An Investigation into Ambulance Laryngoscopes as a Potential Source of Infection Amongst Emergency Medical Service Personnel in a Private Ambulance Service in the eThekwini Municipality of KwaZulu-Natal

By

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DECLARATION

The author, Mr S. Pillay, do hereby declare that this **DISSERTATION** is the result of my own investigation and research, except to the extent indicated in the **REFERENCES** and that it has not been submitted in part or full of any other qualification to any other university.

The author knows and understand the contents of this declaration and considers the prescribed oath to be binding on my conscience. We have no objection to taking the prescribed oath.

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Date: 4TH December 2023

ETHICAL CLEARANCE

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

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DEDICATIONS

This researcher would like to thank Shree Sathya Sai Baba for his guidance and grace during this project, I would like to offer this project at his lotus feet for being the ultimate proof reader and researcher; without him this project would have not been possible.

To my beloved mother Mrs Devi Pillay who raised me as a single mother and widow, words cannot express the gratitude that I have for you mother. I love you. Thank you for the motivation.

I am dedicating this thesis to three beloved people who have meant and continue to mean so much to me. Although they are no longer of this world, their memories continue to regulate my life. First and foremost, to my father Mr Kistappa. A. Pillay whose illnesses inspired and encouraged my interest in the emergency medical services. His simplicity, honesty, determination and hard work ethic continue to inspire me, and I hold his achievements as a measure against my own. I love you, Dad.

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ABSTRACT

Background

Emergency care practitioners (ECPs) provide specialised treatment and management to a great number of critically ill and injured patients in the pre-hospital setting. Overall, these patients have the potential to have a higher incidence of infectious and emerging diseases. Part of patient management is securing the patient's airway through the placement of an ETT into the trachea. This process involves the use of a laryngoscope which is an invasive tool that comes into contact with blood and other biological agents and can provide a medium of transportation of infections if not decontaminated adequately. Disinfection and infection control is a fundamental practice in emergency medical care (EMC) that is often underrated. To date, there is no consistency and an overall lack of consensus with regards to a formalised infection control policy with specific reference to decontamination practices of the laryngoscope in the pre-hospital emergency medical care sector in KwaZulu-Natal. There are limited published research studies investigating ambulances decontamination practices regarding laryngoscope blades and handles.

Purpose:

This study aimed to investigate the microbial composition of ready-to-use ambulance laryngoscopes, determine the common decontamination practices, and establish the minimum concentration of disinfectants required to clean this pre-hospital equipment.

Methodology:

This experimental study used a descriptive design, as the purpose was to identify and quantify the microorganisms isolated from samples of laryngoscope blades and handles, and determine the most efficient disinfection agents required to render these microorganisms harmless using minimum inhibitory concentration (MIC) assay. A questionnaire was used to assess EMS personnel's decontamination practices regarding the disinfection of the equipment. The study was be conducted in a private EMS sector setting in KwaZulu-Natal province area. This service is a 24-hour private EMS, with 27 emergency care practitioners who uses laryngoscope blades and handles to help in AM.

Results:

The results presented in this study showed clearly that there was a high bacterial load found on the ambulance laryngoscope blades and handles under study. This was evident in the colony enumeration as well as the gram stain processes. Furthermore, there was a high level of potentially pathogenic species, namely, *Salmonella*, *Shigella* and *Pseudomonas* sp., which is of great concern. This is an indication of substandard hygiene practices IPC practices. It is evident from the results and the interpretation above that the IPC knowledge and practices regarding laryngoscope blades and handles in the selected EMS in the eThekwini District of KwaZulu-Natal is poor.

Conclusion

Ambulance laryngoscope blades and handles have been found to have an unsatisfactory level of pathogenic micro-organism contamination, and may be a reservoir in the transmission of potentially serious infections to patients and ambulance staff. This underlines the urgent need for the development and implementation of evidence-based ambulance IC guidelines pertaining to the airway tool. These findings should be taken into consideration and used to urgently address the problem of ambulance laryngoscope blades and handles decontamination and infection control.

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Paramedics: Personnel who are registered on the paramedic register with the Health Professions Council of South Africa (HPCSA) under the auspices of the Professional Board for Emergency Care (PBEC) (Sobuwa and Christopher 2019). These individuals are deemed to be healthcare workers (HVWs) and they provide both pre-hospital care and the transportation of ill and injured patients to hospitals for further care. For the purpose of this study the term paramedic includes all EMS personnel who are employed by the private emergency medical services in KZN and who are actively involved in patient care under the categories specified below (BLS, ILS, and ALS).

Basic life support (BLS): Emergency medical services personnel who are trained to provide basic medical care interventions including cardiopulmonary resuscitation, stopping bleeding and basic airway management (AM). They are registered with the HPCSA PBEC on the Basic Ambulance Register and are also known as basic ambulance assistants. For the purpose of this study, this term refers BLS practitioners who are employed by the private emergency medical services in KZN (Sobuwa and Christopher 2019).

Intermediate life support (ILS): Emergency medical services personnel who are trained to provide intermediate medical interventions such as peripheral venous cannulation, defibrillation and needle chest decompression (KwaZulu-Natal Department of Health 2001). They are also known as ambulance emergency assistants and are registered on the AEA register with the HPCSA PBEC. For the purpose of this study this term refers to ILS practitioners who are employed by the KZN EMRS (Sobuwa and Christopher 2019).

Advanced life support (ALS): Emergency medical services personnel who are trained to provide advanced medical interventions such as advanced AM and advanced resuscitation. For the purpose of this study this term refers to ALS trained practitioners who are employed by the private emergency medical services in KZN and include persons registered with the HPCSA in the following categories: Emergency Care Technician, Paramedic and Emergency Care Practitioner(Sobuwa and Christopher 2019).

Emergency care technician (ECT): In this study, the ECT are personnel who have obtained a mid-level, two year qualification in emergency medical care and who are registered as such with the HPCSA in terms of the Health Professions Act (Sobuwa and Christopher 2019).

Emergency medical care: In this study this refers to the evaluation, treatment and care of an ill or injured person in a situation in which such emergency evaluation, treatment and care are required, and the continuation of treatment and care during the transportation of such person to or between health facilities (Sobuwa and Christopher 2019).

Emergency care practitioner: In this study these are Emergency medical services personnel who have obtained a Bachelor of Technology or a four year, undergraduate, emergency care qualification and registered as such with the HPCSA under the auspices of the PBEC (Sobuwa and Christopher 2019).

Emergency medical services (EMS): An organisation or body that is dedicated, staffed and equipped to operate an ambulance, medical rescue vehicle or medical response vehicle in order to offer emergency care (Sobuwa and Christopher 2019)

Health care worker (HCW): Person engaged in direct patient care in either public or private health care settings (Sehume 2016). For the purpose of this study this term refers to all paramedical categories and all other in-hospital healthcare professionals.

LIST OF ACRONYMS

ACLS	Advance Cardiac Life Support
ACS	Acute Coronary Syndrome
AEA	Ambulance and Emergency Assistant
AHA	American Heart Association
AIDS	Acquired Immunodeficiency Syndrome
ALS	Advanced Life Support
AMI	Acute Myocardial Infarction
AST	Antimicrobial susceptibility testing
ATLS	Advanced Trauma Life Support
BAA	Basic Ambulance Assistant
BBBEE	Broad-Based Black Economic Empowerment
BHF	Board of Healthcare Funders
BHSC	Bachelor of Health Sciences
BLS	Basic Life Support
BTEMC	Bachelor of Technology in Emergency Medical Care
BVM	Bag-Valve Mask
CBRN	Chemical, biological, radiological and nuclear
CCA	Critical Care Assistant
CCU	Critical Care Unit
CSSD	Central Sterile Supply Department
CDC	Centers for Disease Control and Prevention
CHF	Congestive Heart Failure
COEC	College of Emergency Care
COPD	Chronic Obstructive Pulmonary Disease
CPAP	Continuous Positive Airway Pressure
CPD	Continuing Professional Development
CPUT	Cape Peninsula University of Technology
CUT	Central University of Technology
CVD	Cardiovascular Disease
CPD	Continuous professional development
CPR	Cardiopulmonary resuscitation
DEMCR	Department of emergency medical care and rescue

DUT	Durban University of Technology
DoH	Department of Health
EC	Emergency Centre
ECSSA	Emergency Care Society of South Africa
ECG	Electrocardiogram
ECP	Emergency Care Practitioner
ECT	Emergency Care Technician
ETI	endotracheal intubation
ETT	endotracheal tube
EMC	Emergency Medical Care
EMD	Emergency Medical Dispatch
EMS	Emergency Medical Services
EMT	Emergency Medical Technician
ETI	Endotracheal Intubation
GCS	Glasgow Coma Scale
GOSe	Glasgow Outcomes Scale extended
GREAT	Grampian Region Early Anistreplase Trial
HAI	
HCAI	Healthcare-associated Infection
HCW	Healthcare Worker
HEI	Higher Education Institution
HH	hand hygiene
HIC	High Income Country
HIV	Human Immunodeficiency Virus
HLD	high-level disinfection
HMC	Hamad Medical Corporation
HPCSA	Health Professions Council of South Africa
HR	Human Resources
HRD	Human Resources Department
HRM	Human Resources Management
ICU	Intensive Care Unit
IPC	Infection Prevention and Control
IM	Intramuscular
ISS	Injury Severity Score

ITLS	International Trauma Life Support
ILS	Intermediate life support
IV	Intravenous
KZN	KwaZulu-Natal
LMIC	Low- and Middle-Income Country
MANCOSA	Management College of South Africa
MERS	Middle East respiratory syndrome
MGD	Millenium Development Goal
MRSA	Methicillin-Resistant Staphylococcus aureus
MVA	Motor Vehicle Accident
NCD	Non-communicable Disease
NDEMC	National Diploma in Emergency Medical Care
NECET	National Emergency Care Education and Training
OPALS	Ontario Prehospital Advanced Life Support
OSD	Occupation Specific Dispensation
PALS	Paediatric Advanced Life Support
PPE	Personal protective equipment -
PBECP	Professional Board for Emergency Care Practitioners
PBEC	Professional Board for Emergency Care
PCI	Percutaneous Coronary Intervention
PEEP	Positive End Expiratory Pressure
PESTEL	Political, economic, social, technological, ecological and legal
PHC	Primary Health Care
PSVT	Paroxysmal Supraventricular Tachycardia
ROSC	Return of Spontaneous Circulation
SA	South Africa
SAMHS	South African Military Health Services
SAPAESA	South African Private Ambulance and Emergency Services Association
SARS	severe acute respiratory syndrome
SD	Standard Deviation
SGB	Standards Governing Body
SPSS	Statistical Package for Social Science

SOP	Standard Operating Procedure
STEMI	ST-Segment Elevated Myocardial Infarction
TB	Tuberculosis
TBI	Traumatic Brain Injury
UJ	University of Johannesburg
VRE	Vancomycin-Resistant enterococc
WHO	World Health Organisation

STRUCTURE OF THE DISSERTATION

Chapter One- introduction

This chapter introduces the study and provides the background to the study. This is done by providing insight into the laryngoscope blade and handle and what it is used for in the pre- and in-hospital environment. This chapter highlights the research problem, presents the rationale for the study, the objectives of the study and the layout of the thesis

Chapter Two-literature review

Presents the literature review which was conducted and which delved into the topic at both the national and international levels. The literature review provides an overview, summary, critique and appraisal of the current state of knowledge about this specific area of research.

Chapter Three-research methodology

This chapter briefly explains the research paradigm used in the study based, and further outlines the research design that was used for the study. The chapter also presents the setting of the study, the target population, sampling approaches that were used, and the inclusion and exclusion criteria that were applied. The chapter introduces the data collection tools as well as the data analysis approaches that were employed as well as the ethical considerations that were observed.

Chapter Four-results

This chapter presents the analysis of the study results which were obtained from the extensive microbiology lab work as well as the questionnaire.

Chapter Five-discussion

This chapter discusses the findings from both the laboratory and questionnaire data collection tools which were used. This chapter correlates the study findings with the literature review in order to conduct an interpretive and deeper analysis so as to address the study's research objectives.

Chapter Six conclusion and recommendations

Presents a summary of the study results, discussion and literature review as well as reflections and conclusions drawn from the results. The study's limitations and recommendations based on the study findings are presented.

A list of all references that were used and the annexures are included at the end of the dissertation.

CHAPTER 1: OVERVIEW OF STUDY/BACKGROUND

1.1 Introduction

This chapter presents the background and the research problem, highlighting the rationale for the study and what motivated the researcher to investigate this area of concern. The chapter ends by presenting the research question, objectives of the study and the layout of the thesis.

1.1.1 The laryngoscope in airway management

Fast and effective airway management (AM) is an absolute priority in any patient emergency. The AM of a patient can mean the difference between life and death or ability and disability. Management and stabilisation of the airway by the emergency care practitioner (ECP) is the single most important skill performed pre-hospital. Advanced life support (ALS) paramedics are required to open, clear, maintain and secure a patent airway as it is of utmost importance and within their scope of practice.

According to Fortunas (2015), the laryngoscope is an invasive tool used to perform the procedure commonly known as laryngoscopy either in the in-hospital or out-of-hospital setting for the purpose of AM. Also known as endotracheal intubation (ETI), laryngoscopy is a procedure performed by various doctors, anaesthetists and by ECPs. ETI is a core skill for paramedics in AM and is regarded as the gold standard of airway protection. With the use of the laryngoscope blade and handle, the endotracheal tube (ETT) is inserted and completely protects the airway thus creating a definitive airway. This important tool, consisting of the laryngoscope blade and handle, allows for the displacement of the tongue and visualisation of the vocal cords and ultimately allows for a placement of an ETT to bypass the vocal cords. The potential benefits of ETI include (Fourtounas 2015):

- Protection against aspiration.
- More effective ventilation and oxygenation.
- Allows suctioning of the airway.
- Delivery of anaesthesia drugs through the airway.

The skill requires significant experience to master, and often the presentation of the patient and situational characteristics may make the task quite difficult. Having said that, the ETI process is never a clean one as the laryngoscope blade is placed in the patient's oral cavity with contact being made between the blade and the surrounding mucous membranes, including any secretions and blood present. If the blades and handles are not adequately decontaminated this contact may allow for the transmission of infections. The is a major concern because South Africa has various patients who suffer from communicable diseases which can be transmitted from patient-to-patient. Some of these diseases are:

- Tuberculosis (TB).
- Human Immunodeficiency Virus (HIV)/AIDS
- COVID-19 and multiple variants.
- Lower respiratory tract infections.
- Pneumonia.
- Malaria.
- Hepatitis A, B, C, D and E.

1.1.2 Emergency care practitioner

In the pre-hospital setting of KwaZulu-Natal, the ECP often has to deal with instantaneous decision-making in uncontrolled environments, which may often be detrimental to themselves as well as the patient. In the emergency medical care setting the ECP is also faced with high call volumes composed of critically ill patients and needs to adapt and improvise in every case (Binks 2011). In the author's experience as an ECP and shift leader, the crew have limited cleaning equipment, and often, are too overwhelmed with the high call volumes to return to the ambulance base to correctly clean contaminated equipment such as the airway kit compromising the laryngoscope blades and handle. In some rural parts of KwaZulu-Natal, the ambulance or response vehicle that the ECP operates in may be 100 kilometres away from the nearest ambulance base or hospital. Ambulance staff members are expected to clean the contaminated equipment as best as they can, often while calls are waiting. Some may use the destination hospital sluice rooms to clean or decontaminate their equipment, however not every hospital trauma unit or hospital management is

accepting of this. This may result in the ECP resorting to cleaning the equipment sub-optimally. This raises the question of the cleanliness of their equipment and more specifically their airway kit comprising laryngoscope blade and handle, which is so valued in the AM of the critically ill patient (Naguran 2008).

Although maintaining and stabilising the patient's airway breathing and circulation are the major priority, hygienic protection of patients and ambulance staff are equally important. Victims of trauma, the immuno-compromised, and the very old and young are transported daily by the ambulance services. If the equipment is not adequately disinfected there is a danger that the very vehicles and equipment designed to save lives may be spreading disease. In addition, emergency medical services (EMS) staff, by the very nature of their profession, have a higher risk of exposure to pathogenic micro-organisms than most other health care professionals (HCPs). Understandably, due to the nature of emergency care work, some reduction in infection control (IC) standards must be accepted, but ignoring the fundamental principles of IC and prevention cannot be excused (Wilbers, Hamaekers and Jansen 2011).

Studies on healthcare associated infections (HCAI), and staff knowledge and practices in IC to date, have been almost exclusively hospital based when it comes to laryngoscopes. Therefore, given the anecdotal evidence presented above, it is important to investigate whether private sector ECPs' laryngoscope blades and handles are appropriately cleaned. A key aspect of such an investigation would be to determine if and to what extent micro-organisms, particularly those that are potentially pathogenic, are present on the airway tool. In addition, an assessment of the IC knowledge and decontamination practices of laryngoscope blades and handles can provide information about what ECPs know and do regarding the prevention of HCAIs (Naguran 2008).

1.2 Purpose of this study

The purpose of the research was to investigate the common practices used for laryngoscope decontamination in the pre-hospital environment, as well as to determine the presence, quantities and identification of bacteria on this piece of equipment. This study also aimed to establish the minimum inhibitory concentration

(MIC) of sampled disinfectant agents required to inhibit the visible growth of microorganisms identified.

1.3 Objectives of the study

- Objective 1. To identify and quantify the prevalence of bacteria and fungi on laryngoscopes blades and handles used by the selected EMSs
- Objective 2. To evaluate the current decontamination practices of the selected EMS personnel regarding the disinfection of laryngoscope blades and handles.
- Objective 3: To establish the minimum concentration of the disinfectants used by the selected EMS required to inhibit the growth of microorganisms during pre-hospital cleaning and disinfection.

1.4 Research hypotheses

1. The types and levels of bacteria and fungi will vary between the sample sites on the laryngoscope blade and handle
2. The types and levels of bacteria and fungi identified on laryngoscope blades and handles will differ from ambulance base to base.
3. The knowledge and practices of the selected EMS staff on laryngoscope blade and handle disinfection will differ at the different bases in the district.
4. The better the knowledge and practices of the selected staff on laryngoscope blade and handles decontamination, the lower the types and levels of bacterial and fungal contamination of the airway tool.

1.5 Null hypotheses

1. There is no difference between the sample sites on the laryngoscope blades and handles and the types and levels of bacteria and fungi.
2. The types and levels of bacteria and fungi on the laryngoscope blade and handles will not differ at the different bases.
3. The knowledge and practices of the selected EMS staff in ambulance laryngoscope blade and handle decontamination IC will not differ at the different bases in the district.

4. There is no relationship between the knowledge and practices of the selected EMS staff on laryngoscope blade and handle decontamination and the types and levels of bacterial and fungal contamination.

1.6 Motivation for the study

The researcher has always had an interest in IC and decontamination practises in the ambulance field. Being an operational ECP in the emergency medical care field, the researcher works 12-hour rotational shifts in an area which is geographically large with high call volumes. This translates to little or no time to return back to base to effectively clean equipment. Not many health facilities allow for the ECPs as well as ambulance crew to disinfect their equipment once they drop off patients, as they are thought to bring harmful pathogens into the hospitals. This leaves the pre-hospital staff with no option but to return to the base or to make do with what they have. The researcher has observed and encountered situations that show lack of IC and decontamination practices with regards to laryngoscope blades and handles specifically. This has led to the conducting of this research.

Senior management from the ambulance service under study have expressed concern regarding the lack of proper IC guidelines and the possible infection risk this may pose to patients and staff. This management has expressed its willingness and full co-operation for the study. Findings of this study could serve as a motivation for possible implementation of a comprehensive IC programme specific for laryngoscope blades and handles.

The second motivation was that the researcher has been unable to locate any South African published research studies that have investigated ambulance laryngoscope blade and handle decontamination or the effectiveness of IC or decontamination processes. In addition, there is no data to even identify the minimum concentration of cleaning agent required to effectively clean the airway tool. It is hoped that this baseline study will generate further research in the field of IC of the airway tool.

1.7 Assumptions of the study

Critically ill patients who require emergency care and airway intervention have the right to a decontaminated ambulance environment, as well as decontaminated equipment and staff practices, and to be protected from HCAIs. It is by assumption that all ECPs disinfect and effectively clean the laryngoscope blades and handles to prevent this, hence an element of IC control is assumed. It was also assumed that every ECP has their own laryngoscope blade and handle kit or use the company issued tool that is present on the vehicle airway kit and that there are IC protocols in place for the ECPs to follow and understand.

1.8 Delimitations of the study

This study was conducted in the province of KwaZulu-Natal in the private EMS sector. All laryngoscope blades and handles located on response vehicles in the selected EMS were investigated in terms of the types and levels of contamination regarding bacteria and fungi. The types and levels of micro-organisms on environmental surfaces of other EMS work environments or equipment were not determined such as bag valve masks or stethoscopes. Another delimitation is that the researcher only sampled one particular private sector EMS and not public EMSs.

1.9 Operational definitions

The following definitions indicate how the key variables have been operationalised for the purposes of this study.

Types of bacteria and fungi: Specimens were cultured and organisms identified according to standard medical microbiology laboratory procedures.

Levels of bacteria and fungi: A semi-quantitative enumeration of bacteria and fungi was obtained by measuring colony forming units.

AST test: Antimicrobial susceptibility testing (AST) is a laboratory procedure performed by medical technologists to identify which antimicrobial regimen is specifically effective for individual patients.

Gram stain test: A Gram stain is a laboratory test that checks for bacteria and its different types , identified by either being gram stain positive or negative by its colour outcome.

Methyl red test: The methyl red test is to check the ability of the organism to produce and maintain sufficient amount of stable acid as end product from glucose fermentation and to overcome the buffering capacity of the system.

PCR colony test: Colony polymerase chain reaction (PCR) is a method for rapid screening of colonies of yeast or bacteria that have grown up on selective media following a transformation step, to verify that the desired genetic construct is present, or to amplify a portion of the construct.

Adequacy of knowledge and practice: A structured questionnaire was used to collect data on the knowledge and decontamination practices of the selected EMS staff regarding ambulance laryngoscope blade and handle ICs. Questions included items on cleaning and self-protection practices, and questions on demographics. This data was scored to determine the extent to which it was in keeping with accepted standards of IC.

1.10 Glossary of terms

Infection control programme (ICP): The establishment's oral or written policy and implementation of procedures relating to the control of infectious disease hazards. This includes identification of the infectious disease process and surveillance; preventing / controlling transmission of infection; programme management / communication; education and research and IC aspects of employee health.

Operational ambulance staff: Staff that work on ambulances providing advanced, intermediate or basic patient life support.

Emergency medical care (EMC): The provision of treatment to patients, including first aid, cardiopulmonary resuscitation, basic life support, advanced life support, and

other medical procedures that occur prior to arrival at a hospital or other healthcare facility.

Emergency medical services (EMS): A group, department, or agency that is trained and equipped to respond in an organised manner to any emergency situation where there is the potential need for the delivery of pre-hospital emergency medical care and/or transportation.

Ambulance infection control programme (AICP): The implementation of policies and procedures to provide a safe and clean patient environment within ambulances, safe working conditions and best practices for all staff, in order to control infectious hazards. This includes prevention, identification and control of HCAI.

Advanced life support (ALS)
The provision of pre-hospital emergency care that paramedics are permitted to render, including advanced AM, electrocardiography, external cardiac pacing, defibrillation, intravenous therapy and medication administration.

Intermediate life support (ILS)
Intermediate level of pre-hospital emergency care that includes basic life support, basic electrocardiography, intravenous fluid therapy, limited medication therapy, trauma care, and other authorised techniques and procedures.

Basic life support (BLS)
Prehospital emergency care provided by persons trained in first aid cardiopulmonary resuscitation, and other non-invasive care.

Healthcare-associated infection (HAI): Infections that are acquired from within a health care setting. The infection was not present or incubating at the time that the patient entered the health care setting.

Blade: this refers to a conventional reusable non-fibreoptic laryngoscope blade that has been decontaminated and is considered “ready-to-use”.

Sample: Specimens collected in a specific manner during the study, by swabbing the blade and handle and sent to the lab for isolation of microorganisms.

Aseptic technique: Precautions, such as sterile gloves and instruments, are added to a healthcare procedure to prevent contamination of a person, object or area by microorganisms.

Decontamination: The removal of pathogenic microorganisms from objects so they are safe to handle, use, or discard (20). The four-step process implemented to remove pathogenic microorganisms from the laryngoscope blades including cleaning, disinfecting, rinsing and drying.

Cleaning: The removal of visible soil or foreign material from objects and surfaces by the use of an enzymatic detergent.

Disinfection: A process that eliminates many or all pathogenic microorganisms, except bacterial spores, on inanimate objects.

Sterilisation: The complete destruction of all living microorganisms, accomplished by physical methods (dry or moist heat), chemical agents, radiation or mechanical methods.

1.11 Structure of the dissertation

As was noted above, Chapter One introduces the study and includes the background to the study, the purpose, objectives, motivation, research hypotheses, assumptions, delimitations and definitions. The literature review that contextualises the study is found in Chapter Two. Chapter Three addresses the study methodology with regards to design, study population, sampling, data collection, study challenges, data analysis and ethical issues. Chapter Four contains the results and discussion for each of the three study objectives. Finally, the conclusion and recommendations can be found in Chapter Five. References and appendices follow.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

In order to assess ambulance laryngoscope blade and handle IC and decontamination practises in the selected EMS, the types and levels of bacteria and fungi were determined, the knowledge and practices of participants were evaluated, and, lastly the minimum concentrations of detergent amount were identified to effectively clean the airway tool. To achieve this, IC in the broader context needed to be examined. A literature search strategy is crucial in identifying previous bodies of knowledge in order to lay a solid foundation for the study. The literature review in this chapter provides the background that contextualises IC and prevention for the EMS setting. It also forms the conceptual framework for this study and contributed to the methodology and discussion of the results. The review will be achieved by discussing the significance of IC, relevant microbiology, identification of micro-organisms including potential pathogens, IC surveillance, and preventing/controlling the transmission of infectious agents. It will then focus on IC management / communication, education and research, knowledge and practice, compliance, and IC aspects of employee health. Finally, the importance of an IC programme and latest technologies in decontamination will be presented.

2.2 Source of literature

In this quantitative study, the researcher began the search of relevant evidence-based literature in January 2020 which was ongoing until the end of May 2023. The researcher was interested in this area of concern due to the fact that the researcher is an operational ECP who has encountered difficulty in disinfection of the airway tool.

According to Cecatti (2019) the researcher has to thoroughly sift the information gathered and find the gold which is the vital information needed to construct a validated literature review. A review of existing literature is important for the following reasons:

- To ensure that the researcher does not replicate a previous study.

- To find what are the most current and legitimate theories about the subject at hand.
- To recognise relevant theoretical or postulation frameworks for a research problem.
- To find widely accepted definitions of key concepts in the field of study.
- To regulate acceptable and appropriate suitable designs and data collection methods for a study(Leite, Padilha and Cecatti 2019).

In order to discover the existing knowledge on laryngoscopes as a potential source of infection literature from various medical, human resources and business publications need to be reviewed (Gangaram 2015). A systematic two-tier step approach was used by the investigator in order to find the most relevant literature pertaining to this study. Step one comprised a hard copy review of journal articles, thesis and dissertations and text books at the libraries at Durban University of Technology (DUT) and University of KwaZulu-Natal (UKZN). This type of search yielded minimal information but was useful nonetheless.

The second step of the literature review involved electronic searches. Repositories (Including of DUT and UKZN), online journals, academic search engines and internet sites were explored. The search engines utilised included: Google, Google Scholar, and PubMed. All material published later than the year 2000 was reviewed. Boolean terms for the online search included (in various forms and combinations):

- Paramedic.
- Healthcare workers.
- Advanced life support
- ALS practitioners.
- Laryngoscope blades and handles.
- Decontamination practises.
- Disinfection protocols.
- Pathogens swabbed and tested.
- Rapid sequence intubation / endo tracheal intubation.
- Infection control in emergency care setting.

The title and abstracts of these items were then analysed utilising the study objectives. All relevant material was included in the study. The researcher did extensive research and realised that there were a lot of studies conducted in the in-hospital setting but few studies in the pre-hospital setting and this was alarming. A point of saturation was reached when these same studies kept re-appearing as the literature search drew to a conclusion.

2.3 The laryngoscope tool

The direct visualisation of the vocal cords was discovered by the late Mr Alfred Kirstein of Germany. Prior to this discovery all observations were under indirect visualisation. The discovery was inspired when one of Kirstein's colleagues mistakenly passed an endoscope intended to view the oesophagus of a patient into the trachea instead, and this motivated interest for direct visualisation of the vocal cords. This event motivated Kirstein to develop the auto-scope, a device that facilitated direct visualisation of the larynx. Many adaptations were made to the device after the first auto-scope or laryngoscope was described in 1895. These modifications led to great improvements in laryngeal visualisation and the development of the laryngoscope which is the tool required to elevate the epiglottis to bring the vocal cords into view. As a result, Kirstein has become known as the pioneer of direct laryngoscopy and the laryngoscope. Basic techniques to remove foreign bodies from the airway and to visualise the tracheobronchial tree for diagnostic purposes resulted from his work. Kirstein's device and techniques are widely accepted in the practice of modern anaesthesiology and laryngology. In-hospital and pre-hospital staff use this tool known as the laryngoscope extensively.

The laryngoscope is made up of the blade and handle. The blade of the laryngoscope is also usually made out of metal or steel, however the use of plastic disposable blades are now an option and are becoming increasingly popular in modern medical devices. The handle is made out of steel to which the laryngoscope blade attaches. There are two basic styles of laryngoscope blade that are currently commercially available worldwide: the curved blade and the straight blade. The Macintosh blade is the most widely used of the curved laryngoscope blades. The most common laryngoscope

blade used for intubation in adults is the curved Macintosh blade. This is inserted into the right side of the mouth to displace the tongue laterally. The tip of the blade sits in the vallecula and is lifted forward to elevate the epiglottis and expose the laryngeal inlet. The Miller blade is the most popular style of straight blade(Saracoglu *et al.* 2023).

2.4 The laryngoscope in airway management

Endo-trachea-intubation (ETI) is a core skill for paramedics in AM and is regarded as the gold standard intervention for airway stabilisation. ETI is a process whereby the ETT is inserted correctly through the vocal cords with the aid of the laryngoscope blade and handle which then completely protects the airway. The potential benefits of ETI include:

- Protection against aspiration.
- More effective ventilation and oxygenation.
- Allows suctioning of the airway.
- Delivery of anaesthesia drugs through the airway.

The skill requires significant experience to master, and often the presentation of the patient and situational characteristics may make the skill of ETI quite difficult. ETI can increase on scene time and drastically affect the golden hour(Turner *et al.* 2020).

2.5 The role of ALS practitioners in EMC

In South Africa, ECPs are extensively trained to provide the highest and most optimal level of care in the pre-hospital environment. They are expected to possess excellent clinical judgement to allow them to function efficiently and independently in unstructured and constantly changing environments. Gangaram (2015) further elaborates that ECPs are equipped with the knowledge, skills and experience to be able to make sound clinical decisions in time critical situations. In relation to this one of their most salient and invasive procedures is the management of the patient's airway which involves the use of a laryngoscope to insert an ETT within the trachea of patients with a compromised airway. This invasive technique is done in conjunction with the administration of paralytic agents to provide the best conditions for ETI or else the patient may gag or vomit together with other bodily fluids which can be detrimental

to the patient as well as the ECP performing the skill. Furthermore, patients that they encounter could be critically ill with communicable diseases that may be disclosed to them or not. ALS practitioners play an important role in reducing morbidity and mortality in patients with life threatening emergencies. These emergencies include cardiac arrest, acute coronary syndrome, cardiac arrhythmias, respiratory emergencies, trauma care and pain management. Due to the ECPs exceptional training, knowledge, skills, experience, versatility as well as their ability to work in dangerous environment, this improves their marketability. It is for these reasons that they are recruited to international EMS systems (Gangaram 2015).

2.6 Healthcare associated infections

Currently the incidence of healthcare associated infections (HAIs) is increasing globally. Infections acquired in-hospital lead to increased duration of hospital stay, complicate patient care, increase morbidity and mortality, and increase the financial burden on patients, their family and the healthcare system. HAIs cause significant morbidity and mortality to patients and deplete already constrained healthcare budgets. In South Africa it is estimated that approximately one in seven patients entering hospitals are at high risk of acquiring HAIs. The tragedy of unsafe IC practices is that they may place patients at risk of greater morbidity or mortality than would derive from the illness being treated. Appropriate anaesthesia practices can decrease the incidence of HAIs (Guidelines for infection control and prevention in anaesthesia in South Africa 2021b).

HAI can be regarded as a patient safety incident stemming from the process of healthcare, and attention has largely focused on the epidemiology and prevention of adverse events. Thus, it is up to the staff in hospital and out of hospital to ensure that the patient has a safe environment. In saying this the ECP has the power to ensure that no harm comes to the patient(Guidelines for infection control and prevention in anaesthesia in South Africa 2021a).

