. Thank you for leaving your homes and families to provide critical life-saving care for the sick and injured.

ACKNOWLEDGEMENTS

Thank you to Dr Simpiwe Sobuwa and Prof Poovendhree Reddy, my supervisors, for their constant guidance, dedication, and support throughout this process.

Thank you to Mr. Dhayasellan Naidoo for his ongoing mentoring and assistance throughout the process.

Thank you, JDJ Diagnostics staff, for their professional assistance during my Microbiology testing.

Thank you to the participants who made this process possible.

Thank you to my family who encouraged and supported me.

To my wonderful wife, Fiona and sons, Dr. Jerome Gengan and Mr. Jayden Gengan, for their unending love and support, which made this possible.

I thank you, Lord, for the strength you have given me during this incredibly difficult time. During the COVID-19 pandemic, you have kept me well and safe, allowing me to persevere in finishing my research study.

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ABBREVIATIONS

ALS: Advanced Life Support

BLS: Basic Life Support

CDC: Centres for Disease Control and Prevention

CFUs: Colony Forming Units

ECP: Emergency Care Personnel

EDC: Emergency Despatch Centre

EMD: Emergency Medical Dispatcher

ESKAPE: *Enterococcus faecium*, *Staphylococcus aureus*, *Klebsiella pneumoniae*, *Acinetobacter baumannii*, *Pseudomonas aeruginosa*, and *Enterobacter* species

HAI: Healthcare-Associated Infection

HCW: Healthcare Workers

HIV/AIDS: Human Immunodeficiency Virus/Acquired Immune Deficiency Syndrome

ILS: Intermediate Life Support

IPC: Infection Prevention and Control

KZN EMS: KwaZulu-Natal Emergency Medical Service

MRSA: Methicillin Resistant *Staphylococcus aureus*

SPF: Safety Protective Footwear

WHO: World Health Organization

GLOSSARY OF TERMS

Advanced Life Support (ALS): is a paramedic who is registered with the Health Professions Council of South Africa at the ALS level. Their scope of practice includes advanced airway management, electrocardiography, external cardiac pacing, defibrillation, intravenous therapy, and various drugs for administration in the event of multiple types of resuscitation, overdose, pain relief, and sedation, as well as all BLS and ILS skills.

Ambulance: An ambulance is a vehicle that is expertly modified with sirens and lights to respond to emergency cases and transport the sick and injured to hospital.

Antibiotic: A chemical agent created by one organism that is toxic to other organisms.

Antibiotic Resistance: The acquired ability of a microorganism to grow in the presence of an antibiotic to which the microorganism is normally sensitive.

Antimicrobial: An antibiotic that is specifically harmful to microorganisms, either resulting in death or growth inhibition.

Aseptic Technique: a manipulation of sterile instruments or culture media to maintain their sterility.

Bacteria: All prokaryotes that are not members of the Domain Archaea.

Biofluid/Blood: Fluids that can be excreted from the body including blood, urine, sweat and bile.

Cleaning: Cleaning is a technique of eliminating dirt or debris from the surface, with the use of water and/or detergents.

Decontamination: A process that eliminates and neutralizes contamination from equipment and personnel.

Disease: An abnormality in a person's physical or mental state that has a negative impact on their overall well-being and manifests as signs and symptoms.

Disinfection: This is a method of removing pathogenic microorganisms from the surface using disinfectants.

Emergency Care Personnel (ECP): Emergency care personnel in an ambulance setting are trained personnel who work on response/ambulance vehicles providing advanced, intermediate, or basic patient life support and are equipped to respond to any emergency and transport to hospital in an organized manner.

Emergency Dispatch Centre (EDC) or “Control Room”: It is the centre that records the call that is received from the public and sends the appropriate medical staff and response vehicle.

Emergency Medical Dispatcher (EMD): Personnel that are trained to receive calls, triage and dispatch the emergency response vehicle.

Emergency Medical Services (EMS): EMS, also known as an ambulance service, provides effective, comprehensive, and coordinated pre-hospital care and treatment for the critically ill, injured, and transport to hospital.

Emergency Vehicle/Ambulance Unit: A vehicle that is used to convey patients to a medical facility or hospital. The ambulance unit is equipped and configured to transport patients either sitting and the more serious to lie on a stretcher bed.

Hand Hygiene: Hands are cleansed of microorganisms, both commensal and pathogenic, by using soap (antimicrobial or non-antimicrobial) and water to clean the surface of the hands.

Healthcare-Associated Infection (HAI): An infection that is acquired from a health care environment whether in a hospital or pre-hospital setting to a patient which did not exist before admission.

Infection: occurs when detrimental organisms, such as bacteria, viruses, or parasites, invade and reproduce within the body.

Micro-Organism: A microscopic organism composed of a single cell or cell cluster, as well as viruses.

Pathogen: An organism that can cause harm to the host it infects.

Pathogenicity: The ability of a microorganism to cause harm to the host.

Sterilization: A process used for the killing of microorganisms. For surfaces, this often involves the use of chemicals.

Sub–District Base: This is an operational base where duties are carried out by Emergency care personnel in a particular geographical area.

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Treatment: Medical care or therapy provided to a patient in order to achieve therapeutic effects.

Virulence: The pathogenicity of a microorganism.

CHAPTER ONE: INTRODUCTION

1.1 STUDY BACKGROUND

Bacterial cross-contamination represents a considerable global risk to emergency medical personnel (Makie, Williams-Claasen and Gojkovic 2020). Emergency Care Personnel (ECPs) are essential professionals within the Emergency Medical Services (EMS), functioning as the primary responders to multiple daily emergency calls and significantly contributing to patient survival (Valdez *et al.* 2015; Hudson, Glaister and Wieden 2018). The nature of their profession exposes ECPs' to several health risks. Functioning with remarkable agility and speed, they are particularly susceptible to contracting and transmitting Healthcare-Associated Infections (HAIs) in the pre-hospital environment (Hudson, Glaister and Wieden 2018). This susceptibility arises from their regular exposure to potentially infected patients through surface contact, aerosol droplets, or bloodborne pathogens (Russell *et al.* 2022).

Emergency care personnel are required to transport patients from pre-hospital environments to hospitals, facilitate inter-hospital transfers, and relocate patients to long-term care facilities (Richey *et al.* 2021). The standard procedure includes stabilising patients on-site, transferring them to hospitals, and informing hospital staff. After the completion of the transfer of patients to hospital staff, ECPs' are responsible for disinfecting the ambulance, contaminated medical instruments, soiled uniforms, and Personal Protective Equipment (PPE) (El-Mokhtar and Hetta 2018). However, the reality often diverges from this best practice. Barr's (2018) study indicated that, owing to short turnaround times and a substantial number of outstanding emergencies, ECPs' often address incoming calls before executing comprehensive disinfection protocols. This predicament is exacerbated by resource limitations, as highlighted in Finlayson's (2017), assessment of Public Sector Emergency Medical Services in KwaZulu-Natal, which revealed that inadequate resources and ineffective management result in prolonged response times for critical patients.

The urgency to address the needs of critically ill patients frequently diminishes the priority of routine cleaning protocols. As a result, there is a potential risk that ambulances and medical equipment may not receive adequate cleaning following each emergency response (Barr 2018; Lindsley *et al.* 2018). The challenge transcends the workplace, as ECPs' returning home in their uniforms after a 12-hour shift elevate the risk of microbial transmission to their families (Makiela *et al.* 2018; Jenkins *et al.* 2022). The global pandemic has exacerbated these issues. Patients were initially transported without the necessary appropriate PPE due to insufficient knowledge regarding the coronavirus, which may have facilitated virus transmission through contact and airborne exposure (Makie, Williams-Claasen and Gojkovic 2020; Jenkins *et al.* 2022). This crisis has highlighted the significance of infection prevention and control (IPC) practices, as well as the roles of personal knowledge, attitudes, education, skills, and behaviours. To mitigate HAIs, it is essential to implement comprehensive policies and procedures that are subject to quality assurance, alongside ongoing education and training for staff (Al Qraad *et al.* 2023).

Despite the significance of hospital infections, there is a limited understanding of microorganisms and their contributions to the transmission of HAIs in pre-hospital environments (Hudson, Glaister and Wieden 2018). Given this context, it is critical to investigate whether community district response vehicles and ECPs' PPE are properly disinfected. Key research components must encompass the identification and evaluation of potentially infectious pathogens in response vehicles and PPE. Additionally, evaluating ECPs' comprehension of IPC procedures would yield significant evidence regarding their cleaning procedures and practices in mitigating HAIs, thereby enhancing safety measures in EMS.

1.2 PROBLEM STATEMENT

The emergency medical services environment presents distinct challenges for IPC, especially regarding the risk of HAIs. Emergency care personnel operate in diverse and often unpredictable contexts, frequently transitioning between community and healthcare environments. This continuous movement, along with the urgent demands of their tasks, generates multiple opportunities for the acquisition and transmission of pathogenic microorganisms. A critical, yet frequently neglected, potential vector for

pathogen transmission in this setting is the Safety Protective Footwear (SPF) utilised by ECPs'. Personal protective equipment interacts with diverse surfaces and substances throughout an ECP's shift, potentially accumulating and harbouring microorganisms associated with nosocomial infections. Despite this risk, there is a notable deficiency in research examining the microbial contamination of SPF in pre-hospital emergency medical services, particularly in the context of KwaZulu-Natal, South Africa.

Furthermore, the cleaning and disinfection practices for SPF among ECPs' remain largely unexplored and potentially variable. The efficacy of existing cleaning protocols and disinfectants applied to SPF remains uncertain, prompting concerns regarding the adequacy of existing IPC strategies in preventing the transmission of HAIs through this potential vector. The issue is exacerbated by the absence of comparative data between operational ECPs', who engage directly in in-patient care and frequently move between different environments, and non-operational ECPs' stationed in emergency dispatch centres (EDCs), who function within a more regulated environment. This gap in knowledge impedes our comprehension of how different work environments within EMS may influence the risk of microbial contamination on SPF.

Moreover, there is insufficient information about the specific types of microorganisms present on ECPs' SPF, particularly those associated with nosocomial infections. The absence of data complicates the evaluation of the actual risk associated with contaminated SPF and hinders the formulation of targeted IPC strategies (Jenkins *et al.* 2023). Given the critical role that ECPs' play in providing emergency medical care and their frequent interactions with vulnerable patients, addressing these knowledge gaps is crucial. The potential for SPF to serve as a vector for the transmission of nosocomial pathogens poses a significant risk to patient safety, as well as to the health of ECPs' themselves and their families. In the absence of a comprehensive Infection Prevention and Control (IPC) policy regarding cleaning procedures for EMS personnel, there is a potential risk of HAIs. It appears that KZN EMS may not have IPC systems as comprehensive as those typically found in hospital settings.

1.3 RESEARCH PURPOSE

The purpose of this study was to evaluate ECPs' SPF for the presence of microorganisms associated with bacterial infections and to determine whether EMS KwaZulu-Natal uMgungundlovu district has an effective infection, prevention, and control procedure or policies.

1.4 RESEARCH PROBLEM

1.4.1. The samples of ECPs' SPF exhibit variations in types and levels of bacteria.

1.4.2. The types and concentrations of bacteria in the SPF will vary between operational and non-operational SPFs.

1.4.3. The cleaning procedures and staff practices will vary across the district's various bases.

1.5 THE OBJECTIVES OF THE RESEARCH STUDY

1.5.1 To identify microorganisms associated with bacterial infections on operational ECPs' SPF after a 12-hour shift.

1.5.2 To identify microorganisms associated with bacterial infections on non-operational ECPs' SPF working in the emergency dispatch centre (EDC) after a 12-hour shift.

1.5.3 To compare the presence of microorganisms associated with bacterial infections on SPF among non-operational ECPs' working in the EDC and operational ECPs'.

1.5.4 To assess ECPs' awareness, perceptions, and reported practices regarding current cleaning procedures and disinfectant use on SPF.

1.6 THE RESEARCHER'S INTEREST IN THE STUDY

The researcher has nearly three decades of experience in emergency care. He began his career as an operational ECP, then advanced to shift officer in the EDC before moving into the Educational and Training sector and becoming a lecturer at the EMS

KwaZulu-Natal College of Emergency Care (KZN COEC). The researcher qualified as a Critical Care Assistant (CCA) at the KZN COEC, and the researcher decided to further his education, obtaining his National Diploma and finally achieving a bachelor's degree in emergency medical care. The researcher spent 15 years in an ambulance/response unit, transporting and treating patients with a wide range of illnesses and trauma-related injuries. Working in an environment with blood-borne diseases, tuberculosis, and human immunodeficiency virus patients, as well as being dispatched for a new emergency right after handover at the hospital, highlighted that there was only so much time to clean and decontaminate the ambulance, PPE, and SPF.

1.7 SIGNIFICANCE OF THE STUDY

The study has the potential to encourage ECPs' to adopt more rigorous disinfection practices for their ambulances, PPE, and SPF, presumably reducing the spread of nosocomial infections. By identifying and addressing contamination risks, the study may assist in limiting the transmission of infections between healthcare workers, patients, and the community. The research may contribute to developing evidence-based IPC guidelines specifically tailored to the pre-hospital environment, leading to improved practices and protocols. By reducing HAIs, the study might indirectly enhance the quality of patient care, decrease hospitalisation rates, and ultimately improve patient outcomes. The study's focus on a relatively unexplored area (bacterial contamination on ECPs' SPF) could inspire further research into IPC in pre-hospital settings, leading to a more comprehensive understanding of infection risks and prevention strategies in this critical field.

The researcher could not locate any published literature that examined bacterial detection on ambulance personnel SPF in South Africa and worldwide. Hopefully, this study will spark further research into IPC in the pre-hospital setting.

1.8 STRUCTURE OF THE DISSERTATION

Chapter 1: Introduction

The initial chapter of this study establishes the context for the research topic. This was accomplished by providing insight into the reported and global burden of microbial prevalence and cross-contamination, with a focus on developing countries where the incidence of bacterial microorganisms is elevated, and resources are insufficient. The chapter subsequently concentrates specifically on prehospital emergency care personnel, whose roles often expose them to risks of pathogenic contamination. The chapter concludes by outlining the study's aim and objectives, alongside the research problem and the researcher's interest in the study.

Chapter 2: Literature review

Chapter 2 provides a comprehensive review of the literature concerning pathogen detection and ICP procedures among ECPs'. The chapter initiates with a discussion focused on microbial exposure in ECPs' subsequently addressing the burden of bacterial diseases in both the in-hospital and pre-hospital environments particularly in developing countries. The chapter then delves into pathogen exposure among ECP providers, focusing on prevalence rates, knowledge, and practices, and emphasizes the need for EMS-specific IPC guidelines. The chapter concludes by outlining the key components of internationally recognized IPC guidelines.

Chapter 3: Research methodology

The third chapter provides an overview of the research design and methodology. The study environment and population are then described. The sampling techniques for phase one, swabbing ECPs' SPF for bacterial detection, and phase two survey questionnaire, as well as data collection processes and data analysis, are discussed. The chapter concludes by investigating the study's validity and reliability, as well as the ethical considerations that were maintained throughout the study.

Chapter 4: Results

This chapter presents the outcomes of phase one and phase two individually. The chapter begins by describing the phase one data analysis results. The chapter then describes the prevalence of pathogen detection alongside the parameters correlated to IPC procedures. The participants' knowledge and practices regarding IPC are then described. The chapter concludes with the results of phase two data analysis.

Chapter 5: Discussion

This chapter integrates and discusses the findings and results drawn from the two phases of the study concerning existing literature. The discussion will concentrate on the prevalence of pathogens among ECP providers, and the factors related to IPC procedures. In addition, chapter five elaborates on ECP providers' knowledge and practices concerning microbial transmission prior to concluding with a critical review of IPC guidelines.

Chapter 6: Conclusion and Recommendations

The sixth chapter presents a summary of the research findings and provides recommendations for the effective prevention and management of bacterial transmission among ECP providers. The chapter concludes with recommendations for future research and a critique of the study's limitations. The list of references and annexures utilised in this study is included at the end of the dissertation.

CHAPTER TWO: LITERATURE REVIEW

2.1 INTRODUCTION

The most common consequence of medical care delivery globally is healthcare-associated infections (HAIs); it has been evidenced that one in 10 patients develops an infection during treatment in a public health facility in poor and low-income states. The ESKAPE group (*Enterococcus faecium*, *Staphylococcus aureus*, *Klebsiella pneumoniae*, *Acinetobacter baumannii*, *Pseudomonas aeruginosa*, *Enterobacter*) is a collection of microorganisms that are difficult to treat due to their extraordinary capability to acquire antibiotic resistance and are the leading causes of bacterial infections internationally, posing a threat to worldwide public health. The acronym is sometimes extended to ESKAPEE to include *Escherichia coli* (Bereanu *et al.* 2024). Numerous studies have demonstrated the ability of ESKAPE group bacteria to form biofilms on biotic and abiotic surfaces, which leads to increased resistance to exogenous antimicrobial factors and antibiotics. Bacterial biofilms are important reservoirs for multidrug-resistant pathogenic bacteria (Yazgan *et al.* 2018; Stallbaum *et al.* 2021; Mahmud *et al.* 2022; Bai *et al.* 2023).

Healthcare-associated infections may result in poor health, mortality and increased expenses for the healthcare system. The excessive use of antibiotic agents in treating patients contributes to challenges related to antimicrobial resistance. The effectiveness of Infection Prevention and Control (IPC) is critical in reducing preventable HAIs (Lowe *et al.* 2021). In the prehospital setting, many low-income communities use the ambulance to transport their ill families to the hospital (Mackay *et al.* 2017). Infection prevention and control remain a significant challenge in the pre-hospital setting (Liang *et al.* 2014). To date, there have been no studies of Emergency Medical Service (EMS) personnel having reported bacterial transmission while carrying out their daily duties (Valdez *et al.* 2015).

This literature review analyses bacterial contamination during ambulance transport of sick or injured patients. This study will review the prevalence of bacterial microorganisms on ambulance surfaces, equipment, personal protective equipment,

and SPF and evaluate their potential contribution to healthcare-associated infections. The study will concentrate on EMS personnel's perceptions and reported practices regarding current cleaning procedures and disinfectant use on SPF.

2.2 SEARCH STRATEGY

Numerous sources were consulted to locate relevant literature related to the research topic. This included using the SUMMON search feature in Durban University of Technology's online library, as well as accessing various online databases. These databases included PubMed, Science Direct, Google, Google Scholar, and institutional repositories from various universities, primarily the Durban University of Technology.

The resources accessed included government documents, journal articles, and dissertations. Although the goal was to access resources no older than ten years, given the scarcity of literature on bacterial contamination on emergency care personnel (ECPs) safety protective footwear (SPF) among EMS providers, resources older than ten years were consulted as needed. Search terms included emergency medical service, pre-hospital contamination, infection, microbial, bacteria, pathogen, nosocomial, MRSA, methicillin-resistant *Staphylococcus aureus*, *K. pneumoniae*, and carbapenem-resistant. Numerous observation and compliance studies were conducted in the hospital setting, yielding a diverse range of results. There were alarmingly few studies done in the EMS setting. The criteria for inclusion in this review were as follows:

- Literature in the English language regarding the study subject, both nationally and internationally. These sources included peer-reviewed and accredited journals, as well as information from centres of excellence, such as the Centres for Disease Control in the USA and the World Health Organisation.
- Relevant and appropriate literature (published or unpublished) for research questions.

Exclusion criteria concerned the quality of the literature. To ensure accuracy, only scientific literature and policy documents were consulted, rather than popular

magazines and newspapers. Additionally, research reports and primary sources were favoured.

2.3 PREVALENCE OF BACTERIAL MICROORGANISMS IN THE PREHOSPITAL SETTING

The duties of Emergency Care Personnel (ECPs) in the prehospital environment require their continuous operation across day and night shifts, encompassing weekends and public holidays (Mtetwa 2022). The ECPs' work in ambulances, which are equipped with various medical equipment that can be used for both trauma and medical patients. ECPs' manage numerous patients potentially harbouring bacterial diseases during their 12-hour shifts. During the transportation of infectious patients, there is a possibility of urination, vomiting, or the spillage of blood and bodily fluids occurring in transit. According to Sharma *et al.* (2021), microorganisms can exhibit considerable drug resistance; therefore, these microorganisms, once airborne in droplets, can then fall onto the floor of the ambulance due to gravity. These droplets can potentially lie dormant until the ECP or a new patient inhales, ingests or touches the fluid. These bacterial organisms can transfer between patients, ECPs' and hospital staff. Even though the use of personal protective equipment (PPE) and non-reusable medical devices reduces the risk of disease transmission to patients and health care workers (HCWs), the ambulance is still susceptible to microbial infection from biological exudations and potential pathogens. It is critical that the vehicle be thoroughly disinfected after each case before being dispatched to a subsequent emergency. Disinfection procedures must be initiated with service-recommended solutions.

This procedure must be adopted in the prehospital setting to reduce pathogenic microorganisms and the probable risk of disease for patients or even emergency care personnel (Sharma *et al.* 2021).

The transfer of infectious organisms plays a critical role in disease transmission (Roberts *et al.* 2011; Lindsley *et al.* 2018). Obenza *et al.* (2022) found that HAIs were primarily transmitted to hospital patients through the hands of HCWs. Methicillin-resistant *Staphylococcus aureus* (MRSA) was found to be inherently similar to *S.*

aureus and nasal MRSA fomites taken from EMS personnel. This implies that MRSA spread between hospital staff and pre-hospital workers is possible (Obenza *et al.* 2022). In a similar study, MRSA was found in 4.6% (13/280) of ambulance workers and 22.5% (9/40) of paramedic firemen in a study conducted in the United States, the researcher and colleagues concurred that transmission from the environment to the human body is possible, posing a risk of infection to EMS workers and patients (Valdez *et al.* 2015). Roberts *et al.* (2011), found 58% of MRSA in a study of paramedic firemen was directly associated with inanimate surfaces, highlighting the transmission of microbes between surfaces and workers.

Similarly, Sexton and Reynolds (2010) investigated the prevalence of bacteria on surfaces within fire stations. A total of 160 specimens collected from their training Centre, office equipment and restrooms revealed *S. aureus* on the sofas, 20% (4/20); student tables, 20% (2/10); and frequently handled areas in departments, 13% (4/30). These areas also had a higher prevalence of MRSA infection at 20% (4/20), 10% (1/10), and 6.7% (2/30), respectively. All locations had a minimum of one confirmed sample for *S. aureus* and MRSA, apart from certain areas in the change room and the emergency care jump bags. The accumulated number of specimens positive for *S. aureus* and MRSA were 10.6% (17/160) and 6.9% (11/160), respectively, whilst MRSA was 64.7% (11/17). MRSA accumulation varied from 10 colony-forming units (CFUs) in the office to 7500 CFUs on the sofas (Sexton and Reynolds 2010). Fomites can serve as a transmission pathway from surface to the mouth, broken skin, unclean fingers, and hand contact with the mouth, face, and eyes, thereby presenting a risk to EMS workers and their patients (Valdez *et al.* 2015; Richey *et al.* 2021).