According to Simmons *et al.* (2023), in the United States nosocomial infections affect 1.7 million people and contribute to 99 000 deaths annually. The cost to treat these infections and patients are not only a financial burden to hospitals individuals

concerned but also to the average person. These infections result in greater pay-outs by insurance companies, resulting in an increase in the standard premiums. In view of these facts, healthcare workers (HCWs) and providers should be doing everything they can to ensure that infections are not spread unknowingly by contaminated equipment be it in pre- or in-hospital settings(Simmons *et al.* 2023).

The World Health Organization (WHO) launched the “Clean Care is Safer Care” campaign based on the patient safety goal of *“Primum non nocere”* (“First, do no harm”). This campaign centres on preventing HAIs and involves promoting HH, blood safety, injection and immunisation safety, safer clinical practices and safer water, sanitation and waste management. Hand washing is advocated as one of the critical aspects in preventing the transmission of infection between patients and to HVWs. It is these basic principles that should be applied at all times to all aspects of healthcare, such as the use of “safe” laryngoscope blades, as patient safety – “doing no harm” – should be a priority (Gqaleni and Bhengu 2020).

In 2022, a study was performed in Libya’s four large hospitals. The aim of the study was to determine the prevalence of HAIs in acute care hospitals and generate updated estimates of the national burden of such infections. The study found that:

- Four per cent of hospitalised patients suffered from at least one HAI.
- Out of 22 000 hospitalised patients, 3500 suffered from infections.
- The dominant infections include pneumonia (21.8%), surgical site infections (21.8%), gastrointestinal infections (17.1%), urinary tract infections (12.9%), and primary bloodstream infections (9.9%) including catheter-associated bloodstream infections.
- Among the pathogens causing HAI, *C. difficile* (12.1%) is the leading pathogen closely followed by *Staphylococcus aureus* (20.4%), *Klebsiella* (10.9%), and *Escherichia coli* (24.2%). These are some of the pathogens that can be found in and around the ambulance equipment as well, especially the airway kit containing the laryngoscope blade and handle.
- Skin and surgical site infections are usually caused by *Staphylococcus aureus* and sometimes include *Methicillin-resistant Staphylococcus aureus* (MRSA)(Daw *et al.* 2023).

The Study on the Efficacy of Nosocomial Infection Control Project pointed out the possibility of reducing infections by a third by combining infection tracking and IC programmes. It was observed and noted that with greater awareness and strict preventive measures undertaken in the hospital settings, there can be a great reduction in the incidence of certain HAI. The implementation of robust infection surveillance and prevention practices has resulted in some success in the prevention of HAI. According to the CDC, the rates of CLABSI have decreased by 46% between 2008 and 2013 (Monegro, Muppidi and Regunath 2022). Hence if this could be transferred to the treatment and care of patients in the pre-hospital setting there would be an early decrease in HAI as well as a decrease in mortality and morbidity.

The current COVID-19 pandemic has created tough times across the globe, and protection of HWCs and their patients has been foregrounded. HCWs must first ensure that they are optimally protected against infections, and that their equipment is clean in terms of disinfection so that they do not transmit pathogens such as the COVID-19 virus and other harmful germs to their patients. The pandemic forced HCWS to carefully consider infection prevention and control (IPC) strategies. With a receptive audience, this is probably the ideal time for the release of this updated version of the IC guidelines in all aspects and in this case the laryngoscope blade and handle(Guidelines for infection control and prevention in anaesthesia in South Africa 2021b).

2.7 The laryngoscope and COVID-19 virus

Since 2019 the world has been effected by the 2019 novel coronavirus (SARS-CoV-2) and its multiple variants. This novel coronavirus disease (COVID-19) is associated with a respiratory illness that may lead to severe pneumonia and ARDS. Although related to the severe acute respiratory syndrome (SARS) and the Middle East respiratory syndrome (MERS), COVID-19 shows some peculiar pathogenetic, epidemiological and clinical features which to date are not completely understood.

COVID-19 seems not to be very different from SARS regarding its clinical features. However, it has a fatality rate of 3,4 %, lower than that of SARS (9.5%) and much

lower than that of MERS (34.4%) however in saying this there is still no cure for this virus at the time of writing this dissertation. The possibility of COVID-19 spreading in the community more easily than MERS and SARS is serious as human-to-human transmission is evident. Human-to-human transmissions have been described with incubation times of between 2-10 days, and is spread via droplets and contaminated hands or surfaces. The reproductive number (R_0) of COVID-19 (2.0–2.5) is still controversial. It is probably slightly higher than the R_0 of SARS (1.7–1.9) and higher than that of MERS (< 1) which is alarming. The coronavirus can survive as long as three days on stainless steel and even plastic, which has serious implications for laryngoscope blades and handles. The thought of transmitting COVID-19 via the laryngoscope bade which has been deemed safe and ready to use is devastating. Therefore, all pre- and in-hospital staff must clean and disinfect all the equipment they have used as carefully as possible (Petrosillo *et al.* 2020).

During the outbreak of SARS-CoV in Toronto 2002, despite existing safety protocols that were in place, half of all SARS-CoV cases were in fact HCWs, of which three died. It was further discovered that the HCWs in Toronto that were at greatest risk of becoming infected were those that were involved in the stabilising and securing of the airway such as ETIs via the use of the laryngoscope blade and handle, and HWCs that were exposed to aerosolised pathogens via nebulisers, CPAP, BiPAP, or high flow nasal oxygen therapy.

It was established that the SARS-CoV HCW infected cases from the Toronto (Canada) outbreak occurred following the intubation of SARS-CoV infected patients in ICU or trauma units, often when a difficult airway was encountered and when more than one attempt at intubation was required, and when more than three people were in the room. Improved measures and adherence to PPE reduced transmission during the second SARS outbreak. This was done to protect and ensure the safety of all HCWs across the board and by extension patients by preventing nosocomial transmission of the novel coronavirus (da Costa, Moreli and Saivish 2020).

SARS-CoV was first identified in Wuhan, Hubei Province, China, at the end of December 2019, and rapidly spread from Wuhan to other areas in China and then internationally. Patients diagnosed with COVID-19 in the early wave of disease were

documented to follow the clinical course of onset of dyspnoea in less than five days of admission, ARDS within eight days in 30% of cases, and the need for invasive mechanical ventilation and extracorporeal membrane oxygenation (ECMO) in 17% and 4% of cases, respectively. Thus, patients were in need of advanced AM and invasive airway therapy hence ETI and mechanical ventilation (Wang *et al.* 2020).

A retrospective observational study conducted in Chicago USA by Hur *et al.* (2020) identified individual risk factors associated with intubation among hospitalised patients with laboratory-confirmed COVID-19 in the Chicago metropolitan area. The following was observed:

- This study included 564 unique hospitalised patients admitted between March 1 and April 8, 2020, who tested positive for COVID-19.
- The rapid transmission of the SARS-CoV-2 virus, which can also be spread by asymptomatic individuals, led to a sharp increase in infections in respiratory depression and a need for ETI and mechanical ventilation, straining the health care system which they nor any other country were prepared for.
- Seventy-eight of these patients were excluded from the study because they had a DNR/DNI order or left the hospital against medical advice, leaving a final cohort of 486 patients to be analysed.
- The first intubation for a patient infected with COVID-19 occurred on March 7, 2020. The number of daily intubations for patients infected with COVID-19 gradually increased, reaching a peak on March 27, 2020, with 12 intubations, it was later observed that an increase of 32% of intubations occurred within 24 hours from arrival at the hospital.

The rate of intubation in the Chicago study was 32%. In China, 12% of hospitalised patient's required mechanical ventilation, while in New York 12.2% to 33.1% of inpatients infected with COVID-19 were intubated. Hur *et al.* (2020) highlighted that a third of intubated patients were intubated upon presentation in the emergency room, a sign of the rapid clinical deterioration experienced by a subset of patients infected with COVID-19 (Hur *et al.* 2020).

Looking at other countries such as England a large study at Intensive Care National Audit & Research Centre in London, looked at 2 249 COVID-19 patients receiving critical care at hospitals in the in UK's Case Mix Programme through April 3 2020 At the conclusion of the study, 1 559 patients were still in the ICU. For the 690 patients with recorded outcomes, half of these patients (50.1%) died, while 49.9% were discharged from critical care. A total of 388 patients received advanced respiratory support, with 128 (33%) of these patients also receiving basic respiratory support afterwards (Vizcaychipi *et al.* 2020).

A large retrospective observational study consisting of 1 591 critically-ill patients COVID-19 in Italy found that a subset of 1 287 patients needed respiratory support. Of those 1 287 patients, 88% were intubated and 11% (137 patients) received non-invasive ventilation. At the conclusion of the study, 58% of overall patients (920) were still in the ICU (Grasselli *et al.* 2020).

Evidently the laryngoscope tool is much needed in the critically ill patient and was frequently used in AM of the COVID-19 positive patient due to respiratory compromise. The question that comes to mind is whether the very tool that anaesthetists, trauma unit doctors as well as ECPs used in a transport vehicle had been properly disinfected to clear harmful bacteria or pathogens and ultimately the SARs-COV19 virus, its variants, and other pathogens.

The laryngoscope blade and handle can be seen as a lifesaving yet harmful tool if not disinfected correctly because it can transfer disease from patient-to-patient. Therefore, decontamination guidelines in relation to the laryngoscope blade and handle need to be designed, implemented and audited amongst all HCWs, especially ECPs who are in the front line with these patients.

2.8 Decontamination guidelines

Chen and Hao (2020) state that procedures utilising reusable medical or surgical instruments that come in contact with a patient's sterile tissue or mucous membranes and that are performed daily in the hospital setting, require proper decontamination prior to being used. The Centres for Disease Control and Prevention (CDC) and

Medicines and Healthcare products Regulatory Agency (MHRA) define the concepts of decontamination, cleaning, disinfection and sterilisation. Decontamination is the combination of cleaning, disinfection and sterilisation. Ensuring the safety or cleanliness of reusable objects is the final result of the removal of pathogenic microorganisms from objects. The term cleaning is the removal of visible soil or foreign material from objects and surfaces. Disinfection is “a process that eliminates many or all pathogenic microorganisms, except bacterial spores, on inanimate objects”. This is further subdivided into low and high-level disinfection. Sterilisation is defined as “a process that destroys or eliminates all forms of microbial life”. This process can be performed using either physical or chemical methods. The proposed use of a reusable item and the associated risk of pathogen transmission will determine the technique chosen(Hao *et al.* 2020).

Disinfection reduces the number of microorganisms present on an item, but most disinfectants are not sporicidal. However, by prolonging the exposure time of some disinfectants, spores may be destroyed thus it is necessary to increase the exposure time for the laryngoscope blades and handles to the disinfectant or cleaning agent, however the amount needed to adequately clean the equipment is of concern. It is important to note that microbial contamination is not decreased to levels obtained by sterilisation. There are three levels of disinfection: low, intermediate and high. Low-level disinfection eradicates most vegetative bacteria, some viruses and fungi, but has no effect against mycobacteria, endospores and the lipid viruses’ such as human immunodeficiency virus (HIV), hepatitis B (HBV) and herpes. Sodium hypochlorite or 70% alcohol and chlorhexidine are low-level disinfectants. Smaller viruses e.g. polio and coxsackie, and most fungi are destroyed by intermediate-level disinfection. Mycobacteria are destroyed by high-level disinfection, however, not all endospores, fungi and viruses are destroyed by this process. By increasing the contact time, to several hours, high-level disinfectants may produce sterilisation. Preventing the transmission of infection, via the laryngoscope blade, should be achieved by cleaning and then high-level disinfection, as per the CDC’s guidelines (Fourtounas 2015).

The Spaulding classification was originally proposed in 1957 and refers to Earle Spaulding’s grouping of medical and surgical instruments and the approach needed to their specific disinfection and sterilisation. This classification comprises three

categories and forms the cornerstone of the CDC's disinfection and sterilisation guidelines. It also forms the basis of the guidelines of the Association for Professionals in Infection Control and Epidemiology (APIC), and the Occupational Safety and Health Administration (OSHA). Spaulding's classification comprises critical, semi critical and noncritical items.

- Critical items are those that come in contact with sterile tissue or the vascular system. These items pose a high risk of transmission of infection and therefore require the necessary sterilisation. Such items include surgical instruments, cardiac and urinary catheters, implants and ultrasound probes for use in sterile body cavities. These are more in-hospital or theatre procedure equipment. These items can either be purchased sterile or sterilised prior to use.
- Semi critical items come into contact with non-intact skin or mucous membranes. The different levels of disinfection are based on demonstrating antimicrobial activity against established marker micro-organisms representing a range of pathogens. Although this classification system is probably as valid today as it was in 1957, the understanding of microbiology and micro-organisms has changed(Rutala and Weber 2019).

The CDC is the leading national public health institute of the United States of America and lists laryngoscope blades and handles as semi critical devices. They recommend Category 1A which is the strongest of all recommendations. Their recommendations are as follows:

- Once the airway tool has been used and whenever possible, use steam sterilisation by autoclaving or high-level disinfection by wet heat pasteurisation at greater than 70 ºC for 30 minutes.
- After disinfection, proceed with appropriate rinsing, drying, and packaging, taking care not to contaminate the disinfected items in the process(Gómez-Ríos *et al.* 2023).

A key issue that Joint Commission and Centres for Medicare and Medicaid Services surveyors look for specifically:

- Wrapping of laryngoscope blades in individual packaging to prevent contamination while being stored for the next use.

- The rationale is that the blade and handle is a semi critical device and needs to undergo appropriate reprocessing and be protected from contamination prior to the next use. These blades are also used in a variety of other locations, such as the emergency department(Gómez-Ríos *et al.* 2023).

Compared to other authorities such as The American Association of Nurse Anaesthetists who have a long history of supporting the IPC clinical practices of its members, they recommend that:

- laryngoscope blades require both high-level disinfection and sterilisation prior to being deemed safe or ready to use and are also in agreement on the CDC/HICPAC above mentioned guidelines(Gómez-Ríos *et al.* 2023).

The South African Society of Anaesthesiologists (SASA) compiled guidelines for IC practices in 2021. These guidelines recommend the use of disposable laryngoscope blades as the preferred option. Options for the reprocessing of the laryngoscope blades and handle include:

- The use of disposable or single-use laryngoscope blades however their efficacy in ETI is questionable.
- Disposable laryngoscope blades should be discarded after single use, and should not be reused, even after sterilisation.
- If reusable laryngoscope blades (RLBs) are used, sterilisation by steam should be monitored as well as the overall handling of the blade and handle. After using it on the patient for ETI the blade must be removed from the handle immediately. However this may be difficult in the pre-hospital setting as the ECR is never in a controlled or safe setting.
- SASA also drives home the point that one must not close the blade on the handle because this will contaminate the handle and if so consider covering the handle in a disposable plastic.
- Looking at high-level disinfection (HLD) for laryngoscope blades and handles SASA mentions that there are significant concerns about the use of HLD in South African in-hospital settings regarding decontamination as there is evidence of poor compliance and in-service training for anaesthetic nurses is needed.

- SASA recommends that disinfection should include removal of the batteries, sterilisation only if blood is present and the exposure and cleaning with Chlorhexidine 2%/alcohol 70% should be used. They also have put into place the increase in availability of laryngoscope blades to decrease time delay between cases. The even call for the sending of the blades and handles to the central sterile supplies department for sterilisation.
- SASA calls for a step by step disinfection plan of action as well as referring to the manufacturing guidelines(Samuel 2021).

Looking at these guidelines it can be deduced that there are no clear formal decontamination guidelines available.

The Medicines and Healthcare products Regulatory Agency makes use of a different classification in their guidelines on sterilisation, disinfection, and cleaning of medical equipment. This classification also contains three categories: high, intermediate and low risk items. This classification can be correlated with the Spaulding classification. High risk items are either introduced into a sterile body area or come into contact with non-intact skin or no intact mucous membranes. The recommended technique for decontamination is sterilisation. Items in the intermediate risk group have come into contact with mucous membranes, were previously used on immunocompromised patients or have been contaminated with virulent microorganisms. Sterilisation or disinfection is required. If items have come in contact with healthy skin or have not come in contact with the patient, they are placed in the low risk category and cleaning is considered adequate. However, there is no consensus among the various organisations' guidelines on rigid laryngoscope decontamination. Whereas most of these organisations, such as the American Association of Nurse Anaesthetists and CDC agree on the classification of laryngoscope blades and handles as semi critical items requiring high-level disinfection as a minimum prior to reuse, the guidelines of the Associated Perioperative Registered Nurses classify the laryngoscope blade as a semi critical item and the handle as a noncritical item requiring only low-level disinfection. This is a worrisome discrepancy from the other guidelines as Williams *et al.* (2010) clearly demonstrated that the handle can be as contaminated as the blade. High- and low-level disinfection achieve immensely different levels of

decontamination. High-level disinfection will eradicate vegetative bacteria, mycobacteria, viruses, fungi and some bacterial endospores; whereas, low-level disinfection does not achieve this.

According to Chen *et al.* (2020) the Chinese Society of Anaesthesiology (CSA) and the Chinese Association of Anaesthesiologists (CAA) formed a task force to produce recommendations for HCWs regarding management of patients in the perioperative setting as well as for emergency AM outside of the operating room. The recommendations were created mainly based on the practice and experience of anaesthesiologists who provide care to patients in China. Therefore, adoption of these recommendations outside of China must be done with caution. The recommendations are based on World Health Organization and National Health Commission guidelines for the prevention and treatment of COVID-19, and the clinical experiences of frontline HCWs. They were aimed at providing recommendations on how to manage COVID patients regarding ETI management as well as disinfection guidelines of equipment. The guidelines recommend that:

- Disposable blades be used for ETI.
- If a video laryngoscope is being used the video laryngoscope blade be disposed of as well.
- Laryngoscope handles, and other non-disposable equipment should be cleaned and disinfected with 2% to 3% hydrogen peroxide, 2 g/l to 5 g/l chlorine disinfectant wipes, or 75% alcohol wipes after the completion of each case and again at the end of the shift (Chen *et al.* 2020).

Ahmed and and Fentie (2021) conducted an observational study to assess the current decontamination practice of anaesthetic equipment in a level one hospital. The study consisted of 70 patients who were operated on during the study period and data was analysed. Direct observation of the anethetists data focused on the way they processed different pieces of anaesthetic equipment after they used them either to reuse or to store them by using a standard checklist. It was observed that 94.2% of anaesthetists followed only the first step of disinfecting the laryngoscope blade and 74.2% of anaesthetists stored both the laryngoscope blade and handle appropriately. The rest of the steps were performed inadequately and none of the anaesthetists

applied alcohol for both blade and handle which this showed that most anaesthetists were disinfecting the blade with water only (Ahmed and Fentie 2021). Anaesthesia equipment should undergo at least HLD to be decontaminated from most infectious microorganisms like HIV, hepatitis, and tuberculosis because it has been in contact with mucus membranes and blood. In the literature, a contamination rate of 57.3% was found, with high-level contamination accounting for 22.2% of these. Common commensals are the most frequently isolated microorganisms (79.1%), but important hospital pathogens such as *Enterobacte* species and *Acinetobacter baumannii* have been isolated from blades with high-level contamination (Lowman, Venter and Scribante 2013). Ahmed and Fentie (2021) recommended that the anaesthetic equipment disinfection protocols needed improvement, and, more importantly, that special attention should be given to laryngoscope disinfection protocols since this equipment is used regularly in theatre between patients. Furthermore, they recommended that the high-level disinfectant solution should be changed every 24 hours. Simply put, there were guidelines in place but the anaesthetists did not follow them even in a level one facility. Comparing this study to the ECPs who are cleaning or disinfecting their tools in the pre-hospital setting they have no clear guidelines on disinfection of the laryngoscope blade and handle which begs the question as to what pathogens are found on the tool after a possible inadequate disinfection process (Ahmed and Fentie 2021).

2.9 What is infection prevention and control?

The World Health Organisation defines IC as a discipline exclusively concerned with preventing nosocomial or healthcare-associated infections. The English Oxford dictionary has defined epidemiology as a specific science and division of medicine which studies the prevalence, dispersion and control of infectious diseases relating to healthcare in a defined population. It is known as the cornerstone of public healthcare and informs critical policy decisions and specifically evidence-based practises by mainly analysing risk factors for diseases and targeted preventive healthcare initiatives. IPC is regarded as a sub-discipline of epidemiology and refers to the practical instead of the academic aspect. Infection control is a fundamental, however often underrated and isolated, part of the healthcare infrastructure.

The main purpose and mission of the World Health Organisation's Infection Prevention and Control in Healthcare initiative is to aid in decreasing dissemination of infections correlated to healthcare by implementing and evaluating IC policies. The ultimate goal is to ensure the utmost safety for patients as well as healthcare personnel. Numerous research studies state that certain policies have to be adhered with in order to significantly suppress the risk of the transmission of infectious diseases(Analgesia 2021).

2.10 Bacterial contamination of laryngoscopes

The laryngoscope is an important invasive instrument in the ECP's armamentarium. This semi-critical tool regularly comes into contact with mucous membranes, saliva and at times, blood, not forgetting the many immunological diseases such as HIV/AIDS, TB or even COVID-19 that the patient may possess. A wide range of micro-organisms, including potentially harmful microbes, have been grown from routinely used laryngoscope blades which leads to the debate on the cleanliness and disinfection of this tool. Currently there is no standardised protocol in place to decontaminate and disinfect this tool. The laryngoscope blades and handles should be cleaned, followed by high-level disinfection, pasteurisation, or sterilisation. The American Society of Anaesthesiology offers no guidelines for the decontamination of this tool. On the subcontinent of India, a survey consisting of 100 participants was aimed at investigating the uniformity of decontaminating procedures. It was established that there was no clear guidelines in laryngoscope decontamination as cleaning procedures differed from one individual to another. This filters to the EMS staff who have no clear guidelines to follow with regard to hygiene as well as decontamination protocols pertaining to the laryngoscope blade and handle, both internationally and nationally(Pino *et al.* 2023).

According to Chawla and Gupta (2016), IC in anaesthesia as well as the pre-hospital sector is an area of scrutiny and concern hence the role of the laryngoscope in the spread of infection is often not well appreciated by practising ECPs. This is depicted in a study conducted by Call and co whereby 60 rigid laryngoscopes in current use were swabbed and analysed. This was done in an attempt to assess whether the decontaminating agents were effective in concentrations and what bacteria was

present after cleaning them. The results showed that of the samples sent for culture, 75% were positive for bacterial contamination. Of these positive cultures, 62.5% yielded coagulase-negative *Staphylococci*, and 17.5% *Bacillus* spp. These results show that this semi critical tool is indeed a transport vehicle for microorganisms that can be transported from health care worker to patient and vice versa.

Blood is an excellent environment for many forms of pathogenic organisms to flourish. Therefore, it can be assumed that nosocomial infections can result from visible and occult blood present on reusable anaesthetic airway equipment used by the EMS staff as well as in-hospital staff. Since these infections often have major economic and health related consequences, prevention should be a top priority for the pre and in-hospital staff(Tarani 2020). Bahera *et al.* (2021) assessed specimens from 213 laryngoscope handles which were deemed 'ready for patient use' in the anaesthetic rooms of 32 operating theatres for bacterial contamination. A further 116 specimens from 58 of the handles were tested for occult blood contamination. One or more species of bacteria were isolated from 86% of the handles, and included organisms such as Enterococci, methicillin-susceptible *Staphylococcus aureus*, *Klebsiella* and *Acinetobacter*. Cultures did not yield any anaerobes, fungi, methicillin-resistant *Staphylococcus aureus*, vancomycin-resistant *Enterococci* or multidrug-resistant Gram-negative bacilli. Although the majority of organisms isolated were not pathogenic, their presence indicates the potential for transmission of pathogens from laryngoscope handles. Strategies to address contamination of handles include revision of procedures for disinfection and storage prior to use, introduction of disposable handles or sheaths, and re-design of handles to eliminate knurled surfaces and contact points(Bahera 2021).

Regarding the decontamination process, one needs to question if the tool is decontaminated effectively and deemed ready or whether the microorganisms are resistant to the process hence creating a perfect environment for the pathogens to breed and ultimately move from patient-to-patient. Lowman, Venter and Scribante (2013) found that laryngoscope blade decontamination was not always effective. A total of 110 samples were examined for bacterial growth, of which 57.3% were positive for microorganism growth. This study was in accordance with the previously conducted international studies, depicting the growth of non-pathogenic and pathogenic

microorganisms on the ready-to-use laryngoscope blades and also microorganisims resistant to certain agents used to clean the blade and handle. Organisms isolated were diphtheroids, viridans *Streptococci*, *Micrococcus* spp, coagulasenegative *Staphylococci*, *Candida albicans*, *Bacillus* spp, *Arcanobacterium haemolyticum*, *Enterobacter* spp and *Acinetobacter baumannii* (Lowman, Venter and Scribante 2013).

Therefore the decontamination process of cleanliness as well as uniformity is questionable. Tarani and Janweja (2020) conducted an online survey of 100 anaesthesiologists in India to determine the methods of laryngoscope decontamination adopted in their respective settings. The authors found that no fixed protocols existed for laryngoscope decontamination, with the method varying from one health facility to another. Thus, there is a need to develop definitive guidelines on this subject which can be implemented in South Africa as well as other countries as the guidelines which exist are incomplete, inconsistent, and inadequate, and there is a lack of consensus(Tarani 2020).

For the pre-hospital environment it is best to use combined methods that involve cleaning, disinfection, and sterilisation together. Enzymatic agents used by the EMS staff vary from company to company depending on cost as well as availability of the agent. A chlorine-releasing agent such as sodium hypochlorite solution (bleach) is a classic example of an intermediate-level disinfection chemical. In sufficient concentrations and with enough contact time, bleach will disinfect surfaces contaminated by the human immunodeficiency virus (HIV) and Hepatitis B. Good examples of locally available intermediate-level disinfectants are SteriTech Concentrated Antimicrobial Solution and SteriTech Disinfecting Cleaner. Items that should be cleaned and disinfected with high-level disinfectants include patient contact items such as laryngoscopes, stethoscopes, mattresses, blood pressure cuffs, splints, scoop stretchers, defibrillation paddles, spider harnesses, and head blocks. High-level disinfectants are far more reliable at disinfection of a wide range of pathogens, and in a much shorter time than intermediate-level disinfectants. Good examples of locally available high-level disinfectants are Prodis XP which contains glutaraldehyde and ammonium chloride, and SteriTech High Level Disinfectant. In addition to cleaning and

disinfection, the laryngoscope blade and handles should be fully sterilised using methods such as pressurised steam(Pino *et al.* 2023).

2.11 The chain of transmission

The chain of transmission can be defined as the links necessary for the transmission of bacterial organisms. The chain comprises six characteristics that explain the transmission of various microorganisms (Table 2.1).

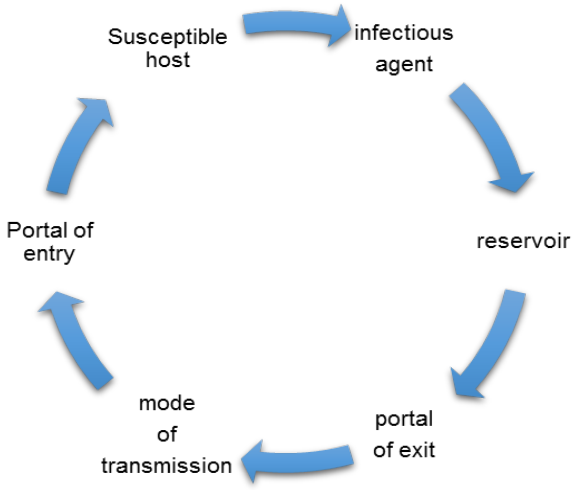

Figure 2.1: The chain of transmission of microorganisms

The chain of transmission is regarded as the method by which all infectious diseases are spread. The primary goal of IPC practises is to break a link in the chain to prevent the transfer of microorganisms.

The six characteristics of the chain of transmission include:

- The infectious agent- A microorganism (viruses, bacteria or fungi) that is capable of causing disease;
- The reservoir- An area that microorganisms are able survive and breed on to be ready for transmission, which includes any area that is not cleaned after exposure, soiled uniform, boots, the individual, the ambulance patient compartment and in this case the laryngoscope blades and handles.

- The portal of exit- The specific path in which the pathogen leaves the reservoir or patient. This could be the patients stools, bodily fluids and in particular through the mouth and nose. An example of this could be a patient with a traumatic brain injury with a compromised airway due to bleeding through the nose and mouth. Another example is when a patient requires laryngoscopy or ETI and is not adequately paralysed and gags or coughs. This allows ejection of bodily fluids through the nose and mouth and onto the airway tool.
- Mode of transmission- according to Faye, Boëlle and Heleze (2015) this is advancement of the bacterium from one host to the next, often transmitted via respiratory droplets which is evident in asthma patients who receive nebulisation, blood contact in trauma patients, or other bodily secretions. Direct contact is person-to-person transmission of pathogens through physical contact. The organisms travel in droplets over less than 1 metre in distance and are inhaled by a susceptible host. Indirect contact includes both vehicle-borne and vector-borne contact. A vehicle is an inanimate go-between, an intermediary between the portal of exit from the reservoir and the portal of entry to the host. Inanimate objects such as soiled linen and surgical instruments such as laryngoscope blades and handles are common channels that can transmit infection.
- The portals of entry- The specific point where the infectious agent enters the new host (nose, skin, or mouth), portal of entry determine the type specific personal protective equipment (PPE) that is required to ensure the safety of healthcare personnel, family and visitors.
- The susceptible host- Any individual who is at risk of infections due to immature immune systems or already compromised in terms of health conditions (paediatrics, geriatrics and the immune-suppressed individuals) (Faye, Boëlle and Heleze 2015).

2.12 Disinfection

According to Ghedini *et al.* (2021) disinfection can be best described as a process that reduces the number of microorganisms present on any item to standards that can be deemed safe and secure from the general public health standpoint. The authors point out that most disinfectants are not sporicidal, in the sense that these disinfectants do

not kill cells that plants, fungi or bacteria that patients contain in and around their bodies may produce. Certain bacteria produce spores has a way to defend themselves and they are evidently thick in nature. In character they can resist high temperatures, humidity and other environmental conditions. That being said, South Africa is a country with high temperatures, especially KZN which has an average humidity of 80% all year round except in winter when humidity is 60%. This does not augur well for the airway tool which may be stored in the airway compartment unwashed or not appropriately disinfected by the practioner (Ghedini *et al.* 2021).

According to Al-Sayah, disinfectants are used to sterilise surfaces and spaces. An area or a device is considered sterilised when the disinfectant completely kills and removes microbial infecting agents. The capacity of a disinfectant to destroy a microbe or bacterium depends on the mode of action of the chemical, the molecular structure of the pathogen's surface, and the intracellular vulnerability.

Due to COVID-19 practitioners in formal health care environments or lay people in a home or work environment recognise the role that surface disinfection plays in infection inhibition and that it is a central pillar of control strategies to control transmissible disease outbreaks. Disinfectant or sanitising products are complex formulations where stability, organoleptic and sensory features, and safety for the environment and consumers, are as important as their micro-biocidal efficacy (Ghedini *et al.* 2021).

2.13 Types of disinfectants

When germicidal agents are applied to inanimate objects such as environmental surfaces or instruments used to perform medical procedures they are then termed disinfectants. Disinfectants work by destroying microbial surfaces, often by alkylation, oxidation, or reaction with proteins. There is a large variety of disinfectants but they do not all achieve the same level of disinfection. Chemical agents or disinfectants are used to achieve high-level disinfection for semi critical items. Disinfectants can be used alone or in combination so as to achieve a better result or more effectively clean the tool or surface so that it can be safe. Examples include alcohols, chlorine and chlorine compounds, paracetic acid, glutaraldehyde, formaldehyde, hydrogen

peroxide, ortho-phthalaldehyde, iodophors, quaternary ammonium compounds and phenolics. Several of these chemicals are toxic and hazardous and personnel exposed to them should always adhere to universal precautions(Ghedini *et al.* 2021). The different disinfectants are briefly discussed below.

2.13.1 Chlorhexidine gluconate

Chlorhexidine gluconate hand disinfectant is a cationic bis-biguanide antiseptic chemical that obliterates and targets organisms via membrane disruption and cytoplasmic precipitation. It is effective against all microbial organisms commonly associated with catheter-related infections and adheres to the stratum, prolonging protection after application for hours. A 4% aqueous solution is marketed for skin cleaning and preoperative surgical hand scrub. A 2% solution in 70% isopropyl alcohol has been approved by the US Food and Drug Administration (FDA) for pre-operative skin prep. Chlorhexidine has immediate antimicrobial activity however it is still slower than that of alcohols. It has good activity against Gram-positive bacteria, somewhat less activity against Gram-negative bacteria and fungi, and minimal activity against mycobacteria. Chlorhexidine is not sporicidal meaning that it does not kill spores which are cells that fungi and bacteria produce. It has in vitro activity against enveloped viruses such as herpes simplex virus, HIV, cytomegalovirus, influenza and RSV, but significantly less activity against non-enveloped viruses such as rotavirus, adenovirus and enteroviruses The antimicrobial activity of chlorhexidine is not affected by the presence of organic material including blood. Chlorhexidine gluconate has been incorporated into a number of HH preparations. Addition of low concentrations (0.5% to 1%) of chlorhexidine to alcohol-based preparations results in significantly greater residual activity than alcohol alone. When used as recommended, chlorhexidine has a good safety record(Brookes *et al.* 2020).

2.13.2 Alcohol

Alcohol disinfectants are not considered high-level disinfectants. Ethyl alcohol and isopropyl alcohol are rapidly bactericidal against vegetative bacteria; they are also tuberculocidal, fungicidal and virucidal. However, they do not destroy bacterial spores and are not able to destroy hydrophilic viruses, such as poliovirus and coxsackie virus.

Medical and surgical items should not be sterilised with alcohol as it lacks the ability to penetrate protein-rich materials. Most alcohol-based hand antiseptics contain either ethanol, isopropanol or n-propanol, or a combination of two of these products. The antimicrobial activity of alcohols results from their ability to denature proteins. Alcohol solutions containing 60% to 80% alcohol are most effective, with higher concentrations being less potent. This paradox results from the fact that proteins are not denatured easily in the absence of water. Alcohols have excellent in vitro germicidal activity against Gram-positive and Gram-negative vegetative bacteria including multidrug-resistant pathogens such as MRSA and VRE, *M. tuberculosis*. However, they have virtually no activity against bacterial spores or protozoan oocysts, and very poor activity against some non-lipophilic viruses. In tropical settings, Due to alcohol's lack of activity against parasites, the extensive use of alcohol-based handrubs, instead of handwashing (which may at least guarantee a mechanical removal effect) is a concern. Some enveloped (lipophilic) viruses such as herpes simplex virus, human immunodeficiency virus (HIV), influenza virus, RSV and *Vaccinia virus* are susceptible to alcohols when tested in vitro. For ethical reasons, in vivo tests were not conducted with HIV. Other enveloped viruses that are somewhat less susceptible, but are killed by 60% to 70% alcohol, include hepatitis B virus and probably hepatitis C virus(Neufeld *et al.* 2020).

2.13.3 Bioscrub antiseptic skin cleaner

Bio scrub antiseptic skin cleaner has 4% chlorhexidine gluconate and is used as a skin wound cleanser and a general skin cleanser. This medicine is used as a surgical hand scrub and to cleanse the skin before surgery to help prevent infections. It is considered a steriliser and antiseptic that can be used to sanitise surgical instruments in the pre- and in-hospital setting. It is on the WHO's listing of essential medicines which is a list of the securest and most efficient medicines required in a health setting. In terms of its impact on bacteria, it causes the cell walls of the bacteria to break down resulting in cell death. However, it is ineffective against adenoviruses and polioviruses. The efficiency of chlorhexidine in relation to herpes viruses has not yet been determined.

2.13.4 Cidex

Another high-level disinfectant is Cidex® which is used for medical and surgical instruments. It is fast acting and effective and is available in three formulations: Cidex®14-Day, Cidex® Plus 28-Day, Cidex® OPA. Cidex® 14-Day is a 2.4% alkaline glutaraldehyde solution. At 25 °C it reportedly kills 99.8% of *Mycobacterium tuberculosis* if the instrument is immersed for 45 minutes. Glutaraldehyde, a high-level disinfectant, is normally available in an acidic solution. This solution requires activation by the addition of alkalinating agents in order to render it sporicidal. This particular formulation can be reused for 14 days (Pearlman 2019).

Cidex® Plus 28-Day contains a higher concentration of glutaraldehyde and has a composition of a 3.4% alkaline solution that is used to obtain high-level disinfection. It destroys the microorganisms on tools or surfaces within 20 minutes at 25 °C. This formulation can be reused for 28 days. Glutaraldehyde is a saturated dialdehyde used as a high-level disinfectant and chemical sterilant however it is not sporicidal. Glutaraldehyde possesses the advantage of being noncorrosive and can therefore be used to decontaminate endoscopic equipment, rubber or plastic equipment, spirometry tubing, transducers, thermometers and anaesthesia and respiratory equipment. An immersion time of 10 minutes will destroy *Mycobacterium tuberculosis*, fungi and viruses. However, immersion times of three hours are required to destroy *Bacillus* and *Clostridium* spores (Pearlman 2019).

Instruments must be thoroughly cleaned prior to placement in glutaraldehyde, as any raw material that is still present will cohere to the surface of the instrument. Prolonged exposure of organic material to the instrument can cause unwanted side effects in HCW, such as skin and mucous membrane irritation, asthma, rhinitis and epistaxis. Cidex® OPA, unlike the other two Cidex® formulations, uses an orthophthalaldehyde solution. No mixing or activation is required prior to use. This formulation can be used on a wide range of medical devices, most importantly devices made of steel. In 12 minutes at 20 °C, it is effective against *Mycobacterium tuberculosis*. The FDA has cleared Cidex® OPA as a high-level disinfectant with immersion times as short as 12 minutes at 20 °C and five minutes at 25 °C (Pearlman 2019).

2.14 Current knowledge of EMS with regard to infection prevention and control

In the pre-hospital emergency medical environment in KwaZulu-Natal, the working day requires many quick decisions in dangerous environments, with an overload of cases. The EMS crew have little or no equipment and often need to make an effort to get sub-minimum material to clean vehicles and equipment. The inappropriate decontamination or IPC practises are also due to the high number of cases and lack of time allocated to clean the EMS vehicles. This could also be due to an appropriate area designated to decontaminate their equipment effectively leaving them with no alternative but to proceed to hospitals or clinics to use their sluice rooms. In rural areas in KwaZulu-Natal certain hospitals with the appropriate cleaning agents are sometimes 100 kilometres away and the EMS crew are required to clean the vehicle which transports critically ill and injured patients to the best of their ability.

Infection and prevention control is an essential component of health care be it in-hospital or pre-hospital. Most HCWs' knowledge of IC principles and standards is poor or inadequate. There is a paucity of research examining paramedic knowledge of IC principles and standards, despite the fact that they are in the front line of patient contact and treatment. If early recognition is achieved from the When EMS personnel recognise the infectious condition of a patient they are transporting (for example MDR TB ,CRE, COVID-19 and HIV-AIDS) they can notify the in-hospital staff who can then prepare appropriate IC control. Once these patients have been transported to the receiving facility the staff should have training knowledge and decontamination skills to conduct disinfection of the ambulance patient compartment and equipment.

Alkarami *et al* (2023), performed a confidential and anonymous mail survey which was distributed to all 160 paramedics working in a state-wide middle-eastern ambulance service. The objective of this study or survey was to determine paramedic knowledge of standard IC definitions and principles in Saudi Arabia EMS. The following was observed:

- Only 40 % of the participants identified the correct links of the chain of infection.
- Correct identification of the definition of 'nosocomial' was made by 27.9% of participants. Less than 17.2%, of participants identified 'standards and additional precautions' as the current system of IC.

- More than 63% of the EMS exhibited lower levels of understanding regarding infection control measures .

Almakrami and co's study clearly shows that participants' knowledge of standard definitions and principles was generally poor. The authors recommended further research be conducted in IPC within the pre-hospital paramedic setting. The authors pointed out that there can be well documented protocols in place but this is not enough on its own. The EMS staff need to be well trained and audited in IPC policies and procedures to ensure that they are putting knowledge into practise(Almakrami 2023)

Mencl *et al.* (2000) conducted a survey of 523 191 EMS personnel regarding the knowledge they possess on IPC with specific regard to the transmission of four infectious diseases, namely: HIV, hepatitis, meningitis and tuberculosis. The survey comprised 100 critical questions relating to their knowledge of universal precautions, transmission routes such as uniforms, equipment, post exposure actions, and parameters examining personal concerns about infectious diseases. The following results were obtained:

- 34% of the EMS reported inadequate knowledge of infectious diseases (IDs) to protect themselves.
- Needlestick was incorrectly reported for TB (37%) and meningitis (60%).
- Their perceived exposure for all four diseases ranged from 65% to 73%, but only 10% to 40% reported follow-up testing. Families' concern about EMTs' exposure was reported as moderate to high by 63% of the respondents.

The research concluded that EMS personnel have limited knowledge of universal precautions, transmission routes and post-exposure action and recommends that further education and continuous training for EMS personnel be conducted in these areas, focusing on routes of transmission, risk of exposure, appropriate use of post exposure prophylaxis and requirements for follow-up testing(Bitely, Miller and Glauser 2019).

Koivulahti, Tommila and Haavisto (2020) examined and compared whether in-hospital staff such as nurses and pre-hospital emergency personnel were able to identify a patient with a potentially communicable infectious disease and activate the respective disaster plan. None of the paramedics were able to identify and recognise that the patients were suffering from a communicable disease, much less smallpox, nor did they adopt any of the IC or prevention measures required for such an infection. The study raised concerns about the ability of paramedics and other emergency medical personnel to detect a patient with a highly contagious disease and subsequently comply with IC standards and principles(Koivulahti, Tommila and Haavisto 2020).

EMS personnel are prone to infectious diseases and often take-home harmful microorganisms. Education and training in IPC in conjunction with comprehensive IPC programmes play a vitally important role in reducing mortality and morbidity of patients, as well as healthcare practitioners. IC surveillance is the primary tool for prevention of infection and for reducing the rate of infection. Despite their importance, little attention has been paid to the role that pre-hospital practitioners and EMS vehicles play in the spread of infectious diseases. Managers and staff lack knowledge in IPC but are keen to gain essential knowledge on infectious diseases as well as have IPC programmes in place(Chetty, Govender and Sobuwa 2022).

According to Yoshikawa (2022), all practitioners in the pre-hospital environment require education and involvement in the implementation of IC policies. Improvement in knowledge and practice requires comprehensive education programmes on IPC with specific regard to bacterial contamination of uniforms. These programmes for paramedics should include vital pillars such as; the management of personal health and safety, occupational exposure, and immunisation. Paramedics are required to possess a good understanding of the transmission of infection, understand prevention, and analyse their practice to obtain improvement. IC skills should be observed and practised and not merely taught and forgotten(Yoshikawa *et al.* 2022).

2.15 Hand hygiene amongst health care workers

The hands of heath care workers (pre-hospital and in-hospital) are the main vehicle in the transmission of infectious agents in the health care setting. HH is imperative and is regarded as the cornerstone in infection and control strategies, playing a major role in reduction of health care associated infections (Mufamadi 2017).

Burkle, Zepeda and Bacon (2004) point out that the laryngoscope handle is placed in the hands of the HCW which raises the issue of how clean are their hands and whether they are transferring harmful pathogens from their hands to the laryngoscope and ultimately to the patient.

Megeus *et al.* (2015) conducted a study to explore the occurrence of HH opportunities and the adherence to HH guidelines during routine anaesthetic care in the operating room. The study population consisted of anaesthetists, instrument nurses, nursing assistants, anaesthesiologists, and surgeons. The most important aspect was the setting up of the airway trolley and whether it was deemed safe and ready for use. A HH opportunity is the time span between two risk-prone hand-surface contacts when one or more of the following five indications/moments 1–5 apply:

- Moment 1: this is the time period before patient contact. The HCW disinfects their hands in an attempt to prevent germ transmission to the patient. This is done, ultimately, to protect the patient from colonisation and against infection.
- Moment 2: this is the time period before an antiseptic task or invasive or non-invasive procedure is about to begin. In the current study, this instance this is the invasive procedure of ETI with the use of the laryngoscope. HH is conducted to prevent germ transmission to the patient and from one body site to another in the same patient, and from the health care area to the patient through inoculation.
- Moment 3: this the time period after exposure to body fluids to protect the HCW from spreading of infection with the patient's germs.
- Moment 4: this is the time period after patient contact to protect the HCW from spreading and potential infection by patient germs.

- Moment 5: this is the time period after contact with patient surroundings to protect the HCW against the establishment of patient germs that may be present in or around patient surroundings.

The authors found the following:

- A total of 2 393 opportunities for HH were recorded.
- During AM such as ETI the overall HH adherence was 3% before ETI and 15.6% after the use of the laryngoscope tool. There were 135 opportunities for HH during this time.
- Factors reported by healthcare professionals that are associated with non-adherence are: high workload, insufficient time, HH not being a prioritised task, forgetfulness, lack of scientific information, and scepticism concerning the importance of HH.
- There was 8% adherence by the anaesthetists and 4% by the instrument nurse who were clearly involved with the setup of the airway trolley.
- Failure to use gloves or change gloves was 43% in all cases, occurring mostly in relation to the insertion of venous lines 50.5% and 40% with regards to AM such as the use of the laryngoscope tool or bag valve mask.

It can be deduced from the study that even in-hospital there is a problem with HH before invasive procedures such as intubation with the aid of a laryngoscope. In this study the operating theatres were known to be strict in terms of IC, but this has not seen. (Megeus *et al.* 2015) concluded it is up to the individual to decide whether HH is important enough to follow.

With regards to HH in the pre-hospital setting, EMSs or ECPs encounter a variety of patients in different surroundings and are thus at high risk of themselves being a source of microbial transmission. multicentre prospective observational. Vikke *et al.* (2019) conducted a large multicentre prospective observational study from December 2016 to May 2017 in EMS including Finland, Sweden, Australia and Denmark. Sixty hours of observation occurred in each country, for a total of 87 patient encounters. In total, there were 1 344 indications for HH. Findings included:

- Only 3% of participants washed their hands before patient contact.

- Before clean/aseptic procedures, 2%.
- After the risk of body fluids, 8%.
- After patient contact, 29% which means that participants were only worried after patient contact about their own well being.
- After contact with patient-related surroundings, 38%.
- Gloves were worn in 54% of all HH indications, and in 64% of the cases the EMS staff used the same gloves irrespective of touching a contaminating site and back to the patient to perform a procedure such as IV therapy or laryngoscopy. This left room for transmission of harmful pathogens to be transferred back and forth between EMS staff and patient (Vikke *et al.* 2019a).

HH compliance among EMS providers was remarkably low, with higher compliance after patient contact compared with before patient contact, and an over-reliance on gloves. By looking at the in-hospital setting and the pre-hospital setting it can be said that HH is imperative before performing certain procedures be these as invasive as ETI or even holding a laryngoscope for visualisation or endoscopy. Chen *et al.* (2020) states that in the Wuhan (China) hospital in China it was observed that anaesthesiologists who were performing ETI on COVID-19 positive patients were contracting the virus and other diseases. Investigation led to traces of the virus being found on the laryngoscope blades and handles which was also related to poor HH and poor disinfection overall. Having established this it can be said that poor HH overall by EMS can lead to the transmission of bacteria and diseases as HH can eliminate the spread of such bacteria or diseases (Chen *et al.* 2020).

2.16 Sheaths and protective barriers

Whether in the pre-hospital environment or in-hospital environment the practitioner using the laryngoscope scope tool will come across patients who require ETI. The tool is in close contact with mucous membranes and can possibly be contaminated with virulent or readily transmissible organisms. As laryngoscopy is often required during ETI, proper cleaning and sterilisation of the airway tool is crucial to prevent cross-contamination among patients.

Disposable sheaths are available that can be placed over the blade and/or handle and which are discarded after use. However, the blade still requires high-level disinfection thereafter as contamination cannot be eliminated with absolute certainty; contamination can occur during application or removal of the sheath or by contaminated hands.

The advantages of using a disposable sheath over the blade of a laryngoscope blade are:

- Readily available and inexpensive.
- Adequate transparency therefore does not interfere with light intensity.
- Accommodates any size blade.
- Easy to apply and remove from tool.
- Good barrier against bacteria and viruses (Muscarella 2007).

Chen *et al.* (2006) conducted a study to test the effectiveness of a latex condom over the laryngoscope blade cover during ETI. Both control (no condom) and study group blades were rinsed with sterile saline after intubation. The rinse was sent for bacteria culture, and appearance of bacterial colonisation was counted as positive. A total of 162 laryngoscopes were examined with 51.2% scopes in the study group and 48.8% in the control group. Rates of positive bacterial culture were 13.3% and 88.6% in the study and control group, respectively. It was established that the use of a condom as a protective barrier sheet over the laryngoscope blade as a cover during laryngoscopy is a simple, inexpensive and effective way to reduce cross contamination between patients (Chen *et al.* 2006).

In addition to the reduction of positive bacterial cultures in the study group, no occult blood was detected on these blades. No intervention is without its limitations. If those responsible for the intubation are not careful, the condom may be torn by the patient's teeth rendering the barrier less effective. Transmission of microorganisms can be significantly reduced by employing this simple and inexpensive method (Chen *et al.* 2006).

2.17 Disposable airway equipment

Anaesthetic workers who use the laryngoscope blades and handles (single-use blade or reusable blade) have mixed perceptions and experiences regarding the use of these two options as well as the ease of intubation amongst other aspects (Ellis, Park and Prussin 2022)

The presence of residual bacteria and protein found on anaesthetic equipment, the concern of potential cross infection of harmful pathogens and the deterioration in the reliability of the light intensity of reusable blades after thermal sterilisation has led to the recommendation of using single-use laryngoscope blades. Disposable blades are as efficient as the standard reusable blades. However, HCWs have mixed opinions regarding the use of and ease of intubation with single-use blades versus reusable blades(Simmons *et al.* 2023).

Jabre *et al.* 2007) performed an observational study in a pre-hospital environment whose objective was to compare the intubation success rates during the first laryngoscopy for two laryngoscope blade types: a metallic reusable and a plastic single-use. The following results were obtained by the study:

- The first-attempt intubation success rate was higher in the metallic blade group (84%) than in the single-use group (76%).
- The incidence of difficult intubation, defined by an intubation difficulty score greater than 5, was lower when metallic blades were used.
- A good laryngeal view (Cormack and Lehane classes I and II) was more frequently observed with metallic blade use (83%) than single-use (67%).
- Alternative airway techniques such as the use of a gum elastic bougie or an intubating laryngeal mask airway were more frequently used in the plastic blade group.

The authors concluded that the use of a plastic disposable laryngoscope blade decreased the success rate of tracheal intubation at the first attempt performed by emergency care providers (Jabre *et al.* 2007).

According to Sherman (2019), disposable blades are often perceived to be cheaper than reusable blades, due to CSSD reprocessing labour in relation to metal blades, and the material costs. However, when considered across an entire institution, the cost of disposable blades can exceed the lifecycle costs of an equivalent number of reusable laryngoscopes. However, when the costs of the CSSD labourer's salary of $50,000 per annum, standard cleaning times, and including periodic refurbishment, Sherman (2019), estimated that reusable handles are more economical than disposable blades. Typical steel reusable devices are rated for thousands of uses, and thus the advantages over disposables can be considerable. In terms of infrastructure complexity, treating reusable laryngoscope handles and blades is likely to be a small fraction of CSSD facility duties (Sherman 2019).

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Moritz, Heinrich and Irouschek (2017) compared reusable metal blades and disposable plastic blades, raising the question of whether a difference in performance exists between different types of blades. The patients were adults requiring elective surgery. The findings confirmed a 35% worse outcome performance for the disposable plastic blades against the reusable metal blade which was found to be durable with positive outcomes. It was noticed that the success rate at the first intubation attempt with the metal reusable blade which was higher than with the single-use plastic blades. The laryngeal view was also of importance, with the reusable metal blades being superior with good visualisation. This issue is important because in trauma or medical conditions, visualisation of the vocal cords is critical(Moritz 2017).

2.18 Conclusion

Little attention has been paid to the role that laryngoscope blades and handles in the pre-hospital environment and ambulance staff play in the spread of HCAI in general, and in South Africa in particular. Given that poor IC practices pose a risk for both patients and staff, it is important to identify the types and levels of microbial contamination including that of potentially pathogenic species on the ambulance laryngoscope blades and handles and to determine knowledge and practices of staff on ECP IC. Achieving this can help managers and researchers gain insight into the current status of IC and prevention in KwaZulu-Natal private ambulance services as well as state EMSs. A comprehensive, EMS specific IC programme, based on international guidelines and standards, but appropriate to the South African setting, can then be designed. This is essential, since well-structured IC programmes, have been shown to play a vital role in reducing mortality, morbidity and costs to both patients and the health care system.

CHAPTER 3: MATERIALS AND METHODS

3.1 Introduction

Professionals in any type of work or industry must recognise that research is an important component of “education and management”. Evidence-based practice must be included in the training of healthcare professionals from the outset(Dubey and Kothari 2022).

In this chapter, the method employed in this study regarding the study design, sampling, data collection, data analysis and interpretation, reliability of data and ethical issues is presented.

3.2 Study design and research setting

The research design is the overall plan for obtaining answers to the research questions. The design incorporates key methodological decisions about the fundamental form of a study and spells out the strategies the researcher plans to adopt to obtain information that is accurate and interpretable. This study made use of a post-positivist paradigm and quantitative analysis, informed mainly by idealism and critical realism. This experimental study was descriptive in design, as the purpose was to identify and quantify the microorganisms isolated from samples of laryngoscope blades and handles and determine the most efficient disinfection agents required to render these microorganisms harmless using a minimum inhibitory concentration (MIC) assay. Lastly, a questionnaire was used to assess EMS personnel’s decontamination practices regarding the disinfection of the equipment. The study was cross-sectional, as the data was collected during a specific period. This study was conducted in a private EMS sector setting in KwaZulu-Natal. The selected EMS is a 24-hour private EMS, with 27 ECPs who use laryngoscope blades and handles as needed to aid in AM. These ECPs worked a four-shift system, rotating through a cycle of two days on, two nights on and four days off duty, each shift was 12 hours long with shift changeovers occurring at 07h00 and 19h00.

3.3 Objective One

To identify and quantify the prevalence of bacteria and fungi on laryngoscope blades and handles used by the selected EMS.

3.3.1 Population

There were 27 ECPs in this study, all of which belonged to the selected EMS in the Kwazulu-Natal area. In this area, there are 9 laryngoscope blades and handles, all of which were analysed in this study (Table 3.1).

Table 3.1: Number of laryngoscope blades and handle sets per base

Ambulance base code	Laryngoscope blade and handle
RB1	1
B1	1
U1	2
TC1	1
SA1	1
K1	1
P1	1
M1	1
Total	9

Figure 3.1: Laryngoscope blades and handles used by the selected EMS

3.3.2 Sampling strategy

All the laryngoscope blades and handles within the KZN district were included in the study. Bacteria and fungi, once removed from a host, are difficult to find and culture from inanimate objects. Therefore, the sites that are most likely to be contaminated were selected, such as the laryngoscope handle and the three sizes of blades.

Processing of samples were conducted by the researcher at the microbiology laboratory, Department of Biotechnology and Food Technology, Durban University of Technology. All consumables required for data collection were provided by the microbiology laboratory. Sterile swabs were used for specimen collection(Aguinis 2023).

Surfaces of each of the laryngoscope blade and handle (Figure 3.1) were sampled, and new swabs were used for each equipment set. The swabs were passed across and rotated over the entire surface of the sites in order to collect as much material as possible. This was to ensure that all specimens were equally represented. The specimens were collected in a consistent, standardised manner for each of the laryngoscope blades and handles in duplicates. After each sample was collected, the swabs were then placed into a tube containing 1 mL saline solution and sealed, and labelled adequately with blade size and handle with other important information. Specimens were then stored at 4 ℃ and transported to a microbiology laboratory in the Department of Biotechnology, Durban University of Technology within 24 hours of collection for analysis.

Each swab sample was labelled with the ambulance identification code, ambulance base code, and the swab site number. A hypothetical example of a swab label and its corresponding checklist details for swabs of the laryngoscope blade and handle of a response vehicle from the Umhlanga base, taken on 18 March 2020 at 19h00 hours, is shown in Table 3.2 and Table 3.3. The selected EMS was re-visited until specimens from all the response vehicles in the population had been obtained. The data collection period spanned three months with sampling once a month. It is important to note that correct personal protective equipment was used by the researcher to avoid contamination of the samples, the laryngoscopes were not tampered with, and the

expiry date of the transport media was checked. Strict protocol was followed to ensure samples and equipment were not contaminated and microbiological standards were strictly followed.

Table 3.2: A hypothetical example of a swab label and its corresponding checklist details for laryngoscope handles

Swab Label	Base	Base Code	Response vehicle Code	Site	Site Code	Date	Time
HUA1.	Umhlanga base	U1	1	Laryngoscope handle	1	18/03/20	19h00

Table 3.3: A hypothetical example of a swab label and its corresponding checklist details for laryngoscope blades

Swab Label	Base	Base Code	Response vehicle Code	Site	Site Code	Date	Time
BUA1.	Umhlanga base	U1	1	Laryngoscope blades small, medium or large	1	18/03/20	19h00

3.3.3 Data collection

The head office of the private EMS company was contacted, the study was explained, and permission was requested to conduct the survey (Annexure 4). The approved research proposal was provided for more detailed information. Once this was granted, permission was sought from the EMS Regional Manager of the KZN District (Annexure 5). The prospective participants had access to an information letter in English or in isiZulu (Annexures 1 and 2).

3.3.4 Sample analysis

3.3.4.1 Serial dilution and colony count

Swabs with 1 mL of saline at the bottom of the tube were used. Once swabs were collected, they were then labelled according to the base and swab site. They were kept safe within polystyrene boxes, cable-tied and brought to the lab for analysis. Samples were stored at 4 ℃.

In the laboratory, multiple plates of cetrimide and XLD agar were prepared and 36 samples were collected via swabs. A weighing boat was then used to measure 56.7 g of XLD agar which was dissolved in 1 L of freshly prepared/distilled water by heating slightly. The cetrimide agar was prepared by mixing 45.3 g of the medium and 10 ml of glycerol in 1 L of distilled water. This was then autoclaved. The agar solutions were poured on the Petri dishes – enough to ensure the bottom of the dish was covered. The lids were kept off and allowed to cool or solidify and thereafter the lids of the Petri dishes were sealed and inverted. This was done to prevent the moisture from condensing on the agar surface. For enumeration and colony count, serial dilution was performed for each swab sample. Dilutions were done in triplicate, as illustrated in Table 3.4.

Table 3.4: Plates per sample

Base	**Swab sample**	**10^{-1} Serial dilution**	**10^{-2} Serial dilution**	**10^{-3} Serial Dilution**
U1	U1 H1	1 x Cetrimide	1 X Cetrimide plate	1 X Cetrimide plate
		1 x XLD	1 x XLD	1 x XLD
Total				6. Agar plates used

A 100 µl aliquot of the dilution was withdrawn and pipetted onto the plate. Thereafter, a spread plate technique was performed. All procedures were conducted under a laminar flow to ensure no contamination. The plates were then incubated for 24 h. The purpose of the spread plate is to produce clearly visible isolated colonies of bacteria which are countable. The following day the plates were inspected for growth and analysis continued further with serial dilution and spread plating. After a week of this process, upon inspection of the plates, all the Petri dishes had grown colonies of bacteria. After incubation colonies were counted using a colony counter.

3.3.4.2 Antimicrobial susceptibility testing

The 72 x15 mL tubes which were filled with 10 mL of tryptic soya broth, cultures from previous cetrimide and XLD agar plates were picked off with an inoculation loop and placed into the 15 mL tube and vortexed. Thereafter, samples were incubated at 37 ℃ for 24 h. Mueller Hinton Agar was used for antimicrobial susceptibility testing (AST).

This particular agar was selected because it is a loose agar which allows better diffusion of the antibiotics than other types of media. The Kirby-Bauer disc diffusion method was used to determine the susceptibility, intermediacy, and resistance of samples. Thereafter, 100 µg of the culture was pipetted onto each Mueller Hinton agar plate and spread evenly using a glass rod. Tetracycline, pipemedic acid, fosfomycin and colistin sulphate were the antibiotics used in this study.

Antibiotic susceptibility testing, or AST, is a widely used method of evaluating antibiotic resistance and determining patient treatment plans in clinical settings. There are several methods of AST, such as agar dilution, broth dilution, and disc diffusion assays. The disc diffusion or 'Kirby-Bauer' method involves spreading bacteria on an agar plate and placing paper discs impregnated with antibiotics on the plate. After incubation, the growth of bacteria or zones of inhibition was inspected and observed by the investigator. Areas around the antibiotic disc where no bacterial growth can be seen are known as 'zones of inhibition'. These zones show that an antibiotic has been successful in stopping bacterial growth or killing the bacteria. By measuring the diameter of these zones, one can compare the efficacy of antibiotics and monitor antimicrobial resistance (Nassar, Hazzah and Bakr 2019). The evidence of this experiment are presented in the Chapter 4.

3.3.4.3 Isolation and identification of isolates

The Gram stain process was used to determine the morphology of pure isolates. It is a common technique used to differentiate two large groups of bacteria based on their different cell wall constituents. The process involved the researcher working in the lamina flow machine; the process consisted of picking off the colonies from the petri dishes and smearing the material onto clear microscope slides which had a drop of distilled water on them. The researcher spread out the smear on the microscope and then waved the microscope slide over the Bunsen burner until it dried. Thereafter, the slides were taken to a nearby sink and a primary stain of crystal violet was applied and allowed to set for 1 min before being rinsed. After this, the mordant or iodine was applied, and after 1 min the slide was rinsed again. Rapid decolourisation with ethanol was then applied and rinsed off. Lastly, a counter stain with safranin was applied was rinsed off after 1 min. The researcher took all the completed slides for microscope

analysis to ascertain whether the samples were Gram-positive or Gram-negative. This was followed by an in-depth description of the shape size. The results are presented in Chapter 4.

3.3.5 Biochemical tests

Two biochemical tests were performed to positively identify the microorganisms, namely, the catalase test and the methyl red test.

3.3.5.1 Biochemical test 1: The catalase test

This biochemical test demonstrates the presence of catalase, which is an enzyme that catalyses the release of oxygen from hydrogen peroxide (H_2O_2). It is used to differentiate those bacteria that produce the enzyme catalase such as *Staphylococci*, from non-catalase producing bacteria such as *Streptococci*.

The enzyme catalase mediates the breakdown of hydrogen peroxide into oxygen and water. The presence of the enzyme in a bacterial isolate is evident when a small inoculum is introduced into hydrogen peroxide and a rapid elaboration of oxygen bubbles occurs. The lack of catalase is evident by a lack of or weak bubble production. The culture should not be more than 24 h old.

----------(1)

Bacteria produce catalase to protect themselves from the lethal effect of hydrogen peroxide which is accumulated as an end product of aerobic carbohydrate metabolism (Rave *et al.* 2019).

3.3.5.2 Procedure of the catalase test

Microscope slides were placed inside sterile petri dishes. Using a petri dish is optional as the slide catalase can be properly performed without it. However, to limit catalase aerosols, which have been shown to carry viable bacterial cells, the use of a petri dish is strongly recommended. A sterile inoculating loop was used in this test however a

wooden applicator stick could have also been used to help smear or place the small amount of organism from a well-isolated 18- to 24-h colony. Thereafter, using a dropper or Pasteur pipette, 1 drop of 3% H_2O_2 was placed onto the organism on the microscope slide. Immediately, the petri dishes were covered with a lid to limit aerosols and observed for immediate bubble formation (O_2 + water = bubbles). Observing for the formation of bubbles against a dark background enhances readability hence the researcher placed the slides against a dark background and took pictures (Rave *et al.* 2019).

3.3.6 Biochemical test 2: the methyl red test

Methyl red determines whether an organism performs mixed acid fermentation and produces stable acid end products. Methyl red is an indicator that detects the pH after an enteric Gram-negative rod has fermented glucose to completion. When bacteria ferment glucose and produce mixed acids this causes a decline in pH. The methyl red pH indicator indicates the change in pH caused by bacterial glucose fermentation. The pH indicator is red at acidic pH and yellow in alkaline pH. If the media turns from a yellow to a red colour this means that the test is a confirmed positive. The results are presented in Chapter 4.

3.3.6.1 Preparation of the test

The tester had to prepare a suitable broth for this biochemical test. The researcher prepared a MR-VP broth which is a liquid medium recommended for qualitative procedures for performing the methyl red (MR) and Voges-Proskauer tests as an aid in the identification of enteric Gram-negative *bacilli*. It contains peptones, buffers, and dextrose or glucose. Different bacteria convert dextrose and glucose to pyruvate using different metabolic pathways.

3.3.6.2 Methyl red solution preparation

The researcher had to prepare the methyl red solution of 0.02%. Then 0.1 g of methyl red was dissolved in 300 mL of ethyl alcohol, 95%. 500 mL of distilled water was then added and dissolved and then stored at 4 ℃.

3.3.6.3 Procedure of methyl red (MR) test

Once the medium was prepared, it could equilibrate to room temperature. Pure cultures that were no more than 24 h old were then added to the medium: 5 mL of the MR-VP broth was poured into 15 mL tubes and then freshly cultured organisms were added to the tubes. They were then labelled and incubated for 24 h. Following 24 h of incubation, 2 to 3 drops of methyl red indicator were added to the tubes or broth.