2.4 PATHOGENIC BACTERIA

2.4.1 *Staphylococcus Aureus*

Rago *et al.* (2012) demonstrated that swabbed specimens from 26 different sites in 71 ambulances across 34 Chicago towns indicated a heightened colonisation of *Staphylococcus aureus*. Approximately 69% of the ambulance vehicles were found to be positive for *S. aureus*. This suggests that ambulances may be a reservoir for *S. aureus*, posing a risk to patients and healthcare workers. An overwhelming 77% of

isolates found were resistant to at least one antibiotic. In a comparable study conducted by Obenza *et al.* (2022), 21 ambulances (n = 105) in the Western United States were examined for MRSA; thirteen samples were isolated from 10 of the 21 ambulance vehicles, resulting in a 47.6% positivity rate for MRSA. A study by Brown *et al.* (2010) found that MRSA is commonly present in ambulances. The researchers tested 51 ambulances in Southern Maine and discovered that 25 (49%) of them were contaminated with MRSA. This suggests that ambulances may be a significant reservoir for MRSA, posing a risk to patients and healthcare workers.

The organism effectively colonises human nostrils by adhering easily to the nasal mucosa, particularly in the nares. The protein on the surface of the organism triggers a protective response, allowing it to persist and thrive in this environment. This ability to colonise and adhere to the nostrils makes it a common site for MRSA to reside, increasing the risk of infection and transmission. Resistant strains cause infection to both healthcare workers and the community (Foster and Geoghegan 2015; Taylor and Unakal 2021). According to Taylor and Unakal (2021), *Staphylococcus aureus* is unlikely to infect healthy skin in individuals with normal immune function. However, if this bacterium manages to enter the bloodstream, it can cause severe and potentially life-threatening infections. This highlights the importance of preventing *S. aureus* from entering the body through cuts, wounds, or other openings in the skin, as well as practising good hygiene and infection control measures to reduce the risk of infection. According to research, most Gram-positive bacteria can survive on dry surfaces for a few days to several months. *Staphylococcus aureus* can survive for a duration of seven days to seven months (Barr *et al.* 2021).

Methicillin-resistant *Staphylococcus aureus* is resilient to numerous antibiotics and is a significant threat in both the hospital and the public environment (Taylor and Unakal 2021). Methicillin-resistant *Staphylococcus aureus* is especially dangerous and remains a major public health concern. The emergence of multidrug-resistant MRSA strains, combined with widespread antibiotic use, has made anti-MRSA treatment a significant challenge (Nazli *et al.* 2024). According to Nandhini *et al.* (2022), some of the treatment regimens like methicillin, penicillin, oxacillin, cloxacillin, cefazolin, cefoxitin, and other popular antibiotics are among the several antibiotics to which it is resistant. Close contact with an infected person can spread MRSA. It can spread from

a human carrier to another person or from an object containing MRSA to a human. Nosocomial infections are any diseases that develop in hospitals or other healthcare facilities. Methicillin-resistant *Staphylococcus aureus* infections occur in healthcare or hospital-related settings. Methicillin-resistant *Staphylococcus aureus* infections occur in community-associated environments. It is easily spread through skin-to-skin contact between healthy individuals. In crowded environments, MRSA can easily infect elderly or disabled people (Nandhini *et al.* 2022). *Staphylococcus aureus* has an unusual ability to develop resistance to all antibiotics. Penicillin-resistant *S. aureus* produces a plasmid-encoded penicillinase that hydrolyses the β -lactam ring of penicillin, which is crucial for its antimicrobial action (Jubeh, Breijyeh and Karaman 2020).

2.4.2 *Enterococcus Faecium*

Several studies have asserted that MRSA and Vancomycin-resistant *enterococci* (VRE) are pathogens that can disperse from inanimate surfaces to patients and from patients to healthcare workers (Ro *et al.* 2012; Lee *et al.* 2013; Álvarez *et al.* 2019). In a separate study by O' Hara *et al.* (2017), the researchers highlighted the 10 most frequently found microbes in 137 ambulances throughout the USA using shotgun sequencing, revealing the prevalence of 90% of antimicrobial resistance markers. A retrospective observational study conducted at a tertiary hospital in Korea classified patients into three groups: pre-hospital (PH), interfacility (IF), and non-ambulance (NA). The study collected swab samples from these groups and analysed them for the presence of specific bacteria. The results showed that in the PA group, the prevalence of *Mycobacterium Tuberculosis*, MRSA, and VRE was 0.3%, 1.8%, and 0.4%, respectively. In contrast, the IF group had a higher prevalence of these bacteria, with TB, MRSA, and VRE present in 0.7%, 4.6% in PH, and 1.5% of patients in NA, respectively (Ro *et al.* 2012).

The study's findings suggest that bacterial contamination is a concern in healthcare settings, including ambulances and hospitals. Notably, the IA had a higher prevalence of TB, MRSA, and VRE, indicating a higher risk of infection or colonisation during transport between healthcare facilities. This highlights the importance of proper infection control measures, such as rigorous cleaning and disinfection protocols, appropriate use of PPE, and hand hygiene practices. Furthermore, patient classification may be useful in identifying high-risk patients and targeting interventions to reduce transmission. Overall, the study emphasizes the need for continued vigilance and improvement in IPC to ensure patient safety and prevent the spread of harmful bacteria in healthcare settings (Ro *et al.* 2012). *Enterococcus faecium* is an infectious Gram-positive organism affecting the healthcare environment. According to Dieterich *et al.* (2018), bacteria affect the gastrointestinal area of patients causing severe diarrhoea. Kim and Marco (2014) concur that, this strain is associated with nosocomial illnesses causing endocarditis and bacteraemia and additionally identified genetic structures in *E. faecium* lineages specifically in the medical and community environments, it may be noted that, these structures were associated to disease patterns in humans. In a comparative study, molecular sequencing of *E. faecium* species suggested a clinical association with various pandemics globally (Lam *et al.* 2012). *E. faecium* may last on inanimate surfaces for approximately 5 days to 4 months (Barr *et al.* 2021).

High-contact items like bed rails, over-bed tables, blood pressure cuffs, alarm buttons, toilet seats, and door handles are frequently the source of *enterococci* (Zhou *et al.* 2020). As a result, *enterococci* can spread indirectly through contaminated ambient surfaces, in addition, directly through the hands of healthcare professionals, patients, or guests. *Enterococci* may re-emerge from contaminated surfaces, which serve as covert reservoirs, and colonise patients who are later admitted to the same room. Increased cleaning methods, such as decontamination with hydrogen peroxide vapour or targeted washing of ambient surfaces with high concentrations of sodium chloride, should be employed to eliminate persistent reservoirs of VRE (Zhou *et al.* 2020). Cephalosporins are broad-spectrum β -lactam antibiotics with minimal toxicity and hypoallergenic characteristics. When exposed to cephalosporin concentrations, *Enterococcus faecium* is inherently resistant (Lee *et al.* 2019).

According to Lee *et al.* (2019), β -lactam antibiotics, such as ceftriaxone, can kill almost all upper gastrointestinal bacteria except *E. faecium*. Their research has shown that when volunteers take oral cephalosporins, their gastrointestinal tracts have a higher percentage of *enterococci*. The colonisable region and the likelihood of contracting an *E. faecium* infection are increased when cephalosporin-susceptible bacteria are eliminated.

2.4.3 *Acinetobacter Baumannii*

Antunes, Visca and Towner (2014) reported that *A. baumannii*, a Gram-negative opportunistic microorganism, is accountable for 2%-10% of hospital infections. This contagious pathogen is accountable for many healthcare hospital-acquired infections, which is due to the multidrug-resistant species (Di Nocera *et al.* 2011). A further study concurs that this bacterium has demonstrated multidrug resistance (MDR) in recent years, primarily as a result of widespread antibiotic overuse (Kyriakidis *et al.* 2021). Their study demonstrated, while the total death rate for *A. baumannii* can reach 56.2%, the estimated prevalence of MDR strains in patients is 79.9%, with the ranges being 56.5% in Argentina and 61.8% in Taiwan to 100% in Central America, Pakistan, Lebanon, Qatar, and Croatia. Both across Europe and among Arab nations, there are variations in carbapenem resistance patterns. Northern and Eastern Europe, as well as the Arab nations (Iraq, Jordan, Lebanon, Palestinian territories, and Syria), have seen an increase in the prevalence of carbapenem resistance in *A. baumannii* isolates (Kyriakidis *et al.* 2021).

A. baumannii causes a wide variety of significant bacterial nosocomial illnesses, along with skin and soft tissue diseases, wound infections, bladder infections and brain swelling (Antunes, Visca and Towner 2014). A study by Huang *et al.* (2011) investigated *A. baumannii* in the intensive care unit at a hospital in Taiwan. Sampling was extracted from hospital patients, medical equipment, and the staff's hands. *A. baumannii* was isolated on the clipboards (62.5%), moving trolleys (50.0%), patients' bags removed from the ambulance (33.3%), and staff hands (31.8%). *A. baumannii* causes nosocomial infection in patients with blood poisoning, heart pathologies, meningeal abscess, lung abscess and urinary tract disease (Huang *et al.* 2011). This emphasises the risk of transmission of *A. baumannii* to vulnerable patients.

2.4.4 *Klebsiella Pneumonia*

Klebsiella pneumoniae is a frequently identified source of nosocomial infections globally, affecting individuals with decreased immunity, children and the advanced aged group (Munoz-Price *et al.* 2013; Henson *et al.* 2017). A previous study by Lin *et al.* (2010) corroborated that *K. pneumoniae* is the main source of Gram-negative infection leading to liver abscess, lung abscess, respiratory complications and epidermis diseases. This causative bacterium is attributed to common infections in many public and private healthcare facilities, with key concerns in the healthcare environment; this bacterium affects the urinary tract pathways and wounds; it may remain longer on inanimate surfaces and colonise various areas of the patient's body (Cao *et al.* 2014; Heidary *et al.* 2018). Previous research showed that *K. pneumoniae* is an opportunistic microorganism leading to urinary tract infections, compromising the prognosis of hospital patients (Clegg and Murphy 2016). In a separate study by Li *et al.* (2023), antibiotics such as carbapenems, cephalosporins, aminoglycosides, and fosfomycin are ineffective against *K. pneumoniae* because of its resistance to these drugs.

The efficiency of conventional treatments against *K. pneumoniae* has decreased as a result of the pathogen's development of antibiotic resistance. Increased efflux, drug inactivation, or changed binding to the target site can all lead to resistance. Resistance is exacerbated by the production of biofilms by numerous *K. pneumoniae* strains. The following five processes are the primary causes of *K. pneumoniae* antibiotic resistance. This includes enzymatic antibiotic inactivation and modification; antibiotic target alteration, porin loss and mutation, enhanced antibiotic efflux pump expression, and biofilm formation. The five ways that *K. pneumoniae* develops resistance to antibiotics (Li *et al.* 2023). Epidemiological surveillance for *K. pneumoniae* is required to prevent its widespread spread, particularly for strains that are highly resistant to antibiotics (Wang *et al.* 2020).

2.4.5 *Enterobacter* Species

Infections caused by *Enterobacter* species represent a significant worldwide health issue (Logan and Weinstein 2017; Peirano *et al.* 2018). A cross-sectional study of 705 adult patients was conducted in Egypt, encompassing university hospitals, between July 2016 to March 2017. A total of 440 *Enterobacteriaceae* isolates were extracted from urinary tract infection (UTI) patients. Patients who had symptoms of fever, dysuria and pain above the pubis were included. The gender distribution of participants was 32.2% males and 67.8% females. Results revealed that 32.5% of isolates were resistant to quinolones, and 20.5% were resistant to fluoroquinolones (Kotb *et al.* 2019). A further descriptive-comparative study, in Sian and Bessat hospitals situated in Hamadan, western Iran, in 2010, isolated samples of *Enterobacteriaceae*. The study aimed to analyse the prevalence of antimicrobial resistance of *Enterobacteriaceae* isolated from hospital-acquired and community-acquired infections. A total of 574 specimens were collected, of which the most common pathogens were *E. coli* and *K. pneumoniae*. Most of the isolates of *Enterobacteriaceae* were resistant to ampicillin (98.8%) (Seyyed Hamid *et al.* 2013). This family of Gram-negative bacilli resides in the gastrointestinal tract of humans and is one of the most frequent causes of community-acquired diseases (Logan and Weinstein 2017).

Enterobacter species are currently identified as resistant species to various antibiotics and carbapenems, referred to as carbapenem-resistant *Enterobacteriaceae* (Bilavsky, Schwaber and Carmeli 2010). Because of their adaptation to the hospital environment and their ease of acquiring a large number of genetic mobile elements including resistance and virulent genes, these infections are commonly linked to a multidrug resistance phenotype. Because they exhibit a constitutive β -lactamase, these species are naturally resistant to ampicillin, amoxicillin, first-generation cephalosporins, and cefoxitin. Additionally, it has been noted that these bacteria produce extended-spectrum β -lactamases, which makes treating them challenging (Davin-Regli, Lavigne and Pagès 2019).

2.4.6 *Pseudomonas Aeruginosa*

The growing prevalence of multidrug resistance among hospitalised patients presents a significant concern in the context of HAIs globally (Fazeli et al. 2012; Nathwani et al. 2014). To illustrate this, a study conducted by Nathwani *et al.* (2014) investigated the presence and resistance of *Pseudomonas aeruginosa* bacteria in hospital settings. The researchers collected 104 samples, comprising 59 clinical samples from patients and 45 samples from hospital staff and the environment. The results showed that the bacteria exhibited high resistance to the antibiotic Ceftazidime but low resistance to Amikacin. Further analysis using PCR-ribotyping revealed that the hospital environment may be the primary reservoir for *P. aeruginosa* infections, suggesting that the bacteria can survive and spread through the hospital environment, posing a risk to patients and staff. In a similar cross-sectional study performed in Alzahra Medical Centre, Esfahan, Iran was conducted between 2009-2010; samples were isolated from the hospital environment, staff, and patients, and all specimens were analysed for bacteria and viruses. Specimens obtained from hospital staff included one faeces sample, four peritoneum samples, two cerebral spinal fluid samples, three blood samples, sixteen throat swabs, twenty-five urine samples, and one flesh sample. Environmental specimens included 113 samples, taken from the showers, taps, patients' wards, and hands. All bacterial isolates from this study demonstrated antibiotic resistance (Fazeli et al. 2012).

Such findings are particularly concerning given that strains of *P. aeruginosa* may exhibit significant antibiotic resistance and are currently classified as superbugs. This Gram-positive bacterium affects various hosts, including humans, leading to lung complications and nosocomial infections (Breidenstein, de la Fuente-Núñez and Hancock 2011). A retrospective study conducted over a two-year period situated in Brazil assessed 54 patients admitted to intensive care unit with *P. aeruginosa* infections. Multi-drug resistance was observed in (37%) 20/54 of samples (Bassetti et al. 2018). The development of biofilm in the lungs of infected patients, which acts as a diffusion barrier to restrict antibiotic access to the bacterial cells, is a component of *P. aeruginosa*'s adaptive resistance. (Pang *et al.* 2019).

Long-lasting and recurring infections in patients are also caused by multidrug-tolerant cells, which can develop in the biofilm and withstand antibiotic treatment. Patients whose *P. aeruginosa* infections are resistant to traditional antibiotics who urgently need the development of novel medicines or other therapeutic approaches (Pang *et al.* 2019).

2.5 THE IMPACT OF BACTERIAL DISEASES IN THE PREHOSPITAL SETTING

Emergency medical service personnel operate continuously and may disseminate bacterial organisms during the treatment and transportation of patients within the ambulance's rear compartment (Noh *et al.* 2011). Noh *et al.* (2011) examined the risk-stratification-based frequency of microbial contamination of ambulance rear compartment floors, medical instruments, and materials. The study was conducted in a Korean metropolitan area and utilised basic-life support ambulance vehicles. Of the 117 ambulances, 13 (approximately 11%) were selected for swabbing and testing for microorganisms. In each of the 13 ambulances, 33 distinct sites were swabbed and tested. A total of (13 x 33) 429 sites were tested across the 13 ambulances. A total of 214 of 429 (50%) specimens revealed positive results for microbes. Four of these were infectious organisms (0.9%) (MRSA and *Klebsiella pneumoniae*), and 210 of these were identified as environmental flora (49.0%). The prevalence of bacteria in the critical, semi-critical airway, and semi-critical breathing apparatus categories was notably elevated, with positive test rates of 15.4% (4 out of 26 specimens) in the critical group, 30.7% (16 out of 52 specimens) in the semi-critical airway group, while 46.2% (48 out of 104 specimens) were identified in the semi-critical breathing apparatus group. The findings revealed a notable prevalence of bacteria within these groups, raising concerns regarding infection control and patient safety. Despite the current cleaning guidelines in the Korean metropolitan ambulances regulations, critical and semi-critical instruments were infected with bacteria and natural flora. This study signifies the need for stringent contamination control and prevention for ambulance vehicles (Noh *et al.* 2011). Several studies have depicted that ambulance vehicles are contaminated with microbes from bodily fluids or excreta. Various emergency medical vehicles have been found to contain potentially harmful bacterial species (Taylor-Robinson 2019).

Forty-nine percent of swab samples from 13 metropolitan ambulances in the United Kingdom tested positive for bacteria; 0.9% of these were identified as highly drug-resistant pathogenic strains comprising of MRSA, methicillin-resistant coagulase-negative *staphylococci*, and *K. pneumoniae* (Taylor-Robinson 2019). Makiela *et al.* (2016) reported that of the 21 ambulances, 47.6% of surface swabs tested positive for MRSA. Furthermore, a significant number of microbes were isolated from helicopter air ambulances, as corroborated by more comprehensive findings from Australia (Makiela *et al.* 2018; Taylor-Robinson 2019). Of the seven isolated species found on the interior of the helicopter, four were identified as nosocomial pathogens, three of which exhibited antibiotic resistance traits. In a similar manner, 49% of rural ambulances exhibited MRSA contamination in at least one internal location. Frequent detection of Gram-negative coliforms from various genera, such as *Enterobacter*, *Klebsiella*, and *Escherichia*, suggests the presence of faecal or soil contamination.

Previous studies by Valdez *et al.* (2015), Hudson, Glaister and Wieden (2018), and Lindsley *et al.* (2018) have emphasised that emergency care personnel are exposed to biofluids of their patients due to the capricious setting they work in, as it is not always easy to anticipate which patients have contagious illnesses. Besides the potential risks within the pre-hospital sector, ECPs' transport patients with Human Immunodeficiency Virus (HIV), Tuberculosis (TB), Multi-Drug Resistance Tuberculosis (MDR-TB) and multiple variants of new pathogens, presenting the ECPs' with increased risk to bacterial and viral diseases (Otieno-Ayayo *et al.* 2015; Lindsley *et al.* 2018).

Emergency medical service ambulances are engineered to transport sick and injured patients to specialised medical or trauma hospitals. Emergency care personnel must act promptly and provide medical intervention in life-threatening situations, thereby exposing themselves to the risk of communicable diseases (Luksamijarulkul and Pipitsangjan 2015). The ECPs' uniform come into contact with different surroundings as they perform their duties and may be infected with possible infectious agents (Mackay *et al.* 2017). The World Health Organisation (WHO) highlighted that droplets coughed or sneezed by contaminated patients may travel a distance of approximately 1 to 2m and land on inanimate surfaces (World Health Organisation, 2020).

These microorganisms can potentially settle on the ambulance floors, uniforms and ECPs' SPF (Singhal 2020). Health-care-associated infection is still a major concern for healthcare workers, families, and communities (Teter, Millin and Bissell 2015). Research indicates that assessing microbial contamination in emergency service vehicles is essential for enhancing staff occupational health and improving patient care quality (Paravar *et al.* 2020).

2.6 HEALTHCARE-ASSOCIATED INFECTION (HAI)

Healthcare-associated infections (HAIs) can be transmitted from healthcare workers' hands to patients (Gotlib 2014). Among every 100 patients admitted, 7 from high-income countries and 10 from low/middle-income countries will acquire a HAI. Numerous patients globally acquire infections caused by antibiotic-resistant microorganisms. According to the available data, inadequate health and hygiene education programs, inappropriate prescription practices in addition to overprescription in clinical settings (primarily in developing nations where access to antibiotics is easier), and a lack of precise laboratory diagnostic tools to prevent the emergence of antibiotics against commonly used drugs in the community are the main causes of the current antibiotic crisis worldwide (Talebi Bezmin Abadi *et al.* 2019).

Health-associated diseases, or hospital-acquired infections, are identified 48 hours after hospital admission, contributing not only to increased costs but also to elevated mortality rates (Revelas 2012; Cristina *et al.* 2013; Al-Tawfiq and Tambyah 2014). The increase in morbidity from HAI was highlighted in a European study where 3360 patients acquired HAIs in the ICU; the most common were respiratory tract infections (22.8%), urinary tract infections (17.2%) and post-operation infections (15.7%) (Al-Tawfiq and Tambyah 2014).

Mehmood *et al.* (2014) conducted a study that involved the collection of 100 samples from tourniquets utilised in private and public hospitals in Pakistan. The research indicated that 51% of the tourniquets exhibited colonisation by microorganisms; of the samples analysed, 17 out of 40 from public hospitals and 32 out of 60 from private hospitals exhibited no microbial growth. Overall, *S. aureus* was isolated from 12 specimens (42%) in the private hospital and from 10 specimens (43%) in the public hospital.

Notably, approximately 90% of elastic tourniquets and 41% of all tourniquets contained bacteria, a finding that demonstrated statistical significance ($p < 0.001$), while 96% of health staff recognised their potential contribution to cross-contamination; these individuals did not uniformly identify staff-associated tourniquets as a possible source of risk. In a survey of health staff regarding the cleanliness of tourniquets before use, 66% affirmed that the tourniquets appeared clean, while only 25% asserted that they should be scrubbed or washed before application (Mehmood *et al.* 2014). Cristina *et al.* (2013) also agreed that healthcare facilities are reservoirs for microorganisms. A study by Magill *et al.* (2014) in 183 US hospitals found that out of 11,282 patients, 452 (4%) had at least one HAI. The most common types of infections were lung infections caused by HAIs, accounting for 21.8% of the total infections, and surgical site infections, also accounting for 21.8% of the total infections. Gastrointestinal infections were another significant source of HAIs, making up 17.1% of the total infections. These findings highlight the importance of infection control measures in healthcare settings to reduce the risk of healthcare-associated infections and ensure patient safety (Magill *et al.* 2014).