3.3.6.4 Methyl red positive organisms

- *Escherichia coli.*
- *Shigella* spp.
- *Salmonella* spp.
- *Citrobacter* spp.
- *Proteus* spp.
- *Yersinia*

3.3.6.5 Methyl red negative organisms

- *Enterobacter*
- *Hafnia*
- *Serratia marcescens.*
- *Klebsiella pneumoniae*.

3.3.7 Polymerase chain reaction

The colony polymerase chain reaction (PCR) protocol is a straightforward laboratory test where a small amount of a colony from a plate or dense bacterial liquid culture is added to the PCR master mix and subjected to thermocycling. Cell lysis occurs during the initial high-temperature incubation. The resulting PCR products can be analysed with gel electrophoresis or other DNA detection methods. This timesaving method is perfect for screening just a few colonies or for high throughput screenings of numerous clones (Jamal *et al.* 2017).

Fresh sub-cultured colonies were placed on new XLD and Cetrimide agar plates. These plates were then labelled and incubated for 24 hours at 37 ℃. These plates were then labelled and incubated for 24 hours at 37 ℃. The pure colonies were then transferred onto a replica plate and then into the PCR tube. The following was prepared before placing into the thermocycler: 6 uL of master mix, 1 uL of forward prime, 1 uL reverse primer, 4 uL of water in a total of 12 uL volume. This was a total volume of 12 uL. Once the PCR tubes were filled with the above, they were labelled and put into the PCR machine to run. The researcher then ran the gel and thereafter inserted the gel into the UV light machine to check for bands.

3.3.8 Data analysis

Data collected from response vehicles' laryngoscope blades and handles were analysed using the IBM SPSS version 24 software. Descriptive statistics were used to analyse data in the form of graphs and charts which represented the presence and quantities of bacterial and fungi that were present in the EMS equipment.

3.4 Objective Two

To evaluate current decontamination practices of EMS personnel regarding the disinfection of laryngoscope blades and handles using a questionnaire

3.4.1 Population and sampling strategy

The population and distribution that was studied is summarised in Table 3.5. In order to find the minimum sample size for the population, the Rasoft sample size calculator was used. It was established that with a 5% margin of error, a confidence level of 95%, a population size of 27 and with a response distribution of 50%, the recommended sample size should be 26 participants. All potential participants were invited to participate in the study.

Table 3.5: Number of ECPs per base

Ambulance base	Number of ECPs
RB1	2
B1	1

U1	5
TC1	5
SA1	5
K1	4
P1	4
M1	1
Total	27

3.4.2 Data collection and measuring instrument

The participants were informed about the research and its requirements. A letter of information and consent to participate form (Annexure 1 and 2) was presented to inform the participants about the study and gain their consent. To test the adequacy of the questionnaire in meeting of the objectives of the study, a pilot study was conducted in order to identify any problem areas. A similar smaller group of five ECPs was approached, and a letter of information and consent was presented to them (Annexure 3). The results from the pilot testing group were not used in the study. The process of collecting data via the questionnaire was only performed once the private EMS company was presented with the letter to the head office of the private EMS company granting permission to conduct data collection (Annexure 4). Afterwards the regional managers of the private EMS company were presented with the letter of permission (Annexure 5) to conduct research or data collection at the relevant private EMS bases as mentioned in Table 3.1. Thereafter, a questionnaire (Annexure 6) was distributed to the participants. The questionnaire was administered during the period of shift change (17h00 and 21h00 hours) as it was the most likely time to access the maximum number of participants. Ambulance bases were re-visited to access participants that were on rest days or unavailable during the first data collection visit. The data was collected during the period from June 2021 to July 2021. All COVID-19 safety protocols were adhered to while administering the questionnaires. Once ethical clearance was obtained from the DUT Institutional Research Ethics Committee, permission was obtained from the Head of the Biotechnology Department, Durban University of Technology to use their microbiology laboratory (Annexure 7).

Participants consenting to participate in the study were required to fill in the questionnaire at the ambulance base, in the researcher's presence. There were 27 ECPs in the EMS under study (Table 3.1) and each questionnaire was assigned a code comprising base code (1 to 8) and a participant member code (1 to 27). Bases and participant names were confidential and were kept anonymous. A timetable for administering the questionnaires was agreed upon with line managers of the EMS centre (Annexure 8). Open-ended questions were used to collect vital information that is more detailed on aspects of IPC of laryngoscope blades and handles. This was done to collect information that may not have been covered in the questionnaire.

Table 3.6: An example of researchers' coding method in this study.

Base	Base Code	Participant	Participant Code	Questionnaire Code
Durban Central	A	Mr Johnson	16	A16

3.4.3 Data analysis

Data collected from the questionnaire was analysed using IBM SPSS version 24. Descriptive statistics were used to analyse data using graphs and charts and exploratory analysis.

3.5 Objective Three

To establish the minimum concentration of disinfectants and protocol required to inhibit pathogen growth during pre-hospital cleaning and disinfection.

3.5.1 Minimum inhibitory concentration (MIC)

The MIC test was performed to establish the minimum concentration of disinfectants and the protocol required to inhibit pathogen growth during pre-hospital cleaning and disinfection. The MIC assay was conducted using the disinfectants commonly used used by the selected EMS personnel to clean laryngoscopes (Rakholiya *et al.* 2014).

3.5.2 Antimicrobial susceptibility assay

In order to ascertain the efficacy of decontaminants used by EMS to clean laryngoscope blades and handles, a modified Kirby-Bauer technique comprising disc agar diffusion assays was utilised (Balouiri *et al.* 2016). The Kirby-Bauer disc diffusion method is the most widely used antibiotic susceptibility test in determining what choice of antibiotics should be used when treating an infection. This method relies on the inhibition of bacterial growth measured under standard conditions. The same principle was used to screen appropriate concentrations of disinfectant to use for decontamination of laryngoscope blades and handles. Thus, filter paper was stamped into small discs and sterilised by autoclaving, then soaked in disinfectants that are commonly used in disinfecting hands and equipment. Different concentrations of each disinfectant to be investigated were 5% 10% 15% and 20% and the final concentration was used for the MIC. Thereafter, a sterile cotton swab was dipped into an overnight culture of each bacterial and fungal strains, adjusted to the turbidity of 0.5 McFarland standard.

Mueller-Hinton agar plates were inoculated by evenly streaking cotton swabs over the agar medium surface and disinfectant discs were then placed on the agar using a sterile forceps. Widely used antibiotics used for treatment of infection were used as standard. The bacteria to grow at 37 ℃ for 24 hrs. Areas of clear media surrounding the discs indicate that the disinfectants have inhibited bacterial and fungal growth. The diameter around the well where the growth did not occur (zone of inhibition) was measured (Annexure 9 and 10).

3.5.3 Data analysis

Data collected from response vehicles' laryngoscope blades and handles was analysed with IBM SPSS version 24. Descriptive statistics were used to analyse data in the form of graphs and charts etc. to represent the presence and quantities of bacterial and fungi that were present in the proposed EMS equipment.

3.5.4 Pilot study / pre-testing

A pilot study can be defined as a small study to test research protocols, data collection instruments, sample recruitment strategies, and other research techniques in preparation for a larger study. A pilot study is an important stage in a research project and is conducted to identify potential problem areas and deficiencies in the research instruments and protocol prior to implementation during the full study. It can also help members of the research team become familiar with the procedures in the protocol. Obtaining consent to participate, swabbing procedure, timing and coding of samples were tested. The data collection tool was then refined and altered. The reliability and validity were ensured through the pilot study(Aguinis 2023).

3.5.5 Delimitations/scope

Once ethical clearance approval was obtained from the DUT Institutional Research Ethics Committee, permission was then obtained from the Head of the Biotechnology Department, Durban University of Technology to use the microbiology laboratory (Annexure 7) and the head office of the private EMS company (Annexure 4). Once the researcher obtained approval and relevant permission letters, potential participants were invited to participate. Those who agreed to participate were informed about the nature of the research and its requirements and signed an informed consent form (Annexure 2). Thereafter, questionnaires were distributed to the participants.

The study was conducted in a private EMS sector setting in the KwaZulu-Natal province. Data was collected from the selected EMS as explained in subsection 5.1. The ambulance bases shown in Table 3.1 were visited and nine laryngoscope blades and handles were surveyed. Only laryngoscope blades and handles that were in operation were included in the study. Laryngoscopes blades and handles that had been decommissioned were not included in the study. All EMS disinfection agents that were currently in use were included in the study.

3.5.6 Limitations

Most EMS staff are BLS or ILS qualified personnel who do not use the laryngoscope scope blade and handle as advanced AM is not within their scope of practice. The

study population therefore was limited to ECPs. The data was collected at various ambulance bases which were far apart and therefore required extensive travelling by the researcher. Ambulance or response vehicles are often in use and therefore it was anticipated that there would be instances that required re-visiting of EMS bases. This was because the laryngoscope blade and handles were kept in the airway kits of the response vehicles in which the ECPs worked shifts.

3.6 Validity and reliability

For Objective One, the specimens were collected according to standard specimen collection procedures to ensure consistency therefore ensuring reliability. A registered laboratory was used to ensure compliance with all laboratory practice regulations therefore ensuring validity.

For Objective Two, validity and reliability were ensured through administering a questionnaire that was based on the literature review that focused on effective IC practices. The questionnaire was pretested and reviewed by IPC specialists to ensure content validity.

For Objective Three, validity and reliability were ensured by conducting MIC tests. The MIC test ascertains the lowest concentration of a disinfection agent that is required to inhibit visible bacterial growth therefore it is an appropriate test. The tests were conducted in accordance with standard laboratory practice guidelines, therefore ensuring consistency in results.

Validity was established by evidence-based reviews, the opinion of experts, and researcher's training on standard principles of sample collection. The Durban University of Technology's Biotechnology Department’s microbiology laboratory was used to identify types and levels of microorganisms including species that are potentially pathogenic, if any. Semi quantitative microbiological enumeration in CFUs determined levels of contamination and further confirm using biochemical test. To ensure reliability, research and academic experts assessed the methodology used to collect specimens. The culture, disinfectant sensitivity testing and identification were performed by a laboratory using international ISO 17025 guidelines(Tan 2022).

Further quality assurance was ensured by the laboratory being South African National Accreditation System accredited.

3.7 Anonymity and confidentiality

The questionnaire was designed to assess IC knowledge and practices and has been phrased in a sensitive manner to prevent embarrassment or to cause any harm to the participant. Furthermore, the identity of individuals and the bases where they are employed was kept strictly confidential throughout the study at all times and even when discussing amongst supervisors. This ensured total anonymity. Respondents that participated in the study were not disadvantaged in any way. The researcher did not exceed the time limit agreed upon for the completion of the questionnaire hence completion of the questionnaire was done under minimal time as it was simple to understand(Tan 2022).

3.8 Ethical considerations

Full ethical approval was obtained from the Institutional Research Ethics Committee (IREC) of the Durban University of Technology (DUT). Four pillars of ethical principles that provided guidance for the researcher were non-maleficence, beneficence, autonomy and justice. Furthermore, the researcher ensured that confidentiality and anonymity were guaranteed. For instance, the name of the organization and participants were not revealed in the final research reports(Tan 2022).

3.9 Permission to conduct research

Permission was sought from the private EMS EXCO (Annexure 3), thereafter an information letter (Annexure 1) was sent to respective EMS bases prior to data collection.

3.10 Challenges / experiences encountered during the pilot test

In certain instances, the base manager was present on arrival. Although permission was sought from the regional Kwa-Zulu Natal district manager, the shift manager was not always aware of the study. Most staff kept a respectful distance, others were

interested in the actual procedure. The researcher reached the following conclusions after the pilot study:

- It is vitally important that the shift supervisors be aware of the data collection.
- The letter of information should be posted in advance at the bases explaining the study without actual dates of data collection, prior to the arrival of the researcher.
- Data collection should take place between 17h00 and 20h00, during the week or Sundays when ambulance caseloads are not so high.
- There were no problems with specimen collection. It was decided to stick with the specimen collection procedure, as stated in the methodology.

CHAPTER 4: RESULTS

4.1 Introduction

This chapter presents the results which emerged from the data collection for the three objectives of this study. The data was obtained by conducting a microbiological survey of ambulance laryngoscope blade and handles to determine contamination levels. A questionnaire survey was also conducted to determine knowledge and practices of the selected EMS ambulance participants regarding IC. Lastly, the minimum inhibition concentration required to effectively inhibit the growth of pathogens during cleaning was determined.

4.2 Objective One: To identify and quantify the prevalence of bacteria and fungi on laryngoscope blades and handles used by EMSs

Table 4.1: Colony count / quantification / enumeration

Base	Swab type	Colony count XLD	Colony count Cetrimide
RB1	RB1 H1	1,5x10`6 CFU/ml	2x10`6 CFU/ml
RB1	RB1 B1	6x10`5 CFU/ml	1,5x10`6 CFU/ml
RB1	RB1 B2	2x 10`6 CFU/ml	8x10`5 CFU/ml
RB1	RB1 B3	7x10`5 CFU/ml	9x10`5 CFU/ml
B1	B1 H1	3x10`6 CFU/ml	1x10`6 CFU/ml
B1	B1 B1	1,5x10`6 CFU/ml	2x10`6 CFU/ml
B1	B1 B2	2x 10`6 CFU/ml	2,8 x10`6 CFU/ml
B1	B1 B3	4x10`6 CFU/ml	2x10`6 CFU/ml
U1	U1 H1	7 x10`4 CFU/ml	2x 10`5 CFU/ml
U1	U1 B1	1x 10`6 CFU/ml	1x 10`5 CFU/ml
U1	U1 B2	8 x 10`5 CFU/ml	1x 10`6 CFU/ml
U1	U1 B3	1x10`6 CFU/ml	3x10`5 CFU/ml
U2	U2 H1	1x10`6 CFU/ml	4x10`4 CFU/ml
U2	U2 B1	1x10`6 CFU/ml	8x10`4 CFU/ml
U2	U2 B2	1,5x10`6 CFU/ml	2x10`5 CFU/ml
U2	U2 B3	1,5x10`6 CFU/ml	5x10`5 CFU/ml

TC1	TC1 H1	1x10`6 CFU/ml	7,5x10`5 CFU/ml
TC1	TC1 B1	4x10`4 CFU/ml	8x10`5 CFU/ml
TC1	TC1 B2	8x10`5 CFU/ml	2x10`5 CFU/ml
TC1	TC1 B3	7x10`5 CFU/ml	3x10 CFU/ml
SA1	SA1 H1	9x10`5 CFU/ml	2x10`6 CFU/ml
SA1	SA1 B1	7,5x10`5 CFU/ml	3x10`4 CFU/ml
SA1	SA1 B2	1x10`6 CFU/ml	2x10`6 CFU/ml
SA1	SA1 B3	2,5x10`5 CFU/ml	1,8x10`6 CFU/ml
K1	K1 H1	9x10`5 CFU/ml	2x10`6 CFU/ml
K1	K1 B1	7x10`5 CFU/ml	3x10 CFU/ml
K1	K1 B2	2x 10`6 CFU/ml	1x10`6 CFU/ml
K1	K1 B3	9x10`5 CFU/ml	1x10`5 CFU/ml
P1	P1 H1	1,5x10`6 CFU/ml	1x10`6 CFU/ml
P1	P1 B1	2,5x10`6 CFU/ml	6x10`5 CFU/ml
P1	P1 B2	1x10`5 CFU/ml	5x10`5 CFU/ml
P1	P1 B3	9x10`5 CFU/ml	5x10`5 CFU/ml
M1	M1 H1	7x10`5 CFU/ml	1x10`6 CFU/ml
M1	M1 B1	1x10`6 CFU/ml	1,5x10`6 CFU/ml
M1	M1 B2	4x10`6 CFU/ml	3x10 CFU/ml
M1	M1 B3	3x10`6 CFU/ml	3,8x10` CFU/ml

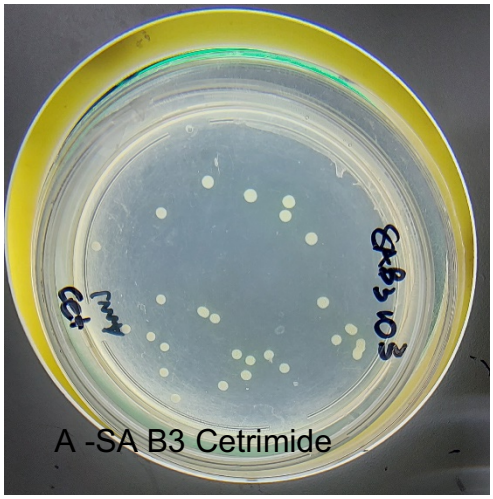
$$\boldsymbol{CFU/ml} = \frac{(\boldsymbol{No.ofcolonies} \times \boldsymbol{totaldilutionfactor})}{\boldsymbol{volumeofcultureplatedinml}}$$

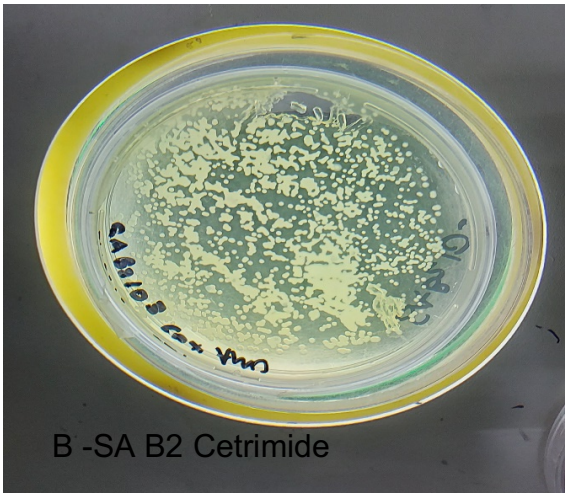
Equation to calculate CFU/ml.

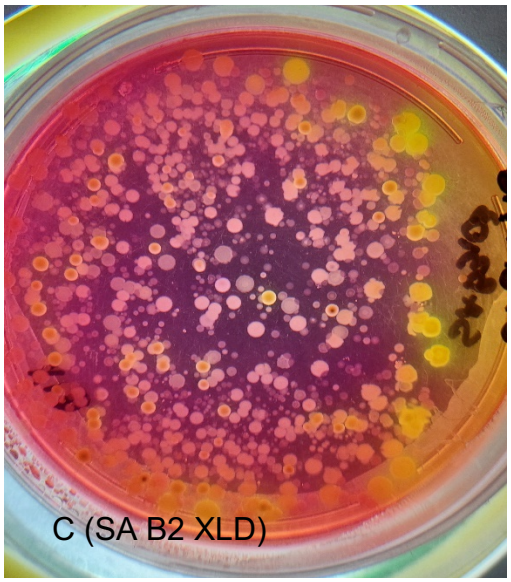
Table 4.1 shows that a high colony count was noted for XLD and cetrimide agar. Even though there was a serial dilution of 10 to 4 the colony count was quite high. The lowest colony count for XLD agar was 4x10`4 CFU/mL, and the highest was 9x10`5 CFU/mL. Looking at the cetrimide agar, the highest colony count was 1x10`6 CFU/mL, and the lowest was 4x10`4 CFU/mL. The agar plates had a high bacterial growth. There were three bases with high colony counts of 9x10`5 CFU/mL for XLD agar and there were four bases with colony counts of 1x10`6 CFU/mL. It is important to note that these bases are geographically far apart. The agar plates were teeming with colonies, suggesting that the disinfection or cleaning methods employed for the tool were

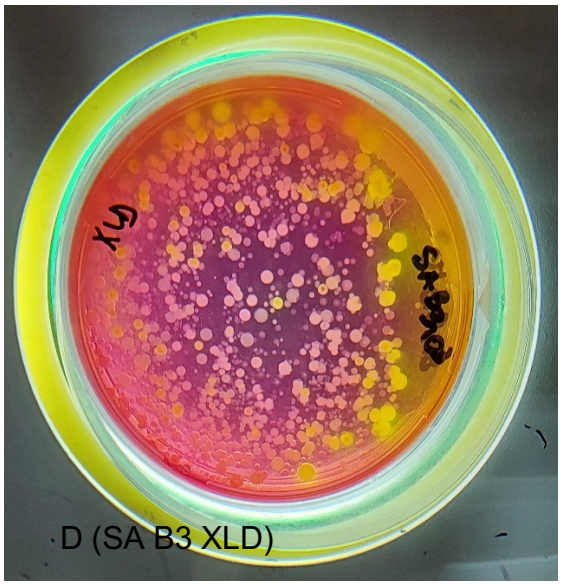
inadequate. Despite the lack of a definitive identification of the bacterial species on the agar plates, inspection revealed the presence of bacteria on the tool. The tool may not have been effectively decontaminated due to the presence of a significant bacterial load, which suggests that the amount or concentration of detergents used might have been insufficient.

The six images in Figure 4.1 are the result of a spread plate serial dilution process. The agar plates show high growth levels even with a serial dilution of 10:4


A -SA B3 Cetrimide


B -SA B2 Cetrimide


C (SA B2 XLD)


D (SA B3 XLD)

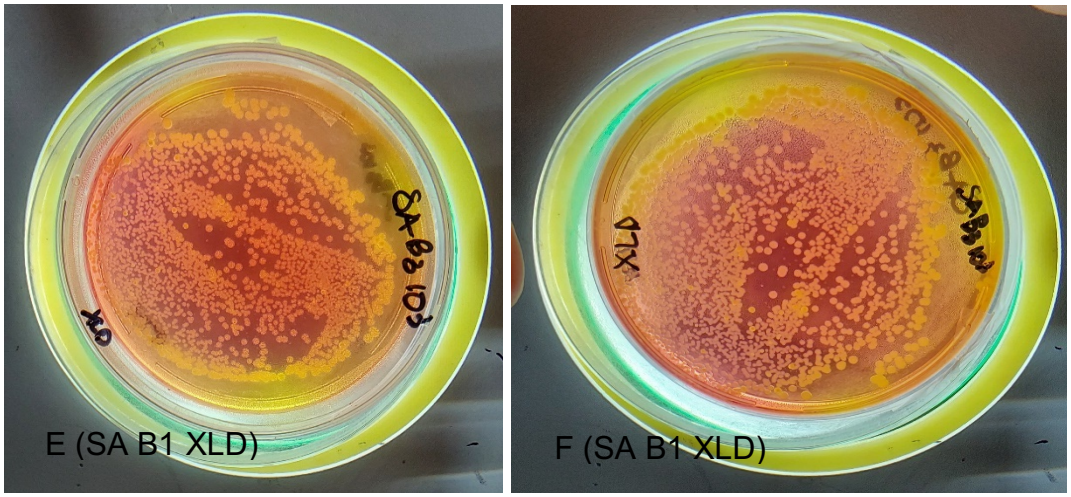


Figure 4.1: Agar plates showing high growth levels with a serial dilution of 10:4

4.2.1 The anti-microbial test

With this test, five antibiotics were used. Table 4.2 shows that 4 out of the 5 antibiotics had positive results in terms of zones of inhibition. Colistin sulphate had little to no effect on 54 samples, with no zones of inhibition. Ampicillin had the largest zone of inhibition of 7 mm and an average of 5.3 mm. Fosfomycin also had largest zone of inhibition of 7mm with an average of 2.6 mm. Tetracycline had a largest zone of inhibition of 5 mm with an average of 2.2 mm. Pipemidic acid's largest zone of inhibition was 5 mm with an average of 2.4 mm. Colistin sulphate's largest zone of inhibition was 4mm with an average of 0.6 mm.

Table 4.2: Zones of inhibition

Base	Swab type	Agar	Ampicillin (mm)	Fosfomycin (mm)	Tetracycline (mm)	Pipemidic Acid (mm)	Colistin Sulphate (mm)
RB1	RB1 H1	XLD	5	3	1	2	2
RB1	RB1 B1	XLD	3	4	2	6	3
RB1	RB1 B2	XLD	4	4	3	2	3
RB1	RB1 B3	XLD	5	3	1	3	3
RB1	RB1 H1	CET	4	2	2	2	Nil
RB1	RB1 B1	CET	6	3	1	2	Nil
RB1	RB1 B2	CET	5	5	2	2	Nil
RB1	RB1 B3	CET	5	3	3	2	Nil
B1	B1 H1	XLD	4	4	2	6	Nil

B1	B1 B1	XLD	5	4	2	2	Nil
B1	B1 B2	XLD	6	7	1	2	Nil
B1	B1 B3	XLD	7	6	1	1	Nil
B1	B1 H1	CET	4	5	2	3	Nil
B1	B1 B1	CET	3	4	3	4	Nil
B1	B1 B2	CET	4	2	2	4	Nil
B1	B1 B3	CET	4	3	2	4	Nil
U1	U1 H1	XLD	5	2	1	2	NIL
U1	U1 B1	XLD	7	1,5	1,5	1,2	NIL
U1	U1 B2	XLD	6	1,5	1,5	1,5	NIL
U1	U1 B3	XLD	4	1	1	1	NIL
U1	U1 H1	CET	3	1	1	1	NIL
U1	U1 B1	CET	6	2	2	2	NIL
U1	U1 B2	CET	5	2	1	1	NIL
U1	U1 B3	CET	7	1,5	1,5	1,5	nil
U2	U2 H1	XLD	4	2,5	2	2	NIL
U2	U2 B1	XLD	3	2	2	1	NIL
U2	U2 B2	XLD	6	1,5	1,2	1,2	NIL
U2	U2 B3	XLD	7	2	2	1	NIL
U2	U2 H1	CET	4	2,5	1,5	1,2	NIL
U2	U2 B1	CET	1	2	2,9	1	NIL
U2	U2 B2	CET	1	2,5	2	1	NIL
U2	U2 B3	CET	2	2	2	1,5	NIL
TC	TC1 H1	XLD	3	1,5	2	1,5	NIL
TC	TC1 B1	XLD	5	1	1	0,5	NIL
TC	TC1 B2	XLD	7	1	2	1,5	NIL
TC	TC1 B3	XLD	4	1,1	1,5	0,5	NIL
TC	TC1 H1	CET	4	-	1	-	NIL
TC	TC1 B1	CET	3	1	0,5	0,5	NIL
TC	TC1 B2	CET	1	1,5	2	1,5	NIL
TC	TC1 B3	CET	nil	1	1	0,5	NIL
SA	SA1 H1	XLD	1	3	3	3	Nil
SA	SA1 B1	XLD	nil	2	4	4	Nil
SA	SA1 B2	XLD	4	4	5	3	Nil

SA	SA1 B3	XLD	3	2	3	3	Nil
SA	SA1 H1	CET	3	3	5	nil	nil
SA	SA1 B1	CET	3	1	3	6	Nil
SA	SA1 B2	CET	3	2	2	5	Nil
SA	SA1 B3	CET	4	3	1	4	Nil
K	K1 H1	XLD	5	0,5	1	0,6	0,3
K	K1 B1	XLD	3	0,7	1	1	0,5
K	K1 B2	XLD	2	1,6	1	1,5	1
K	K1 B3	XLD	3	1	1	0,5	nil
K	K1 H1	CET	7	0,5	1	0,5	0,6
K	K1 B1	CET	7	0,8	0,7	0,6	0,5
K	K1 B2	CET	7	1,2	1	1	0,4
K	K1 B3	CET	7	1,5	0,5	nil	nil
P1	P1 H1	XLD	7	4	5	3	4
P1	P1 B1	XLD	5	3	4	4	4
P1	P1 B2	XLD	5	6	3	3	5
P1	P1 B3	XLD	4	6	3	4	3
P1	P1 H1	CET	4	1	2	4	6
P1	P1 B1	CET	4	4	3	7	5
P1	P1 B2	CET	4	4	3	1	4
P1	P1 B3	CET	4	4	4	5	1
M1	M1 H1	XLD	4	2	2	2	Nil
M1	M1 B1	XLD	3	2	1,5	2	Nil
M1	M1 B2	XLD	3	nil	1,5	nil	Nil
M1	M1 B3	XLD	7	nil	1	nil	Nil
M1	M1 H1	CET	5	2	1,5	1,5	NIL
M1	M1 B1	CET	4	3	1	2	Nil
M1	M1 B2	CET	3	1	1	1	nil
M1	M1 B3	CET	4	nil	1	1	nil

4.2.2 The Gram stain results

Table 4.3: Gram stain per base

Base	Swab type	Gram-positive XLD	Gram-Neg XLD	Gram positive CET	Gram-neg CET
RB1	RB1 H1		Negative	Positive	
RB1	RB1 B1	Positive		Positive	
RB1	RB1 B2	Positive	Negative	Positive	
RB1	RB1 B3	Positive		Positive	
B1	B1 H1	Positive		Positive	
B1	B1 B1	Positive		Positive	
B1	B1 B2	Positive		Positive	
B1	B1 B3	Positive		Positive	
U1	U1 H1	Positive		Positive	Negative
U1	U1 B1	Positive		Positive	
U1	U1 B2	Positive			Negative
U1	U1 B3		Negative	Positive	
U2	U2 H1		Negative	Positive	
U2	U2 B1	Positive		Positive	
U2	U2 B2	Positive		Positive	
U2	U2 B3		Negative		Negative
TC1	TC1 H1	Positive			Negative
TC1	TC1 B1	Positive		Positive	
TC1	TC1 B2	Positive	Negative	Positive	
TC1	TC1 B3	Positive			Negative
SA1	SA1 H1	Positive		Positive	
SA1	SA1 B1	Positive		Positive	
SA1	SA1 B2	Positive		Positive	
SA1	SA1 B3	Positive		Positive	
K1	K1 H1	Positive	Negative	Positive	
K1	K1 B1	Positive		Positive	
K1	K1 B2	Positive		Positive	
K1	K1 B3	Positive	Negative	Positive	
P1	P1 H1	Positive		Positive	
P1	P1 B1	Positive		Positive	

P1	P1 B2	Positive		Positive	
P1	P1 B3	Positive		Positive	
M1	M1 H1	Positive			Negative
M1	M1 B1	Positive		Positive	Negative
M1	M1 B2	Positive		Positive	
M1	M1 B3	Positive	Negative	Positive	

Table 4.3 shows the Gram stain results for the XLD agar and cetrimide agar, respectively. For the 36 samples for XLD agar, it was established that 32 samples were Gram-positive species and nine were Gram-negative species. Looking at the cetrimide agar group, there were 31 Gram stain positive species and seven Gram stain negative species. With regards to the Gram stain positive bacteria for the XLD group, the following bacteria were identified according to the morphology of the isolates:

- *Staphylococcus* spp.
- *Listeria* spp.
- *Corynebacterium*
- *Mycobacterium*
- *Rhodoccus*

Looking at the Gram-negative bacteria found on the XLD agar, these were likely to be the following:

- *Salmonella .* spp.
- *Shigella.* spp.
- *Yersinia .* spp.
- *E. coli*
- *Proteus .* spp.
- *Enterobacter*
- *Klebsiella pneumonia*

Looking at the Cetrimide agar, there were many Gram-negative bacteria present which were most likely the following:

- *Pseudomonas aeruginosa*.
- Fluorescein and Pyocyanin.
- *Pseudomonas aeruginosa.*

Figure 4.2(a) to 4.2(h) showing the Gram stain images below from K base.