Weiner *et al.* (2016) examined antimicrobial resistance sequences in microorganisms obtained from device-associated and procedure-associated HAIs reported by hospitals. The research indicated that 463 hospitals documented multiple HAIs, with a predominant 89% being general care facilities. Furthermore, 309 hospitals, representing 67%, had between 200 and 1000 admission beds. The findings underscore the prevalence of antimicrobial resistance in healthcare environments and the necessity for ongoing vigilance in infection control measures. Overwhelmingly 28,502 HAIs were reported among 25,384 ill patients in the United States. The most prevalent infections presented by patients were attributed to coagulase-negative staphylococci (15%), *Enterococcus* species (12%), *Candida* species (11%), *Escherichia coli* (10%), *Pseudomonas aeruginosa* (8%), *Klebsiella pneumoniae* (6%), *Enterobacter* species (5%), *Acinetobacter baumannii* (3%), and *Klebsiella oxytoca* (2%) (Weiner *et al.* 2016). Healthcare-associated infections (HAIs) significantly affect morbidity and mortality rates and contribute to the rise of multidrug-resistant microorganisms, with over 70% of these pathogens exhibiting resistance to at least one commonly utilised antibiotic.

This intensifies the challenge healthcare facilities are confronted with in terms of clinical management of the patients and cross-infection with these microorganisms (Weiner *et al.* 2016).

The increased escalation of multidrug resistance in diseases associated with HAIs, such as *Clostridium difficile*, highlights the significance of bacterial identification and monitoring. Research by Barr *et al.* (2021) highlighted the risk of exposure to blood-borne pathogens and diseases faced by EMS workers and firefighters. To investigate this, the researchers evaluated four EMS fire stations in the USA by swabbing high-use areas, including floors, uniform washing machines, fire engine medical bags, and firefighter clothing. Results revealed that microbial nucleic acid appeared in the fire stations keyboards ($n = 13$), on floors ($n = 10$), and in wash machines ($n = 9$); in the fire engines on medical jump kits ($n = 7$), on the dashboard ($n = 6$), and on seats ($n = 2$); and on firefighter clothing ($n = 3$). These findings are consistent with previous research illustrating that multiple microorganisms were found in every sample across all fire stations (Roberts *et al.* 2011; Sheahan *et al.* 2019; Taylor-Robinson and Makiela 2019). Highlighting the importance of proper infection control measures to protect EMS workers and firefighters from occupational exposure to blood-borne pathogens.

2.7 PATHOGENIC BURDENS WITHIN HEALTH CARE FACILITIES

Kanwar *et al.* (2019) conducted a study examining nosocomial bacterial contamination on healthcare staff uniforms during active patient care. The study involved the collection of samples from uniforms worn by 41 healthcare staff members at the completion of their shifts, aiming to evaluate the extent of contamination present on garments frequently used in both hospital and home settings.

The results indicated that 44% of participants (18 out of 41) had uniforms contaminated with multiple types of microorganisms. Additionally, visible contamination was noted on 20% of uniforms (8 of 41) and 29% of footwear (12 of 41). The findings indicate that healthcare staff uniforms and footwear might serve as reservoirs for nosocomial bacteria, potentially contributing to HAIs.

A recent study, in Cleveland Medical Centre Ohio, examined the frequency of contamination on hospital staff's hands, footwear, and uniforms with healthcare-associated microbes. The study included 41 participants, comprising 25 nurses (61%) and 16 physicians (39%). Notably, all nurses were wearing scrubs that they intended to wear at home, whereas none of the physicians wore scrubs. The findings revealed that 18 out of 41 staff members (44%) were contaminated with one or more pathogens. Moreover, the contamination was predominantly found on their clothing (20%) and shoes (29%). This highlights a concerning risk of hospital staff unintentionally transporting harmful microorganisms on their personal attire, potentially leading to the spread of infections (Kanwar et al. 2019). In figure 2.1, below shows that health care-associated infections, especially MRSA, can be present in the clothes and shoes that doctors and nurses bring home from medical institutions. The prevention of disease transmission through clothes is affected by these discoveries (Kanwar et al. 2019).

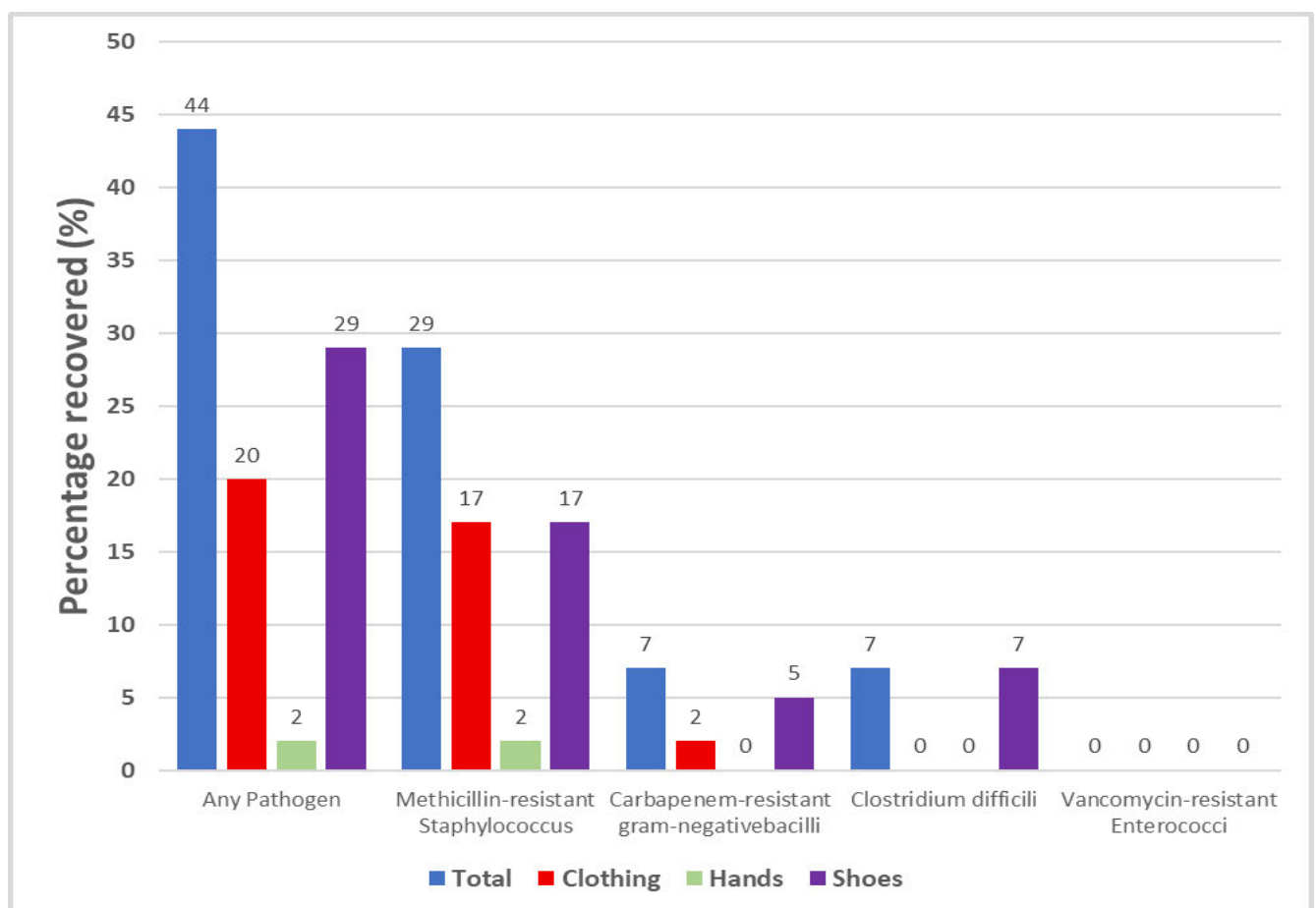


Figure 2.1: Frequency of healthcare-associated microbe contamination of hospital staff palms, footwear, and uniforms (Kanwar et al. 2019).

In a similar study at the University of Maryland Medical Centre and the R Adams Cowley Shock Trauma Centre, 720 samples were obtained from 90 HCWs (79 nurses and 11 patient care technicians) over the 8-month study period during the last 4 hours of their shift. As presented in the primary study, 30% (217/720) of scrubs were contaminated with pathogenic bacteria (Thom *et al.* 2018). In a separate study, a systematic review was undertaken by hospitals in the United States, and the findings revealed that the healthcare workers' uniform, including doctors' white coats and scrubs, was a potential source for microbial transmission in a hospital environment (Goyal *et al.* 2019). Goyal *et al.* (2019) undertook a study revealing significant differences in bacterial contamination rates on healthcare workers' uniforms based on laundering locations. The contamination rate for individuals who laundered their uniforms at home was notably high, ranging from 64% to 89%, in contrast to a significantly lower rate observed among those who used the hospital's laundry facilities. A significant 44% of staff who laundered their uniforms at home tested positive for coliform bacteria, whereas none (0%) of those utilising the in-house hospital laundry exhibited such contamination. This indicates that laundering uniforms at home could pose a considerable risk for bacterial contamination, underscoring the necessity of appropriate laundry protocols to mitigate the transmission of pathogenic bacteria in healthcare environments.

A study performed in a hospital in Washington State investigated the persistence of pathogens on nurses' uniforms following a shift, including after their return home. Ten nurses received disinfectants for the purpose of decontaminating their uniforms prior to both day and night shifts. The uniforms were subsequently collected and analysed in a laboratory, yielding concerning results. Four uniforms from the day shift and three from the night shift were found to be positive for MRSA, an antibiotic-resistant bacterium. Furthermore, infectious bacteria such as *Bacillus*, *Micrococcus*, *Staphylococcus*, and *Micrococcus roseus* remained present on the uniforms even 48 hours post-shift completion. This indicates that, despite efforts to disinfect their uniforms, nurses may continue to transport harmful pathogens to their homes, underscoring the necessity for enhanced infection control strategies (Sanon and Watkins 2012).

The studies have highlighted the need for a standardised infection, prevention and control policy for both hospital and ambulance services, which should include hand washing techniques, general defences against blood fluids, sanitising and decontamination, fumigation of medical apparatus/devices, disinfecting surfaces, use of sterilisers, aseptic techniques, and appropriate removal of wastes, needles and management of soiled bed linens and SPF disinfection (Gichuhi *et al.* 2015). A study of 135 medical practitioners and interns in an International Safety Centre, United States Trauma Hospital, observed that 1.5% were positive for MRSA and 35.7% were positive for Methicillin-sensitive *Staphylococcus aureus* (MSSA). None of the 61 interns were positive for MRSA, but 59% were positive for MSSA. Of the 74 assisting medical practitioners, 2.7% were positive for MRSA, and 23.3% were positive for MSSA (Mitchell, Spencer and Edmiston Jr 2015).

In a previous study, Nathwani *et al.* (2014) included at least 20 hospitalised patients from Ninewells Hospital, Scotland, UK, with laboratory-confirmed resistant *P. aeruginosa* infection and reported all causes of mortality, length of stay, hospital costs, re-admission, or recurrence between January 2000 and February 2013. There were 23 studies reviewed, encompassing 7,881 patients with susceptible *P. aeruginosa*, 1,653 with resistant *P. aeruginosa*, 559 with MDR *P. aeruginosa*, and 387 non-infected patients without *P. aeruginosa*). The reporting showed an increase in mortality in patients with resistant *P. aeruginosa* 34% (95% CI 27% - 41%), compared to 22% (95% CI 14% - 29%) in patients with susceptible *P. aeruginosa*. The meta-analysis found that MDR *P. aeruginosa* had a more than 2-fold increased risk of mortality (RR) 2.34, 95% confidence interval (CI) 1.53 - 3.57) and resistant *P. aeruginosa* had a 24% increased risk (RR 1.24, 95% CI 1.11 - 1.38). An adjusted meta-analysis of data from seven studies found that patients with any resistant *P. aeruginosa* had a statistically nonsignificant increased risk of mortality (adjusted RR 1.24, 95% CI 0.98 - 1.57). According to studies, patients with MDR and *P. aeruginosa* infections had longer hospital stays. The study had several limitations, including heterogeneity in the MDR definition, a focus on nosocomial infections, and potential confounding in analyses (Nathwani *et al.* 2014).

2.8 IN-HOSPITAL PATHOGEN MONITORING AND INVESTIGATION

Hospital floors may play a critical part in the transmission of HAIs, including pathogens such as *MRSA* and *VRE*. Patients can acquire bacterial infections by direct contact. Healthcare workers often come into contact with the same inanimate surfaces, indicating potential for pathogen transmission from hands to susceptible patients (Otter *et al.* 2013). One method employed by Matthew *et al.* (2022) uses a Rapid Room Disinfection device (Tru-D), which is a fully automatic mobile unit that uses ultraviolet-C to destroy various pathogens. The usage of this device in hospitalised patient rooms was tested. Several cultures of pathogens were gathered from surface areas that were frequently handled before and after the use of the Tru-D. After normal hospital room disinfection, results yielded an overwhelming 18% of *MRSA* pathogens detected in frequently handled and difficult-to-reach places; however, after placing Tru-D in the room for 45 minutes, the result showed a remarkable 0% pathogen detection (Nerandzic *et al.* 2010; Matthew *et al.* 2022). This research also shows that hospital floor disinfection and surface cleaning were of sub-standard quality (Nerandzic *et al.* 2010). In a separate study by Ohl *et al.* (2012) revealed, that privacy curtains in the hospital wards were potential sites for bacterial contamination. Healthcare workers and patients often directly contact privacy curtains. This may promote the transfer of bacteria from patients and HCWs to curtains. The study revealed that 12 out of 13 curtains (92%) identified during the study had contamination within one week of use. Forty-one out of 43 curtains (95%) showed bacterial contamination, including 21% with *MRSA* and 42% with *VRE*. Eight curtains yielded *VRE* at multiple time points, that is, 3 with resolution of a single isolate and 5 with various types, implying frequent recontamination (Ohl *et al.* 2012).

A recent study by Kumar, Kumar and Kumar (2020), concluded that hospital theatre floors and surfaces are a possible source for bacteria and nosocomial infections. In a study conducted in Switzerland at a university tertiary care centre, HCWs' shoe soles were tested for *C. difficile* twice per shift while caring for a patient infected with toxigenic *C. difficile* from October 2019 to July 2020. Results revealed *C. difficile* contamination of shoe soles was found in 37 samples (17.8%) of HCWs caring for *C. difficile* patients (Büchler *et al.* 2022).

Clesham, Ryan and Murphy (2018) suggested that theatre shoes that retain Gram-positive bacteria, which include antibiotic-resistant isolates, have the potential to transfer to the environment. The results from 40 theatre shoes illustrated 65% coagulase-negative staphylococci, 40% MSSA and MRSA (Clesham, Ryan and Murphy 2018; Kumar, Kumar and Kumar 2020).

A study was undertaken by Nwankwo and Akande (2015) to determine the number of bacterial microorganisms on operating theatre footwear in Murtala Mohammed Specialist Hospital in northern Nigeria. A total of 136 specimens were collected from various departments, including 54 from the main theatre, 50 from maternity, and 32 from gynaecology. Initial visual inspection revealed that 80 (58.8%) of the samples had no visible blood stains. However, 56 (41.2%) did show visible blood stains. Further analysis using chemical testing detected blood stains in an even higher percentage of samples - 92 (67.6%), highlighting the presence of blood on surfaces that may not be visible to the naked eye. This raises concerns about the effectiveness of cleaning protocols and the potential risk of infection transmission (Nwankwo and Akande 2015). In a comparable study in a tertiary hospital in Solapur, India, Danave, Sharma and Ingole (2019) examined the presence of blood and microorganisms on footwear used in the operating theatre. The researchers obtained 140 swab specimens, comprising 70 from the surface and 70 from the underside of the footwear, utilizing sterile cotton moistened with saline. The findings indicated that 24 samples (34.2%) tested positive for blood, whereas 46 samples (65.71%) did not show a positive result. Additionally, the predominant microorganisms isolated were gram-positive *cocci*, comprising 59 (84.3%) of the samples, whereas Gram-negative bacteria were present in 11 (15.71%) of the samples (Danave, Sharma and Ingole 2019). A notable difference was identified in the bacterial types isolated from the soles of individuals utilizing operation theatre footwear. Gram-positive bacteria were predominant, comprising 52 isolates (74.3%), while gram-negative bacteria represented 18 isolates. *Staphylococcus epidermidis* was the most prevalent among the Gram-positive bacteria, accounting for 24 isolates (34.2%). This was followed by *Staphylococcus aureus* with 12 isolates (17.1%), *Bacillus* species with 10 isolates (14.3%), and diphtheroid species with six isolates (8.5%).

Pseudomonas aeruginosa was identified as the predominant Gram-negative bacterium, accounting for 66.66% (12 cases), while *E. coli* represented 8.5% (6 cases). The findings in Table 2.1 highlight the necessity of stringent IPC protocols in operating room environments to reduce bacterial transmission (Danave, Sharma and Ingole 2019).

Table 2.1: Microorganism isolated on the soles of theatre footwear (Danave, Sharma and Ingole 2019).

Organisms	Operation Theatre Footwear (n=70)	Theatre Staff Sole of Footwear (n=70)
Coagulase-negative <i>Staphylococcus</i> (CONS)	49 (70%)	24 (34.2%)
<i>Staphylococcus aureus</i>	08 (11.4%)	12 (17.1%)
<i>Streptococcus</i> species	02 (3%)	-
<i>Bacillus</i> species	-	10 (14.3%)
<i>Diphtheroid</i>	-	06 (8.5%)
<i>Pseudomonas aeruginosa</i>	07 (10%)	12 (17.1%)
<i>Citrobacter</i> species	03 (4.2%)	-
<i>E. coli</i>	01 (1.4%)	06 (8.5%)

2.9 PRE-HOSPITAL PATHOGEN MONITORING AND INVESTIGATION

Chen *et al.* (2021) stated that nosocomial bacteria are a major issue in the healthcare industry. The team of researchers alluded to the fact that healthcare facilities are always full of patients, and many are immunocompromised, increasing the risk of cross-transmission. Healthcare facilities are also required for the care of patients with life-threatening diseases and contribute an important role in IPC during epidemics (Chen *et al.* 2021). Obenza *et al.* (2022) demonstrated a concerning prevalence of nosocomial pathogens in emergency paramedical ambulances, identifying four out of seven species present.

All ambulances in the study in Southern Maine, United States, exhibited a 100% prevalence of infection-causing bacteria, encompassing those typically associated with HAIs as well as a range of other microbial types. The identified microorganisms included MRSA, *K. pneumoniae*, *Klebsiella* species, and *E. coli*. The study identified the presence of microbes on multiple surfaces within ambulances, such as the blood pressure cuff, oxygen humidifier glass, walls, door grips, beds, carrying chairs, and cervical collars. This underscores the necessity for improved disinfection and infection control measures in these vehicles.

Microbes from the environment, emergency vehicle equipment, and HCW hands are potential sources of hospital-acquired diseases (Farhadloo *et al.* 2018). The investigators utilised a before-disinfection and after-disinfection strategy to evaluate microbial contamination in the posterior and anterior compartments of ambulances, along with medical equipment. The data indicated a significant decline in microbial contamination before and after cleaning, with a reduction from 52% to 8% following the application of an antibacterial solution. Coagulase-negative staphylococci were initially prevalent on medical equipment; however, their numbers significantly decreased following the implementation of the cleaning protocol, demonstrating the efficacy of the antibacterial solution in mitigating bacterial contamination (Farhadloo *et al.* 2018).

Pathogenic bacteria monitoring is important in the pre-hospital healthcare sector to ensure that microbial load monitoring is performed, which reduces pathogen distribution. However, this protocol is not practised by the ambulance sector (Sheahan *et al.* 2019). In a descriptive study conducted by Paravar *et al.* (2020), 18 sites were sampled in 12 emergency vehicles from Kashan City, Iran, including ambulances from rural areas. The researcher also included swabs from the nasal passages of ambulance staff. The results revealed contamination at all sites. Furthermore, the conclusions deduced that the oxygen cylinder carried the greatest number of pathogens, and city ambulances carried more viruses compared to rural vehicles. Presently, there is limited or insufficient knowledge regarding EMS biosafety factors and EMS transmission of pathogenic organisms (Hudson, Glaister and Wieden 2018).

Bacteriological contact between inanimate objects and the surroundings where humans reside may potentially have major medical complications, as microorganisms can attach to individuals and progressively spread from person to person (Lax *et al.* 2015). As far as data reveals, no previous research has investigated the presence of bacterial pathogens on SPF globally and the different mitigation strategies to disinfect the SPF in the prehospital environment.

2.10 GLOBAL AMBULANCE BACTERIAL RISK STRATIFICATION

In July 2012, a cross-sectional study was performed on 10 basic life support ambulances (BLSAs) within the metropolitan area of Bilbao, Spain. While all ambulance vehicles had records of cleaning and disinfection, there were no established written protocols. The research indicated that 44 of 60 samples (73%) exhibited positive results for microbial growth. The sites most frequently exhibiting bacterial growth included the inner passenger door handle of the stretcher, the steering wheel, and the left handle. The predominant bacteria isolated were coagulase-negative staphylococci, followed by methicillin-susceptible staphylococci. *Staphylococcus aureus* was identified in three samples collected from two distinct ambulances. Furthermore, additional bacteria, including *Enterobacteriaceae*, nonfermenting Gram-negative bacilli, enterococci, and *Bacillus* species, were identified in 26 samples (Varona-Barquin *et al.* 2017).

In a separate study in South Korea, thirty ambulances were selected, 13 from the regional centre and 17 from the South Korean private sector. These ambulances were sanitised and wiped clean every 5-8 days, respectively. The equipment was also cleaned and sanitised every 22 and 30 days, respectively; of the 955 specimens taken, 159 (16.6%) showed bacteria present (Yoo *et al.* 2012). A further study by Dias, Sousa and Viegas (2022) concluded that out of the 12 ambulance patient compartments, 5 mops and cloth samples were taken, and Gram-negative microbes were present in all areas. Correct germicidal procedures for the pre-hospital emergency medical setting are important and necessary to reduce the presence of microorganisms that can be transferred to new patients, family members and to the paramedics themselves (El-Mokhtar and Hetta 2018; Dias, Sousa and Viegas 2022).

These microorganisms can attach to the paramedic uniforms, including the SPF. Vikke *et al.* (2018) reported that pathogenic bacteria have been prominently found in ambulances and on staff uniforms. MRSA has become a problematic nosocomial pathogen affecting patients in hospitals and ambulances (Roberts *et al.* 2011; Vikke, Giebner and Kolmos 2018).

A study evaluating Chicago ambulances revealed that MRSA was found in 69% of all ambulances, 77% of isolates showed resistance to one antibiotic and 34% to two antibiotics (Rago *et al.* 2012). A similar study by Obenza *et al.* (2022) suggested that cross-contamination in relation to out-of-hospital HCWs and inanimate surfaces is prevalent. Data were collected from Iran, the United States, Egypt, Denmark, Spain, Saudi Arabia and Germany, fire bases, ambulances, and fire engines. The study included personnel protective clothing, living areas and nasal cavities. The results revealed a 580/1064 (54%) MRSA detected in the samples, suggesting cross-contamination of pathogens between HCWs and surfaces is prevalent. Another study revealed that the MRSA pathogen can spread from the surface to healthcare providers to patients due to the limited space in the patient compartment and proximity of the patient to the HCW (Ro *et al.* 2012). Healthcare institutions are continuously involved in finding strategies to prevent health-associated infections, which can lead to serious diseases in both healthcare workers and patients (Quinn *et al.* 2015).

The ambulance staff are more prone to nosocomial pathogen exposure than the general population; these pathogens disperse easily over a long distance (Alrazeeni and Al Sufi 2014). A cross-sectional study tested 222 prehospital staff, and seven tested positive for MRSA (Schablon *et al.* 2018). Different areas of the ambulance that patients encounter should be frequently analysed, as these areas can transfer harmful germs and bacteria to healthcare professionals and patients (Bielawska-Drózd *et al.* 2018). Brown *et al.* (2010), Vikke and Giebner (2015) noted a prevalence of *E. coli* (27.7%), *Bacillus cereus* (2.22%) *Clostridium* and *Enterococcus* (21.11%) were among Danish paramedics before washing their uniform. Prior research generally confirms that bacterial pathogens are present in ambulance stations, however, prior studies have failed to evaluate the knowledge gap between disinfecting and cleaning protocols in this specific area (Makiela 2016; McGuire-Wolfe 2020).

Research conducted by Naguran (2008) and Williams-Claassen (2013) in KwaZulu-Natal examined the dissemination of contamination within ambulances, uncovering significant results. Thirteen bacterial species were identified, of which ten are potentially infectious. The research team refuted the justification that insufficient detergent availability and limited cleaning time account for irregular cleaning practices. The primary factors include time constraints resulting from a high volume of emergency cases, the absence of departmental policies, and insufficient education and training for emergency dispatch personnel regarding the prioritisation of ambulance cleaning after each use. The findings underscore the necessity for improved time management, explicit policies, and adequate training to guarantee the regular cleaning and disinfection of ambulances, thereby preventing the transmission of infections and safeguarding the well-being of patients and EMS personnel (Williams-Claassen 2013).

2.11 ATTITUDE AND KNOWLEDGE OF HEALTH CARE PERSONNEL ON IPC PRACTICES

Barrera-Cancedda *et al.* (2019) highlighted that infectious diseases produce substantial morbidity and mortality globally. An unequal prevalence of the disease morbidity associated with infectious diseases persists in Sub-Saharan Africa. It has been estimated that 61% of neonatal and maternal deaths in sub-Saharan Africa are due to infectious diseases in health care facilities. Understanding IPC strategies will ensure the safety of patients and communities (Barrera-Cancedda *et al.* 2019; Moodley *et al.* 2021; Jones, Marimuthu and Bearman 2022). The recent pandemics, such as the Ebola virus and Coronavirus, have emphasised the impact of infectious diseases in communities and the healthcare environment. A recent study by Moodley *et al.* (2021) investigated IPC practices in reducing the transmission of pathogens at healthcare facilities. A cross-sectional design was employed, and a questionnaire was administered to 47 health facilities; results revealed that 50.7% of staff were prepared to address patients with coronavirus and 55.6% of respondents had not received IPC training at the time of the survey (Moodley *et al.* 2021). A further study conducted among health science student doctors, nurses, and radiologists at the University of Namibia assessed student attitudes and understanding of IPC.

Student doctors received an overall score of 73%, while nurses received 66% and radiology received 61% (Ojulong, Mitonga and lipinge 2013). In a more recent study, a quantitative study surveyed 571 staff in South India for the awareness, attitude, and practices of IPC in private tertiary hospitals. The result revealed an increased level of knowledge, positive mindsets, and excellent IPC procedures. Among the IPC procedures, “changing gloves between contacts with different patients” was the most often practised and “washing hands after removal of gloves” was the least practised (Thazha *et al.* 2022). The researchers determined that increased awareness and education are necessary to enhance IPC knowledge in the prehospital context. This was in contrast to another study where a cross-sectional, multicentric, hospital-based survey was conducted at Guru Teg Bahadur Hospital, Delhi, India, on 328 nurses from January to November 2018 using a self-administered questionnaire from public and private tertiary- and secondary-level hospitals in North India. Their results revealed that IPC practices decreased, with a knowledge score of 51%, good practice of 73%, and a good practice score of 57%. The gaps were identified across all components, with major gaps in the knowledge of the care of devices (74%), barrier nursing/isolation precautions (60%), indications of using hand rub (55%), understanding the meaning of HAIs (50%) and optimum use of PPE (44%). In attitude and practices, injection safety emerged as the weakest area, with > 40% of nurses being neither aware nor practising the correct techniques of reconstituting, administering injectable medicines and maintaining asepsis (Gupta *et al.* 2020).

A study in Saudi Arabia by Khan (2020) investigated EMS providers' experiences and practices, alongside the motivations that underpin perceptions of standard IPC. According to data presented by Khan (2020), EMS providers have a low level of compliance concerning preventive measures, associated risk perceptions and self-justification of personal skills. The study employed qualitative methods, including two separate focus group discussions and twenty in-depth interviews with prehospital and inter-facility EMS providers. Using the Framework approach, data was thematically analysed. The participants ranked respiratory infections as the most concerning nosocomial risk. The failure to fully disclose medical history to EMS providers was deemed a significant threat.

Beliefs about the influenza vaccine's low efficacy and toxic effects, as well as low perceptions of influenza risks, were widespread. While common misperceptions contributed significantly to the inappropriate use of preventive measures, with reliance on intuition and personal experiences as attributed to a lack of knowledge of appropriate guidelines and formal IPC training programs (Khan 2020).

2.12 BENEFITS OF CLEANING AND DISINFECTING SURFACES

According to Querido *et al.* (2019), the correct use of disinfectants is an important part of reducing and preventing ambulance and hospital-associated diseases. Querido *et al.* (2019) indicated that in-hospital soiled surfaces and medical equipment contribute to the contamination of both HCWs and patients. An investigation on improving infection prevention in hospitals revealed that disinfecting measures are often inadequate, leaving microorganisms on inanimate surfaces (Doll, Stevens and Bearman 2018). Multiple studies revealed that disease transmission is initiated from the hands of healthcare workers and general assistants (20–40%), the patient's endogenous flora (40–60%) and contamination from the environment (Querido *et al.* 2019). Stiefel *et al.* (2011) discovered that the percentage of infection on HCW gloves after direct contact with the patient's skin surface was comparable (40% versus 45%) after direct contact with surfaces contaminated with MRSA, suggesting that communal surfaces present a significant hazard. An identical study in the University Hospital of Cleveland, Guerrero *et al.* (2012) yielded similar results, suggesting that the risks of hand infection after engaging with patient skin were the same when touching used communal areas (50% vs 50%) (Stiefel *et al.* 2011; Guerrero *et al.* 2012).

The culture of disinfecting hospital floors, ambulance cabins and PPE should become second nature to all HCWs. Disease-causing microorganisms from these surfaces can lead to cross-contamination to patients, HCWs, communities and person-to-person transmission (Rutala and Weber 2004). According to Quon, Dilauro and Ryan (2017), a study investigating decontamination compliance by HCW revealed that only 26% of radiologists disinfected their workspace daily, 24% confirmed that they had never cleaned and disinfected their workspace, and overwhelmingly 100% said they had never received any training regarding disinfection to their workspace.

There are two ways in which cleaning can be accomplished: sterilisation and disinfection. Sterilisation reduces various bacterial species on floor surfaces and equipment, while disinfection reduces most microorganisms (Naguran 2008). Cleaning with water and soap, in addition, aids in the removal of germs from a surface; cleaning with a combination of disinfecting material has a better effect in removing pathogenic organisms (Naguran 2008; Quon, Dilauro and Ryan 2017).

The best practice in preventing disease transmission is the removal of biomedical spills. Mitigating risks will depend on the rate at which the spill may be safely contained (Williams-Claassen 2013; Singh *et al.* 2014). Carling *et al.* (2008) reported that less than 50% of in-hospital floors and surfaces were considered hygienic after cleaning, as indicated in Table 2.2, which illustrates the hospital policy for cleaning different areas. A disturbing 30% of bedpans, restroom rails and door handles were disinfected. This necessitates action to enquire about the transmission of pathogens from contaminated areas directly contacted by HCW hands and gloves, increasing the risk of transmission to patients (Carling *et al.* 2008). Prior investigations have proven that rooms of diseased patients infected with microorganisms are often contaminated; when a new patient is admitted to the same room, there is a high prevalence of developing colonisation with infection (Carling *et al.* 2008; Otter *et al.* 2013; Querido *et al.* 2019).

In Table 2.2, eco-friendly cleaning and disinfection techniques for patient sites are listed, along with their advantages, disadvantages, and limitations (Doll *et al.* 2015; Doll, Stevens and Bearman 2018). Microbial contamination in the hospital environment must be reduced as part of an infection prevention strategy. This is especially true in an era when hospital-acquired infections and multidrug-resistant organisms are under increased scrutiny. The burden of microbial contamination identified in the literature is determined by several factors, including culture methods, culture sites, occupant characteristics, and cleaning practices used at the hospital (Doll *et al.* 2015; Doll, Stevens and Bearman 2018).

Table 2.2, Eco-friendly cleaning and disinfection of patient sites
(Doll *et al.* 2015; Doll, Stevens and Bearman 2018).

Cleaning Strategy	Advantages	Disadvantages	Limitations
1. Detergent Surface Cleaning Agents	Non-toxic to staff and environment	Inferior microbial killing compared to disinfectants	Can become contaminated with bacteria
2. Disinfectant Surface Cleaning Agents	Increased reduction in bacterial colony count compared to detergents	Toxic fumes and waste	Efficacy depends on concentration, contact time Additional training is necessary for use
3. Monitoring Cleaning With ATP/ Fluorescent Markers	Objective assessment of surrogate markers of residual contamination after cleaning	Requires purchase of supplies for monitoring	Poor correlation with actual microbial colony counts on surfaces
4. Monitoring Cleaning Via Direct Observation	Easy and inexpensive	Time-consuming, perceived subjectivity	Poor correlation with actual cleanliness of rooms by more objective methods
5. Addition Of Extra Staff to Target 'High Touch' Surfaces	Effective in decreasing microbial surface contamination on 'high touch' surfaces	Requires additional human resources	Impact of reduced 'high touch' surface contamination on infection transmission is unknown

Table 2.3: Eco-friendly cleaning and disinfection of patient sites (Continued)

(Doll *et al.* 2015; Doll, Stevens and Bearman 2018).

Cleaning Strategy	Advantages	Disadvantages	Limitations
6. Dedicated Teams For 'High Risk' Areas	Optimization of existing resources rather than requiring new staff or equipment	Shifts attention to a specific problem area, rather than improving cleaning across all areas	Efficacy difficult to assess in isolation given use in a bundle of other interventions
7. Antimicrobial 'self-cleaning' surfaces	Effective in decreasing microbial surface contamination	Expensive	Long-term durability of results unknown ability to reduce infection transmission requires further study
8. 'Touchless' Cleaning Robots	Effective in decreasing microbial surface contamination	Expensive requires staff training and human resources for deployment Patients/staff may not be present in the area during robot cleaning	Complex surfaces may be incompletely targeted by robot technology

2.13 DISINFECTANTS IN THE PRE-HOSPITAL ENVIRONMENT

Medical transport is an important component in the management of local healthcare; recent advances in the functionality and safety of such transport have necessitated a thorough examination of issues concerning the management of biological risks. Indeed, ambulances are high-care environments which are particularly vulnerable to microbial contamination from biological excretions and secretions; additionally, the emergency creates pressure for rapid pre-hospital care and repeated calls at short time intervals, which makes routine cleaning and disinfection critical. This issue is increasingly important in light of the rising prevalence of multi-resistant bacteria in hospitals and the community, which has implications for the emergency care system (Nobile *et al.* 2018).

According to Rutala and Weber (2014), to keep patients safe at healthcare facilities, hospitals need to monitor which pathogens cause HAIs, outbreaks, and ward closures, as well as monitor which pathogens are unique to their facility. According to the data, the product chosen should be effective against the most common microorganisms. Since the pathogens that cause the vast majority of HAIs (79.1%) are vegetative bacteria such as *S. aureus*, Enterococcus species, *E. coli*, coagulase-negative Staphylococcus, *P. aeruginosa*, *Klebsiella* species, and *Enterobacter* species (Rutala and Weber 2014).

Contamination of the environment, ambulance equipment, and staff hands thus plays a significant role in nosocomial infections in emergency patients. Contamination of equipment and devices is a major source of nosocomial infections. An experimental study performed at Qom University of Medical Sciences, Qom, Islamic Republic of Iran, with a before-and-after design to determine microbial contaminations in the rear and front cabins of ambulances, as well as medical equipment used by EMS, was performed; the contamination rates were 52% and 8% before and after the use of the disinfection solution, respectively. The most commonly isolated bacterial agent was coagulase-negative staphylococci (53%). Following the application of a disinfectant, the level of contamination in all equipment significantly decreased (Farhadloo *et al.* 2018).

2.14 DAILY DISINFECTION OF THE BACK AND FRONT CABIN OF THE AMBULANCE

According to Williams-Claassen (2013), cleaning areas with conventional soap, water, and detergents reduces bacteria and contamination risks. According to the Centres for Disease Control and Prevention (CDC), viruses can settle on various surfaces and infect people who come into contact with them. Disease control and prevention recommends cleaning these areas with soap and water, then using detergents. Williams-Claassen (2013) found that cleaning the ambulance's back and front cabins before and after shifts reduces contamination. The researcher suggests using prescribed detergents with a designated mop to clean the cabins (Williams-Claassen 2013).

The latest study has also found evidence in Portugal that cleaning and disinfecting ambulances should become a priority in avoiding the prevalence of bacterial microorganisms that can be transported with patients and ambulance crews, and suggests that the back cabin must be disinfected after each case, before becoming available for the next call out (Viegas *et al.* 2021). Ambulances are often infected with microorganisms transmitted by patients during transport that can be transferred to other patients and HCWs. Physical sanitisation is tiresome and requires extra time, and constant contamination is frequent even after washing. Ultraviolet germicidal irradiation (UVGI) has been proposed as a first-option disinfection method for ambulance patient compartments (Lindsley *et al.* 2018; Makie, Williams-Claasen and Gojkovic 2020; Song *et al.* 2020).

A real-time air disinfection device has been configured as an enclosed air disinfection device incorporated into an ambulance fixture, with a pulsed xenon UV (PX-UV) lamp as the light source, capable of emitting a broad spectrum of 200 nm- 320 nm. To test the disinfection effect of PX-UV, *E. coli* and *Staphylococcus aureus* were used. The 30-minute PX-UV treatment reduces *E. coli* concentrations to below detection levels, whereas the PX-UV treatment disinfects 99.91% of the *Staphylococcus aureus*. UV can kill bacteria, viruses, fungi, and spores, but different microorganisms respond differently to UV. Gram-negative bacteria, followed by *Staphylococcus*, are the most sensitive (Song *et al.* 2020).

In another study performed by the, Italian Study Group of Hospital Hygiene of the Italian Society of Hygiene, revealed that the microbial quality of the air within emergency transport vehicles was assessed in addition to the surfaces, and while the results were satisfactory, the presence of potentially pathogenic microorganisms in the air and on surfaces in ambulances represents a hazard for medical staff and patients, reinforcing the idea that cleaning and disinfection techniques should be continuously developed and implemented (Nobile *et al.* 2018).

2.15 TRANSMISSION OF MICROORGANISMS FROM INANIMATE SURFACES

According to research, inanimate surfaces around or near patients may become contaminated with MRSA and VRE (Deshpande *et al.* 2017; Barr *et al.* 2021). Other surfaces have been shown to become contaminated by patient movement, and these new surface locations become reservoirs for pathogens to live and proliferate (Makiela 2016). On surfaces devoid of moisture, microorganisms can survive for several days (Barr *et al.* 2021). Pathogens can be transferred from inanimate surfaces through direct contact, from the surface to the hand to the face, or from the surface to the eyes and mouth. As a result, approved chemical cleaning of these areas has been shown to reduce and disrupt microorganism transmission from the inanimate surface to the hands (Deshpande *et al.* 2017). Ordinary surfaces can contribute to the cross-contamination of epidemiological microorganisms such as MRSA, VRE, rotavirus, and *Clostridium difficile* in this case. In contrast, infected bacterial surfaces in the healthcare environment play an important role in secondary disease transmission. Patients, on the other hand, can contact inanimate surfaces by repeatedly touching them with their hands, increasing the uptake of microorganisms from these surfaces by other healthcare personnel (Kramer and Assadian 2014; Russotto *et al.* 2015).

2.16 HAND DISINFECTING

Hand hygiene compliance among healthcare workers remains a major issue in medicine. Physicians are notorious for their lack of compliance. Hand hygiene violations result in the transmission of community-acquired and hospital-acquired microorganisms between patients and healthcare providers, which can lead to nosocomial infections. Despite efforts to change, compliance remains low. While poor hand hygiene is common in hospitals, these behaviours may be shared by pre-hospital providers as well. Even though hygiene is an important part of the healthcare system, it has received little attention in the pre-hospital healthcare worker population (Bucher *et al.* 2015).

Bucher *et al.* (2015) conducted a study at Robert Wood Johnson Medical School, Department of Emergency Medicine, New Brunswick, New Jersey, in which an online

survey was distributed to EMS providers with demographic and hand hygiene questions. Overall, pre-hospital providers reported poor hand hygiene practices in all clinical situations.

Women washed their hands more frequently than men on average, but the differences were unlikely to be clinically significant (Mardiko and von Lengerke 2020). Poor hygiene was reported following invasive procedures. The presence of hand sanitiser in the ambulance did not improve reported hygiene rates, but it did improve reported stethoscope cleaning rates (absolute difference 0.4, $p=0.0003$). According to Stahmeyer *et al.* (2017), at Hannover Medical School, Institute for Epidemiology, Germany, only 42% of HCWs washed their hands before patient contact, and only 50% cleaned their hands after patient contact.

A startling number of HCWs washed their hands for less than 15 seconds, indicating noncompliance with the standard 30 seconds (Stahmeyer *et al.* 2017). Vikke *et al.* (2019) discovered that basic hand disinfection promotes good hygiene and reduces microbial transmission. Washing with water and soap, according to Barr *et al.* (2017), is the gold standard for reducing the transmission of health-associated infections in pre-hospital settings.

Hand disinfection with appropriate personal protective equipment will protect healthcare workers from occupational diseases (Lambe *et al.* 2019). In the healthcare setting, using approved disinfectants and hand washing techniques (Figure 2.2) will help to prevent healthcare-acquired infections (Barr *et al.* 2017; Gould *et al.* 2017).

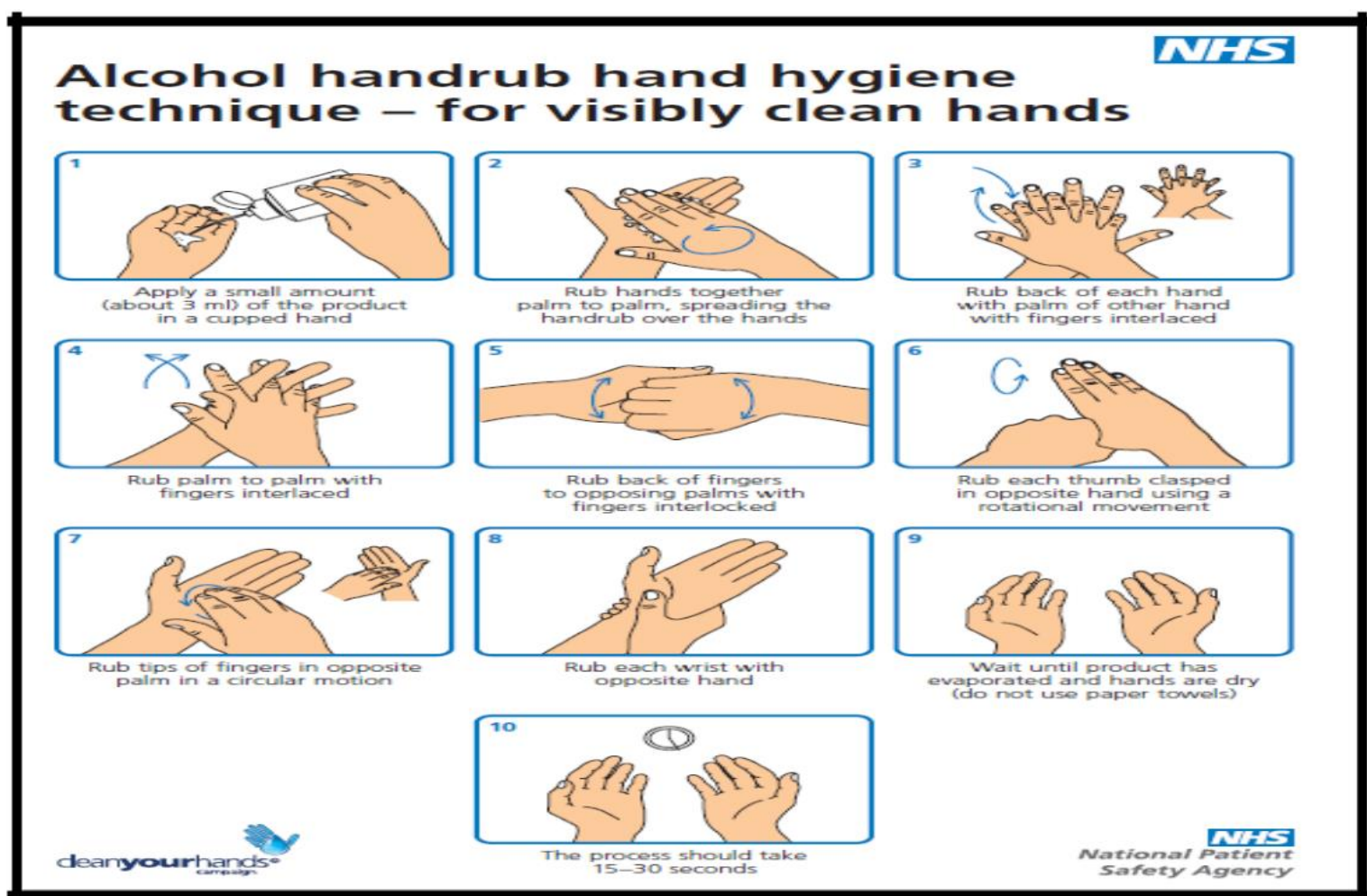


Figure 2.2: Alcohol hand rub hygiene technique (Gould *et al.* 2017).

2.17 AMBULANCE STAFF PERSONAL PROTECTIVE EQUIPMENT (PPE)

Personal Protective Equipment among HCWs has received a lot of attention in recent years. Cash *et al.* (2021) highlighted the need for appropriate PPE training for ECPs' in a pre-hospital setting. Cash *et al.* (2021) raise several concerns about gaps in PPE training in the pre-hospital environment. He alluded to the 2004 Ebola virus outbreak and questioned EMS personnel's preparedness for the 2019 coronavirus disease. Cash *et al.* (2021) collected data from the National Registry of Emergency Medical Technicians over 40 weeks, from 1st October 2019 to 30th June 2020. The findings revealed that 62% of EMS personnel exhibited inadequate COVID-19 training, and the majority of staff were dissatisfied with the training offered. To prevent staff absenteeism during pandemics, the author concludes that EMS should continuously provide education and training, as well as ensure the availability of PPE.