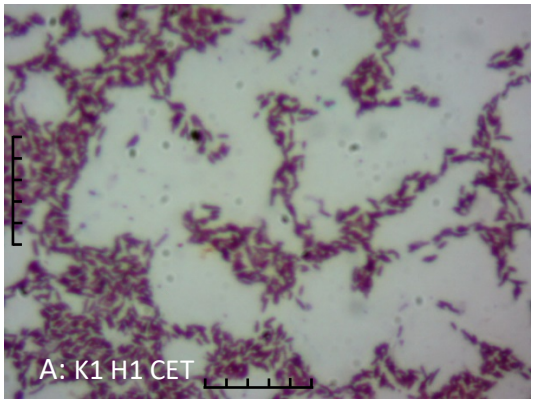
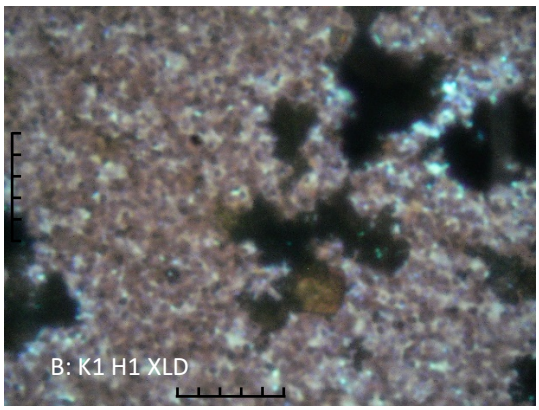


Figure 4.2(a): Crystal violet in colour, Gram-positive due to the cell walls retaining the purple colour after the Gram stain process, bacilli in shape



4.2(b): Crystal violet in colour, Gram-positive due to the cell walls retaining the purple colour after the Gram stain process, bacilli in shape

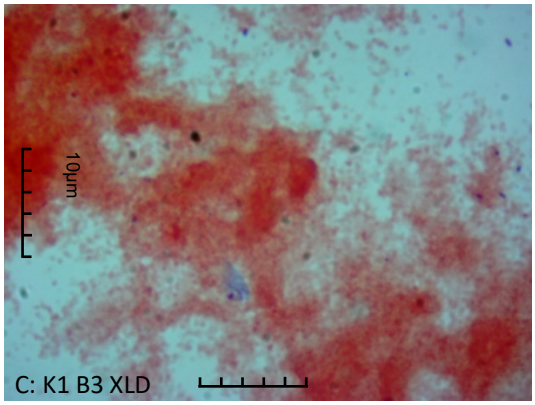
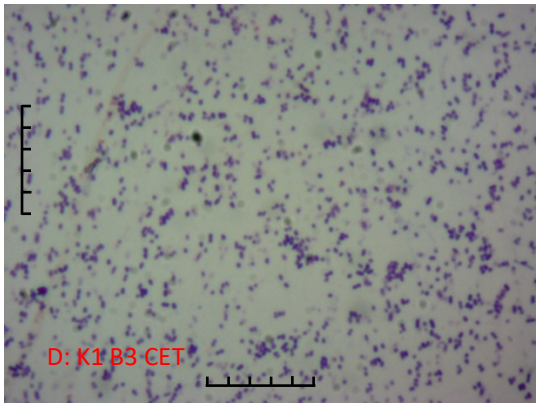
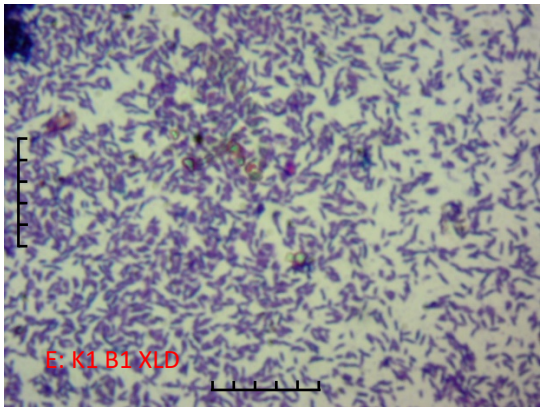


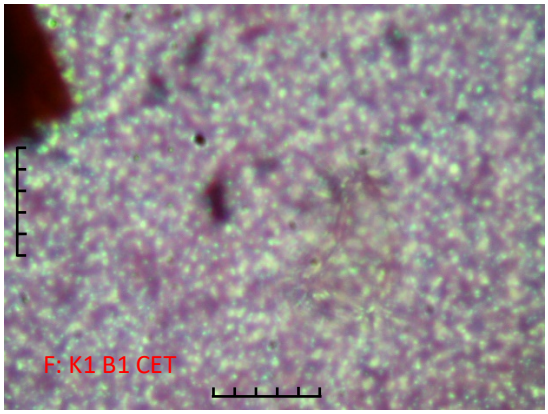
Figure 4.2(c): Gram-negative red in colour and coccus



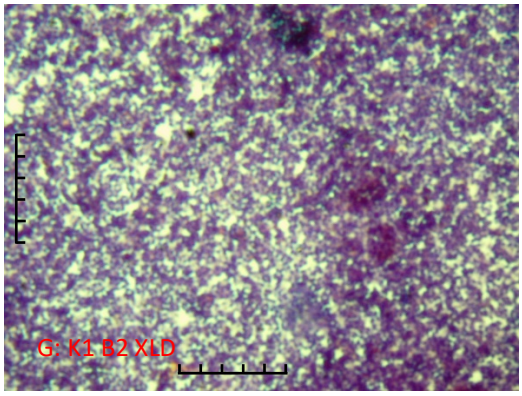
4.2(d): Gram-positive and coccus



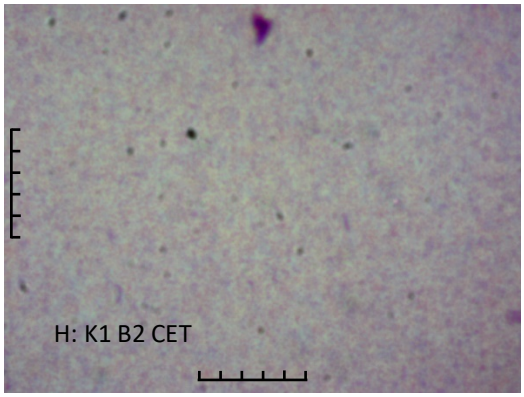
4.2(e): Gram-positive bacillus



4.2(f): Gram-positive



4.2(g): Gram-positive clustered



4.2(h): Gram-positive and neg bacillus

4.2.3 The catalase test results

Table 4.4: Catalase test results

BASE	Swab type	Agar type	Result
RB1	RB1 H1	XLD	Positive
RB1	RB1 B1	XLD	Positive
RB1	RB1 B2	XLD	Positive
RB1	RB1 B3	XLD	Positive
RB1	RB1 H1	CET	Positive
RB1	RB1 B1	CET	Positive
RB1	RB1 B2	CET	Positive
RB1	RB1 B3	CET	Positive
B1	B1 H1	XLD	Positive
B1	B1 B1	XLD	Positive
B1	B1 B2	XLD	Positive
B1	B1 B3	XLD	Positive

B1	B1 H1	CET	Positive
B1	B1 B1	CET	Positive
B1	B1 B2	CET	Positive
B1	B1 B3	CET	Positive
U1	U1 H1	XLD	Positive
U1	U1 B1	XLD	Positive
U1	U1 B2	XLD	Positive
U1	U1 B3	XLD	Positive
U1	U1 H1	CET	Positive
U1	U1 B1	CET	Positive
U1	U1 B2	CET	Positive
U1	U1 B3	CET	Positive
U2	U2 H1	XLD	Positive
U2	U2 B1	XLD	Positive
U2	U2 B2	XLD	Positive
U2	U2 B3	XLD	Positive
U2	U2 H1	CET	Positive
U2	U2 B1	CET	Positive
U2	U2 B2	CET	Positive
U2	U2 B3	CET	Positive
TC	TC1 H1	XLD	Positive
TC	TC1 B1	XLD	Positive
TC	TC1 B2	XLD	Positive
TC	TC1 B3	XLD	Positive
TC	TC1 H1	CET	Positive
TC	TC1 B1	CET	Positive
TC	TC1 B2	CET	Positive
TC	TC1 B3	CET	Positive
SA	SA1 H1	XLD	Positive
SA	SA1 B1	XLD	Positive
SA	SA1 B2	XLD	Positive
SA	SA1 B3	XLD	Positive
SA	SA1 H1	CET	Positive
SA	SA1 B1	CET	Positive

SA	SA1 B2	CET	Positive
SA	SA1 B3	CET	Positive
K	K1 H1	XLD	Positive
K	K1 B1	XLD	Positive
K	K1 B2	XLD	Positive
K	K1 B3	XLD	Positive
K	K1 H1	CET	Positive
K	K1 B1	CET	Positive
K	K1 B2	CET	Positive
K	K1 B3	CET	Positive
P1	P1 H1	XLD	Positive
P1	P1 B1	XLD	Positive
P1	P1 B2	XLD	Positive
P1	P1 B3	XLD	Positive
P1	P1 H1	CET	Positive
P1	P1 B1	CET	Positive
P1	P1 B2	CET	Positive
P1	P1 B3	CET	Positive
M1	M1 H1	XLD	Positive
M1	M1 B1	XLD	Positive
M1	M1 B2	XLD	Positive
M1	M1 B3	XLD	Positive
M1	M1 H1	CET	Positive
M1	M1 B1	CET	Positive
M1	M1 B2	CET	Positive
M1	M1 B3	CET	Positive

A Catalase test was conducted for both Cetrimide and XLD agar. All 36 samples were reactive and positive. The most likely bacteria that grow on XLD agar are specific, such as:

- *Shigella spp* and *salmonella H2S negative.*
- *E. coli*
- *Proteus. Spp.*
- *Enterobacter/ Klebsiella*

For XLD agar there was a 100% positive result, in this instance positive means that there was positive identification for the above bacteria.

The Cetrimide agar produced growth of the following bacteria:

- *Pseudomonas aeruginosa*.
- Fluorescein and Pyocyanin.
- *Pseudomonas aeruginosa* .

Figure 4.3 shows the catalase results for M base.

Figure 4.3: Catalase results for M base

4.2.4 The Methyl red test results

Table 4.5: Methyl red test results

Base	Swab type	MR Test result Gram pos XLD	MR Test result Gram neg XLD	MR Test result Gram pos Cet	MR Test result Gram Neg Cet
RB1	RB1 H1		Negative/Red	G Pos/NR	
RB1	RB1 B1	Positive/Red		G Pos/NR	
RB1	RB1 B2	Positive/Red	Negative/Red	G Pos/NR	
RB1	RB1 B3	Positive/Red		G Pos/NR	
B1	B1 H1	Positive/Red		G Pos/NR	
B1	B1 B1	Positive/Red		G Pos/NR	
B1	B1 B2	Positive/Red		G Pos/NR	
B1	B1 B3	Positive/Red		G Pos/NR	
U1	U1 H1	Positive/Red		G Positive	Negative/Yellow
U1	U1 B1	Positive/Red		G Pos//NR	
U1	U1 B2	Positive/Red			Negative/Yellow
U1	U1 B3		Negative/Red	G Pos/NR	
U2	U2 H1		Negative/Red	G Pos/NR	

U2	U2 B1	Positive/Red		G Pos/NR	
U2	U2 B2	Positive/Red		G Pos/NR	
U2	U2 B3		Negative/Red		Negative/Yellow
TC1	TC1 H1	Positive			Negative/Yellow
TC1	TC1 B1	Positive		G Pos/NR	
TC1	TC1 B2	Positive	Negative/Red	G Pos/NR	
TC1	TC1 B3	Positive			Negative/Yellow
SA1	SA1 H1	Positive/Red		G Pos/NR	
SA1	SA1 B1	Positive/Red		G Pos/NR	
SA1	SA1 B2	Positive/Red		G Pos/NR	
SA1	SA1 B3	Positive/Red		G Pos/NR	
K1	K1 H1	Positive	Negative/Red	G Pos/NR	
K1	K1 B1	Positive/Red		G Pos/NR	
K1	K1 B2	Positive/Red		G Pos/NR	
K1	K1 B3	Positive	Negative/Red	G Pos/NR	
P1	P1 H1	Positive/Red		G Pos/NR	
P1	P1 B1	Positive/Red		G Pos/NR	
P1	P1 B2	Positive/Red		G Pos/NR	
P1	P1 B3	Positive/Red		G Pos/NR	
M1	M1 H1	Positive/Red			Negative/Yellow
M1	M1 B1	Positive/Red		G Positive	Negative/Yellow
M1	M1 B2	Positive/Red		G Pos/NR	
M1	M1 B3	Positive	Negative/Red	G Pos/NR	

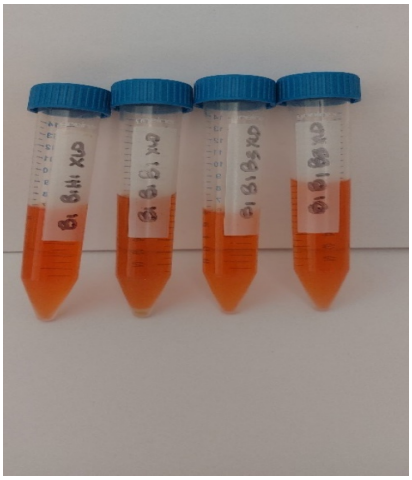


Figure 4.4: Base B1 with all Gram-positive bacteria

The methyl red test was performed, and it was noted that for the XLD agar there were Gram-positive and gram-negative bacteria (Table 4.5). Of the 36 specimens, 32 were Gram-positive and 24 turned red for the methyl red test. This indicates that they were positive for the following bacteria:

- *Staphylococcus* spp.
- *Listeria* spp.
- *Corynebacterium*
- *Mycobacterium*
- *Rhodoccus*

It was also noted that for the 36 specimens there were 9 specimens that were Gram-negative for the XLD group and then turned red for the methyl red test, which means this test confirms the following bacteria:

- *Salmonella.* spp.
- *Shigella.* spp.
- *Yersinia.*
- *e. coli.*
- *Proteus*.
- *Enterobacter*.
- *Klebsiella pneumonia*.

For the Cetrimide group 29 of the 36 specimens were Gram-positive and for the methyl red test there was no result meaning there was no change in colour. This is evidence that the cetrimide agar only allowed Gram-negative bacteria or pseudomonas to grow on this agar. The remainder of the specimens (seven) were Gram-negative (as per Figure 4.5) and they turned yellow during the methyl red test/ reaction, this confirmed that the bacteria could possibly be the following:

- *Pseudomonas aeruginosa*.
- Fluorescein and Pyocyanin.
- *Pseudomonas aeruginosa.*

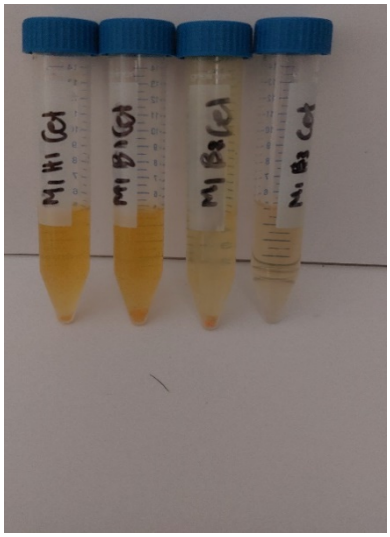


Figure 4.5: M base

4.2.5 PCR colony test

As can be seen from Figure 4.6, the PCR test yielded positive tests with lanes 1 and 3 salmonella and lane 5 shigella.

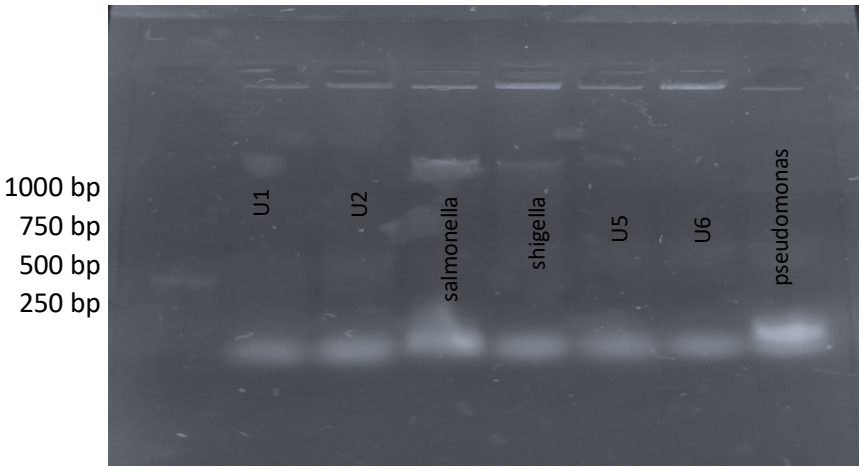


Figure 4.6: PCR results (1)

Figure 4.7 shows lanes 3 and 4 positive for salmonella and shigella respectively and lane 7 pseudomonas

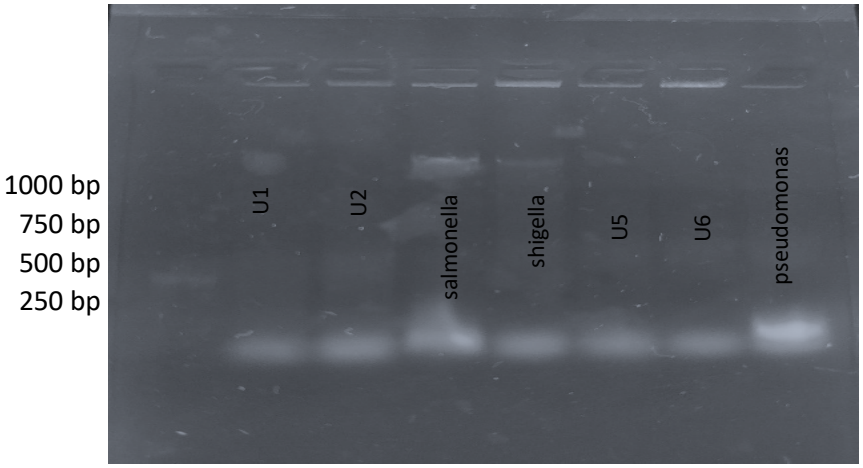


Figure 4.7: PCR results (2)

4.2.6 Conclusion

The results presented in this study showed clearly that there was a high bacterial load found on the ambulance laryngoscope blades and handles under study. This was evident in the colony enumeration as well as the gram stain processes. Furthermore, there was a high level of potentially pathogenic species, namely, *Salmonella*, *Shigella* and *Pseudomonas* sp., which is of great concern. This is an indication of substandard hygiene practices IPC practices. It is evident from the results and the interpretation above that the IPC knowledge and practices regarding laryngoscope blades and handles in the selected EMS in the eThekwini District of KwaZulu-Natal is poor. Thus, it is imperative that a formalised infection and prevention control protocol be devised and implemented so that, going forward, EMS staff in general have formalised guidelines.

4.3 Objective Two: To evaluate the current decontamination practices of EMS personnel for the disinfection of laryngoscope blades and handles

4.3.1 Introduction

A survey was used in the form of a questionnaire. This was done in order to evaluate the current decontamination knowledge and practices of EMS personnel regarding the disinfection of laryngoscope blades and handles. The questions were tested in a pilot study to ensure there were no errors and, if there were, these were corrected for the final survey. Below are the results for the final questionnaire questions. Most questions

were in the form of multiple choice, with the participant ticking the box they regarded as providing the right answer.

4.3.2 Age

In addition to being a good descriptive variable, age is important. With regards to the age of the 27 participants, all 27 participants divulged their age, thus there was a 100% response. As per Table 4.8 and Figure 4.8, the youngest of the participants was 21 years old and the eldest 54. This shows a wide range in terms of age.

Table 4.6: Age of participants

Number of participants	Youngest	Oldest	Average
27	21	54	35

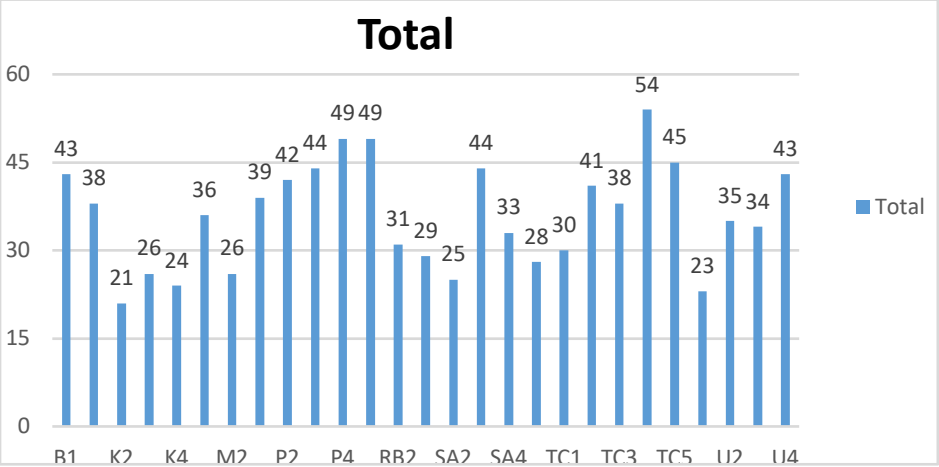


Figure 4.8: Age of participants

4.3.3 The overall years in terms of work experience in the EMS

There was a wide range in terms of work experience in the EMS among the participants. Fourteen (51%) participants had over 10 years of experience in the EMS field. A further 8 (29%) had between 5 and 9 years experience in the EMS. Two participants had 1 year of work experience while 3 (10%) had less than 1 year.

4.3.4 What is your understanding of the words decontaminate or disinfection?

According to Figure 4.9, 59% of the participants chose the answer that defined decontamination or disinfection as a way to eliminate all types of germs through physical or chemical means in healthcare facilities. Out of 27 participants, only 19% picked the correct answer that the process eliminates most harmful microorganisms except bacterial spores on non-living objects. A small 11% of the participants chose the option that it is the removal of visible soil from objects and surfaces that is normally achieved manually or mechanically using water with detergents or enzymatic products. Seven per cent of the participants answered that they did not know and 4% were unsure.

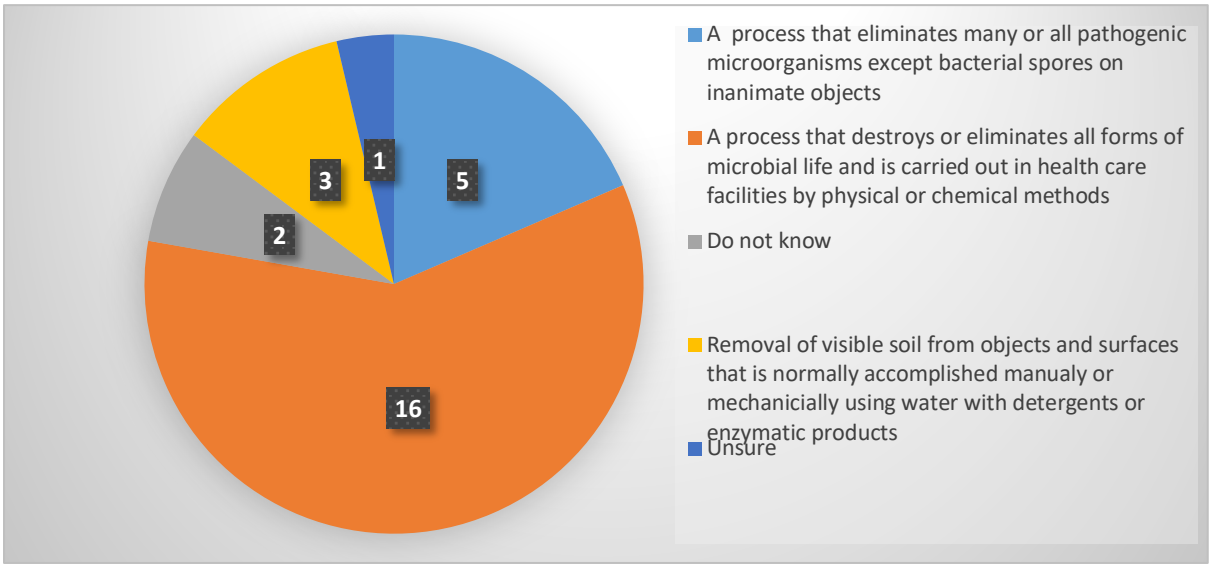


Figure 4.9: Participants' understanding of the word decontaminate

4.3.5 What is your understanding of the term 'infection control' in the emergency medical services?

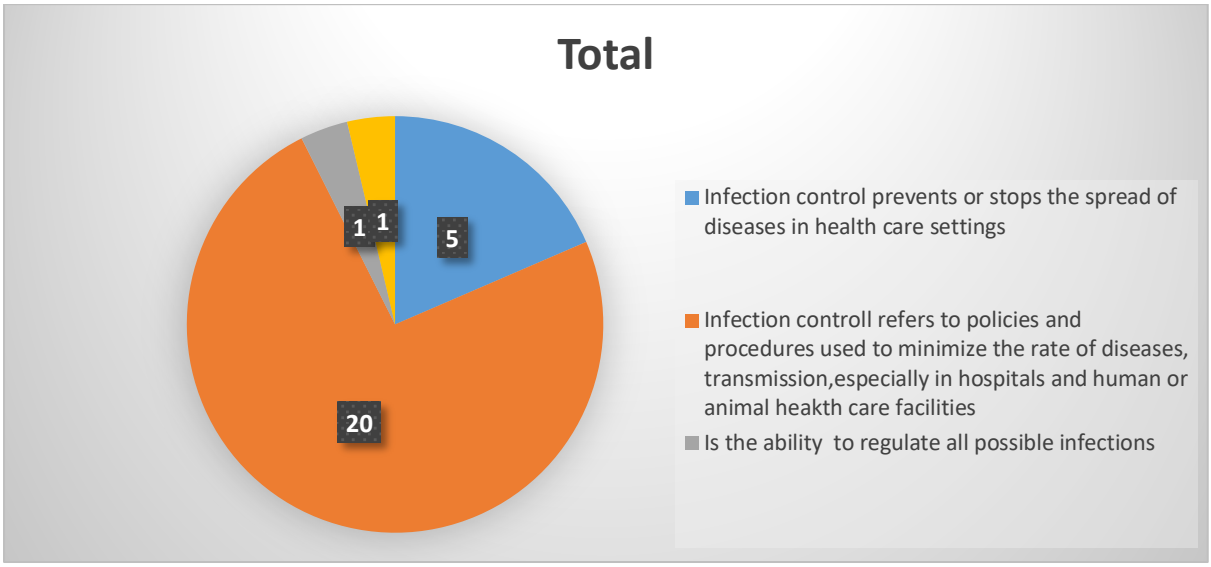


Figure 4.10: Participants' understanding of the term 'infection control' in the EMSs

Figure 4.10 shows the range of answers regarding their understanding of the term 'infection control' in the EMS. It was evident that a large amount (74%) of the study population identified the correct meaning of IC as policies and procedures used to minimise the rate of diseases transmission, especially in hospitals and human or animal health care facilities. Eighteen per cent chose IC as preventive measure or the stopping of the spread of diseases in healthcare settings. Four per cent chose the ability to regulate all possible infections and 4% were unsure of the meaning.

4.3.6 Do you feel that you have sufficient knowledge about infection control practices regarding the laryngoscope blade and handles?

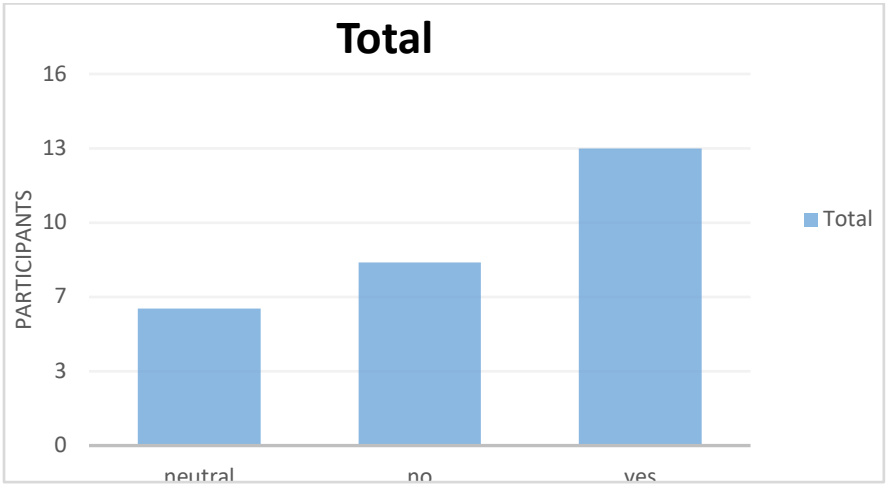


Figure 4.11: Sufficient knowledge in infection control and practices

Figure 4.11 shows 48% of the participants responded to this question by saying “Yes” and 30% said “No”.

4.3.7 Are you confident in inspecting the response vehicle laryngoscope blade and handle with bare hands?

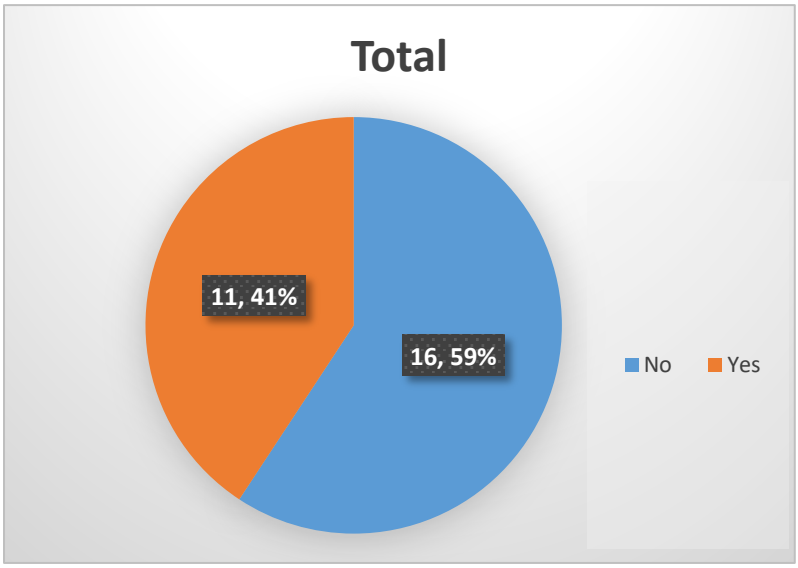


Figure 4.12: Confidence in inspecting the response vehicle laryngoscope blade and handle with bare hands

Inspecting equipment upon shift takeover or arrival is a key factor as an ECP. This is done to check if all the equipment is in working order. Figure 4.12 shows that 59% of the participants would not want to inspect the laryngoscope blade and handle with bare hands. However, 41% of the participants were comfortable inspecting the laryngoscope with bare hands.

4.3.8 Do you wash your hands before disinfecting the laryngoscope blade and handle

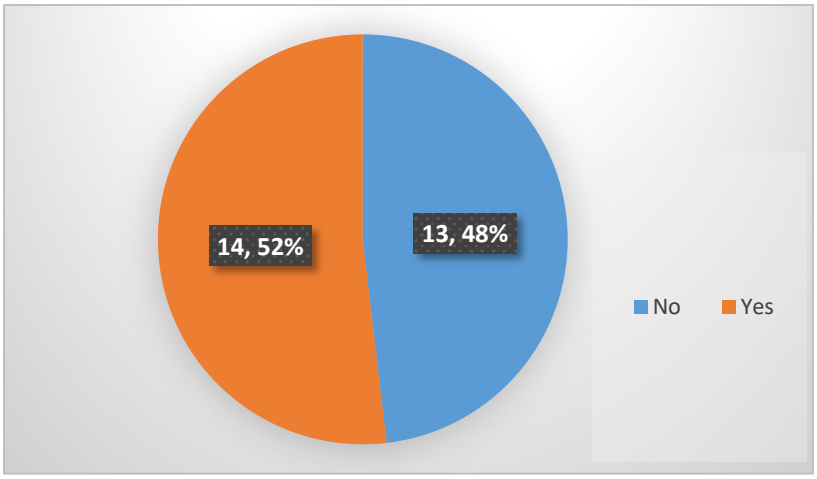


Figure 4.13: Washing of hands before disinfecting the laryngoscope blade and handle

Due to the global pandemic of COVID-19, the importance of HH is one of the most emphasised measures to prevent the transmission of infectious diseases. Concerning the above question, 52% of the participants wash their hands before disinfecting the laryngoscope blade and handle while 48% do not wash their hands prior to disinfection of the tool (Figure 4.13).

4.3.9 When preparing for ETI, what hand hygiene methods do you use.

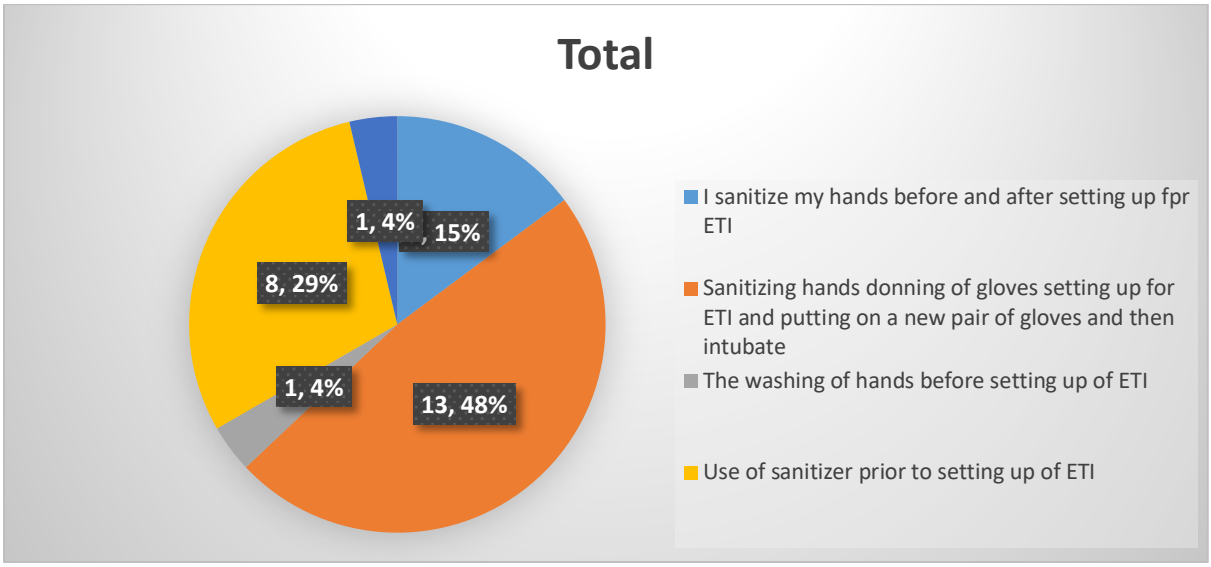


Figure 4.14: Hand hygiene methods that are used prior to ETI

Poor compliance in the pre- and in-hospital sectors by HCWs with HH is a universal problem. Figure 4.14 shows that a total of 48% of the participants chose the option of sanitising their hands, donning gloves, before setting up for ETI, putting on a new pair of gloves and then intubating. A total of 29% of the participants opted for the use of sanitiser before establishing ETI. A smaller portion of participants (15%) opted for the sanitising of their hands before and after establishing ETI. This showed that they had confidence in their hand sanitiser and relied on it to clean their hands. A further 4% of the participants said that they wash their hands before and after establishing the ETI. It was also noted that another 4% of participants just washed their hands before the setting off ETI and not after.