According to Oh and Uhm (2016), PPE non-compliance among EMS personnel increases their risk of contracting bloodborne diseases such as HIV, hepatitis B and C, and others. Between September 2014 to January 2015, 907 (85.5%) convenience sample questionnaires were collected in Korea. The findings indicated that 44.5% developed respiratory disease and 29.5% influenza. Blood and body fluids were found to be common among 356 (40.2%) participants, and 77.5% of participants indicated that job training and educational information about disease risks and PPE management were not consistently provided (Oh and Uhm 2016). Sheahan *et al.* (2019), as well as Maguire, O'Neill, and Maniscako (2021), emphasised the lack of knowledge on how PPE is used in the EMS environment to reduce risks for ECPs' and their patients. Furthermore, ECPs' who are exposed to various airborne pathogens in the enclosed spaces in the back cabins of ambulances require special attention (Alshammaria, Baila and Parilloa 2019; Maguire, O'Neill and Maniscalco 2021). The need for PPE education extends beyond the current risk of disease transmission; ECPs' knowledge and understanding of bacterial infection and common influenza pandemics have manifested in staff unwillingness to work during pandemics. The employee's reluctance to work stems from the belief that the employer will not provide the necessary PPE (Cash *et al.* 2021).

2.18 SAFETY PROTECTIVE FOOTWEAR (SPF)

Surfaces and fomites play an important role in the transmission dynamics of healthcare-associated infections. One such example is shoes worn by health care personnel, patients, and visitors. Walking on contaminated floors disperses airborne particles more effectively than mopping or sweeping (Rashid *et al.* 2016). Safety protective footwear is used in many industries to protect workers while they perform their daily tasks (Janson, Newman and Dhokia 2019, 2021). Safety protective footwear technology has advanced to make this footwear more durable. Conventionally, SPF is manufactured with a hardened midsole, a non-slip outer sole, a toe cap guard and durable leather outside (Janson, Newman and Dhokia 2019). A study conducted by McGuire-Wolfe (2020) discovered microorganisms in five Pasco County fire rescue stations, 191 surfaces in 23 fire trucks, 5 fire houses, and 3 taken from the soles of the firemen's protective boots.

The results showed that firemen's safety boots had the highest bacterial count of any site swabbed, with over 900,000 bacteria and 378,000 colony-forming units (cfu) per boot. Further research was carried out in an orthopaedic theatre at a university teaching hospital. At the end of a regular theatre day, forty theatre shoes (20 pairs) were chosen at random from the male locker room, as the majority (>80%) of the department's staff was male. These shoes were worn by surgeons, nurses, and porters who worked in the orthopaedic theatre regularly. Theatre employees were not informed of the study due to the risk of bias due to changes in cleaning practices (Clesham, Ryan and Murphy 2018). In 32 shoes (80%), the faecal blood test was positive. The results revealed, 25% of MRSA-infected shoes, *Staphylococcus haemolyticus* (30%), *Staphylococcus epidermidis* (15%), *Staphylococcus hominis* (15%), *Staphylococcus sciuri* (5%), *Staphylococcus cohnii* (5%), *Staphylococcus capitis* (5%) and other species of coagulase-negative Staphylococci were cultured (Clesham, Ryan and Murphy 2018).

The structure of SPF is described in Figure 3; SPF is worn by EMS personnel as part of their PPE and provides additional protection while reducing occupational hazards. There are currently no cleaning procedures for EMS SPF that have been identified through research. It is worth noting that the current EMS Standard Operational Procedure in KwaZulu-Natal, South Africa, does not include a cleaning policy or procedure for SPF.

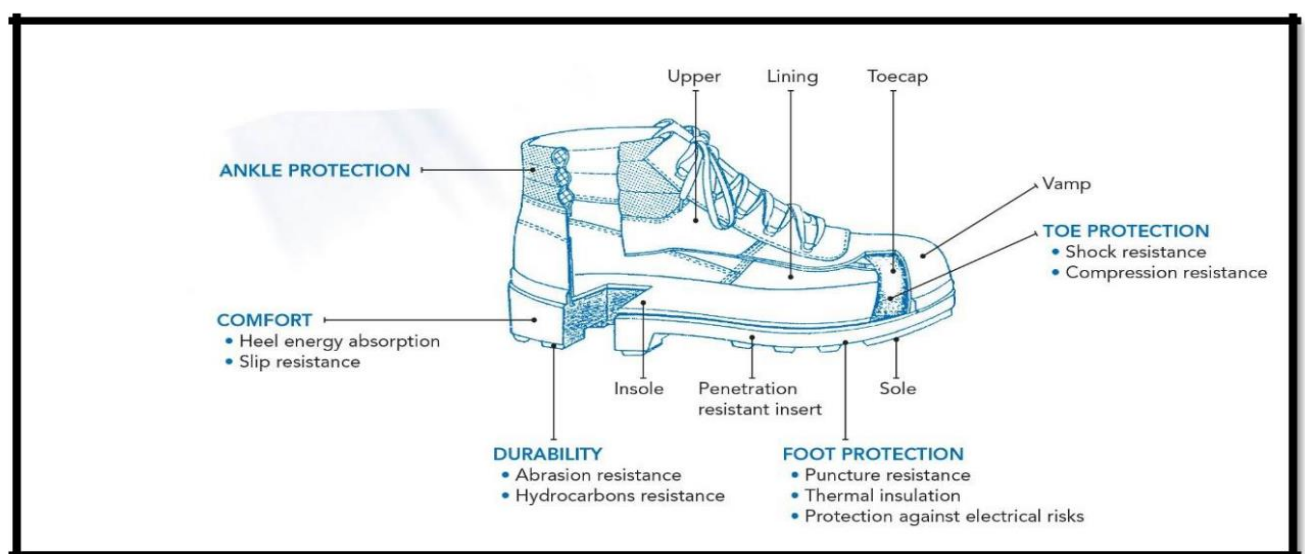


Figure 2.3: Structure of safety protective footwear (SPF)

2.19 CONCLUSION

Microorganisms have been associated with HAIs discovered in ambulances globally. Multi-drug-resistant pathogens found in ambulances are a concern in the pre-hospital setting due to the difficulty in treating the associated infections. As a result, a distinct framework is required to establish successful IPC guidelines throughout patient care. The majority of prior studies have identified bacterial microorganisms prevalent during patient treatment; however, no studies on the level of infection exposure and transmission from paramedic SPF have been conducted globally or in a pre-hospital setting in South Africa. This research explores pathogen detection on ECPs' SPF. As evidenced through existing literature data, there are insufficient guidelines for healthcare facilities and emergency services; the healthcare community should work together to develop safe microbial assessments. To reduce microbial cross-contamination, reduce mortality, prevent disability, and improve occupational safety for all EMS providers, an overall consensus in the methodology for cleaning, disinfecting, educating, and self-disinfecting strategies in IPC should be prioritised.

CHAPTER THREE: RESEARCH METHODOLOGY

3.1 INTRODUCTION

This chapter provides an overview of the research methodology utilised in the study by depicting the data collection, data validation and analysis.

3.2 RESEARCH DESIGN

A research design is an overall strategy for answering a research question, which includes specifications for increasing the study's reliability (Polit and Beck 2014). The design incorporates significant methodological findings about the fundamental form of a study and specifies the strategies the researcher intends to use to generate correct and understandable evidence. This study entailed two (2) different methods of data collection. During the first phase, the Safety Protective Footwear (SPF) of Emergency Care Personnel (ECP) was swabbed to detect the presence of microbial contamination, and the second phase was data collection using a closed Likert scale paper-based survey questionnaire. A quantitative descriptive design was used in this study, which was coupled with laboratory analysis to determine the variety and extent of microbial contamination of ECPs' SPF. Additionally, a questionnaire collected data to evaluate current IPC procedures.

3.3 STUDY SETTING

The research was conducted in the public sector within the uMgungundlovu District of KwaZulu-Natal (KZN): across all four bases at Grey's, Edendale, Appelsbosch, and Howick. Grey's is the largest of the four bases, housing the majority of the ambulances and personnel. Grey's staff and ambulances also assist the three other bases when ambulances are in short supply, during massive casualty incidents, and major vehicle accidents along the busy National Route. Grey's Hospital houses the Emergency Dispatch Centre (EDC), Planned Patient Transport (PPT), and the Grey's Operations Division.

Ambulance services and the EDC work together continuously to provide emergency care and transportation to the community at all times. In the event of an emergency,

the EMS EDC accepts calls via national emergency numbers. The EDC operator prioritises incoming calls and sends out qualified personnel accordingly. The district is made up of seven local municipalities: Msunduzi, Impendle, Umshwathi, Mkhambathini, Mpofana, Umngeni, and Richmond. uMgungundlovu has a population of 1,017,762 and 272,667 households. Out of 1,017,762 people in the uMgungundlovu district municipality, 48% (485,922 people) are male and 52% (531,843) are female (KwaZulu-Natal Department of Health 2012). Informal settlements are a significant feature of the uMgungundlovu District Municipality, with a large proportion of the regional population living in them. When ambulances are dispatched, they are not limited to urban areas but rather respond to all citizens in need of treatment and transportation to the hospital.

The district emergency medical services (EMS) manager signed a letter requesting permission to conduct the study (Annexure A), along with the Health Research & Knowledge Management Unit (Annexure B).

3.4 STUDY POPULATION

The target population in a study denotes the complete set of individuals that the researcher aims to examine (Grove and Gray 2018). The study focused on operational ECPs', EDC, and PPT employed by Emergency Medical Services in the uMgungundlovu District. The allocation of the number of personnel in the uMgungundlovu District per base is provided in Table 3.1 below.

Table 4.1: Staff Distribution within the uMgungundlovu District.

uMgungundlovu EMS bases	Number of staff per base
Grey's	91
Planned Patient Transport	28
Emergency Dispatch Centre	32
Edendale	59
Howick	52
Appelsbosch	41
Total	303

Table 3.1 shows, that Grey's EMS base employs the highest number of staff, including those in PPT and EDC roles. All operational ECPs', EDCs', and PPT staff associated with EMS were included in the study period. All EMS ECPs' were selected for participation in the study due to their role in delivering pre-hospital emergency care and transportation to the majority of public sector patients in the uMgungundlovu District.

3.5 PHASE ONE: QUANTITATIVE PHASE

3.5.1 SPF Sampling

The sample size for this study was determined using Raosoft, which is an online software. Using a 7.87% margin of error and a 95% confidence level, the software calculated that a sample of 60 ECPs' would be required for the study. However, due to limited funding and the exorbitant cost of Microbiology testing, only 53 ECPs' were conveniently selected from Grey's base. A thorough sampling strategy was devised to enhance the generalisability of the study findings. Furthermore, Grey's base is representative of the other bases in the uMgungundlovu district. The visit to Grey's base for specimen collection went unannounced. Furthermore, the specimen sites were unfamiliar to the ECPs'. This was required to prevent changes in staff behavioural practices. At the end of the day shift at 07:00, twenty operational ECPs' were swabbed on the SPF, followed by a sampling of twenty ECPs' after the night shift at 19:00, with thirteen samples collected from the EDC. Specimen collection occurred between 18:00 and 19:00 and between 06:00 and 07:00, respectively, at Grey's base, as this timeframe was when ECPs' were most likely to return to their bases. All specimens were collected at a consistent time each day.

The selection of Grey's base for this phase was due to its largest staff complement, attributed to the operational, EDC, and PPT departments. Phase one involved comparing bacterial prevalence between the two shifts, night and day shifts. The researcher conducted a visit to Grey's base and collected specimen samples from 53 ECPs' SPF to assess the presence of *Enterococcus faecium*, *Staphylococcus aureus*, *Klebsiella pneumoniae*, *Acinetobacter baumannii*, *Pseudomonas aeruginosa* and *Enterobacter* species (ESKAPE) pathogens.

3.5.2 Inclusion Criteria

- ☐ Operational ECPs' from uMgungundlovu district.
- ☐ EDC ECPs' from uMgungundlovu district.
- ☐ PPT ECPs' from uMgungundlovu district.
- ☐ ECPs' with service issued SPF. The SPF provided by EMS is a standard issue; therefore, to maintain consistency and reliability of results, the researcher opted not to swab any SPF that the employer did not provide.

3.5.3 Exclusion Criteria

- ☐ ECPs' from outside the uMgungundlovu district.
- ☐ EMS managers.
- ☐ Staff with non-service issued SPF.

3.6 PHASE TWO: QUESTIONNAIRE ADMINISTRATION

A convenience sampling method was employed to recruit 303 ECPs' for objective 4. Raosoft sample size calculator was used, a 7.87% margin of error and a 95% confidence level, the software determined that a sample of 170 ECPs' would be required for the study. The response rate was 165 (54%), with 138 participants declining to participate. This may be ascribed to the researcher interacting with participants during standard working hours, while ambulances were required to respond to high-priority cases. Emergency care personnel work on a schedule of four (4) shifts weekly. The duration of each shift is 12 hours, comprising two (2) day shifts from 07:00 and 19:00 and immediately followed by two (2) night shifts from 19:00 and 07:00, followed by four days off. Emergency care personnel are present throughout the district at any given time due to the nature of their work. The study focused on a target population of 303 ECPs' across all bases within the uMgungundlovu District. A total of 165 questionnaires were collected from July 15 to July 18, 2022, across all EMS bases in the uMgungundlovu district.

3.6.1 Inclusion criteria

- ☐ All ECPs' from the uMgungundlovu district.

- ☐ Planned patient transport,
- ☐ EDC
- ☐ EMS managers.

3.6.2 Exclusion Criteria

- ☐ Non-EMS personnel.
- ☐ EMS administrative staff.

3.7 DATA COLLECTION METHOD

3.7.1 Phase One: Swabbing

The researcher arrived at the site at 18:00 to collect samples from the day shift staff before participants washed their vehicles and applied water on their SPF before the shift change at 19:00. As the vehicle approached the base, the researcher communicated the details of the research (Annexure C), and consent forms were reviewed and signed (Annexure D). A clean linen saver was first positioned on the ground. The participant placed their SPF onto the linen saver without removing the SPF. A swab was taken from an area of 5 cm², and a plastic outline was placed on the SPF to maintain the specified parameters. A COPAN Eswab® microbiology collection tool with a 1ml vial containing a liquid transport medium (which was supplied by the laboratory), was opened and applied to the SPF. Each SPF was subjected to swabbing in distinct areas, utilising an identical technique of a 5 cm² plastic outline. Protocols to prevent sample contamination were adhered to; the researcher donned gloves, a face mask, and an eye shield during sample collection. Thereafter, the swab specimen was inserted back into the tube. The specimen tubes were placed in a sealed transport container and delivered to an accredited microbiology laboratory the same evening. The following day, the researcher arrived at the site at 06H00 to collect samples from the staff, completing a night shift at 07H00. The same technique and procedure were used, with specimens placed in a sealed transport container and delivered to the same accredited microbiology laboratory. The specimen technique was intended to avoid selection bias; therefore, all 53 ECPs' SPF were included in the study. Each of the 53 SPF, left or right, was sampled to ensure accurate representation.

3.7.2 Data Analysis Swabbing

A Gram stain was used for categorising microorganisms as Gram-positive or Gram-negative based on their peptidoglycan properties (Tripathi and Sapra 2020). Pathogen identification and antimicrobial resistance profiles were obtained following phenotypic culture using a laboratory automated system, identifying different species or strains of microbes or other bacteria. The samples were plated onto culture media for phenotypic identification. Blood agar, Chocolate agar, MacConkey agar, and Colistin/nalidixic agar were used as culture media. SPF swabs were streaked onto the culture plates to obtain single colonies. Plates were incubated aerobically at 35-37 degrees Celsius for 18-24 hours.

Once growth was established, selected colonies (Gram-positive, Gram-negative, or fungi) were isolated, and a suspension equivalent to 0.5 McFarlane units was prepared. This organism-containing suspension was then fed into an automated identification platform. For organism identification and susceptibility testing, the automated Vitek 2 (bioMérieux) system was used. The Vitek 2 system identifies the organism using fluorogenic technology. For sensitivity testing, a turbidimetric method was used, which employs a 64-well card with information stored in a barcode. The type of card, expiry date, lot number, and card identification are all included in the information. ID-GN (Gram-negative bacilli identification), ID-GP (Gram-positive cocci identification), AST-GN (Gram-negative susceptibility), and AST-GP (Gram-positive susceptibility) cards are commonly used. The automated platform performs sensitivity testing by continuously monitoring growth in all wells. Amikacin, amoxicillin-clavulanic acid, ampicillin/amoxicillin, cefepime, ceftriaxone, ceftazidime, cefuroxime (Oral), ciprofloxacin, gentamicin, meropenem, nitrofurantoin, piperacillin/tazobactam, and trimethoprim-sulfamethoxazole are tested against Gram-positive. Clindamycin, cloxacillin, erythromycin/azithromycin, linezolid, penicillin/ampicillin, tigecycline, and vancomycin are tested against Gram-positive isolates. Specimen processing and pathogen identification, together with antimicrobial susceptibility testing, were carried out following the microbiology laboratories' standard operating procedures.

Sample collection was standardised; that is, samples were collected in the same way, from the same location per identified site, using the same surface area. The

laboratory's accreditation by the South African National Accreditation System provided additional quality assurance.

3.7.3 Phase Two: Survey Questionnaire

The data collection method employed in phase two was a survey. The survey involved the creation of a series of questions aimed at gathering staff opinions and experiences (Annexure E). The researcher aimed to optimise the return rate and facilitate the generalisation of findings by targeting the complete population of 303 ECPs' in the uMgungundlovu district. The study report includes response rates, which compare the number of participants to those who were suitable. The goal is to highlight any non-response bias. The ECPs' responded to a set of closed-ended questions regarding their perspectives and experiences related to cleaning and disinfecting within the EMS environment. The researcher arrived at the bases during the shift changeover to facilitate participation from both day and night shift staff. The researcher articulated the questionnaire's purpose and requested participation; participants who consented were asked to read and sign the consent form.

3.8 RELIABILITY AND VALIDITY OF THE DATA COLLECTION TOOL

Phase one data was collected from Grey's base at 19h00 on a day shift and 07h00 on a night shift. Sample collection was standardised, which means that samples were collected in the same way, from the same location of the SPF, using the same surface area. Samples were placed in a sealed bag into a cooler box and transported to a reputable laboratory. Microscopy and culture of the swabbed SPF were performed under the laboratory's standard operating procedures.

3.9 PILOT STUDY

The pilot survey involved five ECPs from Grey's EMS base. These ECPs' were chosen for their representativeness of the population and convenience, as they were all available in one location. These ECPs' had various years of experience in the operational setting. All participants had to read and sign the letter and questionnaire

(Annexure F). The questionnaires were evaluated and analysed for readability, simplicity, and the clarity and conciseness of the instructions provided. The pilot study was carried out before the actual survey to ensure that the questions were understandable to a diverse population. The pilot study determined that completing the questionnaires took approximately 15 minutes. The results showed that participants understood the questions, so the questionnaire was not modified. The findings from the pilot study were not used in the main study.

3.10 DATA ANALYSIS

The research data was gathered and entered into the latest version of the Statistical Package for Social Sciences (SPSS) Version 20.5. Descriptive statistics were employed for demographic characterisation and frequency distributions, utilising frequency and cross-tabulation tables, as well as various graph types.

Inferential techniques encompassed the application of correlation analyses and chi-square tests, with p-values ≤ 0.05 considered significant for assessing associations among key variables.

3.11 ETHICAL CONSIDERATIONS

The Institutional Research Ethics Committee (IREC) of the Durban University of Technology, reference IREC 128/21 (Annexure G), provided ethical approval for the study's conduct. Human rights, confidentiality, privacy, equitable treatment, prevention of distress and harm, and informed consent were safeguarded (Brink, Van der Walt and Van Rensburg 2006). A request for permission to conduct research was submitted to the KZN Department of Health. Permission from the EMS KZN district manager was secured to conduct research at Grey's base. A formal consent form signed by selected participants was included in the study. The participants received a briefing regarding the survey and the research methodology. Conversely, participants were not compelled to participate in the survey; their involvement was entirely voluntary and based on informed consent. The data collection and research did not compromise participant welfare or autonomy. The participants' confidentiality was also maintained in managing data. The details and personal information of the participants were kept anonymous, and only the researcher had access to maintain their privacy (Brink and

Van der Walt 2006). All information gathered during data collection was saved on the researcher's personal password-protected computer and will be deleted after 5 years.

3.11.1 Respect

All participants received comprehensive information regarding the study, including letters that detailed the study's objectives, and the intended use of the data collected. The information letter indicated that participation was completely voluntary and that participants had the option to withdraw from the study without facing any consequences. All participants were requested to sign the informed consent forms for inclusion in the study.

3.11.2 Beneficence

The informational letter further indicated that all collected data would remain anonymous and that no research participants would be identified. All identifying material was stored on a password-protected personal computer. Only the researcher had access to any identifying material. The participants had no negative repercussions. Conversely, the research may advantage the participants, given that the results might inform the revaluation of EMS rules and infection control protocols, thereby enhancing the participants' working conditions.

3.11.3 Principle of Justice

During the study, all participants had access to the researcher and research supervisors through direct communication, phone, or email to inquire or seek clarification regarding information, instructions, and questions. Participants were assured that opting out of the study at any time would not result in bias or unfair treatment. They were also made aware that confidentiality would always be maintained. Participants received equitable treatment during the research process, with a strong emphasis on safeguarding their privacy. Participants who declined to participate in the study or opted to withdraw were not subjected to discrimination. The researcher confirmed that all participants received and signed a letter of consent, which included the option for personal notification upon the study's completion and

public release of the results. No complaints were filed against the researcher or the study throughout the research process.

CHAPTER FOUR: RESULTS

4.1 INTRODUCTION

This chapter outlines the findings of the study concerning the detection of microorganisms linked to bacterial infections and the assessment of infection prevention and control measures in the uMgungundlovu district of KwaZulu-Natal.

4.2 PHASE ONE: RESULTS FROM THE SWABBING OF SAFETY PROTECTIVE FOOTWEAR

Objective 1: To identify microorganisms associated with infections on operational ECPs' SPF after a 12-hour shift.

Objective 2: To identify microorganisms associated with nosocomial infections on non-operational ECPs' working in the emergency dispatch centre (EDC) after a 12-hour shift.

Phase one of the study achieved Objective One (1) and Objective Two (2) of the study, which entailed the identification of microorganisms associated with bacterial infections, including potentially pathogenic bacteria on operational Emergency Care Personnel (ECPs') Safety Protective Footwear (SPF) following a 12-hour shift, which included non-operational ECPs' working in the EDC.

Fifty-three (35%; $n = 151$) samples, comprising of 91 from Grey's operational ECPs', 28 Patient Planned Transport (PPT) operational ECPs' and 32 non-operational EDC, ECPs' were swabbed at Grey's Base during the data collection period from the 16 July 2022 to the 17 July 2022. The distribution of the 53 ECPs' whose SPF was swabbed was 41 operational ECPs' and 12 ECPs' from the EDC. The laboratory findings by JDJ Laboratory revealed the presence of six (6) distinct pathogens on the SPF of seven (7) ECPs', The SPF of seven (7) ECPs' were six (6) operational ECPs' and one (1) ECP from the EDC. *Pantoea agglomerans* was identified as the most prevalent pathogen on the SPF.

Objective 3: To compare the presence of bacterial microorganisms associated with bacterial infections on SPF among non-operational ECPs' working in the EDC and operational ECPs.

The SPF of the seven (7) ECPs was as follows: Six (6) operational ECPs, which were 15% of the sample size and one (1) ECP from the EDC, which was 8.3% of the EDC sample size. Table 4.1 and Table 4.2 below show the presence of the different pathogens found on the SPF. As shown in Tables 4.1 and 4.2, a Fisher's exact test was used to investigate the relationship between bacteria found on operational and non-operational ECPs'. The correlation between these two variables was found to be significant ($p = .016$). A higher proportion of bacteria was located on operational ECPs' SPF than on non-operational ECPs SPF.

Table 5.1: Microorganisms identified on Six (6) Safety Protective Footwear of Operational ECP.

Participant Number	<i>Pantoea agglomeratus</i>	<i>Enterococcus faecium</i>	<i>Enterococcus casseliflavus</i>	<i>Escherichia coli</i>	<i>Pasteurella canis</i>	<i>Acinetobacter radioresistens</i>
2	Positive	No trace	No trace	No trace	No trace	No trace
3	Positive	Positive	No trace	No trace	No trace	Positive
4	Positive	No trace	Positive	No trace	No trace	No trace
13	Positive	No trace	No trace	No trace	No trace	No trace
24	No trace	No trace	No trace	No trace	Positive	No trace
29	Positive	No trace	No trace	No trace	No trace	Positive

Table 6. 2: Microorganisms identified on one (1) Safety Protective Footwear of Non-Operational (EDC) ECP.

Participant Number	<i>Pantoea agglomeratus</i>	<i>Enterococcus faecium</i>	<i>Enterococcus casseliflavus</i>	<i>Escherichia coli</i>	<i>Pasteurella canis</i>	<i>Acinetobacter radioresistens</i>
14	No trace	No trace	No trace	Positive	No trace	No trace

The data from Table 4.3 on the next page includes the sensitivity profile of various bacterial species to a range of antimicrobial agents. The bacterial species examined include *Pasteurella canis*, *Enterococcus faecium*, *Enterococcus casseliflavus*, *Escherichia coli*, *Pantoea agglomerans*, and *Acinetobacter radioresistens*. *Pasteurella canis* was resistant to Ampicillin but sensitive to all other tested antibiotics. *Enterococcus faecium* exhibited resistance to Ampicillin and Amoxicillin-Clavulanic Acid but was sensitive to other antibiotics. *Escherichia coli* was sensitive to Ampicillin and Ciprofloxacin. All bacterial strains were sensitive to Imipenem. Ampicillin had the lowest efficacy, with multiple strains showing resistance. Beta Lactams, including Ampicillin-Amoxicillin-Clavulanic Acid, Piperacillin-Tazobactam and Cefepime, are first-line antibiotic treatments.

Table 4.3: Prevalence of antibiotic resistance and sensitivity to antimicrobial agents (n=7).

Antimicrobial Agent	<i>Pantoea agglomeratus</i>					<i>Enterococcus faecium</i>	<i>Enterococcus casseliflavus</i>	<i>Escherichia coli</i>	<i>Pasteurella canis</i>	<i>Acinetobacter radioresistens</i>	
	P2	P3	P4	P13	P29	P3	P4	P14	P24	P3	P29
Safety protective footwear (SPF)											
Ampicillin	R	S	R	N	N	R	S	S	R	N	N
Amoxicillin-Clavulanic Acid	R	S	R	R	N	S	S	S	R	R	N
Piperacillin-Tazobactam	S	S	S	S	N	S	N	S	S	S	S
Cefuroxime	S	S	S	S	S	S	N	S	S	S	N
Ceftazidime	S	S	S	S	N	S	N	S	S	S	S
Cefepime	S	S	S	S	S	S	N	S	S	S	S
Imipenem	S	S	S	S	S	S	N	S	S	S	S
KEY											
S = Sensitive			R = Resistant			N = Nil			P = Participant		

Antimicrobial Agent	<i>Pantoea agglomerans</i>					<i>Enterococcus faecium</i>	<i>Enterococcus casseliflavus</i>	<i>Escherichia coli</i>	<i>Pasteurella canis</i>	<i>Acinetobacter radioresistens</i>	
Safety protective footwear (SPF)	P2	P3	P4	P13	P29	P3	P4	P14	P24	P3	P29
Ciprofloxacin	S	S	S	S	S	R	S	S	S	S	S
Trimethoprim-sulfamethoxazole/ Cotrimoxazole	S	N	S	S	S	S	N	S	S	S	S
Linezolid	N	N	N	N	S	S	S	S	N	N	N
Erythromycin	N	N	N	N	N	R	R	S	N	N	N
Gentamicin	S	S	S	S	S	S	N	S	S	S	S
Tobramycin	S	S	S	S	S	S	N	S	S	S	S
Amikacin	S	S	S	S	N	S	N	S	S	S	S
Meropenem	S	S	S	S	S	S	N	S	S	S	S
Ertapenem	S	S	S	S	S	S	N	S	S	S	N
KEY											
S = Sensitive			R = Resistant			N = Nil			P = Participant		

4.3 PHASE TWO: SURVEY QUESTIONNAIRE

Objective 4: To assess ECPs' knowledge, perceptions, and reported practices regarding current cleaning procedures and disinfectant use on SPF.

Phase two of the study used a paper-based Likert scale survey questionnaire to assess the current knowledge, cleaning procedures, disinfectant efficacy and attitudes of ECPs' regarding EMS IPC policy and procedures.

- **Demographic Characteristics**

The age group 40 – 49 years was the most frequent. There were 109 (66.1%) males and 56 (33.9%) females ($p < 0.001$). Individuals identifying as African formed the majority ($n = 138$, 83.6%), followed by Indians ($n = 22$, 13.3%), Coloured ($n = 4$, 2.4%) and White ($n = 1$, 0.6%). The professional experiences and perspectives of participants who work in the KwaZulu-Natal (KZN) Emergency Medical Services (EMS) were evaluated to collect information on KZN EMS personnel's professional background, training experience, and perspectives on infection prevention and control. The professional experience and training are associated with participants who work in KZN EMS. Most respondents (49.7%) have between 10 and 19 years of experience in KZN EMS, are Basic Life Support certified (50.3%), and worked at Grey's base (53.9%). Table 4.4 below summarises the sample's demographic data.

Table 4.4: Demographic Characteristics

AGE		
Category	Frequency (n)	Percentage (%)
20 – 29	3	1.8
30 – 39	56	33.0
40 – 49	70	42.4
50 – 59	33	20.0
60 – 69	3	1.8
TOTAL	165	100

Table 4.4: Demographic Characteristics (Continued)

SEX	Frequency (n)	Percentage (%)
Males	109	66.1
Females	56	33.9
TOTAL	165	100
RACE	Frequency (n)	Percentage (%)
African	138	83.6
Coloured	4	2.4
Indian	22	13.3
White	1	0.6
TOTAL	165	100

- Participants' IPC Perceptions, Practices and Cleaning Procedures**

The distribution of IPC training/knowledge across different age groups did not show a statistically significant difference (Fisher's Exact Test = 0.574, $p = 0.981$). This suggests that age is not a determining factor in the likelihood of having IPC perceptions, practices and cleaning procedures among KZN EMS personnel. Gender differences in IPC perceptions, practices and cleaning procedures were also not statistically significant (Fisher's Exact Test = 0.385, $p = 0.385$), indicating that both male and female EMS personnel were equally likely to have received IPC training or to possess IPC perceptions, practices and cleaning procedures. No significant differences were found in IPC perceptions, practices and cleaning procedures across different racial groups (Fisher's Exact Test = 3.983, $p = 0.201$). The measured variables were categorised into three primary groups: training, information sources, and perceptions, regarding infection prevention and control, as shown in Table 4.5.

Table 4.5: IPC Perceptions, practices and cleaning procedures

Age (years)					
Age Category	No	Yes	Frequency (n)	Percentage (%)	Chi square
20-29	1	2	3	1.8	<0.001
30-39	18	38	56	58.8	

40-49	24	46	70	78.2	<0.001
50-59	12	21	33	98.2	
60-69	1	2	3	1.8	

Table 4.6: IPC perceptions, practices and cleaning procedures (Continued)

Sex					
Category	No	Yes	Frequency (n)	Percentage (%)	Chi square
Male	40	69	109	66.1	<0.001
Female	16	40	56	33.9	
Race					
Category	No	Yes	Frequency (n)	Percentage (%)	Chi square
African	46	92	138	83.6	<0.001
Coloured	0	4	4	2.4	
Indian	9	13	22	13.3	
White	1	0	1	0.6	

- Participants' Experience and Qualifications**

As shown in Table 4.7 below, IPC within KZN EMS was assessed for the distribution of responses across various categories, such as years of service, medical qualifications, sub-base, and disinfection training. A significant portion of the KZN EMS staff has considerable experience, with nearly half (49.7%) having worked for 10-19 years. However, years of service do not appear to correlate with IPC training or knowledge ($p = 0.623$). The majority of personnel hold basic life support qualifications (50.3%), and the medical qualifications level significantly influences IPC training/knowledge ($p = <0.001$), suggesting that those with more advanced qualifications may have received more IPC-related education. Years of service with KZN EMS have had no significant effect on the distribution of IPC training/knowledge (Fisher's Exact Test = 1.794). The concentration of responses around Grey's base suggests that the distribution of EMS personnel across sub-bases does not follow an expected pattern if the location is unrelated to IPC practices ($p < 0.001$). The analysis also shows no significant differences in IPC training/knowledge among personnel from

different EMS sub-bases (Fisher's Exact Test = 2.177, $p = 0.552$), indicating a uniform approach to IPC training across different locations. The majority of participants reported receiving PPE disinfection training. The overwhelming affirmation for IPC inclusion and workshops ($p < 0.001$) indicates a specific orientation towards IPC practices within the KZN EMS.

The distribution indicated that a greater proportion of respondents were short of an EMS SOP/policy on SPF ($p=0.016$). This identifies opportunities for policy advancement. The dominance of self-research as the main source of information indicates that the reliance on individual initiative for IPC information markedly diverges from anticipated patterns of information dissemination, highlighting potential enhancements in formal IPC education and communication strategies ($p < 0.001$).

Table 4.7: Participants' experience, qualification and knowledge of infection prevention and control (n=165)

KZN EMS experience (years)			
Category	Frequency (n)	Percentage (%)	p-value
< 10	45	27.3	< 0.001
10-19	82	49.7	
20-29	25	15.2	
30-39	13	7.8	
EMS Medical qualification			
Category	Frequency (n)	Percentage (%)	p-value
Basic life support	83	50.3	< 0.001
Intermediate life support	66	40.0	
Emergency care technician	4	2.4	
Advanced life support	12	7.3	
KZN EMS Sub-base			
Category	Frequency (n)	Percentage (%)	p-value
Grey's base	89	54.0	< 0.001
Appelsbosch base	29	17.6	
Edendale base	23	13.9	

Howick base	24	14.5	
Disinfection training			
Category	Frequency (n)	Percentage (%)	p-value
Yes	98	59.4	< 0.001
No	67	40.6	

Table 4.8: Participants' experience, qualification and knowledge of infection prevention and control (n=165) (Continued).

prevention and control (n=165) (Continued).

IPC in training program			
Category	Frequency (n)	Percentage (%)	p-value
Yes	157	95.2	< 0.001
No	8	4.8	
IPC Workshops			
Category	Frequency (n)	Percentage (%)	p-value
Yes	153	92.7	< 0.001
No	12	8.3	
EMS SOP/Policy on SPF			
Category	Frequency (n)	Percentage (%)	p-value
Yes	63	38.2	< 0.001
No	102	61.8	
Information source for SPF cleaning			
Category	Frequency (n)	Percentage (%)	p-value
Friend	9	5.5	< 0.001
Family member	3	1.8	
Crew mate	27	16.4	
Self-research	126	76.4	

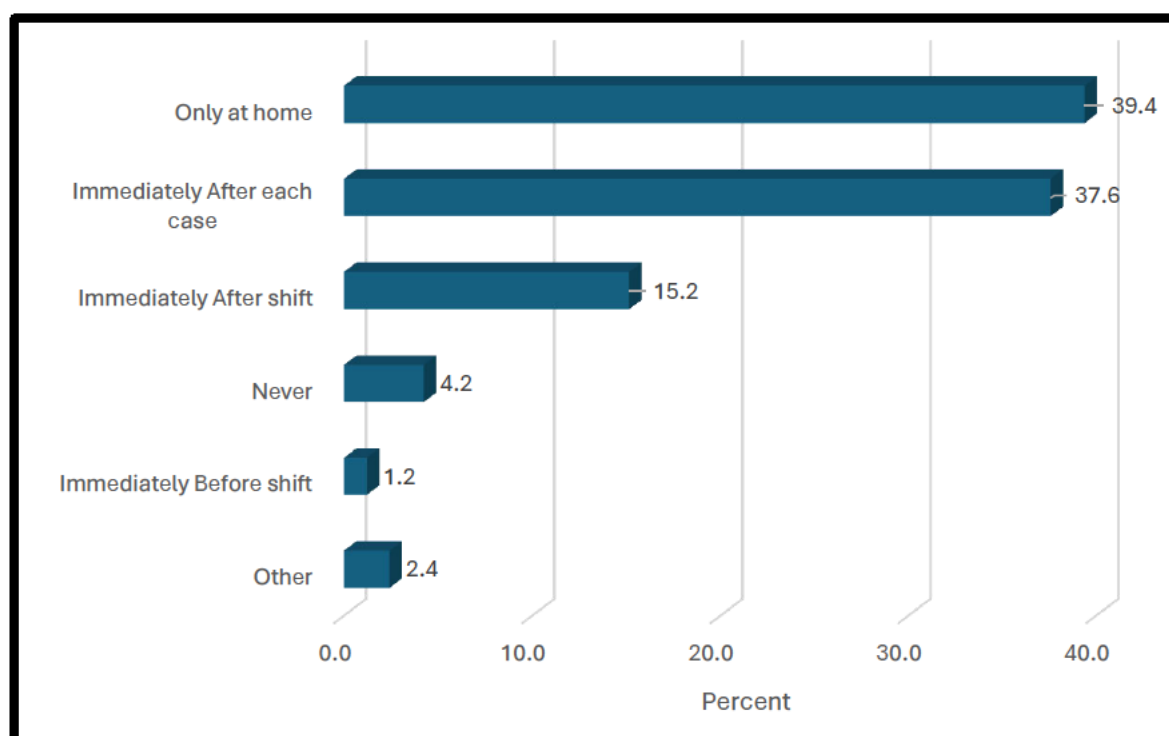
*p<0.05 was considered statistically significant (Chi-Squared test/Fisher-Freeman-Halton Exact Test)

• Cleaning Practices of SPF

Figure 4.1 shows, that the majority of participants cleaned their SPF at home (39.4%) and immediately after each case (37.6%), while 15.2% of participants cleaned their

SPF immediately after the shift. Cleaning immediately before a shift was the least common, accounting for only 1.2%.

Figure 4.1: Cleaning practices of SPF (n=165)



- Cleaning Solutions Supplied by KZN EMS**

Table 4.9 shows, that Jik (n=111, 67.3%) was frequently supplied by the organisation, followed by disinfectant (n=109, 66.1%). Eighty-six respondents (52.1%) used water, and 67 (40.6%) used soap. Cidex was the least used agent by the participants, 12 (7.3%).

Table 4.9: Categories of cleaning agents provided by the organisation (n=165)

Cleaning solutions supplied by KZN EMS			
Cleaning Agent	Yes n (%)	No n (%)	Frequency (n)
Water	86 (52.1)	79 (47.9)	165
Soap	67 (40.6)	98 (59.5)	165
Cidex	12 (7.3)	153 (92.7)	165
Biocide	27 (16.4)	138 (83.6)	165
Jik	111 (67.3)	54 (32.7)	165
Disinfectant	109 (66.1)	56 (33.9)	165

None	8 (4.8)	157 (95.2)	165
Other	7 (4.2)	158 (95.8)	165

- **Cleaning Solutions Preferred for SPF**

The cleaning solutions preferred by participants for their safety protective footwear are summarized in Table 4.10; water is the most frequently used cleaning solution ($n = 94$, 57%), seventy-seven (46.7%) participants used disinfectant, while Jik was used to clean the SPF by (32.1%) of participants ($p < 0.001$). A very small percentage of respondents (4.2%) prefer using Cidex.

Table 4.10: Personal preferences for cleaning agents ($n=165$)

Cleaning solutions supplied by KZN EMS			
Cleaning Agent	Yes n (%)	No n (%)	Frequency (n)
Water	94 (57.0)	71 (43)	165
Soap	65 (39.4)	100 (60.6)	165
Cidex	7 (4.2)	158 (95.8)	165
Biocide	11 (6.7)	154 (93.3)	165
Jik	53(32.1)	112 (67.9)	165
Disinfectant	77 (46.7)	88 (53.3)	165
None	12 (7.3)	153 (92.7)	165
Other	2 (1.2)	163 (98.8)	165

- **Availability of Cleaning Solutions**

Table 4.11 shows, that 147 (89.1%) have seen cleaning solution at the EMS bases, while 16 (9.7%) have responded no to cleaning solutions at the bases and 2 (1.2%) have never seen any cleaning solutions.

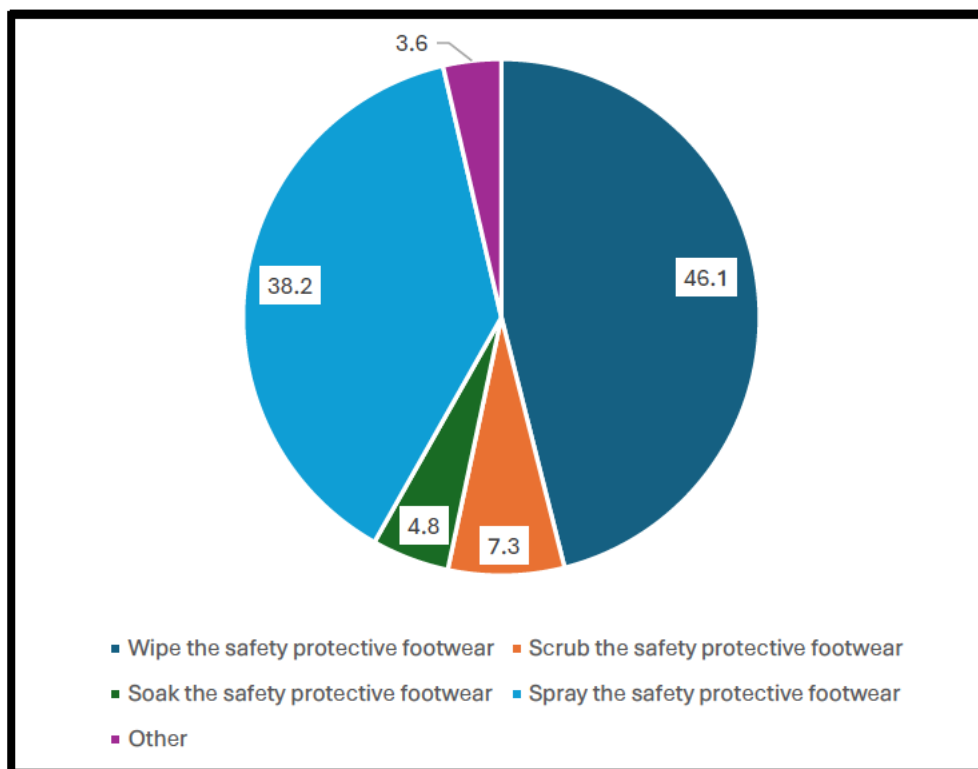
Table 4.11: Availability of Cleaning Solutions

Availability of Cleaning Solutions		
Category	Frequency (n)	Percentage (%)
Yes	147	89.1
No	16	9.7
Never seen any cleaning solution	2	1.2

- **Methods Used for Cleaning SPF**

In Figure 4.2, the methods used by ECPs' in the disinfection of SPF are highlighted. Wiping and spraying were the most frequent techniques used, with 76 (46.1%) and 63 (38.2%) of the respondents using these methods, respectively. Scrubbing and soaking were used by only 12 (7.3%) and 8 (4.8%) respondents. The majority of respondents, 147 (89.1%), indicated that solutions such as Jik, Cidex and disinfectant were available at the base; however, 16 (9.7%) indicated that there were no cleaning solutions available, and 2 (1.2%) had never seen any cleaning solutions.

Figure 4.2: Methods used for cleaning SPF



- **Use of PPE During Cleaning**

The majority of participants (81.8%) wear gloves while cleaning their SPF. Some respondents (74.5%) indicated that they used their SPF outside the professional setting, even while driving their private vehicle, while others did not. Some respondents (52.1%) indicated that they walk into their home with their SPF. The majority (69.7%) had patients' body fluids spill on their SPF (Table 4.12).

Table 4.12: Use of additional protective measures during cleaning (n=165).

	Yes <i>n</i> (%)	No <i>n</i> (%)	Frequency (<i>n</i>)
Gloves are worn when cleaning SPF	135 (81.8)	30 (18.2)	165
SPF used while driving own vehicle	123 (74.5)	42 (25.5)	165
Walk into your home with SPF	86 (52.1)	79 (47.9)	165
Patients' body fluid spilt on SPF	115 (69.7)	50 (30.3)	165

- Exposure to Bodily Fluids**

Table 4.13 shows, that 134 (81.2%) participants reported that they were exposed to blood, while 101 (61.2%) encountered vomit. Seventy-four (44.8%), 40 (24.2%) and 53 (32.1%) were also exposed to urine, faeces, and body fluids, respectively. Forty-one (24.8%) admitted to having been exposed to body tissue. The assessments of contamination risk associated with the footwear show that 151 (91.5%) of participants believe their SPF was a possible source of contamination, while 14 (8.5%) believe it was not a possible source of contamination ($p < 0.001$).

Table 4.13: Exposure to various types of bodily fluids (n=165)

	Yes <i>n</i> (%)	No <i>n</i> (%)	Chi Square <i>p</i> -
Blood	134 (81.2)	31 (18.8)	< 0.001
Urine	74 (44.8)	91 (55.2)	<0.186
Faeces	40 (24.2)	125 (75.8)	< 0.001
Vomit	101 (61.2)	64 (38.8)	< 0.004
Body Fluids	53 (32.1)	112 (67.9)	< 0.001
Body Tissue	41 (24.8)	124 (75.2)	< 0.001

- **Behavioural Responses to Contamination Incidents**

Table 4.14 shows, that 73 of the participants (44.2%) prefer to clean their SPF at the hospital, while 41 (24.8%) stopped and cleaned their SPF with an EMS-specified solution. Thirty-four (20.6%) stop and rinse with soap and water, 10 (6.1%) stop and only rinse with water, while two (1.2%) admitted to not cleaning their SPF.