4.3.10 Do you wear gloves when washing the laryngoscope blade and handles?

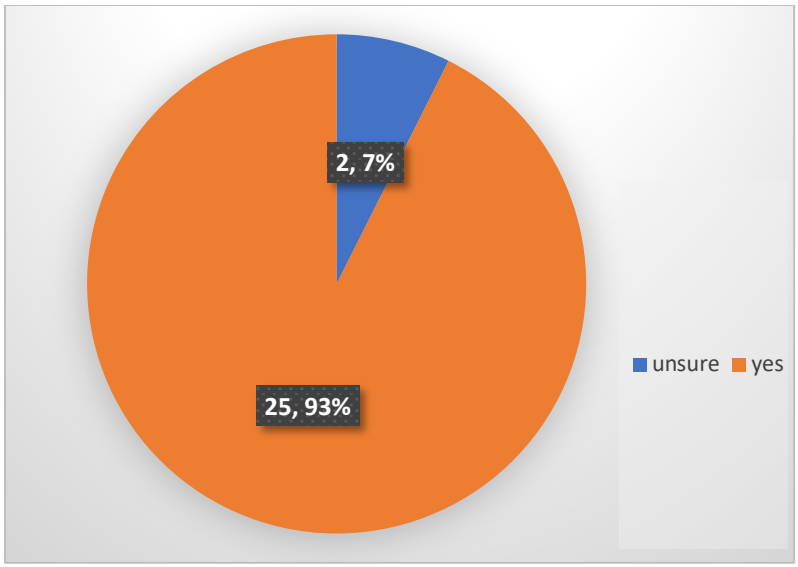


Figure 4.15: Showing wearing gloves when washing the laryngoscope blade and handles

HCWs' hands can become a reservoir for microorganisms during patient care and can transmit pathogens such as COVID-19 variants, hepatitis and TB. Figure 4.15 shows that 93% of the participants wear gloves when washing laryngoscope blades and handles and 7% are confident of not using gloves when washing the airway tool.

4.3.11 Do you have sufficient time to clean and disinfect the laryngoscope blade and handles on shift?

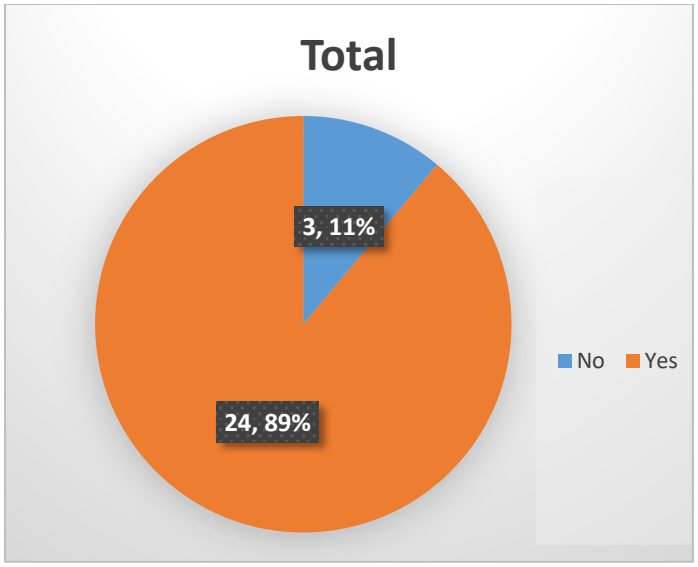


Figure 4.16: Sufficient time for cleaning and disinfecting of the laryngoscope blade and handles on shift

Figure 4.16 shows a high number of participants (n = 24) indicated that they always had sufficient time to clean the laryngoscope blades and handles. Three participants indicated they did not have sufficient time to clean.

4.3.12 Is cleaning and disinfection equipment readily available at the Base?

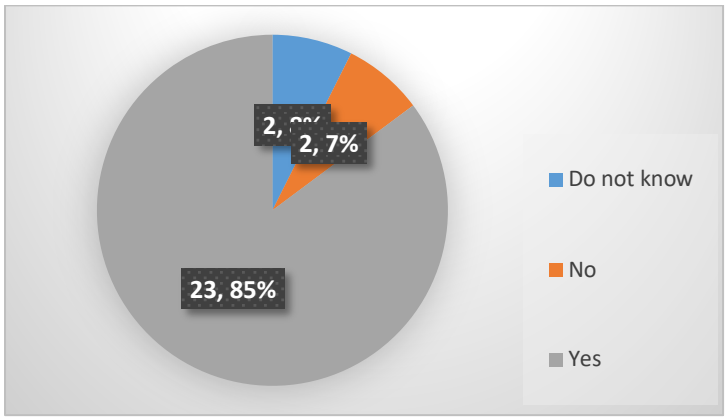


Figure 4.17: Availability of cleaning and disinfection equipment at the Base

A large portion of the participants (85%) answered that cleaning agents are available for them to use, hence no delay in terms of decontaminating and cleaning. Some participants (15%) did not know, while others (8%) were unsure if there were cleaning agents available at the base. The rest (7%) said there are no cleaning agents or equipment available (Figure 4.17).

4.3.13 Which would you prefer in your airway kit [disposable blades versus reusable blades]

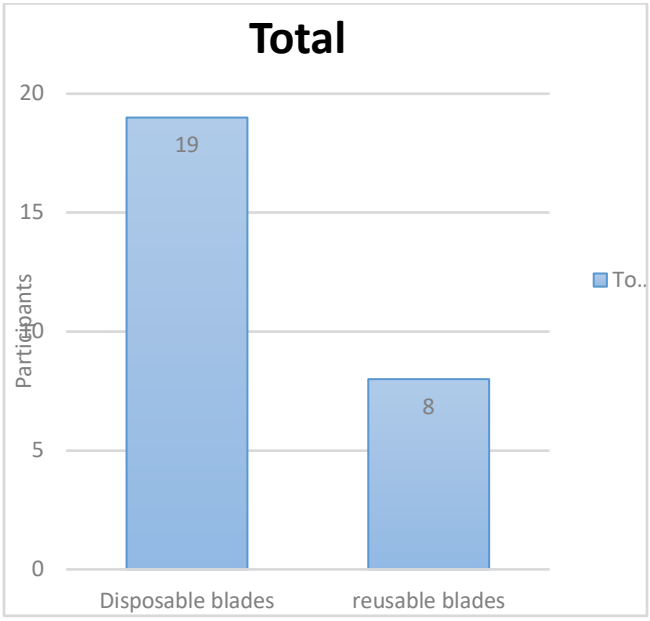


Figure 4.18: Which would you prefer in your airway kit

A very interesting question was posed to the participants regarding whether they prefer disposable blades or reusable blades. The participants (70%) opted for disposable blades, with the remaining 30% choosing reusable blades (Figure 4.18).

Figure 4.19 shows work experience versus the choice of disposable or reusable blades.

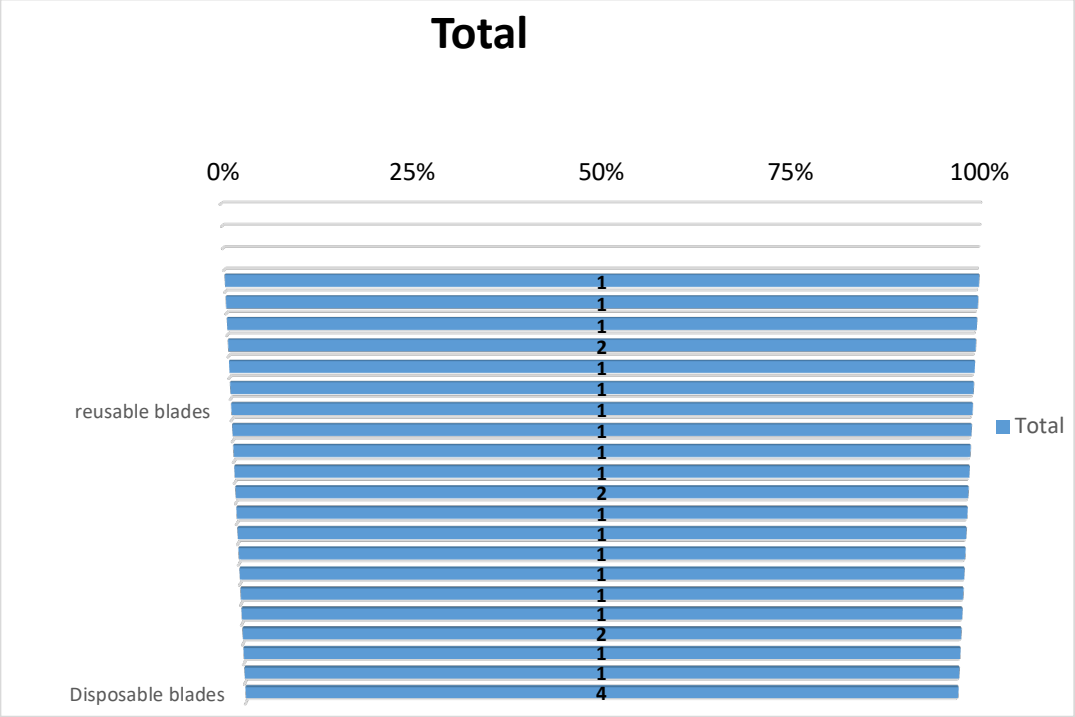


Figure 4.19: Work experience versus disposable or reusable blades

It is important to note that 10 participants of the disposable group had over 9 years' experience as ALS.

4.3.14 The availability of a second pair of laryngoscope blades and handles at base/on board the response vehicle

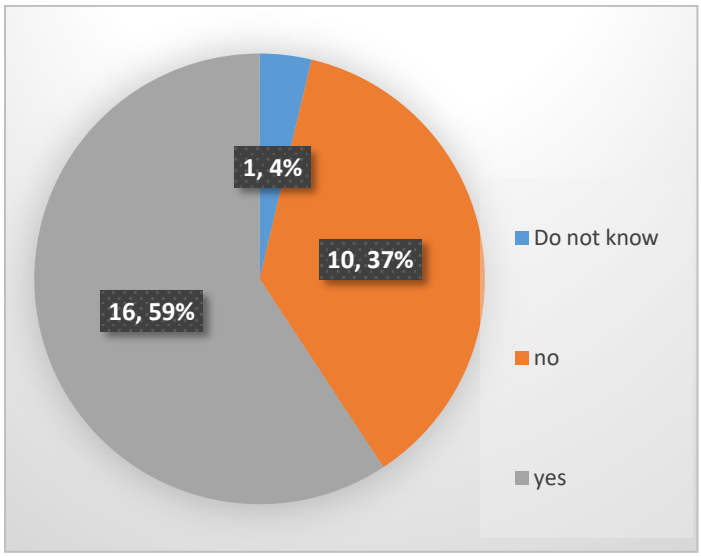


Figure 4.20: The availability of a second pair of laryngoscope blades and handles at the base / on board the response vehicle

Figure 4.20 shows that 59% of the participants indicated that there is a second set of laryngoscope blades and handles, 37% said “No” and 4% said they do not know if there is any.

4.3.15 Were you ever in a situation whereby you needed a second pair of laryngoscope blades and handles to intubate due to the first pair of laryngoscope blade and handle being contaminated?

Regarding this question, 56% of the participants answered “No”. This raises the question as to what option they followed when faced with a second patient needing AM. The balance of the participants (44%) answered “Yes” to the above question. It is also important to note that of the 44% who answered “Yes”, seven of these participants had ALS experience of over 10 years.

4.3.16 Would it be beneficial to have a second pair of laryngoscope blades and handles included in your airway kit?

This question was a follow-up to the previous question which queried whether the participants were ever in a situation whereby they needed a second pair of laryngoscope blades and handles to intubate due to the first pair of laryngoscope blades and handle being contaminated. The vast majority of participants (27.96%) answered that it would be beneficial to have a second set of the airway tool present in the airway kit or on board the response vehicle (Figure 4.21). Forty-four per cent of the participants answered that it would not be beneficial to have a second set of airway tools, whereas 56% needed an additional laryngoscope set in the previous question. This does not correlate with the 96% who say that the second set of the laryngoscope blade and handle would be beneficial.

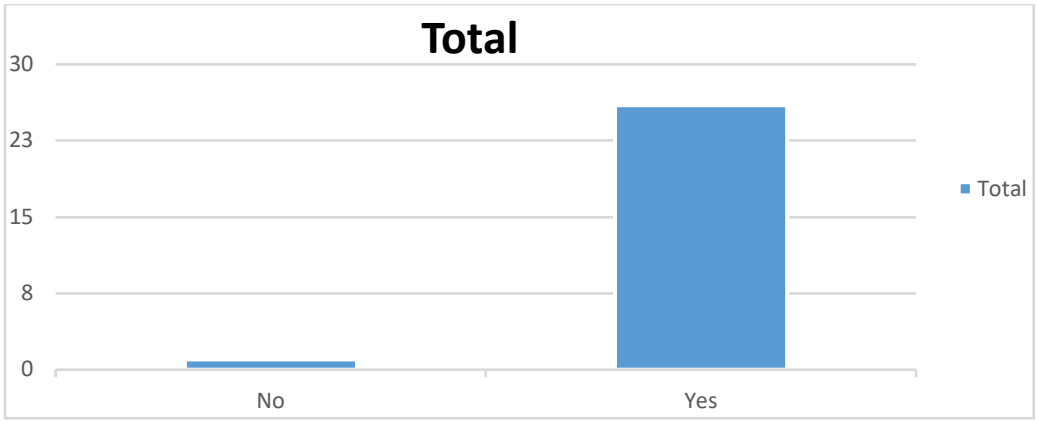


Figure 4.21: The benefit of having a second pair of laryngoscope blades and handles included in your airway kit

4.3.17 Are you aware of what CSSD is?

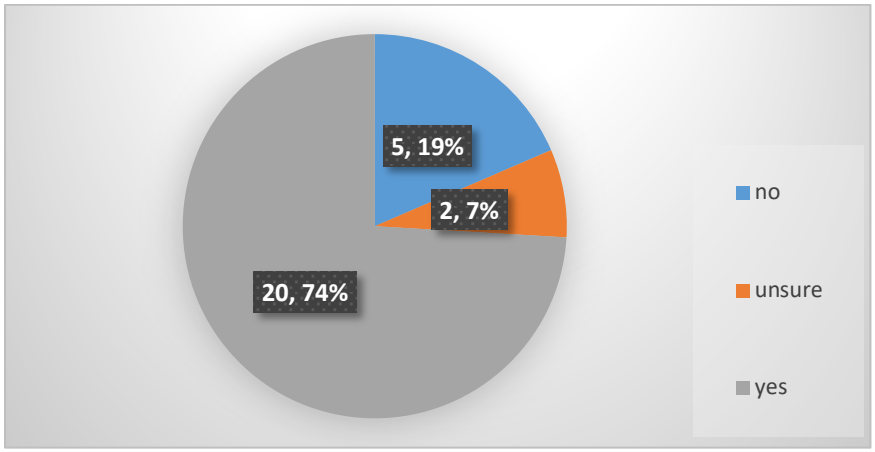


Figure 4.22: The awareness of CSSD

It is crucial to comprehend the role of CSSD in both pre- and in-hospital healthcare settings. Of the 27 participants, 19% did not know or were not aware of what CSSD is. A further 7% were unsure of what CSSD is (Figure 4.22).

4.3.18 How do you clean and disinfect the laryngoscope blade and handles while on duty

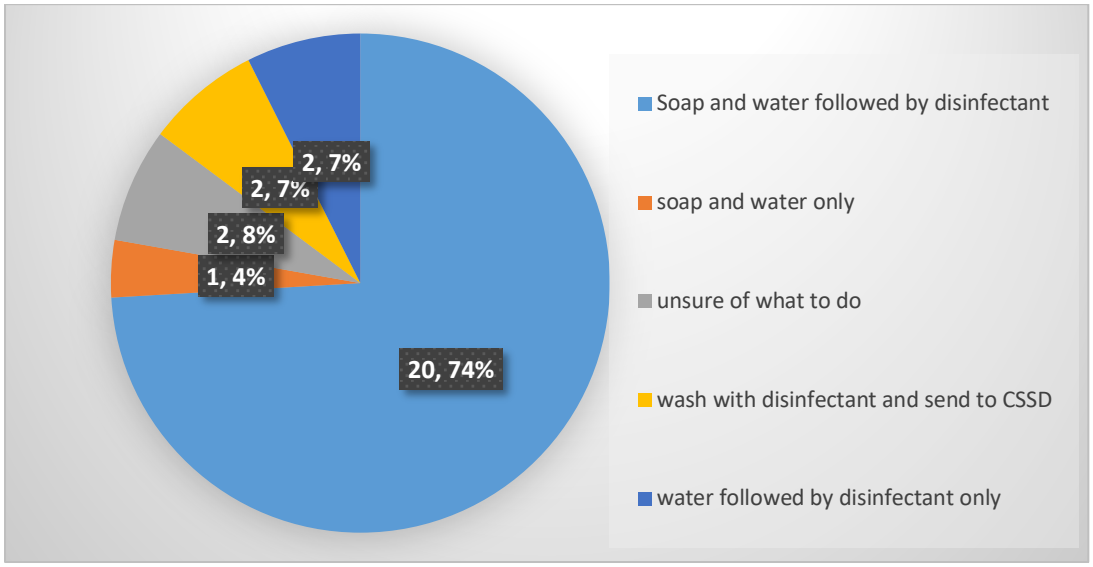


Figure 4.23: The different ways in which laryngoscope blades and handles are cleaned and disinfected while on duty

Figure 4.23 shows that 74% of participants used soap and water followed by disinfectant, while 7% washed with disinfectant and sent to CSSD, and another 7% washed with water and then disinfectant. Eight per cent of the participants were unsure of what to do and 4% used soap and water only.

4.3.19 When are the laryngoscope blade and handle usually cleaned

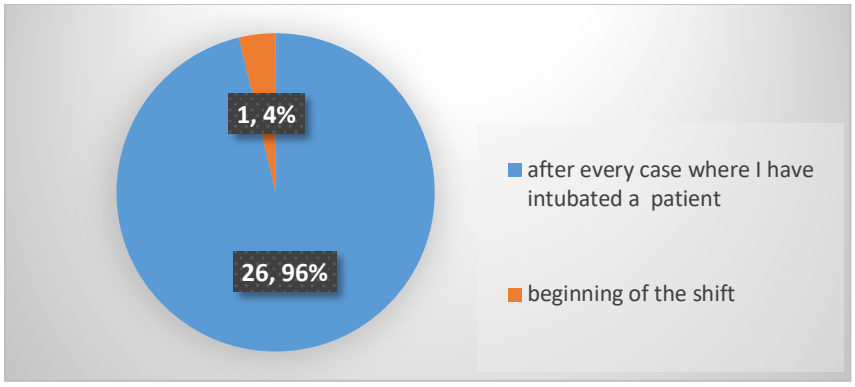


Figure 4.24: When the laryngoscope blade and handle are usually cleaned

At the time of the investigation, most of the participants (96%) answered that they clean the laryngoscope blade and handle after every case where intubation was

needed, and 4% of the participants cleaned the tool at the commencement of every shift (Figure 4.24).

4.3.20 In terms of disinfectant who prepares the solution?

Figure 4.25 shows that the majority of participants (74%) took the responsibility themselves to prepare the disinfectant solution. Fifteen per cent of the participants used any amount of the solution regardless of its strength. Interestingly, 7% did not know who prepares the disinfectant solution and 4% asked their manager for assistance to help prepare the solution. It is quite clear the participants are self-sufficient and responsible to prepare the disinfectant solution.

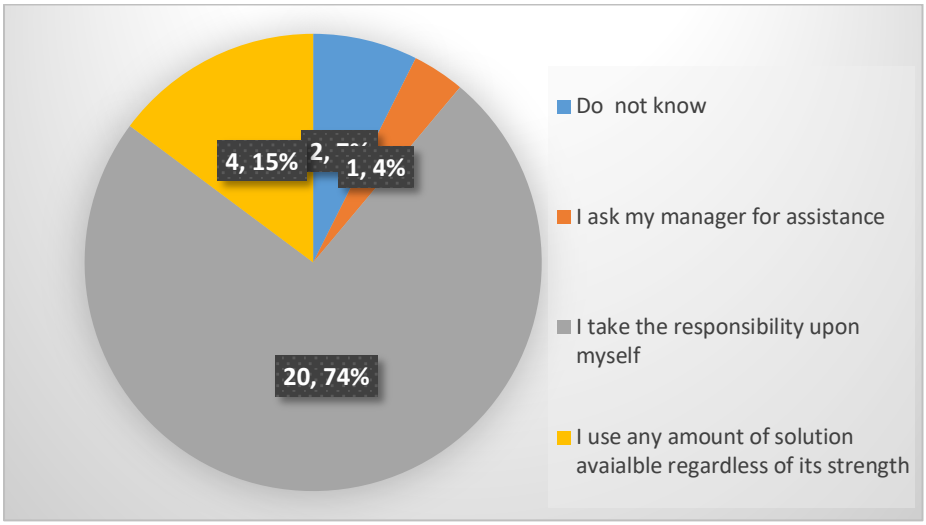


Figure 4.25: The different approaches to preparing the disinfectant solution

4.3.21 Is there anything special that you use in terms of PPE when performing endotracheal intubation for suspected high risks patients such as: COVID-19, TB viral or bacterial, HIV and Cancer?

This was an open-ended question and was formulated to gather richer data regarding the practitioner's safety precautions in terms of PPE when performing ETI on high risk patients. More than 95% of the participants said that they would wear full PPE, which consists of a full garment with goggles / safety glasses, a visor, and double gloves. More than 95% of the participants sanitised thoroughly before and after using PPE when performing ETI on high-risk patients. One per cent of the patients mentioned that they would not opt to perform ETI on these patients as they felt the risks for

contraction of these diseases were very high. One per cent of the participants said they would not want to add anything else as they were comfortable with double gloves, protective eyewear, and a surgical mask because they felt that the additional PPE would make conditions uncomfortable. This 1% of participants also mentioned that the visor hinders the proper visualisation of the vocal cords, thus increasing the number of attempts at ETI.

4.3.22 During COVID-19 restrictions where you allowed to use the hospitals' sluice rooms to disinfect the laryngoscope blades and handles after hand over?

Fifty nine per cent of the participants said "Yes" they could use the destination hospital sluice room to disinfect the airway tool, while 26% said they could not. It was interesting to note that 15% of the participants were unsure if they could use the hospital sluice rooms to disinfect the tool.

4.3.23 Do you think it is possible for microorganisms/pathogens such as the COVID-19-virus to be transmitted from one patient to another without adequately disinfecting the laryngoscope blades and handles between patients/cases?

This question ascertained the awareness of diseases and whether the participants were aware of the microorganisms or pathogens being transferred from patient-to-patient due to inadequate disinfection of the laryngoscope blade and handle. The majority (92%) of the participants said "Yes" there is a possibility of harmful bacteria or viruses such as COVID-19, TB and other diseases to being transmitted from patient-to-patient. This meant that participants were aware of such transmission of diseases and understood the importance of disinfection of not only the airway tool but all the equipment used between cases. Only 4% of the participants answered "No" to this question. This meant that they are unaware of the dangers of such diseases, their transmission avenues, and the ramifications that they may have long and short term.

4.3.24 Does your emergency medical service base have its own sluice room designated for decontamination?

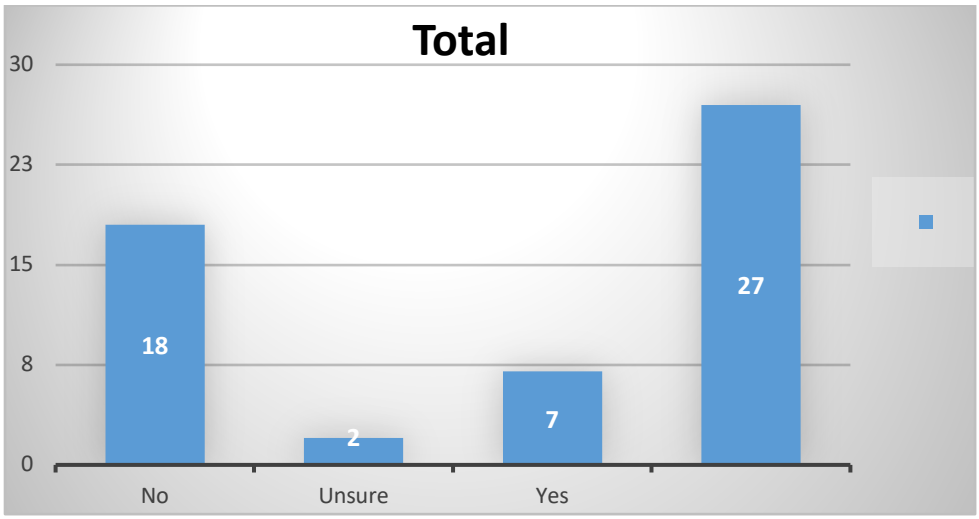


Figure 4.26: Own emergency medical service base and own sluice room designated for decontamination

This question was posed to find out if the bases had their own sluice room or not. Figure 4.26 shows that 18 participants answered “No” to this question two participants answered “ Unsure”, and seven answered “Yes”. What was interesting was that of the 18 participants who indicated “No”, 12 of these belonged to the same bases as participants who answered “Yes” to the question.

4.3.25 If no to the above question what do you do in terms of designated sites to decontaminate the laryngoscope blade and tool?

This was an open-ended question to engage with the participants what their options were if they had no sluice room at their respective bases. A portion of the participants opted to use the hospital sluice room with permission. Some participants had difficulty, as the receiving hospital did not allow their sluice rooms to be used. Other participants opted to use the wash bay to disinfect the tool. The disinfection was not done in a controlled environment, although the wash bay is intended for washing emergency vehicles.

4.3.26 Do you think it is safer to decontaminate/disinfect the laryngoscope blade in a controlled environment such as a designated sluice room?

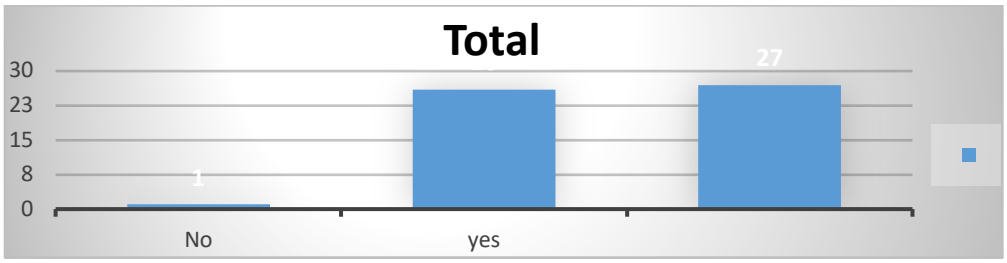


Figure 4.27: is it safer to decontaminate/ disinfect the laryngoscope blade in a controlled environment such as a designated sluice room

In terms of safety, Figure 4.27 shows that 26 of the participants indicated it was safer to decontaminate the tool in a controlled environment.

4.3.27 In terms of arriving at a mass casualty where there were multiple red code patients requiring endo-tracheal intubation, what was your preparation between the patients in terms of the cleaning of the laryngoscope blades and handles?

This open-ended question aimed to uncover the strategies used for providing ETI to numerous critically ill patients during a mass casualty incident. All participants answered this question. This was the information contained in responses:

- The use of Medi-wipes to wipe down the laryngoscope blade, handle, and then perform ETI after every use.
- The use of D-Germ or any other detergent liquid poured onto the blade and handle and then cleaned and then perform ETI.
- The use of a Medi-wipe to clean the blade, handle, and then use a condom over the blade. However, the vision of the vocal cords would and may be hampered by the protective sheath.
- Some of the practitioners would rather use an laryngeal mask airway or alternative airway device not requiring ETI.
- Some of the practitioners would call for additional resources such as Helicopter Emergency Medical Services or call more ECPs to scene.

- Some of the practitioners mentioned that they have never been in mass casualty situations before, and they needed guidance for this type of scenario. This response was attributed to the younger ECPs at the relevant bases.
- Some opted to use different size blades between patients. This meant detaching the current contaminated blade and then attaching a clean blade. They felt that there was a huge risk in using the same laryngoscope blade and handle at mass casualty scenes, even if it was cleaned.

4.3.28 What methods do you use to disinfect hard to reach places on the laryngoscope blade and handle during cleaning process? What are your methods?

This was an open-ended question and there were no correct answers. The following methods were communicated:

- Carry a toothbrush in the airway pouch they would use on site to scrub difficult areas of the blade and handle.
- Some participants said they would use the toothbrush with water, some with chlorine-based detergents or a detergent that was available at the sluice room for receiving facilities.
- Some said that they would dismantle the entire tool and soak in water or chlorine or in a container of detergent and then use a toothbrush to scrub down the tool.
- The use of a gauze or sponge to help scrub the tool.

4.3.29 In your service, are there currently formal policies on infection control practices regarding laryngoscope blades and handles?

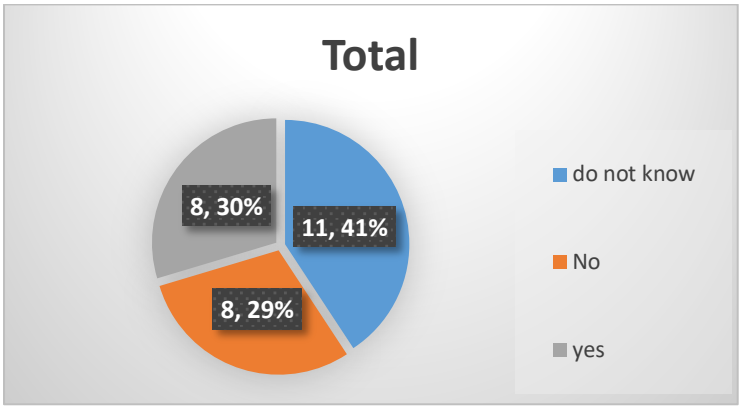


Figure 4.28: Are there currently formal policies on infection control practices regarding laryngoscope blades and handles

As part of a generic IC programme, policies and procedures for preventing/controlling the transmission of infectious agents, employer education, and IC aspects of employee health need to be in place. The regulations for hazardous biological agents (South Africa, 2001) cover the policies and procedures for IC in South Africa. Figure 4.28 shows that of the 27 participants who responded, 8 (30%) indicated that there were IC policies regarding laryngoscope blades and handles, 8 (30%) said “No”, and 11 (41%) answered “Unsure”. Looking at these numbers, it is clear that there is some confusion whether there are any formal IC policies present or not.

Thirty per cent of the participants answered “Yes” to the question, indicating that that they were sufficiently informed about them. This is inconsistent with the fact that this author could not locate any policies and procedures on IC.

4.3.30 Do you think that EMS should have a formalised infection control protocol regarding the laryngoscope blade and handle disinfection?

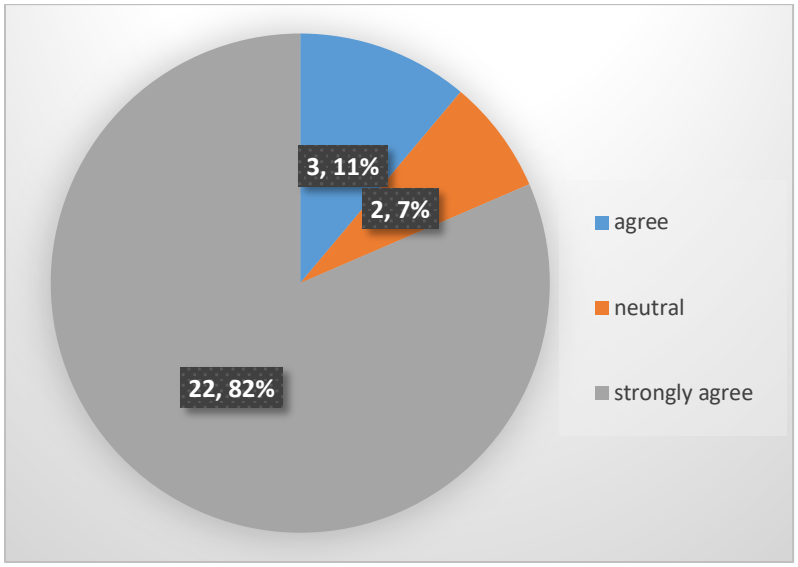


Figure 4.29: Do you think that EMS should have a formalised infection control protocol regarding the laryngoscope blade and handle disinfection

Figure 4.29 shows that the majority of participants (82%) strongly agreed that there should be a formal IC protocol which would control the transmission of microorganisms and promote best practice, however; there was a small (7%) number of participants who were neutral in their response.