Table 4.14: Behavioural responses to contamination incidents (n=165)

	Yes (%)	No (%)	Frequency (n)
Stop and rinse with soap and water	131 (79.3)	34 (20.6)	165
Stop and rinse with water only	155 (93.9)	10 (6.1)	165
Stop and clean with the EMS-specified cleaning solution	124 (75.1)	41 (24.8)	165
Clean at the hospital	92 (55.7)	73 (44.2)	165
Do not clean	163 (98.7)	2 (1.2)	165
Other	160 (96.9)	5 (3.0)	165

CHAPTER FIVE: DISCUSSION

5.1 INTRODUCTION

The study aimed to identify potentially pathogenic bacteria in Emergency Care Personnel (ECP) Safety Protective Footwear (SPF) in KwaZulu-Natal Emergency Medical Service (KZN EMS), uMgungundlovu District, and evaluate current Infection Prevention and Control (IPC) strategies. While previous studies have discovered potentially pathogenic bacteria in ambulance equipment, various locations such as floors, doors, and stretchers, etc, they have not specifically addressed bacteria found on SPF and whether these bacteria are transmissible between patients, families, and communities. The study indicated that out of the seven SPF samples, six were contaminated with potentially pathogenic microorganisms, signifying a health risk. A questionnaire was carried out to evaluate the existing IPC procedures. The results indicated that ECPs' possessed insufficient knowledge regarding techniques and methods for cleaning their SPF, suggesting a deficiency in IPC education. The study's findings may inform the development of strategies to enhance information dissemination and education to reduce disease transmission effectively.

5.2 DEMOGRAPHIC CHARACTERISTICS OF THE PARTICIPANTS

The EMS profession has historically been perceived as a male-dominated field. This assertion aligns with the study's findings, which revealed a significantly higher percentage of male participants (66.1%) in contrast to female participants (33.9%), which is consistent with findings of studies that found that the emergency care profession has traditionally been male-dominated (Naguran 2008; Kyed 2020; Chetty, Govender and Sobuwa 2022). The participants' ages ranged from 21 to 60. The majority of participants (42.4%) were between the ages of 40 and 49, with 33.0% aged 30 to 39. According to the study, the majority of staff with 10 to 19 years of experience were Basic Life Support (BLS) (50.3%), followed by Intermediate Life Support (ILS) (40.0%). Advanced Life Support staff accounted for 4.8% of those aged 50 to 59 and 2.4% of those aged 40 to 49.

These BLS, ILS, and ALS were divided among four sub-bases: Edendale, Howick, Appelsbosch, and Grey's, with Grey's having the largest staff complement (54.0%) due to the inclusion of the emergency dispatch centre (EDC) and planned patient transport (PPT) components, which are not found at the other bases. In recent years, there has been an excess of BLS, with private and provincial training institutions producing around 10,000 BLS-qualified personnel each year (Sibanda 2018). As shown in Table 4.7, this could explain the higher number of BLS participants in the study. Historically, the BLS program functioned as an entry point into the EMS system. This result is similar to those observed in previous studies (Finlayson 2017; Tiwari *et al.* 2021).

5.3 BACTERIA IDENTIFIED ON ECP SAFETY PROTECTIVE FOOTWEAR

The findings of this study offer valuable insights into the bacterial contamination of SPF used by ECP's. The findings highlight the potential role of SPF as vectors for bacterial transmission in pre-hospital settings, which has important implications for IPC practices in EMS. These findings are consistent with the findings of McGuire-Wolfe (2020), who discovered that at Pasco County Fire Rescue station, more than 500 firefighters regularly wear boots to trauma scenes, patient homes, and communal areas at the fire stations. The findings revealed that after three swabs taken from the bottom of firefighter boots, the boots had the highest bacterial colony-forming units (CFUs), with over 900,000 and 378,000 CFUs per boot. As previously demonstrated, contact with bacterial environments exposes EMS personnel to a wide range of potentially fatal pathogens.

Compared to their colleagues around the world, EMS personnel in South Africa may be more susceptible to infection. The study found that 39.4% of participants only cleaned their SPF at home, while 75.4% used their SPF outside of their professional environment, which poses a significant health risk. With regards to the bacteria found on ECPs' SPF, the majority of the potentially pathogenic bacteria found in the study were attributable to the poor knowledge and cleaning practices.

This finding is consistent with other studies, which found that poor staff behaviours and inadequate awareness about infections, insufficient training, lack of self-education, and poor knowledge of drug-resistant bacteria could lead to higher rates of HAIs (Goedken *et al.* 2022; Jenkins *et al.* 2023; Taylor *et al.* 2024). A previous study performed in KZN revealed, there was insufficient training and education on infection control practices (Williams-Claassen 2013). However, contrasting results have also emerged from earlier studies, which revealed positive attitudes, and good IPC practices among HCWs (Thazha *et al.* 2022).

5.4 PREVALENCE AND DISTRIBUTION OF BACTERIA

This study also revealed that of the 53 SPF samples analysed, seven (7 = 13.2%) were found to be contaminated with bacteria, of the seven (7), six (6) was identified from the operational ECPs', and one (1) from the Emergency Despatch Centre (EDC). The EDC participants are not directly involved in patient care; instead, they receive emergency calls and dispatch qualified ambulances. In some instances, EDC staff may be called for operational duties to assist in major incidents while wearing their SPF and may therefore return to their station at the EDC and pose a risk, and possibly cross-contamination to other ECPs' working in the EDC. While the bacteria found on ECPs' SPF might not be alarmingly high, this prevalence rate is still concerning, given the critical nature of ECPs' work and their frequent close contact and interactions with vulnerable patients. These findings are consistent with those reported by Lena *et al.* (2021), who discovered that HCWs frequently wipe their hands on their uniforms and come into contact with patient belongings and linen without using protective barriers, thereby unknowingly carrying infectious microorganisms. Naguran (2008) in his study found that EMS staff had poor knowledge of hand hygiene. Because a large proportion of healthcare workers wear uniforms to and from work, there is a risk of bacteria spreading between hospitals and communities. Vikke and Giebner (2016) conducted an interesting inspection of ambulance personnel's work attire; the study revealed infection with potentially pathogenic bacteria such as *Bacillus cereus* (27.78%), *Clostridium spp.*, *Enterococcus spp.* (2.22%), and *S. aureus* (21.11%).

Nigam and Cutter (2003) discovered a similar summary of bacteria while conducting a swab investigation of the workplace and medical instruments. In this case, the most common bacteria were coliforms (31.5%), *S. epidermidis* (29.4%), and *Bacillus spp.* (21.9%). Luksamijarulkul and Pipitsangjan (2015) found a similar microbiological profile in the analysis of ambulance surfaces, with *Staphylococcus spp.* (47%), Gram-negative bacilli (32%), and Gram-positive bacilli (12%). Because of the scarcity of literature on bacteria on ECPs' SPF and uniform among South African EMS personnel, it was unlikely to draw any conventional differences with previous South African studies.

This study revealed that the most prevalent microorganism identified was *Pantoea agglomerans*, which was found on five (71.4%) of the contaminated SPF samples. *P. agglomerans* is an opportunistic bacterium that has been associated with various infections, particularly in immunocompromised individuals (Mardaneh and Pouresmaeil 2024). These findings are consistent with other studies, which also reported that *P. agglomerans* is an opportunistic bacterium (De Champs *et al.* 2000; Kaur *et al.* 2020; Lorenzi *et al.* 2022). Its prevalence on SPF is concerning, suggesting that ECPs' may inadvertently be transporting this bacterium between different environments and patients. This study revealed that *P. Agglomerans* was resistant to both ampicillin and amoxicillin-clavulanic acid. Furthermore, the benefit of the amoxicillin-clavulanic acid combination has been prescribed for years, but this short-term approach has rapidly brought patients to a new reality in which acceptable antibiotic choices for the next infection are increasingly threatened (Huttner *et al.* 2020).

This study also revealed that the second most common organism, found in two out of seven (28.5%) contaminated samples, was *Acinetobacter radioresistens*. While *A. radioresistens* is generally considered less pathogenic than other *Acinetobacter* species, its prevalence is still noteworthy. *Acinetobacter* species are known for their ability to survive on surfaces for extended periods and their potential for developing antibiotic resistance (Wang *et al.* 2019). The detection of *Enterococcus faecium* and *Enterococcus casseliflavus* is particularly alarming, as this study indicated that one in seven (14.2%) contaminated samples tested positive. These organisms belong to the

ESKAPE group of pathogens, comprising *Enterococcus faecium*, *Staphylococcus aureus*, *Klebsiella pneumoniae*, *Acinetobacter baumannii*, *Pseudomonas aeruginosa*, and *Enterobacter* species, recognised for their capacity to circumvent antibiotic effects and their significant role in bacterial infections (De Oliveira *et al.* 2020).

Escherichia coli was detected in one sample (14.2%), which is also significant. *E. coli* is a common bacterium in the human gut, but some strains can cause serious infections. Its presence on SPF indicates possible faecal contamination, which could have serious consequences for patient safety. Finally, the detection of *Pasteurella canis* in one sample (14.2%) is surprising and intriguing. *P. canis* is commonly associated with animal bites, especially from dogs. (Kim *et al.* 2016). Its presence on SPF raises concerns regarding the potential exposure to animal-related emergencies or the personal activities of ECPs' outside of work hours. The identified bacteria, including *P. agglomerans*, *E. faecium*, *E. casseliflavus*, *E. coli*, *P. canis*, and *A. radioresistens*, are known to be associated with nosocomial infections, highlighting the potential risk of cross-contamination and healthcare-associated infections (HAIs) in the pre-hospital setting (Mardaneh and Pouresmaeil 2024).

The antibiogram data show a concerning trend of antibiotic resistance in some of these isolates. Notably, *P. agglomerans*, *E. faecium*, and *A. radioresistens* showed resistance to first-line antibiotics such as ampicillin and amoxicillin-clavulanic acid. The presence of such resistant strains on ECPs' SPF highlights the need for effective infection prevention and control (IPC) measures to prevent the spread of these difficult-to-treat infections. The observed resistance to first-line antibiotics, particularly beta-lactams, raises concerns about the potential difficulty in treating infections caused by these bacteria. The effectiveness of commonly used antibiotics, such as ampicillin, was significantly low, with multiple strains exhibiting resistance. However, this contradicts the findings of a Polish study, which discovered that continued treatment with large initial doses of oral amoxicillin plus clavulanic acid is an extremely effective and safe substitute therapy for *K. pneumoniae*-caused UTIs. Despite the presence of amoxicillin/clavulanic acid-resistant bacterial strains, this therapy proved to be completely effective (Wilkowski *et al.* 2023). This finding in the study emphasises the importance of judicious antibiotic use and the development of alternative treatment

strategies to combat these resistant bacteria. While all bacterial strains were susceptible to imipenem, a broad-spectrum carbapenem antibiotic, its use should be limited to severe infections due to the risk of increasing antibiotic resistance (Larsson and Flach 2022).

With regards to *Pasteurella canis*, *Enterococcus faecium*, *P. agglomerans* and *A. radioresistens*, which are resistant to first-line antibiotics. Gentamicin, Tobramycin, and Amikacin are aminoglycosides used to treat serious bacterial infections. Quinolones, such as Ciprofloxacin, Trimethoprim-sulfamethoxazole/Cotrimoxazole, are antibiotics that can be taken orally or topically. Tobramycin, Oxazolidinones, Linezolid, Azithromycin, Clarithromycin and Erythromycin are second-line treatments which are classed as Macrolides. These antibiotics treat infections such as pneumonia, sinusitis, pharyngitis, and tonsillitis. Cephalosporins are second-line treatments, namely cefuroxime and ceftazidime, and are commonly used to treat skin infections. The reason for high antibiotic resistance may be attributed to over-dispensing of medication. An interesting comparative study of private and public sector hospitals in Johannesburg, South Africa, found that resistance to first-line antibiotics may be due to over-prescribing of these medications. Their research found that unnecessary antibiotics were prescribed in the public sector (78.4%) versus the private sector (66.7%) (Lagarde and Blaauw 2023). This was consistent with an earlier study, which found that physicians may prefer prescribing antibiotics over discouraging patients who do not require them due to time constraints (Guma *et al.* 2022).

Enterococcus faecium and *Enterococcus casseliflavus* are resistant to second-line antibiotics. The sensitivity to other antibiotics, including aminoglycosides (gentamicin, tobramycin, amikacin) and quinolones (ciprofloxacin), offers potential treatment options, but their effectiveness might be limited by factors such as patient-specific considerations and the potential for adverse effects. The presence of multidrug-resistant organisms like *E. faecium* and *Enterococcus casseliflavus* on ECPs' SPF in this study is particularly alarming, as these bacteria are known to cause serious infections, including bloodstream infections, urinary tract infections, and endocarditis. As indicated in chapter 2, resistance of these strains to second-line antibiotics, such

as erythromycin, further complicates treatment options and highlights the urgent need for improved IPC measures in the pre-hospital setting.

The findings from this study highlight the variability in cleaning practices among ECPs'. However, this is not unique to the South African EMS setting, as a Pereira, Colombia ambulance service reported that due to the lack of disinfection procedures in these ambulance areas, these bacteria can thrive. The success of the decontamination method will vary for a variety of reasons, including the surface material, the type of bacteria, the quality with which the scrubbing procedure is carried out, the concentration in which the disinfectant is used, the disinfection protocol, and the interaction of patients and EMS personnel with various equipment and surfaces (Alvarez-Aldana *et al.* 2018). While most participants clean either at home or immediately after each case, this study revealed a concerning proportion (4.2%) of the participants reported never cleaning their SPF.

This underscores the need for standardised and enforced cleaning protocols to ensure patient and worker safety. The preference for cleaning at home (39.4%) may be due to convenience or a lack of adequate facilities at work; this was prevalent in a study conducted by Williams-Classsen (2013). However, in an ambulance, repeated cleaning and sterilisation methods are not always practical. The fast-paced environment, rapid turnover of emergency calls, and adherence to cleaning protocols all make it difficult to maintain non-contaminated conditions for EMS personnel and patients (Finlayson 2017; Obenza *et al.* 2022). However, this practice could lead to cross-contamination if proper cleaning procedures are not followed and for those wearing their SPF at home, potentially placing their families at risk. The high percentage of participants cleaning immediately after each case (37.6%) is encouraging, suggesting a fair understanding of infection control principles. However, the fact that not everyone adheres to this practice emphasises the need for continued education and reinforcement. The study findings revealed relatively low cleaning frequencies immediately after shift (15.2%) and immediately before shift (1.2%) are noteworthy. Cleaning after a shift could help prevent the spread of pathogens between shifts and transmission to other places and surfaces, while cleaning before a shift ensures equipment is ready for use.

Most participants indicated they had received disinfection training and recognised the incorporation of IPC in their training programs and workshops; however, a notable percentage reported the lack of an EMS Standard Operating Procedure (SOP), or policy specifically related to SPF cleaning. This discrepancy highlights a possible divide between theoretical understanding and practical application of IPC measures, especially regarding SPF disinfecting.

Furthermore, the reliance on self-research as the primary source of information for SPF cleaning raises concerns about the adequacy of formal IPC education and communication within the KZN EMS. This suggests a need for more structured and accessible channels for disseminating IPC information and guidelines, ensuring that ECPs' have the necessary knowledge to protect themselves and their patients from potential infections.

The lack of significant associations between IPC knowledge, perceptions, cleaning procedures and demographic factors such as age, sex, and race suggests a relatively uniform approach to IPC training across the KZN EMS employees. However, the observed discrepancies in the distribution of EMS personnel across sub-bases and the absence of a standardised SPF cleaning policy highlight areas for potential improvement in IPC practices. The study demonstrated a concerning variability in SPF cleaning practices among ECPs'. While it is encouraging that a significant proportion of participants (37.6%) clean their SPF immediately after each case, a majority still do not follow this optimal practice. The prevalence of home as the primary cleaning location (39.4%) prompts an examination of the potential for cross-contamination between domestic and workplace settings. Of particular concern is the low percentage of ECPs' who clean their SPF immediately before shift (1.2%). This practice could be crucial in ensuring that SPF is free from contaminants at the start of each workday. The variability in cleaning practices suggests a need for standardised protocols and better education on the importance of regular and timely SPF cleaning.

The research indicated that the organisation offers a variety of cleaning agents, with Jik (bleach) being the most frequently supplied at 67.3%, followed closely by disinfectant at 66.1%. The widespread availability of these effective disinfectants is advantageous. Nonetheless, the limited availability of water (52.1%) and soap (40.6%)

is troubling, given their essential role in fundamental cleaning practices. This study is consistent with a study in which participants from certain bases in KZN felt they did not have adequate access to water for cleaning and disinfection (Williams-Claassen 2013). The limited availability of specialised cleaning agents such as Cidex (7.3%) and Biocide (16.4%) suggests that the organisation's cleaning agent supply strategy should be reconsidered. Advanced disinfectants may play an important role in combating resistant pathogens found on SPF. 4.8% of respondents reported that the organisation did not provide any cleaning agents. The provision gap may impair certain ECPs' ability to maintain appropriate hygiene standards for their SPF.

This study's findings reinforce the variability in cleaning practices among healthcare workers. A notable percentage (4.2%) of individuals reported never cleaning their equipment, despite the majority cleaning either at home or immediately after each case. This highlights the necessity for standardised and enforced cleaning protocols to guarantee the safety of patients and workers. The inclination towards home cleaning (39.4%) may be attributed to convenience or insufficient facilities in the workplace. This practice may result in cross-contamination if adequate cleaning protocols are not adhered to. The significant proportion of individuals who clean immediately after each case (37.6%) is promising, indicating a solid comprehension of infection control principles. The lack of universal adherence to this practice underscores the necessity for ongoing education and reinforcement. The low frequencies of cleaning immediately after shift (15.2%) and immediately before shift (1.2%) are significant. Post-shift cleaning may mitigate the transmission of pathogens between shifts, whereas pre-shift cleaning ensures equipment readiness for operation and minimises the potential of infecting patients. The tables and figures present findings that demonstrate the varied disinfecting practices utilised by participants concerning their SPF. The most common method employed is wiping the SPF while wearing gloves, utilised by 76 participants (46.1%). This can be ascribed to its simplicity and convenience.

Scrubbing the SPF is the second most prevalent practice, preferred by 63 participants, accounting for 38.2% of the total. This method may be regarded as more effective in eliminating contaminants. Nonetheless, the comparatively lower adoption rate than wiping indicates possible challenges, including the necessity for increased time and effort. Soaking and spraying were the predominant methods employed, while

significantly fewer participants utilised alternative approaches. The other category, comprising six participants (3.6%), suggests the presence of additional disinfecting practices not explicitly enumerated, necessitating further examination to elucidate their characteristics and frequency. This study's findings highlight several important aspects concerning the utilisation and potential contamination of SPF among ECPs'. Numerous participants don gloves during the cleaning of their SPF, and instances of patients' bodily fluids spilling on them underscore the risk of contamination.

The use of SPF by some participants outside of work, including while driving, and their subsequent entry into homes with it raises concerns regarding the potential transmission of pathogens to other environments.

The significant prevalence of exposure to blood, vomit, and other bodily fluids highlights the need for strict IPC protocols. The common belief among participants that their SPF may serve as a potential source of contamination further supports this concern. The behavioural responses to contamination incidents, despite the acknowledged risk, exhibit considerable variability. A substantial number of individuals clean their SPF using hospital-grade or EMS-approved cleaning solutions; however, some fail to clean them entirely or simply rinse with water, which may not eliminate all pathogens. This suggests a possible lack of understanding or adherence to proper decontamination procedures.

The findings of this study emphasise the significance of infection prevention and control (IPC) in mitigating the transmission of potentially pathogenic and antibiotic-resistant bacteria in pre-hospital settings. The presence of these bacteria on ECPs' SPF highlights the necessity for improved decontamination procedures, standardised cleaning protocols, and continuous education and training on IPC practices. Effective implementation of IPC measures can mitigate the risk of HAIs, thereby safeguarding both ECPs' and the patients they serve.

5.5 CONCLUSION

This chapter presented an interpretation of the study's findings, which revealed a gap in the maintenance of effective cleaning and sanitising practices for ECPs' SPF. The microbiological survey discovered a gap that is linked to negative health consequences. The survey of knowledge and practices revealed a widespread lack of IPC cleaning procedures, as well as the ineffectiveness of standard cleaning methods in removing microorganisms from SPF.

The issues identified comprised the absence of designated cleaning equipment, inadequate time allocated for comprehensive cleaning, and the lack of established procedures for the decontamination of medical equipment. While the primary objective of EMS is to save lives, maintaining hygiene for patients and ambulance personnel, as well as ensuring occupational health, is equally critical. The use of emergency care ambulances, PPE, and standard precautionary frameworks, SPF without transparent and standardised protocols significantly increases the risk within the EMS environment, particularly regarding the potential for pathogenic transmission.

Chapter Six (6) provides the Summary, Recommendations, Limitations and Conclusion for this study.

CHAPTER SIX: SUMMARY, RECOMMENDATIONS, LIMITATIONS AND CONCLUSION

6.1 INTRODUCTION

This study represents an investigation in the uMgungundlovu District that identified pathogenic exposure linked to bacterial infections on Emergency Care Personnel (ECP) Safety Protective Footwear (SPF). There is limited data from South Africa regarding pathogenic exposure through this transmission route. This chapter summarises the study findings, presents recommendations for preventing bacterial exposure among ECP providers, discusses the limitations of the study, and concludes with the study's overall conclusions.

6.2 SUMMARY

The first three study objectives were to determine the prevalence of pathogens on emergency care personnel's SPF at Grey's base in the uMgungundlovu District. According to the study, 13% of the ECPs' who took part in the microbiological survey had bacteria on their SPF while performing their operational duties. According to the study, most of the pathogens' exposure was attributed to poor cleaning techniques and a lack of a comprehensive cleaning procedure that is lacking in KZN EMS. It is common knowledge that health care workers encounter bacteria and other microorganisms regularly. These exposures are common during trauma and medical procedures, as well as routine clinical examinations. This exposure can spread from health care workers to their patients, communities, and homes.

The fourth objective 4 was to assess ECPs' knowledge, perceptions, and reported practices regarding current cleaning procedures and disinfectant use on SPF, which included all EMS sub-bases. The questionnaire was distributed to all the EMS bases. The questionnaire included 23 questions covering the following topics: Demographics, evaluation of current cleaning procedures and disinfectant efficacy on ECPs' SPF, hand hygiene, IPC workshops and training, disinfecting SOP/policy, body fluid spillage, and cleaning solutions. According to the findings, participants have increased the frequency with which they cleaned their SPF due to the recent COVID-19

pandemic. This was also observed in Samariten Ambulance in Sweden, where hygiene routine and cleaning compliance had improved during the Covid 19 pandemic (Olsson *et al.* 2022).

The participants' lack of knowledge about the risks of IPC was a significant finding of this study. This demonstrates the level of interest in IPC among health professionals, which is most likely related to their belief in IPC as a key to infection control in the public health setting. According to the findings, possible reasons for these ECPs' inadequate IPC knowledge include a lack of a comprehensive policy strategy as well as scarce IPC training programs. Another significant finding was that many of the participants were performing unsafe IPC, which could make them susceptible to bacterial exposure and pathogen infection. The importance of infection control in healthcare settings cannot be overstated, as both patients and healthcare workers can spread microorganisms. Furthermore, healthcare is increasingly being provided outside of hospitals in settings such as primary health care clinics, nursing homes, emergency departments, and patients' homes.

The importance of airborne microorganism transmission in the pre-hospital setting, as well as the risk of cross-infection between patients and HCWs', is well documented, particularly in the case of blood-borne pathogens. Another significant finding was that many of the participants were engaging in unsafe practices that could expose them to pathogens and possibly infect them with bodily fluids. These unsafe practices included not cleaning their SPF after each case or patient, failing to attend IPC updates, driving their vehicles while wearing their SPF, and walking into their homes while wearing their SPF. A lack of awareness of the risks of IPC could be one of the causes of such dangerous practices. Again, this lack of awareness could be attributed to a lack of clear IPC guidelines as well as inadequate training programs.

KwaZulu-Natal (KZN) Emergency Medical Service (EMS) must ensure an adequate supply of cleaning materials and disinfectants, which must be readily available to ECPs. However, the responsibility cannot be placed solely on EMS, as ECPs must ensure that they have used the required disinfectant material appropriately. In a study by McClelland *et al.* (2020), they discovered that using the AmbuGard dry misting

decontamination system for ambulances is very effective. It works for $\pm$ 30 minutes and is 99.99% effective against common pathogens. In this study, 57% of the ECPs preferred water and 39% soap to clean their SPF.

While most participants stated that they had received IPC training, an alarming 49.7% of ECPs' did not attend. Many of the ECPs' who participated in this study lacked the fundamental knowledge required to prevent pathogen transmission. Furthermore, the study discovered that a substantial proportion of the participants were unfamiliar with the KZN EMS IPC protocol or SOP. As a result, this study recommends that EMS provide current training aimed at pathogen awareness, prevention, and management on a regular basis, and that updated EMS-specific IPC management protocols/SOPs be distributed to all ECPs'. Registers must also keep track of participation in IPC training programs and to serve as proof of receipt and check compliance with the IPC protocols/SOPs.

6.3 RECOMMENDATIONS

The study examined new evidence on pathogens in ECPs' SPF in KZN uMgungundlovu District. The findings of this study indicate that policies aimed at preventing pathogenic exposure in the pre-hospital setting require all sectors of EMS and the Health Department to ensure that all IPC procedures are implemented. The following recommendation could help reduce pathogenic spread among ECPs':

6.3.1 Training and Specific Disinfecting of SPF

Pathogen exposure can have a negative impact on ECPs' health. This study discovered that many ECPs' were unaware of IPC and how to clean/disinfect their SPF and ambulances. Furthermore, many participants were unaware of EMS IPC policy or whether it even existed. This study recommends that KZN EMS provide specific training and awareness of IPC procedures, that this information be distributed on a regular basis to all staff, and that attendance at IPC workshops be tracked. EMS training providers must register personnel on a database and flag poor attendance. KZN EMS does not have a specific policy for cleaning SPF; most IPC policies are adopted from the hospital environment and are not specific to the prehospital setting.

In this study, it was discovered that ECPs' have relied on their own research on how to disinfect their SPF. KZN EMS needs to provide a specific cleaning procedure for ECPs' SPF. Thus, it is critical to recognise that ambulances may be a source of contamination, necessitating more stringent IPC procedures and disinfection systems.

6.3.2 Provision of cleaning solutions

It is critical to maintain an adequate supply of cleaning solutions. KZN EMS must ensure that all ambulances have adequate cleaning solutions at the bases, including those carried on the ambulances. Dedicated cleaning areas in hospitals must be designated for EMS personnel, and the facility must be stocked with supplies and monitored by shift officers. There should be rigorous decontamination procedures in place, including preliminary mopping or cleaning to reduce microbial loads on surfaces stained with dreadful impurities such as blood, vomit, or body tissues, followed by scrubbing and sterilisation with various decontaminants such as 1 to 10% w/v hypochlorite solution, 70 to 80% v/v alcohol, glutaraldehyde, quaternary ammonium chloride, etc. However, this is not solely the responsibility of the organisation; employees must also be involved in this area of responsibility.

6.4 RECOMMENDATIONS FOR FUTURE RESEARCH

The research study examined new evidence on pathogens on ECPs' SPF in KZN's uMgungundlovu District, paving the way for future research on the subject. Additional research could focus on both private and public EMS provincially and nationally. Swabbing was carried out with only a few participants from a single region's EMS Grey's base; however, this could be increased to all bases of KZN EMS. However, given the scarcity of literature on SPF pathogen exposure among ECPs' in South Africa, the results of this study may pave the way for larger regional or national studies. In addition, microbial analysis was quantitative, and future research could include enumerating pathogen loads associated with disease transmission.

6.5 LIMITATIONS OF THE STUDY

While this study provides valuable insights, it has several limitations. The sample size of 53 SPF is relatively small, and the study was conducted at a single point in time.

Longitudinal studies with larger sample sizes would provide a more comprehensive understanding of microbial contamination patterns on SPF over time. Furthermore, all bases in the uMgungundlovu district, as well as private sector ECPs, would help to better understand microbial contamination. Another limitation was a limited budget. Although 53 ECPs' SPF were sampled, the study would have been more comprehensive if additional SPF from all bases had been sampled. Another limitation was that some SPF were swabbed after ECPs' cleaned their vehicles, which allowed water to drop on their SPF, which may have resulted in poor bacterial identification. On the other hand, some managers and employees were unwilling to complete the questionnaire for this study, fearing that their identities would be revealed, thus limiting the research findings. A further limitation of the study was that participants may have perceived the researcher's seniority within the hierarchical structure of the study setting as intimidating, potentially inhibiting their willingness to share their experiences and perspectives candidly due to concerns about victimisation.

There were several articles and journals that were found and analysed the data, but the main findings about the use of disinfecting and cleaning styles and implications in the pre-hospital environment were not highlighted clearly. Given the scarcity of literature on bacterial contamination of ECPs' SPF among EMS providers in South Africa. This research is the only study performed in South Africa and globally that examined bacterial contamination on ECPs' SPF. The findings of this study pave the way for more provincial or national studies on the subject.

Additionally, this study did not assess the antibiotic resistance profiles of isolated organisms or investigate the potential for biofilm formation on SPF. These factors could significantly impact the risk of bacterial transmission and the effectiveness of cleaning protocols. Future research should aim to address these limitations and expand on these findings. Studies investigating the effectiveness of different cleaning protocols for SPF, the potential for bacterial transfer from SPF to patients or healthcare environments, and the role of SPF in the broader context of pre-hospital IPC would be particularly valuable.

6.6 CONCLUSION

South Africa has a higher burden of nosocomial bacterial infections than the developed world; therefore, close pathogenic monitoring of all ECPs' will help to reduce the threat of antimicrobial resistance. Due to the unpredictable and fast-paced nature of the pre-hospital environment, as well as the high prevalence of nosocomial infections, ECPs' from South Africa are among the most vulnerable to nosocomial infection. It was discovered that the knowledge of the ECPs' working in the KZN EMS uMgungundlovu District regarding IPC procedures is suboptimal, while their practice of cleaning and disinfecting their ambulances and SPF falls within the boundaries of perilous practices. This risky practice, combined with a lack of knowledge about IPC, is linked to the prevalence of pathogens found on the SPF in this study. There should be a more effective disinfecting IPC protocol. The results of this study demonstrated the need for such guidelines.

ANNEXURES

Annexure A: Letter of approval from EMS Manager uMgungundlovu District



KWAZULU-NATAL PROVINCE
HEALTH
REPUBLIC OF SOUTH AFRICA

DIRECTORATE:

C/o Greys Hospital
Private Bag X9001, PIETRERMARITZBURG, 3200
Tel.: 033-921600
Email: cyprian.mthimkhulu@kznhealth.gov.za
www.kznhealth.gov.za

EMERGENCY MEDICAL SERVICES :
uMgungundlovu district

INTERNAL MEMO

Date: 26/08/2021	File No:
To: Mr JD Gengan COEC	From: Mr CS Mthimkhulu EMS District Manager uMgungundlovu District

Subject: Ethics Approval – Letter of Support

The aforementioned matter serves as reference.

The request to conduct study within EMS uMgungundlovu District for Mr JD Gengan is received and permission is granted.

Kind regards

Mr. CS Mthimkhulu
EMS District Manager
Umgungundlovu District Health

Annexure B: Letter of approval from Health Research & Knowledge Management Unit - Department of Health



KWAZULU-NATAL PROVINCE

HEALTH
REPUBLIC OF SOUTH AFRICA

DIRECTORATE:

Postal Address: Private Bag X9050

Physical Address: 330 Langalibalele Str, PM Burg: 3201

Tel: 0333953189/3123/2805 Fax: 033-3943782

Email address: hrkm@kznhealth.gov.za

www.kznhealth.gov.za

Health Research & Knowledge Management Unit

NHRD Ref: KZ_202109_019

Dear Mr J D Gengan
(DUT)

Approval of research

1. The research proposal titled '**Detection of bacterial microorganisms associated with nosocomial infections on emergency care personnel (ECP) safety protective footwear (SPF) and evaluation of routine IPC procedures**' was reviewed by the KwaZulu-Natal Department of Health (KZN-DoH).

The proposal is hereby **approved** for research to be undertaken at Greys EMS.

2. You are requested to take note of the following:

- a. *All research conducted in KwaZulu-Natal must comply with government regulations relating to Covid-19. These include but are not limited to: regulations concerning social distancing, the wearing of personal protective equipment, and limitations on meetings and social gatherings.*
- b. *Kindly liaise with the facility manager BEFORE your research begins in order to ensure that conditions in the facility are conducive to the conduct of your research. These include, but are not limited to, an assurance that the numbers of patients attending the facility are sufficient to support your sample size requirements, and that the space and physical infrastructure of the facility can accommodate the research team and any additional equipment required for the research.*
- c. *Please ensure that you provide your letter of ethics re-certification to this unit, when the current approval expires.*
- d. *Provide an interim progress report and final report (electronic and hard copies) when your research is complete to **HEALTH RESEARCH AND KNOWLEDGE MANAGEMENT, 10-102, PRIVATE BAG X9051, PIETERMARITZBURG, 3200** and e-mail an electronic copy to hrkm@kznhealth.gov.za*
- e. *Please note that the Department of Health shall not be held liable for any injury that occurs as a result of this study.*

For any additional information please contact Ms G Khumalo on 033-395 3189.

Yours Sincerely

Dr E Lutge

Chairperson, Health Research Committee

Date: 11/10/2021

GROWING KWAZULU-NATAL TOGETHER

Annexure C: Letter of information



LETTER OF INFORMATION

Warm greetings

Hello, my name is Jerry Gengan. I am a registered master's student at the Durban University of Technology Health Sciences Faculty, I would like you to participate in my study.

Title of the Research Study: Detection of bacterial microorganisms associated with nosocomial infections on emergency care personnel (ECP) safety protective footwear (SPF) and evaluation of routine infection, prevention, and control (IPC) procedures in the uMgungundlovu district of KwaZulu-Natal.

Principal Investigator/s/researcher: Mr. Jerry D. Gengan, BEMC.

Co-Investigator/s/supervisor/s: Dr Simpiwe Sobuwa PhD, Professor Poovendhree Reddy PhD.

Brief Introduction and Purpose of the Study: I am Jerry Gengan a student at Durban University of Technology doing research for my master's degree in emergency medical care. I would like to invite you to participate in the research. This research study will involve approximately fifty-four (54) operational ECPs employed by the Department of Health working for the Emergency Medical Services at Grey's base. The purpose of this study is to assess paramedical safety protective footwear for the presence of nosocomial bacterial micro-organisms in the uMgungundlovu district of KwaZulu-Natal, before and after a twelve-hour day and night shift, and a 15-minute questionnaire to evaluate routine IPC procedures.

Outline of the Procedures: For you to be included in this study you must be employed by the Department of Health and work for the Emergency Medical Service at Grey's EMS base uMgungundlovu District in KZN. The data collection will involve the swabbing of the service issued safety protective footwear and a completion of a 15-minute questionnaire. To be included in this study you must complete and sign the consent form.

Benefits: ECPs working in the operational setting will be provided with information on how much of nosocomial bacterial microorganisms that can be carried by their safety protective footwear. When this research study is completed, the results will be published, and the completed dissertation will be available at the DUT library.

Reason/s why the Participant May Be Withdrawn from the Study: You will be excluded from the study if you work outside of Grey's central base. If you do not read the letter of information and sign informed consent form. Participation in this research study is voluntary. You have the right not to participate or withdraw from this study at any time. If you do not want to participate in this study, and want to withdraw, you can do so with no negative action.

Remuneration: You will **NOT** receive any cash remuneration.

Costs of the Study: You will not be expected to cover any costs towards the study.

Confidentiality: The researcher will make sure that all information and data collected will always remain confidential. The names on the plastic bags are just for recognition purposes, bags will be discarded, once the samples are handed over to the microbiologist.

Research-related Injury: There should be no related injury to the participants. However, if there is any related injury, all participants are registered workers for the Department of Health and are covered by the Workmen's compensation Act (WCA)

Persons to Contact in the Event of Any Problems or Queries:

Dr Simpiwe Sobuwa or simpiweS@dut.ac.za, my co-supervisor, Prof Poovendree Reddy. Please contact Jerry Gengan the researcher 0845969495, my supervisor 0835258211 or the Institutional Research Ethics Administrator on 031 373 2375. Complaints can be reported to the DVC: Research, Innovation and Engagement Prof S Moyo on 031 373 2577 or moyos@dut.ac.za

Annexure D: Consent form



Statement of Agreement to participate in this research study:

- I hereby confirm that I have been informed by the researcher Jerry Gengan about the nature, conduct, benefit, and risks of this research study. Research Ethics Clearance Number 128/21
- I have also received, read, and understood the above written information letter regarding the study.
- I am aware that the results of the study, including personal details regarding my sex, age, date of birth, initials and diagnosis will be anonymously processed into a study report.
- In view of the requirements of research, I agree that the data collected during this study can be processed in a computerised system by the researcher.
- I may, at any stage, without prejudice, withdraw my consent and participation in the study.
- I have had sufficient opportunity to ask questions and (of my own free will) declare myself prepared to participate in the study.
- I understand that significant new findings developed during this research which may relate to my participation will be made available to me.

Full Name of Participant	Date	Signature

I, Jerry Devraj Gengan herewith confirm that the above participant has been fully informed about the nature, conduct and risks of the above study.

Full Name of Researcher

Date

Signature

Full Name of Witness (If applicable)

Date

Signature

Annexure E: Survey questionnaire

The Awareness and understanding of EMS Infection, prevention, and control (IPC) policy and procedures.

Questionnaire for Emergency care personnel (ECP) working in the EMS KZN uMgungundlovu District regarding the awareness and understanding of EMS Infection Prevention Control policy and procedures (IPC).

Thank you for taking time to read and answer the questions on the form provided. It is appreciated that you have agreed to be part of this research study. All answers in this research form will be kept confidential. Only the researcher will have access to the information provided.

Directions for participant: Please **tick** ✓ the answer on the appropriate box provided. If **OTHER** is ticked an explanation is required.

• Section A: Demographics

1. What is your age? _____

2. What is your gender?

Male	
Female	

3. What is your race?

African	
Coloured	
Indian	
White	
Other, specify	

- **Section B: General**

4. Number of years worked in KZN EMS? _____

1. State in which medical qualification you are registered in?

Basic life support	
Intermediate life support	
Emergency care technician	
Advanced life support	
Other specify	

6. In which KZN EMS sub-base do you work in?

Grey's base	
Appelsbosch base	
Edendale base	
Howick base	

7. Have you attended any training on disinfecting your Personal Protective Equipment (PPE)?

Yes (1)	
No (2)	
Not Sure (3)	
Training was available, I chose not to Attend (4)	

8. Do you think IPC should be discussed on your course?

Yes (1)	
No (2)	
Not Sure (3)	

9. In your opinion should there be regular workshops on IPC?

Yes (1)	
No (2)	
Not Sure (3)	

10. Is there an EMS SOP/Policy on disinfecting SPF?

Yes (1)	
No (2)	
Not Sure (3)	

11. Where did you get information on how to clean your SPF?

Friend	
Family Member	
Crew Mate	
Self-Research	

- **Section C:** To evaluate current cleaning procedures and efficacy of disinfectants used on ECPs safety protective footwear (SPF)?

12. When do you clean your safety protective footwear?

Immediately After each case (1)	
Immediately After shift (2)	
Immediately Before shift (3)	
Only at home (4)	
Never (5)	
Other (6)	

If **other** is ticked, an explanation is required:

13. What cleaning solutions does EMS KZN provide **YOU** to clean your PPE?

You can choose more than one answer below:

Water (1)	
Soap (2)	
Cidex solution (3)	
Biocide D (4)	
JIK (5)	
Disinfectant (6)	
None (7)	
Other (8)	

If **other** is ticked, an explanation is required:

14. What cleaning solution do you use to clean your safety protective footwear?

You can choose more than one answer below:

Water (1)	
Soap (2)	
Cidex solution (3)	
Biocide D (4)	
JIK (5)	
Disinfectant (6)	
None (7)	
Other (8)	

If **other** is ticked, an explanation is required:

15. Which cleaning technique do you use to clean your safety protective footwear?

Wipe the safety protective footwear	
Scrub the safety protective footwear	
Soak the safety protective footwear	
Spray the safety protective footwear	
Other	

If **other** is ticked, an explanation is required:

16. Do you wear gloves when you clean your safety protective footwear?

YES (1)	
NO (2)	

17. Do you wear your safety protective footwear whilst driving your personal vehicle after shift ends?

Yes (1)	
No (2)	

18. Do you walk into your home with your safety protective footwear after shift ends?

Yes (1)	
No (2)	

19. Did you ever have patients' body fluid spilled on your safety protective footwear?

Yes (1)	
No (2)	

20. What was your reaction when you noticed patients' body fluids on your safety protective footwear?

Stop and rinse with soap and water	
Stop and clean with EMS specified cleaning solution	
Clean at hospital	
Do not clean	
Other	

If **other** is ticked, an explanation is required:

21. Is cleaning solution like jik, cidex or disinfectant etc readily available at your base?

Yes (1)	
No (2)	
Never seen any cleaning solution (3)	

22. How common is it for you to encounter the following body fluids on your safety protective footwear?

	YES (1)	NO (2)
Blood		
Urine		
Faeces		
Vomit		
Other human body fluids		
Body tissues		

23. In your opinion do you think that your safety protective footwear is a possible source/site for contamination?

Yes (1)	
No (2)	

Annexure F: Pilot study



LETTER OF INFORMATION: QUESTIONNAIRE PRE-TEST GROUP

Name of research student: JD Gengan

Contact No: 0845969495

Name of supervisor: Dr Simpiwe Sobuwa

Contact No.: 031 3735203

Name of Co – Supervisor: Professor Poovendhree Reddy

Name of institution: Durban University of Technology

Dept. of Emergency Medical Care & Rescue

Dear Participant,

I am conducting a research project to complete a master's degree in emergency medical care through the Department of Emergency Medical Care and Rescue, Durban University of Technology.

Title of research: Detection of bacterial microorganisms associated with nosocomial infections on emergency care personnel (ECP) safety protective footwear (SPF) and evaluation of routine infection, prevention, and control (IPC) procedures.

Purpose of the research: The purpose of the study is to assess ECPs safety protective footwear for the presence of nosocomial bacterial micro-organisms and infection control procedures in the uMgungundlovu district of KwaZulu-Natal, by completing a ten-minute questionnaire. I am requesting you to participate in the pre-testing of the questionnaire as you are representative of the population in the study.

This research study will involve approximately fifty-four (54) operational Emergency Care Personnel (ECP) employed by the Department of Health working for the Emergency Medical Services at Grey's base. The purpose of the study is to assess ECPs safety protective footwear for the presence of nosocomial bacterial micro-organisms and infection control procedures in the uMgungundlovu district of KwaZulu-Natal, before and after a day and night twelve-hour shift.

I am requesting you to participate in the pre-testing of the questionnaire as you are representative of the population in the study. The structured questionnaire has been designed to collect data on the awareness and understanding of EMS Infection, prevention, and control (IPC) policy and procedures. Having an unpretentious, orderly format, the sequencing of the questionnaire items, clear, non-leading and non-threatening wording of the items, and the length of the questionnaire have been considered.

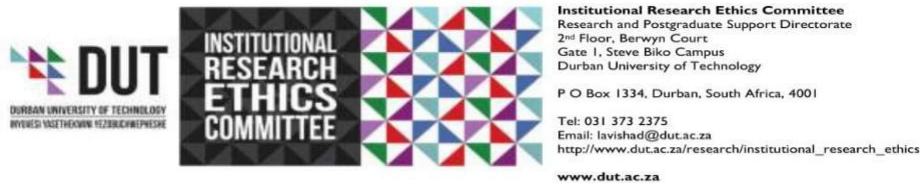
The purpose of pre-testing is the assessment of the operational parameters of the attached questionnaire that will be utilised to gather the information required for the above-mentioned research study. Please note that your identity and information will be treated with the utmost confidentiality. Please feel free to ask any questions that you may have about your role in this evaluation, so that you clearly understand what is expected of you. Please complete the questionnaire, taking note of the following:

There is no collaboration with anyone else in answering any of the questions. Anything that was unclear or ambiguous to understand. Anything that made you feel reluctant to answer a question. The layout. The time taken to complete the questionnaire.

Please feel free to offer constructive criticisms once the questionnaire has been completed.

Thank You
Jerry Gengan

Annexure G: Letter of approval from the Durban University of Technology's Institutional Research Ethics Committee



8 November 2021

Mr J D Gengan
14 Adjmer Crescent
Pietermaritzburg

Dear Mr Gengan

Detection of bacterial microorganisms associated with nosocomial infections on emergency care personnel (ECP) safety protective footwear (SPF) and evaluation of routine IPC procedures
Ethical Clearance number IREC 128/21

The Institutional Research Ethics Committee acknowledges receipt of your notification regarding the piloting of your data collection tool.

Kindly ensure that participants used for the pilot study are not part of the main study.

In addition, the IREC acknowledges receipt of your gatekeeper permission letter.

Please note that **FULL APPROVAL** is granted to your research proposal. You may proceed with data collection.

Any adverse events [serious or minor] which occur in connection with this study and/or which may alter its ethical consideration must be reported to the IREC according to the IREC SOP's.

Please note that any deviations from the approved proposal require the approval of the IREC as outlined in the IREC SOP's.

Yours Sincerely

Prof J K Adam
Chairperson: IREC

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