4.3.31 Apart from what you have already stated in the above responses, are there any comments or problems regarding infection control that you would like to mention?

The second last question of the tool asked respondents if they had any general comments on IC, and 16 of the participants (59%) made comments and 41% did not. This is a summary of the comments provided by the participants:

- A protocol or standard operating procedure (SOP) needs to be in place for the disinfection of the laryngoscope blades and handles, as this is an area of concern and is lacking.
- The addition of clinical governance to monitor and observe the strict adherence to these SOPs or protocols.
- The appropriate training or workshops to be set up for these SOPs or protocols pertaining to laryngoscope blade and handle.

- That there is a need for a dedicated sluice room for the EMS at each respective base.
- Participants felt their knowledge of IC and different diseases was poor and felt that they, as EMS providers, should have further training.
- For severe cases whereby the patient required ETI and had diseases such as COVID-19, MDR TB, XDR TB and other critical diseases, the participants felt the need to use CSSD to assist.

4.3.32 Would you be interested in learning more about decontamination and infection control regarding the laryngoscope blade and handles?

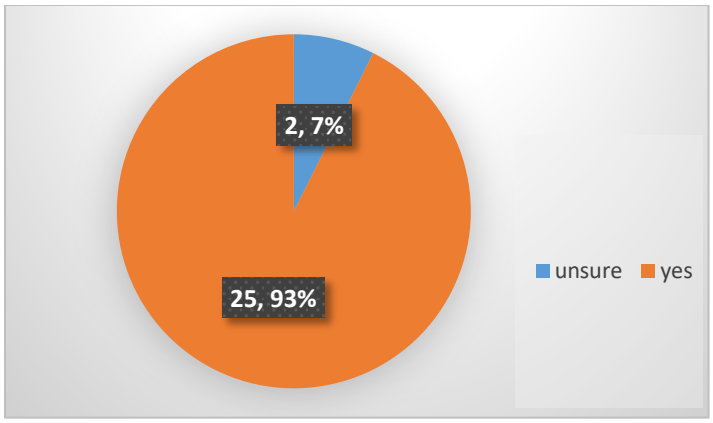


Figure 4.30: Interest in learning more about decontamination and infection control regarding the laryngoscope blade and handles

Figure 4.30 shows that most of the respondents (93%) desired more information on IC. Interpreting the numbers further, participants felt that this was an area of concern that made them feel inadequate and made them wonder whether they were practising at the recommended and correct standards.

4.3.33 Conclusion

In summary, the results show that there is no consistency regarding the disinfection of the tool. It can also be deduced that there is no clear protocol in place for participants to follow. There is a clear gap in IC education overall and this could directly affect the mortality and morbidity of the patient as well as HCAI.

4.4 Objective Three: To establish the minimum concentration of disinfectants and protocol required to inhibit the growth of microorganisms during pre-hospital cleaning and disinfection

To fulfil this objective, the researcher tested all the disinfectants that the private company used to disinfect or clean the laryngoscope tools in service in their company. The following disinfectants or agents were used and then diluted to comply with this objective:

- D-Germ hand disinfectant, which comprises 0,5% chlorohexidine gluconate in 70% propyl alcohol.
- Bioscrub anti-septic skin cleanser, which is a 4% chlorhexidine gluconate.
- Alcohol surface disinfectant.

The researcher diluted the disinfectants into the following strengths: 1%, 5%, 10%, 15%, 20%, and 50%. The researcher did this to investigate the minimum concentration needed to clean and disinfect the tool effectively.

Table 4.7 shows the results which were obtained from this experiment:

Table 4.7: Minimum inhibition concentration tests results

Disinfectant	5%	10%	15%	20%	50%
D-Germ	5mm	No bacteria detected	No bacteria detected	No bacteria detected	No bacterial present
Bioscrub	1mm	5mm	6mm	7mm	N/A
ASB	No effect	3mm	6mm	No bacteria detected	No bacteria present

D-Germ

The disinfectant 5 % D-Germ produced a 5 mm zone of inhibition, but there was still a significant volume of bacterial growth on the agar plate. It was also noted that with incremental increase in concentration there was less bacterial growth. The minimum amount needed to adequately disinfect was at 10% (Figure 4.31).

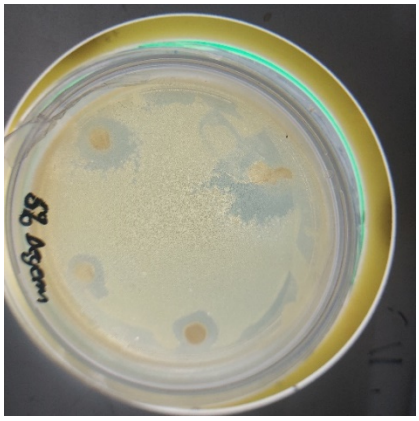


Figure 4.31: D-Germ discs

Bioscrub

When the concentration of the bio scrub decreased the zone of inhibition increased as noted in the Table 4.7. However, at 50% there was no positive feedback This could be because the disc was not adequately saturated with the solution to start with (Figure 4.32).

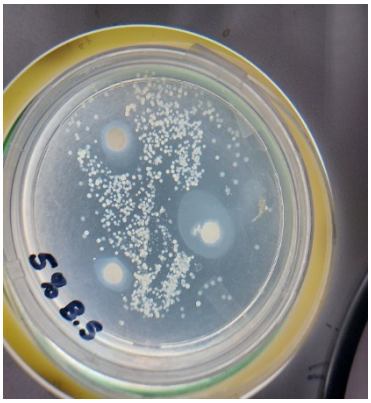


Figure 4.32: Bio scrub discs

Alcohol surface disinfectant

Testing established that with an MIC of 20% for the alcohol surface disinfectant, there was no bacterial growth at all.

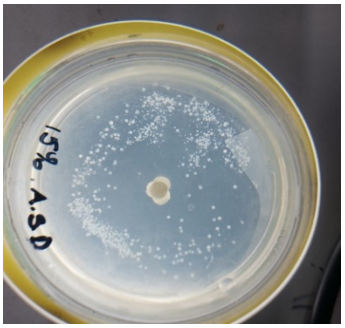


Figure 4.33: Alcohol surface disinfectant disc – 15%

4.4.1 Conclusion

Table 4.7 shows that for the D-Germ disinfectant an MIC of 10% was established, for Bioscrub 50%, and for alcohol 20%. Thus, only 10% of the D-Germ disinfectant was needed to disinfect the tool effectively, indicating that the bacteria were not resistant or immune to the disinfectant. Needing 50% of the Bioscrub disinfectant could mean that the bacteria had some immunity, or the Bioscrub needed to be activated in terms of application. Bioscrub is a thick liquid that needs to be mixed, foamed, and applied to the surface to effectively disinfect.

CHAPTER 5: DISCUSSION

5.1 Introduction

The preceding chapter presented and discussed the results. This chapter further correlates these findings with the findings from the literature review in order to conduct an interpretive and deeper analysis in an attempt to address the study's research objectives.

5.2 Objective One: To identify and quantify the prevalence of bacteria and fungi on laryngoscope blades and handles used by the selected EMS

The first objective was to identify and quantify the prevalence of bacteria and fungi on laryngoscope blades and handles used by employees of the selected EMS. Within this objective the following had to be achieved and will be discussed: colony count/enumeration, the Gram stain process to identify whether there was Gram stain positive or negative bacteria, as well as the biochemical tests to further identify the different types of bacteria. Antibiotic-susceptibility testing as well as colony PCR testing will be described. The results of the tests will be discussed in this section.

5.2.1 Colony count/enumeration

Table 4.1 shows that a high colony count was present for XLD and Cetrimide agar. The lowest colony count for XLD agar was 4x10`4 CFU/mL, and the highest was 9x10`5 CFU/mL. Regarding cetrimide agar, the highest colony count was 1x10`6 CFU/mL, and the lowest was 4x10`4 CFU/mL. There was a wide variance in colony counts and it is important to note that the bases are also geographically far apart. Regarding XLD agar, there were three EMS bases with the high colony counts of 9x10`5 CFU/mL for and there were four bases with colony counts of 1x10`6 CFU/ml. It is important to note these bases were also far apart. The agar plates were saturated with colonies/bacteria and this could mean that whatever methods were used to disinfect or clean the tools were ineffective. Although there was no clear indication at this point what specific bacteria were on the agar plates, there was a clear indication that the bacterial load was high. It is also clear that the amount and/or concentration

of detergents used were not effective and lastly, this proves that there are not any evidence-based guidelines available or present (Liu, Whitehouse and Li 2018).

5.2.2 Antimicrobial susceptibility testing

The AST conducted on colonies resulted in four out of the five antibiotics displaying positive results in terms of zones of inhibitions. The four antibiotics were Ampicillin, Fosfomycin, Tetracyclin and Pipemedic acid. It was noted that Colistin sulphate had little to no effect on certain of the 54 samples. Ampicillin had the largest zone of inhibition of 7 mm and an average zone of inhibition of 5.3 mm. Fosfomycin also had a high zone of inhibition of 7 mm with an average of 2.6 mm. Tetracycline had a maximum zone of inhibition of 5 mm, with the average being 2.2 mm. Pipemidic acid's largest inhibition zone was 5 mm with an average of 2.4 mm. Colistin sulphate's largest zone of inhibition was 4 mm with an average of 0.6 mm. Overall, the antibiotics had a good effect on the bacteria (van Belkum *et al.* 2019).

5.2.3 Gram stain

There were two groups, the XLD agar and the Cetrimide agar, with 36 samples in each group (see Table 4.3 for results). In the XLD agar group there were 32 Gram stain positive species and 9 Gram stain negative. In the Cetrimide agar group there were 31 Gram stain positive species and seven Gram stain negative. The Gram stain test was conducted to determine the morphology of pure isolates. This is a common technique used to differentiate between two large groups of bacteria based on their different cell wall constituents. With regards to the Gram stain bacteria for the XLD group, the following are the most likely species present (Sizar, Leslie and Unakal 2023):

- *Staphylococcus* spp.
- *Listeria* spp.
- *Corynebacterium*
- *Mycobacterium*
- *Rhodoccus*

Regarding the Gram-negative bacteria found on the XLD agar, the following are the most likely species present (Liu, Whitehouse and Li 2018):

- *Salmonella spp.*
- *Shigella spp.*
- *Yersinia*
- *E. coli*
- *Proteus . spp.*
- *Enterobacter*
- *Klebsiella pneumonia*

For the Cetrimide agar, there were many Gram- stain negative bacteria that were present and are suspected to be *Pseudomonas aeruginosa* (Silhavy 2016).

5.2.4 Biochemical test 1 – Catalase test

The Catalase test was conducted on the bacterial species isolated from the XLD and cetrimide media (Table 4.6 and Figure 4.3). All the samples were reactive and positive. Positive does not necessarily mean that they are bacteria. Even if the result was negative, bacteria could still be bacteria. It is noted that specific bacterial species that have been isolated are positive for the Catalase test (Bano *et al.* 2020) Positive in this instance meant that there was a positive identification for bacteria. Bacteria that grow on XLD agar are specific, such as:

- *Shigella spp*
- *Salmonella H2S negative.*
- *E. coli*
- *Proteus.*
- *Enterobacter / Klebsiella*

For XLD agar, there was a 100% positive result, meaning the test was positive for the above bacteria (Bano *et al.* 2020).

Similarly, there was a positive result for the Cetrimide agar, which is an indication for the presence of *Pseudomonas aeruginosa* (Bano *et al.* 2020).

5.2.5 Biochemical test 2 – The Methyl red test

Table 4.5 shows the results of the Methyl red test. For the XLD agar there was presence of Gram positive and Gram-negative bacteria. Of the 36 specimens, 32 were Gram positive specimens of which 26 turned red for the Methyl red test. This indicates that they were positive for the following bacteria:

- *Staphylococcus spp.*
- *Listeria spp.*
- *Corynebacterium*
- *Mycobacterium*
- *Rhodoccus*

From the findings in this study, *Staphylococcus* spp. is a frequent coloniser of humans and one of the foremost opportunistic bacterial pathogens causing major morbidity and mortality of 30% globally (Yamashoji, Al Mamun and Bari 2020). *Staphylococcus aureus* colonises approximately 20% to 30% of humans persistently in the nose and frequently in other sites such as the skin, throat, axillae, groin and intestine. Colonisation is harmless, but it is a risk factor for developing subsequent infections which can range from mild skin and soft tissue infections to serious invasive infections, including osteomyelitis and septic arthritis, bacteraemia or septicaemia, pneumonia and endocarditis. *S. aureus* infections can be acute, recurrent, or chronic and persistent (Howden, 2023). *Listeria monocytogenes* is the causative agent of listeriosis, a foodborne infection with severe manifestations in people with weakened immunity, pregnant women and newborn infants. Listeriosis ranges from mild disease with flu-like symptoms and diarrhoea to life-threatening conditions such as bacteraemia and infections of the brain or placenta. It also affects the central nervous system (CNS) causing neuromeningeal listeriosis, typically a meningoencephalitis, and maternofoetal/neonatal (MFN) listeriosis, presenting as miscarriage, stillbirth or neonatal sepsis (Vázquez-Boland 2020). From January 2017 to July 2018, South Africa witnessed the world's largest listeriosis outbreak. Of the 1060 laboratory-confirmed cases of listeriosis reported by the National Institute of Communicable Diseases (NICD), 216 deaths were recorded (Kaptchouang Tchatchouang *et al.* 2020). *Corynebacterium* species are facultative anaerobic nonsporulating Gram-positive bacilli. Findings of *Corynebacterium* in blood cultures are often regarded as a

potential contamination from skin flora, although invasive infections with *Corynebacterium* such as sepsis and infective endocarditis are common (Bläckberg 2021). Non-tuberculous mycobacteria (NTM) are ubiquitous, free-living, environmental saprophytic organisms known to occupy water systems, soil and vegetation and belong to the genus *Mycobacterium* which include *Mycobacterium tuberculosis* (TB) and *Mycobacterium leprae*. NTM are found worldwide and cause infections that are easily missed, and are difficult to diagnose and difficult to treat (Ratnatunga 2020). *R. equi* infection, although rare, is recognised as an important cause of cavitary lung infections, especially in the HIV population where mortality can be as high as 50% (Cappelletti 2020). These were a few of the bacteria that were found on the laryngoscope blade and handle that were filtered down into the Gram stain positive group for the XLD agar. These bacteria also tested positive for gram staining and were positive for the Catalase test and Methyl red test. Evidently, these Gram stain positive bacteria are harmful to the patient and may even cause patient-to-patient transmission and patient to practitioner transmission. The presence of this bacteria may cause an increase in morbidity and the duration of patient stay at the hospital and even death in certain circumstances.

Out of the 36 specimens in the XLD group, there were 9 specimens that were Gram-negative and then turned red for the Methyl red test, which confirmed the following bacteria (Yamashoji, Al Mamun and Bari 2020):

- *Salmonella spp.*
- *Shigella spp.*
- *Yersinia*
- *E. coli*
- *Proteus . spp.*
- *Enterobacter*
- *Klebsiella pneumonia*

Looking at this group of bacteria found on the Gram-negative group, it was interesting to note that *Salmonella* spp. was discovered as this species is unique in its own right. In 2017 the Global Burden of Diseases, Injuries and Risk Factors Study (GBD) estimated that *Salmonella enterocolitis* resulted in 95·1 million cases and 50 771

deaths (Schroeder *et al.* 2005). Stanaway *et al.* (2017) estimated that 535 000 cases of non-typhoidal salmonella invasive disease occurred in 2017, which caused 77 500 deaths in Southern South Africa. In addition to diarrheal disease, *Salmonella* infections can invade normal sterile sites, resulting in bacteraemia, meningitis and other focal infections (Stanaway 2019). *Shigella* spp. was also found and shigellosis is caused by nonmotile, facultative anaerobic Gram-negative bacilli of the Enterobacteriaceae family, including *S. dysenteriae*, *S. flexneri*, *S. boydii*, and *S. sonnei*. *Shigella* spp. have high effectiveness in invasive systems that enable bacteria to invade and multiply within the human intestinal epithelia, ultimately leading to severe inflammatory colitis, which is referred to as bacillary dysentery or shigellosis (Zhu *et al.* 2021). *Shigella* spp. and enterotoxigenic *Escherichia coli* are bacterial pathogens that are frequently associated with diarrhoeal disease and are a significant cause of mortality and morbidity worldwide. The Global Burden of Diseases, Injuries, and Risk Factors study 2016 (GBD 2016) reported that the number of diarrhoea deaths attributable to shigella was 212 400 deaths and to enterotoxigenic *Escherichia coli,* 51 186 deaths (Khalil 2018). *Yersinia enterocolitica* is a gram-negative bacillus that causes a zoonotic disease called yersiniosis. The infection is manifested as acute diarrhoea, mesenteric adenitis, terminal ileitis and pseudo appendicitis. In rare cases, it can even cause sepsis (Aziz 2023). *K. pneumoniae* is an important pathogen for respiratory tract infections, often leading to severe pneumonia and multiorgan infections. It can also cause urinary tract infection, meningitis, sepsis and biliary tract infection in hospitalised patients, entering the human body through contaminated respirators, atomisers or catheters in addition to self-contamination from the colonised bacteria (Chang *et al.* 2021)

In the Cetrimide group 29 of the 36 specimens were Gram-positive and for the Methyl red test there was no result meaning there was no change in colour. This is characteristic of the cetrimide agar, only allowing Gram negative bacteria or pseudomonas to grow. The 7 isolates were Gram negative and they turned yellow during the Methyl red test, which confirmed that the bacteria could possibly be the following:

- *Pseudomonas aeruginosa*
- fluorescein and pyocyanin

- *Pseudomonas aeruginosa*

Pseudomonas spp. is found commonly in soil and in water. Of the many different types of *Pseudomonades*, the one that most often causes infections in humans is called *Pseudomonas aeruginosa*, which causes infections in the blood and lungs (pneumonia). These bacteria are constantly evolving to negate the effects of the antibiotics used to treat the infections they cause. Antibiotic resistance occurs when the organism no longer responds to the antibiotics designed to kill them. If they develop resistance to several types of antibiotics, these germs can become multidrug-resistant (Chang *et al.* 2021).

5.3 Objective Two: To evaluate the current decontamination practices of the selected EMS personnel regarding the disinfection of laryngoscope blades and handles

This chapter discusses the results which were presented in the previous chapter. The quantitative and qualitative results are discussed together to provide a more in-depth understanding. The results are interrogated within the context of other relevant national and international studies on the research topic. The results arose from responses to a questionnaire.

5.3.1 Age

In this survey, a total of 27 individuals participated, with the youngest and oldest participant being 21 and 57 years old, respectively.

5.3.2 Response rate

A survey was developed in the form of a questionnaire in order to evaluate the current decontamination practices of personnel from the selected EMS regarding the disinfection of laryngoscope blades and handles. The questionnaire was also designed to assess the current IC and disinfection knowledge of the participants. The questions were compiled, made relevant, and tested in a pilot study to ensure there were no errors. Any errors were then corrected for the formal survey.

The survey yielded a 100% (n = 27) response rate. A possible reason for this high response rate was due to the surveys being personally disseminated to the participants at their respective ambulance bases. The questionnaire was also sent via email to attain responses from participants who were difficult to meet with due to high call volumes and large geographical areas to cover hence returning to base to meet the researcher would have been difficult. When questionnaires were emailed, a follow up was done a few days to a week later. The reason for this was to give the participants time to ponder their responses, as they felt they had a lot to contribute to the study. There was a wide range in terms of age of the 27 participants, with the youngest being 21 and the oldest being 54 years of age, with a mean age of 35 years.

5.3.3 In your service, are there currently formal policies on infection control practices regarding laryngoscope blades and handles?

As part of a generic IC programme, policies and procedures for preventing/controlling the transmission of infectious agents; employer education, and IC aspects of employee health need to be in place. In South Africa, generic policies and procedures for IC are covered under the Regulations for Hazardous Biological Agents (South Africa, 2019). To ascertain whether policies and their associated procedures were in use in this study setting, the participants were asked if policies and procedures for IC for the laryngoscope blade and handle existed. Eight (30%) of the participants indicated that there were IC policies regarding laryngoscope blades and handles and 29% said they did not exist. It must be noted that 11 (41%) participants were not sure or did not know if this existed or not. Looking at these numbers, it is clear that there is some confusion over whether there is any formal IC policy present or not.

Thirty per cent of the participants indicated that policies and procedures were in place and that they were sufficiently informed about them. This is inconsistent with the fact that the researcher was unable to locate any policies and procedures on IC among the policy documents of the selected EMC.

5.3.4 Do you think that EMS should have a formalised infection control protocol with regards to the laryngoscope blade and handles?

The majority of 35 (82%) of the participants strongly agreed that there should be a formal IC protocol, which would control the transmission of microorganisms and promote best practice. However, 7% of the participants expressed an impartial response. A small percentage (11%) agreed that there should be a formalised IC protocol with regards to the laryngoscope blade and handles only. Chaskar *et al.* 2017, established that there was no uniformity of laryngoscope disinfection practices. A survey was carried out regarding existing practices of disinfection of laryngoscope in the Indian context. The authors went on to compare bacterial growth on the front, back and light bulb of the laryngoscope blade when washing with water only. Fifty-eight per cent of the samples showed a significant growth of pathogenic microorganisms which was due to not having any formal policies in place for disinfection of the tool (Chaskar *et al.* 2017).

5.3.5 Do you feel that you have sufficient knowledge about infection control practices regarding the laryngoscope blade and handles?

This question was posed to understand participants' knowledge of IC practices on laryngoscope blades and handles. Figure 15 showed that 48% of the participants answered "Yes" and 30% answered "No" while 22% were impartial in their response. The 30% of participants who responded with "No" could point to the fact that they have very little knowledge pertaining to IC of laryngoscope blades and handles. This result shows that education strategies and training should be implemented in this area as the risk for exposure is extremely high, especially if individuals have very little knowledge in this area. This can be related to the high bacterial load found as shown in Table 4.1, that little to no knowledge of IC can result in high bacterial load.

As mentioned, most respondents were unaware of IC policies and procedures, and even though they did believe they existed, most felt they needed more information on them. This is a point of interest and concern, as it has clearly been shown that in many first world countries, where sound IC programmes are in place, the incidences of HCAIs are low. Well-structured IC programmes play a vital role in reducing mortality,

morbidity and costs to both the patients and the health care system. Without policies and procedures, an IC programme cannot be regarded as being well-structured and effective (Chang *et al.* 2021). Furthermore, when workers are exposed to biological agents, information and instructions must be given to them or set out on notices displayed in the workplace. Such information should be contained in the policies and procedures of an organisation (Murhekar 2022). The researcher of this study did not notice any policies or procedures and was unable to locate any IC policies and procedures during base visits.

5.3.6 Would you be interested in learning more about decontamination and infection control regarding the laryngoscope blade and handles

Figure 30 shows that 93% of the participants were interested in learning more about IC, which was an encouraging sign. However, it is an area of concern, as it is a manifestation of the lack of training being given in this regard. Initial refresher training and education are vital to ensure a successful IC programme, whether in the pre-or in-hospital environment (WHO, 2019). EMS staff must be educated on safe working procedures and occupational risks to their health, particularly with respect to transmission of infection. The regulations for Infection control (South Africa 2001) state that an employer shall, before any employee is exposed or may be exposed, ensure that the employee is adequately and comprehensively informed and trained on both the practical aspects and theoretical knowledge. Interpreting the numbers further, participants felt it was an area of concern that made them feel inadequate and made them question their practising at the recommended and correct standards.

5.3.7 When are the laryngoscope blade and handles usually cleaned?

It is considered best practice to decontaminate medical equipment that is reusable immediately once it has been contaminated. At the time of investigation, 96% of participants answered that they cleaned the laryngoscope blade and handle after using on patients that required AM, and 4% of participants cleaned the tool at the commencement of every shift. The majority of the participants seemed to be under the impression that the previous shift adequately disinfected and replaced the laryngoscope blade and handle into the airway kit if it was used. It is possible from the

participants' responses, that at the time of the investigation, there seemed to be no standardised cleaning schedule of the tool in any of the bases. The frequency of cleaning seems to depend on the perception of risk.

5.3.8 How do you clean and disinfect laryngoscope blade and handles while on duty

Figure 4.23 shows that a large portion of the participants (20% to 74%) used soap and water followed by disinfectant, two (7%) washed with disinfectant and then sent to CSSD, and two (7%) washed with water and then disinfectant. Rather alarmingly, 8% of the participants were unsure of what to do and 4% used soap and water only. Clearly there was no set protocol for disinfecting tools and equipment. The cleaning methods are inconsistent and there seems to be a dire need for a protocol or procedure on how to disinfect the tool. Having a protocol in place would mean the management staff would need to have regular audits to control this area of IC. Set methods or protocols would establish a direction for effective decontamination and cleaning methods, more importantly, and should be evidence based (Guidelines for infection control and prevention in anaesthesia in South Africa 2021a). The emergence of new pathogens such as SARS and COVID-19 exposes the ECP to the additional risks of infectious and communicable diseases. This risk is particularly high in South Africa where HIV/AIDS, tuberculosis, malaria, hepatitis B, measles and diarrhoea are endemic and account for 40% of mortality (Bradshaw *et al.* 2003).

The National Health Act and the Occupational Health and Safety Act (OHSA) provides a general legislative and policy framework for the protection of healthcare service providers as well as the patient in South Africa. International and national policies and guidelines exist for preventing the transmission of infectious diseases in the healthcare setting. However, it is unclear to what extent these general policies have been translated into specific policies and programmes to particularly address the high risks facing EMS personnel (Mahomed *et al.* 2007).

5.3.9 Do you have sufficient time to clean and disinfect the laryngoscope blade and handles?

Figure 4.16 shows that an unexpectedly high number of participants (24) answered that they always had time to clean the laryngoscope blades and handles. However, three answered that they had no time to clean; this warrants further investigation, as two of these participants were from distant or outer lying bases. It was initially thought that these participants were from a rural or outer lying base since the call rates tend to be lower at the distant bases and staff generally have more time to clean. Surprisingly, one participant was from an urbanised base and thus was closer to a hospital sluice room or base to clean. Working in an EMS is fast paced and requires "on the job" cleaning between cases to ensure equipment, especially invasive equipment, is adequately disinfected and cleaned.

There are many factors that may influence time available for cleaning or disinfecting the laryngoscope blade and handle on duty. The selected EMS covers a wide geographical area, thus compromising the time to effectively return to base to clean. This leaves the emergency service vehicle unavailable due to equipment not being cleaned or disinfected. The other factor may be attitudes and behaviours of the participants. Realising the urgency to clean the equipment is important as this directly impacts the availability of the emergency vehicle for cases (Stein, Wallis and Adetunji 2015).

5.3.10 Is cleaning and disinfection equipment readily available at the Base

The availability of cleaning equipment at their EMS base would be another factor that would influence participants' decision to clean or disinfect the tool. Figure 4.17 shows that 85% of participants answered "Yes" indicating that cleaning agents were available for utilisation, hence no delay in terms of decontaminating and cleaning of tools and equipment. Approximately 15% of participants were unsure about the availability of cleaning agents, while 7% answered "No".

This leaves room for investigation as to why and how they are decontaminating the tools for intubation. Of the 8% of participants who answered, "Do not know", some

belong to bases where certain participants indicated “Yes” there were cleaning and disinfectant agents available. This could mean that these participants did not try and find the location of the disinfecting agents at base, therefore did not rely on the disinfecting agents to clean their tools, and ultimately being disinterested regardless of disinfection agents being provided at bases. It could also possibly mean that the participants are demotivated and feel that there should be a separate team in charge of disinfection or decontamination. This is pointing to behaviour patterns of the participants and could mean that they are possibly not enthusiastic about disinfection and cleaning (Bharti 2021).

5.3.11 What is your understanding of the word’s decontamination or disinfection

Figure 4.9 shows that a large portion of the participants (59%) chose the answer option that defined the word decontaminate or disinfect as “a process that destroys or eliminates all forms of microbial life and is carried out in health-care facilities by physical or chemical methods”. Nineteen per cent of the 27 participants chose the option “it is the process that eliminates many or all-pathogenic microorganisms except bacterial spores on inanimate objects” and 11% of the participants chose with the option “removal of visible soil from objects and surfaces that is normally achieved manually or mechanically using water with detergents or enzymatic products”. Lastly, 11% of the participants chose “Do not know”. As seen by the responses, there were mixed views or understanding of the words, which is a concern. This could also be due to lack of practical training or education in this area and raises the question of whether it is included within their syllabus or modules at their respective learning facilities (Alrazeeni and Al Sufi 2014). With the wide age gap of the participants, it would be wise to question what mentorship is rendered by senior staff to the younger staff, and if there is a lack of understanding or consensus with regards to disinfection (Lane, Rouse and Docking 2016). Mentorship is important as the older and wiser staff with years of experience are expected to have greater understanding and knowledge in all areas within the EMS – especially disinfection and decontamination. If the older staff lack knowledge in this area of decontamination, it could mean that they had poor training or education on this aspect or there was a lack of training provided (Lane, Rouse and Docking 2016).

5.3.12 Are you confident in inspecting the response vehicle laryngoscope blade and handle with bare hands?

Inspecting equipment upon shift handover or arrival is a key responsibility of an ECP. This is done to ensure that all equipment is in optimal condition in order to help save a patient's life. Hence, the checking of the practitioners' tools for airway breathing and circulation management is compulsory and a checklist needs to be completed. This also means that the user must be "hands on" and physically check the airway tool for bodily fluids such as blood, vomit, or secretions. There are many diseases and viruses that may be present in, around, and on, the patient and in this instance, within the oral cavity as well as the upper and lower respiratory tract of the patient such as the many variants of COVID-19, TB and HIV (Bauchner, Fontanarosa and Livingston 2020). Figure 4.12 indicates that 59% of the participants answered "No" they would not inspect the laryngoscope blade and handle with bare hands. This indicates that they are aware of the health risks involved when inspecting the tool or any other equipment with bare hands. It could also mean that the practitioner may fear attaining any of these harmful pathogens and transmitting them to and from the patient and other surfaces that may be deemed clean. However, 41% of the participants answered "Yes", which indicates a lack of awareness about health risks. The practitioners could be aware but rely on disinfecting their hands afterwards (Yang, Yu and Xu 2020).

5.3.13 Do you wash your hands before disinfecting the laryngoscope blade and handle?

HH is one of the most important measures to prevent the transmission of infectious diseases. Hands can become a collection site for microorganisms during practice. Performing effective HH is necessary to protect both the HCW and the patient, thereby contributing to safer and higher quality care (Loveday *et al.* 2014).

Figure 4.13 shows that 52% of the participants do wash their hands before disinfecting the laryngoscope blade and handle, while 48% do not wash their hands prior to disinfection of the tool. Thus, the majority of the participants (52%) acknowledged the potential transmission of pathogens to the tool and then into the patient's oral cavity, as a result of not washing their hands prior to disinfection. Possible reasons for the

high proportion of participants (48%) not washing hands their hands could be a lack of training, burn-out from caseloads and job demands, or just fatigue. Donnelley *et al.* (2019) conducted a study to determine if fatigue and shiftwork variables were related to safety outcomes in Canadian paramedics and found that out of the of 717 participants, 55% reported being fatigued at work. They were also less likely to report injuries, three times as likely to follow safety compromising behaviours such as improper handwashing or disinfection of equipment, and 1.5 times more likely to report errors/adverse outcomes. Fatigue over time is very common and contributes to staff being burnt out and not following protocols and procedures (Donnelly *et al.* 2019).

5.3.14 When preparing for ETI, what hand hygiene methods do you use?

Compliance by HCWs in the pre- and in-hospital sectors with HH is a universal problem. According to Loveday *et al.* 2014, poor HH is prevalent in these environments and such behaviour is also exists amongst EMS personnel. IPC practices as well as knowledge of transmission of multidrug-resistant organisms within the EMS have highlighted sub-optimal standards which must be urgently upgraded (Loveday *et al.* 2014). The hands of the practitioner are regarded as a vector or reservoir of microorganisms during practice. Performing effective HH is necessary to protect both the health professional and the patient, thereby contributing to safer and higher quality care (Vikke *et al.* 2019b). Figure 4.14 shows that 48% of the participants chose the option of sanitising their hands, donning of gloves, setting up for ETI, putting on a new pair of gloves and then intubating. They felt that this was the safer option and made them comfortable, especially with the ETI of severely compromised patients. Figure 4.14 shows that 29% of the participants opted for the use of sanitiser before setting up for ETI however; this raises the question as to what their options were after completing the procedure. A smaller portion of participants (15%) opted for sanitising their hands before and after setting up for ETI, which showed that they had confidence in their hand sanitiser and relied on it to clean their hands. Lastly, 4% of the participants said that they wash their hands before and after setting up for ETI, however this raises the question as to what training they had for hand washing. It was also noted that another 4% of participants just washed their hands before setting of ETI and not after.

According to Suen *et al.* (2019), the evidence is that handwashing is approximately 85% effective in removing microorganisms on hands, and hand drying provides a further reduction in transient flora. In the pre-hospital setting, the drying of hands is questionable, let alone the washing of hands. Inadequately dried hands of paramedic staff are more likely to transmit microorganisms compared with completely dry ones.

5.3.15 Which would you prefer in your airway kit? [disposable blades versus reusable blades]

A very interesting question was posed to the participants regarding whether they prefer disposable blades or reusable blades. Both have their pros and cons. Figure 4.18 shows that 70% of participants chose disposable blades, while the remaining 30% chose reusable blades for their airway kit. The cost factor of the disposable blades needs to be looked at versus the patient-to-patient cross contamination risk with reusable blades. Ultimately, risking patients' lives by using medical equipment which has not been effectively decontaminated is of huge concern to the company and, most importantly, to the patient. The participants' years of experience as well as the answer to either disposable versus reusable blades were displayed. It is important to note that 10 participants of the disposable group had over 9 years of experience as ALS and ETI, indicating that they understand the need for clean and safe equipment that is used invasively and therefore has the potential to harm and even death to the patient if inadequately cleaned or ultimately disposed of.

5.3.16 The availability of a second pair of laryngoscope blades and handles at base/on board the response vehicle

Figure 4.20 shows results regarding the availability of a second set of the tool, establishing that 59% of the participants answered "Yes" to this question. However, 37% of the participants answered "No" and 4% answered "Do not know". Having a second set of the tool would be highly beneficial, especially in KwaZulu-Natal where there is a high call volume daily, leaving little time to appropriately disinfect or clean. Having a clean back up set would increase turnaround time. In a follow-up question, in which participants were asked "Were you ever in a situation whereby you needed a second pair of laryngoscope blades and handles to intubate due to the first pair of

laryngoscope blade and handle being contaminated?", 56% answered "No". This could mean that these participants either cleaned the tool after the first intubation or possibly used a protective sheath such as a condom over the blade for the second intubation on scene.

5.3.17 How do you clean and disinfect the laryngoscope blade and handles while on duty?

A high number of participants (20, 74%) used soap and water followed by disinfectant, two (7%) washed with disinfectant and then sent to CSSD, two (7%) washed with water and then disinfectant, 8% of the participants were, alarmingly, unsure of what to do and 4% used soap and water only. It is evident that there is a wide variety of methods utilized to clean or disinfect the tool. It is also evident that there were no set protocols or cleaning standards. The majority of participants (96%) indicated that they clean the laryngoscope blade and handle after a patient who required AM, while 4% cleaned the tool at the commencement of every shift. Dissecting this question and its response could indicate that the participants do not open the airway kit upon taking over of the response vehicle in order to clean the tool. They could be under the impression that the previous ALS cleaned and disinfected adequately after they used it (Fourtounas 2015). This is because it is standard practice that ALS share one set of laryngoscope blades and handles. However, if the ALS had their own AM tool, this would mean that these participants would only clean the tool when visibly dirty (Zhu *et al.* 2021). This is an area of concern as bacteria, pathogens and viruses are on the tool. Influenza viruses can survive on solid surfaces like metal and plastic for 24 h to 48 h, and on cloth, paper, and tissues for at least 12 h.

5.3.18 In terms of disinfectant who prepares the solution?

This study found that 74% of participants take it upon themselves to prepare the disinfecting solution, while 15% of the participants used any amount of the solution regardless of the strength of the solution. Interestingly, 7% did not know who generally prepares the disinfectant solution and only 4% asked their manager for assistance to help prepare the solution. It is important to note that at some bases there may be a variety of disinfectants to choose from. However, the question arises as to what

strength of the solution will be effective in terms of disinfecting the tool indefinitely. A point to note also is that 15% of the participants are using any amount of the solution possibly because they want a stronger solution to effectively disinfect or they are unsure of what quantity of solution to use. From the findings of Objective One it is evident that the amount of the detergent as well as the knowledge of the detergent is inadequate, as was evident from the high bacterial load found on the agar plates and colony counts. It can be deduced that if the knowledge was adequate and that the detergents were correctly used, then the bacterial load would be low. Looking at the 4% of the participants who asked for assistance from their manager shows honesty as well as enthusiasm to learn more about the volume of solution needed to disinfect as well as the correct methodology of disinfecting (Mookerjee *et al.* 2022).

5.3.19 Is there anything special that you use in terms of PPE when performing endotracheal intubation for suspected high-risk patients such as: COVID-19, TB viral or bacterial, HIV and Cancer?

More than 95% of the participants chose the option of wearing full PPE, which consists of a full garment with goggles/ safety glasses, a visor and double gloves. It was noted that participants mentioned that they were fearful of performing ETI in such cases, even with full PPE, as they feared contracting diseases such as COVID-19. Again, more than 95% of the participants sanitised thoroughly before and after using PPE and then performing ETI on these high-risk patients. Thus 95% of the participants understood the ramifications of not wearing PPE. Sanfilippo *et al.* (2022) found in their study that although it takes a few extra minutes to don the garments or PPE, this did not hinder the success rates of ETI let alone cause a catastrophic delay. In the current study, 1% of the participants stated that they would opt to not perform ETI on these patients as they felt the risks for contraction of these diseases were very high and they would just transport these patients in a comfortable position (left lateral) with oxygen administered via an oxygen mask. A further 1% of the participants said that they would not want to add any other PPE as they were comfortable with double gloves, protective eyewear and a surgical mask; they felt that the additional PPE would make conditions uncomfortable. These participants also mentioned that the visor hinders visualization of the vocal cords, thus increasing the number of attempts at ETI.

5.3.20 Are you aware of CSSD is?

The CSSD is responsible for preparing medical/surgical supplies and equipment such as the laryngoscope tool so that they are sterile and ready for use in patient care. Consistently high standards in sterilisation techniques and product quality are vital with centralised pre-disinfection, cleaning, packing, and sterilisation. As the number and variety of surgical procedures and the types of medical devices are constantly growing, optimised processing is very important for efficiency, economy, and patient safety (Pan, Hu and Yi 2020).

An understanding of what the CSSD does as well as their function in the health sector, be it pre- or in-hospital, is of utmost importance. Figure 4.22 shows that 19% of the participants did not know or were not aware of what CSSD was, and 7% were unsure. This could be due to the training of the participants in terms of what the cleaning centres or disinfecting areas of the workplace are, as well as what the CSSD offers. When looking at the inconsistent cleaning methods, it would be seem that the selected EMS, together with the CSSD at that base hospital, need to communicate and come to an agreement to arrange for the tools to be decontaminated and cleaned at the CSSD. A sterile airway kit could also be exchanged for a used one. This, however, would require good communication and agreement between managers of the pre-hospital organisation and the relevant hospital (Song *et al.* 2022).

5.3.21 Do you think it is possible for microorganisms/pathogens such as the COVID-19 virus to be transmitted from one patient to another without adequately disinfecting the laryngoscope blades and handles between patients/cases?

This question was designed to ascertain the awareness of the possibility of diseases and microorganisms or pathogens being transferred from patient-to-patient or HCW due to inadequate disinfection of the laryngoscope blade and handle. There were 92% of the participants answered “Yes” to this question. This means that the great majority of participants were aware of this possibility. Just 4% of participants indicated that they were unaware of the dangers of such diseases, their transmission avenues, and the ramifications that they may have long and short term. The remaining 4% of the

participants chose not to answer this question. This could mean that they were unsure of the transmission of harmful viruses and bacteria.

5.3.22 In terms of arriving at a mass casualty where there were multiple red code patients requiring endo-tracheal intubation, what was your preparation between the patients in terms of the cleaning of the laryngoscope blades and handles?

This open-ended question was created to ascertain what methods were used between multiple critically ill patients requiring ETI at a mass casualty scenario. This was a broad question, and there were no right or wrong answers. All participants answered this question, and conveyed the following information:

- Some participants used Medi-wipes or disinfection wipes to wipe down the laryngoscope blade and handle after every use before the next ETI. The disinfection wipes or towels which are soaked in disinfectants and ready to use have become broadly accepted for decontamination of high-touch surfaces because of their convenient implementation and reliable performance. Their efficacy is, however, questionable. A study was conducted by Song, Vossebein and Zille (2019), whose aim was to investigate the variables that impact on the disinfection performance of disinfectant wipes in surface disinfection in hospitals, found that there were several variables that influence the disinfection efficacy of disinfection wipes besides the external factors. These include:
  - The disinfectant type and concentration play a major role in destroying pathogens and bacteria. It was evident that the preferred disinfectants to be used for the disinfectant wipes were quats-alcohol wipes, hydrogen peroxide wipes and hypochlorite wipes (Chang *et al.* 2013).
  - The disinfection wipe material and its constituents are important factors. These disinfection wipes offer a cleaning procedure by the mechanical action of wiping, which can remove the organic debris as well as disinfect. The removal of the microorganism depends on the inherent properties of the wiping material, such as fabric structure and fibre types as well as by the applied pressure force. The quantity and concentration of the disinfectant solution released by the wipe on the target surface is responsible for the bactericidal activity. The recommended wipes for

disinfection of all surfaces can be selected from either macrofibre, composite, biodegradable and or flushable wipes (Edwards *et al.* 2017).

- The interaction, application method and storage time of the disinfectant.
- Wiping strategy including the applied pressure force, wiped surface area, the geometry of the mechanical action, number of passes, and time on the surface. There is however more research that needs to be done on the correct method to wipe down surfaces as well as training strategies (Powell *et al.* 2015).

- Some of the practitioners mentioned that they have never been in mass casualty incidents before and they needed guidance and training for this type of scenario. This response was more common amongst the younger ECPs at the relevant bases and also indicates inexperience and lack of mentorship (Cameron, Pooler and King 2020).
- Some participants reported that they would opt to use different size blades between patients. This meant detaching the current contaminated blade and then attaching a clean blade, however this would impact the patient as the blade may not be adequately sized to displace the tongue, ultimately leading to poor visualization of the vocal cords and poor ETI success rates. The concern is that even though the contaminated blade can be changed at a mass casualty incident, the practitioners' hands can cause contamination even after disinfection of the blades or even when reaching for a different size blade. Therefore, HH and the use of gloves need to be enforced to prevent this type of contamination (Choi *et al.* 2021).
- Some participants felt that there was a risk of using the same metal laryngoscope blade and handle even though it had been cleaned. This risk was evident in a study by Wibmann *et al.* (2021) in which they examined the survival of SARS-CoV-1 and -2 on surfaces. The authors could not observe viable SARS-CoV-2 on copper after 4 h, on cardboard after 24 h, and on stainless steel and plastic after 72 h (Wißmann *et al.* 2021).

It can be deduced from the feedback that the participants have various innovative methods of improving on scene disinfection. However, these methods are not

consistent and there appears to be no standardised policy or protocol in place for such scenarios.

5.3.23 What methods do you use to disinfect hard to reach places on the laryngoscope blade and handle during cleaning process? What are your methods?

This was also an open-ended question and again there were no correct answers but more of a general idea of what methods the participants were using to disinfect the hidden areas or corners of the laryngoscope blade and handle. The following information was obtained:

- The participants generally carry a toothbrush in the airway pouch that they use on site to scrub difficult areas of the blade and handle.
- Some participants said they would use the toothbrush with water. Some of the participants said they would use the toothbrush with chlorine-based detergents or any other detergent that was available at the sluice room for receiving facilities.
- Some said that they would dismantle the entire tool and soak in water or chlorine or in a container of detergent and then use a toothbrush to scrub down the tool.
- The use of a gauze or sponge to help scrub the tool.
- The use of hot water at sluice rooms – however not every facility allows the paramedics to use their sluice room and not all sluice rooms have hot water and cleaning detergents. If hot water was available, they opted to soak the blade and handle in water and thereafter scrub with a brush or wipe down with gauze.

The results showed inconsistency and lack of a standard protocol for disinfecting tools/equipment. The use of a toothbrush is questionable as well, due to the uncertainty of whether a sterile toothbrush (new or cleaned) is being used at every cleaning interval and if it is being stored correctly afterwards. The use of hot water could also mean that the participants are not well versed with the use of detergents and are reluctant to use them.

5.3.24 Apart from what you have already stated in the above responses, are there any comments or problems regarding infection control that you would like to mention?

This question was posed for general comments on IC; 16 of the participants (59%) made comments and 41% did not. The participants provided positive and constructive input which can pave the way forward for the formulating of SOPs and protocols for disinfection of equipment and more specifically laryngoscope blade and handles. The following suggestions were provided by the participants:

- A protocol or SOP needs to be in place for the disinfection of the laryngoscope blades and handles, as this is an area of concern.
- The addition of clinical governance to monitor and observe the strict adherence to these SOPs or protocols and even random checks should be done.
- The appropriate training or workshops to be set up for these SOPs or protocols.
- There is a need for a sluice room for the EMS at each base and these should be separated from the wash bay for ambulances.
- Participants felt their knowledge of IC and different diseases was poor and felt they as EMS providers should have workshops to attend to have an insight on IC and various diseases and preventions. This is positive, as this could lead to educational programmes for current staff and future staff.

5.3.25 Conclusion

Knowledge is a basis of good and well-informed practice. Overall, the knowledge and practices of participants regarding IC was poor. This was substantiated by the unacceptably high levels of microbial contamination of the airway tool. There were no significant differences between the bases. In certain cases, although the knowledge score was better, this did not equate to better practice. This seems to do with participants not having adequate resources, lack of IC policies and procedures and good quality assurance from management.

5.4 Objective Three: To establish the minimum concentration of the disinfectants used by the selected EMS required to inhibit the growth of microorganisms during pre-hospital cleaning and disinfection

The surfaces of equipment in hospitals, health facilities and the pre-hospital environment are important routes of transmission of microorganisms between patients, visitors and healthcare professionals. The control and prevention of the spread of Nosocomial infections can only be controlled or prevented through thorough cleaning, disinfection, or sterilisation of reusable surfaces and objects that (Rozman *et al.* 2022). MICs are defined as the lowest concentration of an antimicrobial that will inhibit the visible growth of a microorganism after overnight incubation (Wieland *et al.* 2017).

While antibiotic resistance is a well-recognised and researched topic in the medical field, less attention is paid to the possible cross-resistance and/or co-resistance mechanisms in the case of disinfectants. The current researcher aimed to determine the MIC of three different disinfectant products currently used in EMSs. As mentioned in previous chapters, the disinfectants used in this particular EMS are D-Germ hand disinfectant, Bioscrub and antimicrobial surface cleaner disinfectant. Table 4.7 shows that for the D-Germ disinfectant an MIC of 10% was established, for Bioscrub 50%, and for alcohol 20%. If a concentration of only 10% of the D-Germ disinfectant was needed to effectively disinfectant the tool, this means that the bacteria were not resistant or had very little immunity towards to the disinfectant. The MIC of Bioscrub at 50% means that the bacteria has some immunity or the Bioscrub needs to be activated properly in terms of correct application. Bioscrub is a viscous liquid that needs to be mixed, foamed and applied to the surface to be an effective disinfectant.

Various factors affect the efficiency of the disinfectant, such as choosing the right type and concentration of disinfectant, the time of interaction, the method of application, and the strength and direction of wiping. Each disinfectant comes with instructions for use and storage, as these two variables have a significant impact on the effectiveness of disinfection. When the disinfectants are not used correctly, the role of a disinfectant can change quickly and the disinfectant itself can become a source of infection (Song, Vossebein and Zille 2019). Another important factor affecting proper hygiene is the

training and education of staff regarding disinfection and the ramifications. EMS staff need to understand various disinfectants and the correct way to use them, and more importantly, the proportion needed to effectively disinfect the equipment (Boyce 2016).

Rozman *et al.* (2022) investigated the MIC of five different disinfectants currently in use in hospitals in Australia. Samples were taken from multiple objects and surfaces used in relation to therapeutic procedures. Surfaces were sampled before and after disinfection. The most frequently encountered species on multiple-use objects were identified as *Staphylococcus*, *Micrococcus*, and *Bacillus.* The authors found that the amount and concentrations used were much lower than the correct amounts of the disinfectant regulated by the Guidance on the Biocidal Products Regulation. They found that for the alcohol disinfectant, the MIC value was much higher, and the strain of bacteria was identified as *Staphylococcus* spp. This was also noted among the other disinfectants, that they had a higher MIC value. The authors comment that widespread use of disinfectants affects the increase in the proportion of antibiotic-resistant bacteria (Rozman *et al.* 2022). If the resistance and frequency of mutations increases and develops against many commonly used disinfectants in clinical and industrial settings, this alone can burden global public health (Forman *et al.* 2016).

According to Hardy *et al.* (2018), much research is needed in the clinical setting on the issue of disinfectants. The risks and benefits of using disinfectants in healthcare facilities as well as in the EMS need to be weighed to identify and determine additional precautions for the development and use of disinfectants. Regularly monitoring bacterial susceptibility to disinfectants would be sensible for EMS who rely heavily on them and may not have access to CSSD. Regular monitoring will prevent the spread of bacterial resistance against disinfectants and antibiotics.

5.4.1 Conclusion

In conclusion, the findings of this study indicated that ambulance laryngoscope blades and handles of the selected EMS exhibited contamination from various types of microbial species. The evidence of this was clearly seen in the high colony count observed during the enumeration process, as well as in the results of the Gram stain procedure. Additionally, it was observed that there existed a substantial number of

potentially pathogenic species including *Salmonella*, *Shigella* and *Pseudomonas* sp. on certain sites.

Generally, overall knowledge is seen as a basis of good and well-informed practice. In certain cases, although the knowledge score was good, this did not equate to better practice. This seems to be related in this study to participants not having adequate resources, lack of IC policies and procedures, and good quality assurance from management. There were no significant differences between the EMC bases. The reason behind the unacceptably high levels of microbial contamination on the airway tools could be attributed to the incorrect concentration of detergent used, thus substantiating this claim. It was established that when an optimum concentration or amount of detergent was used, this yielded positive results as there was no bacterial growth noted after. It is evident from the results and the interpretation above that the IPC knowledge and practices regarding laryngoscope blades and handles in the selected EMS in the eThekwini District of KwaZulu-Natal, is poor.

CHAPTER 6: CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

Findings were that there was a variety of microbial species contamination of ambulance laryngoscope blades and handles. This was evident in the high colony count during enumeration as well as the Gram stain processes. Furthermore, there was a high level of potentially pathogenic species such as *Salmonella*, *Shigella* and *Pseudomonas* sp., on certain sites, which can be an indication of poor hygiene practices. Therefore, there is an urgent need for programmes to be created in order educate the ALS students and staff on IC with regards to the laryngoscope blade and handle. The 100% response rate of ambulance staff members to this survey indicates their willingness and commitment to improving IC practices. These are strengths that should facilitate the formalizing of IC programmes using the findings of the study. The knowledge and practices survey identified the lack of an airway tool IC programme in general, and the inadequacy of standard cleaning procedures. There were many shortfalls identified in the cleaning practices and procedures. These included a lack of designated cleaning areas, confusion with regards to effective cleaning methods, and the lack of suitable decontamination processes for laryngoscope blade and handles. Although saving lives is the top priority in EMS, hygienic protection of patients and ambulance staff are equally important. It was established that using the correct amount or concentration of detergents needed to effectively decontaminate the laryngoscope blade and handle can limit the ambulance staffs' role in the transmission of HCAI.

6.2 Recommendations

- The EMS management to establish IC programmes with the aim of preventing, identifying and controlling infections within the health care facility in the pre-hospital field.
- Ongoing workshops to be implemented to help staff become more knowledgeable regarding potential sources of micro-organisms and an understanding of how they spread and who may be susceptible to them, including the preparation and correct use of disinfectants.

- Development of a partnership between EMS and CSSD at relevant base hospitals where the EMS are situated. Here the agreement could include the exchange of contaminated tools for clean ones, so that staff are ready for the next emergency.
- Investment in disposable blades rather than reusable ones. This would eliminate or decrease HCAI.
- A designated sluice room area to allow EMS staff at bases to disinfect and clean equipment in an appropriate manner.

6.3 Areas for future study

Infection control regarding laryngoscope blades and handles requires further evidence-based research. Proposals arising from the findings of this study are:

- Decontamination of laryngoscope blade and handles via CSSD compared to decontamination performed by the EMS on their own.
- Establishment and evaluation of comprehensive IC surveillance systems that include EMS, so that HCAIs contracted in the prehospital phase can be identified.
- Implementation of hand hygiene protocols in the EMS.

6.4 Closing statement

There is an urgent need for the development and implementation of evidence-based guidelines for the disinfection of laryngoscope blades and handles, both nationally and internationally. The findings of this study clearly establish the need for such guidelines because of the high colony count during enumeration as well as the Gram stain processes. Furthermore, there was a high level of potentially pathogenic species found and poor IC knowledge across all bases which can relate to incorrect usage of the disinfectants and their concentrations. It is evident that hands on training is needed, control of this training, and that surveillance and auditing be implemented in all organizations within the EMS regarding IC.

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ANNEXURES

Annexure 1: Letter of information

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Title of the Research Study

An investigation into ambulance Laryngoscopes as a potential source of infection in a private ambulance emergency service in the eThekwini district of KwaZulu-Natal.

Principal Investigator/s/researcher

Full names and surname : Sugandran Pillay

Qualifications : Bachelors of health sciences degree in Emergency Medical Care (DUT)

Co-Investigator/s/supervisor/s:

1. Full names and surname : Mr S Naguran

Qualifications : MTech EMC (DUT)

2. Full names and surname : Dr Abimbola Motunrayo Folami

Qualifications : Ph.D: Biotechnology (DUT)

Brief Introduction and Purpose of the Study:

Emergency care practitioners (ECPs) provide specialised treatment and management to a great number of critically ill and injured patients in the pre-hospital setting. Overall, these patients have the potential to have a higher incidence of infectious and emerging diseases. Part of patient management is securing the patient's airway through the placement of ETT into the patient's trachea. This placement of the tube is either due to a variety of medical conditions or the patient experiencing a traumatic event in which both instances the patient cannot protect their airway; hence this airway can be classified as a compromised

airway. This process involves the use of the laryngoscope, which is an invasive tool that comes into contact with blood and other biological agents and can provide a medium of transportation of infections if not decontaminated adequately. Disinfection and infection control is a fundamental practice in Emergency Medical Care (EMC) that is often underrated.

The purpose of this study is to determine the infection prevention and control practices regarding laryngoscope blades and handles amongst Emergency Medical Service personnel in a private ambulance service in the eThekwini district of KwaZulu-Natal, and to evaluate the current knowledge on infection control and whether they would like the implementation of a formalised infection control policy.

Dear participant,

I am conducting a research project in order to complete a Masters degree in Emergency Medical Care through the Department of Emergency Medical Care and Rescue, Durban University of Technology.

We are asking 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 knowledge and practices of staff in ambulance infection control. Principles such as having a simple, uncluttered 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.

Outline of the Procedures:

The study consists of two parts. The first part requires you to complete a simple fifteen-minute questionnaire and requires your honest response. It is concerned with your knowledge and decontamination practices of laryngoscope blades and handles. This will be completed while you are at the base, at shift change. You are not required to state your name or address and all information will be treated in the strictest confidence. There will be no way of identifying you from the returned questionnaires. The second part of the study aims to find out if there are any potentially dangerous bacteria and fungi on laryngoscope blades and handles post disinfection. Neither the ambulances nor the staff who work on them will be

identified from the results of the study. This will be performed by swabbing the laryngoscope blades and handles. It is important to note the blades and hands will not be removed or taken away from the airway kit for analysing but rather swabbed and then put back into the kit.

Risks or Discomforts to the Participant:

There are no risks. This research study is a questionnaire-based study and will not pose any risks or discomfort to you of any kind. Questionnaires will be anonymous. No names will appear on the questionnaire.

Benefits:

You will contribute to the body of available information regarding infection prevention and control in the emergency care field.

Reason/s why the Participant May Be Withdrawn from the Study:

The participant may choose to not participate in the study due to any unforeseen circumstances such as Noncompliance, illness, adverse reactions, etc. there will be no adverse consequences for the participant should they choose to withdraw

Remuneration:

You will not receive any form of remuneration for your participation in this research study.

Costs of the Study:

You will not be expected to cover any costs towards the research study.

Confidentiality:

There will be total anonymity throughout the study with no discrepancies being allowed such as the participants name or response being revealed to the employer or company they are based at.

Research-related Injury:

No research-related injury is expected. All Covid19 prevention protocols will be followed. You may ask questions of an independent source if you wish (see

supervisor contact details above). If you are not satisfied with any area of the study, please feel free to forward any concerns to our supervisor.

Storage of all electronic and hard copies including tape recordings

All raw data will be stored under strict conditions under lock and key. All soft data will be password protected.

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

You may contact the researcher Mr Sugandran Pillay 0784807872 or on e mail sugandran.pillay@gmail.com or the study supervisors (0313735203) or the Institutional Research Ethics Administrator on 031 373 2375. Complaints can be reported to the Director: Research and Postgraduate Support Dr L Linganiso on 031 373 2577 or researchdirector@dut.ac.za.

Annexure 2: Consent form

CONSENT

Full Title of the Study:

An investigation into ambulance Laryngoscopes as a potential source of infection in a private ambulance emergency service in the eThekwini district of KwaZulu-Natal.

Names of Researcher/s:

Names of research students : Mr S Pillay
Contact No : 0784807872

Statement of Agreement to Participate in the Research Study:

- I hereby confirm that I have been informed by the researcher, ____ (name of researcher), about the nature, conduct, benefits and risks of this study. Research Ethics Clearance Number ____________,
- I have also received, read and understood the above written information (Participant Letter of Information) 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 the course of this research which may relate to my participation will be made available to me

F [illegible] D [illegible] [illegible] [illegible] /

I, ([illegible]) [illegible]

Mr Sugan Pillay 04/12/202

F [illegible] D [illegible] [illegible]

F [illegible] ([illegible]) D [illegible] [illegible]

F [illegible] G [illegible] ([illegible]) D [illegible] [illegible]

Annexure 3: Letter of information: questionnaire pre-test group

LETTER OF INFORMATION: QUESTIONNAIRE PRE-TEST GROUP

Title of the Research Study

An investigation into ambulance Laryngoscopes as a potential source of infection in a private ambulance emergency service in the eThekwini district of KwaZulu-Natal.

Principal Investigator/s/researcher

Full names and surname : Sugandran Pillay

Qualifications : Bachelors of health sciences degree in Emergency Medical Care (DUT)

Co-Investigator/s/supervisor/s:

2. Full names and surname : Mr S Naguran

Qualifications : MTech EMC (DUT)

2. Full names and surname : Dr Abimbola Motunrayo Folami

Qualifications : Ph.D: Biotechnology (DUT)

Brief Introduction and Purpose of the Study:

Emergency care practitioners (ECPs) provide specialised treatment and management to a great number of critically ill and injured patients in the pre-hospital setting. Overall, these patients have the potential to have a higher incidence of infectious and emerging diseases. Part of patient management is securing the patient's airway through the placement of ETT into the patient's trachea. This placement of the tube is either due to a variety of medical conditions or the patient experiencing a traumatic

event in which both instances the patient cannot protect their airway; hence this airway can be classified as a compromised airway. This process involves the use of the laryngoscope, which is an invasive tool that comes into contact with blood and other biological agents and can provide a medium of transportation of infections if not decontaminated adequately. Disinfection and infection control is a fundamental practice in Emergency Medical Care (EMC) that is often underrated.

The purpose of this study is to determine the infection prevention and control practices regarding laryngoscope blades and handles amongst Emergency Medical Service personnel in a private ambulance service in the eThekwini district of KwaZulu-Natal, and to evaluate the current knowledge on infection control and whether they would like the implementation of a formalised infection control policy.

Dear participant,

I am conducting a research project in order to complete a Masters degree in Emergency Medical Care through the Department of Emergency Medical Care and Rescue, Durban University of Technology.

We are asking 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 knowledge and practices of staff in ambulance infection control. Principles such as having a simple, uncluttered 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.

Outline of the Procedures:

The study consists of two parts. The first part requires you to complete a simple fifteen-minute questionnaire and requires your honest response. It is concerned with your knowledge and decontamination practices of laryngoscope blades and handles. This will be completed while you are at the base, at shift change. You are not required

to state your name or address and all information will be treated in the strictest confidence. There will be no way of identifying you from the returned questionnaires. The second part of the study aims to find out if there are any potentially dangerous bacteria and fungi on laryngoscope blades and handles post disinfection. Neither the ambulances nor the staff who work on them will be identified from the results of the study.

Risks or Discomforts to the Participant:

There are no risks. This research study is a questionnaire-based study and will not pose any risks or discomfort to you of any kind. Questionnaires will be anonymous. No names will appear on the questionnaire.

Benefits:

You will contribute to the body of available information regarding infection prevention and control in the emergency care field. .

Reason/s why the Participant May Be Withdrawn from the Study:

The participant may choose to not participate in the study due to any unforeseen circumstances such as Noncompliance, illness, adverse reactions, etc. there will be no adverse consequences for the participant should they choose to withdraw

Remuneration:

You will not receive any form of remuneration for your participation in this research study.

Costs of the Study:

You will not be expected to cover any costs towards the research study.

Confidentiality:

There will be total anonymity throughout the study with no discrepancies being allowed such as the participants name or response being revealed to the employer or company they are based at.

Research-related Injury:

No research-related injury is expected. All Covid19 prevention protocols will be followed. You may ask questions of an independent source if you wish (see supervisor contact details above). If you are not satisfied with any area of the study, please feel free to forward any concerns to our supervisor.

Storage of all electronic and hard copies including tape recordings

All raw data will be stored under strict conditions under lock and key. All soft data will be password protected.

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

You may contact the researcher Mr Sugandran Pillay 0784807872 or on e mail sugandran.pillay@gmail.com or the study supervisors (0313735203) or the Institutional Research Ethics Administrator on 031 373 2375. Complaints can be reported to the Director: Research and Postgraduate Support Dr L Linganiso on 031 373 2577 or researchdirector@dut.ac.za.

Annexure 4: Letter to the head office – private emergency services

LETTER TO THE HEAD OFFICE – PRIVATE EMERGENCY SERVICES

Pending date

Dear Sir / Madam

Re: Permission to conduct research

I am conducting a research project in order to complete a Masters degree in Emergency Medical Care through the Department of Emergency Medical Care and Rescue, Durban University of Technology.

Title of research:

An investigation into ambulance Laryngoscopes as a potential source of infection in a private ambulance emergency service in the eThekwini district of KwaZulu-Natal.

Name of Research Student:	Mr. S. Pillay
Position:	Students
Contact No:	0784807872
Name of Supervisor:	Mr. S. Naguran
Contact No:	031 373 5336/ 083 786 3376
Name of Co-Supervisor:	Dr AM Folami
Contact No.:	031-3732689/ 0662002880

The purpose of this study is to determine the infection prevention and control practices regarding laryngoscope blades and handles amongst Emergency Medical Service personnel in a private ambulance service in the eThekwini district of KwaZulu-Natal, and to evaluate the current knowledge on infection control and whether they would like the implementation of a formalised infection control policy.

The study consists of two parts. The first part requires the ECP to complete a simple fifteen minute questionnaire and requires their honest response. It is concerned with their knowledge and decontamination practices of laryngoscope blades and handles. This will be completed while they are at the base, at shift change. The ALS/ECP are not required to state their name or address and all information will be treated in the strictest confidence. There will be no way of identifying the relevant practioners from the returned questionnaires. The second part of the study aims to find out if there are any potentially dangerous bacteria and fungi on laryngoscope blades and handles. Neither the ambulances nor the staff who work on them will be able to be identified from the results of the study.

All interested staff in the private emergency services of the eThekwini district, KwaZulu-Natal would be chosen for the study. This district has been chosen as it has an adequate sample size of staff for a study of this size. There are also no clear protocols existing regarding infection control, particularly cleaning and decontamination of laryngoscope blades and handles

All data will be coded and handled confidentially to ensure anonymity. The name of the ambulance service, the bases in the district and the staff will not be identified. Participation in the study is voluntary and participants will be required to complete a consent form.

Collection of data will take place at shift change. The researchers will be responsible for all data collection. The study will not impact on the normal operations of the service as data collection will occur at bases before handover.

This study hopes to contribute to reducing healthcare associated infection for patients, Emergency Medical Care staff and their families. A report containing the findings of the study will be forwarded to you. You are free to use the findings to implement a protocol. A copy of the research proposal is attached.
Do not hesitate to contact us if you require any information regarding my research study.

Thank You

Sugan Pillay
Research Student

Annexure 5: Letter to the KwaZulu-Natal regional manager of private emergency services

LETTER TO THE KWAZULU-NATAL REGIONAL MANAGER OF PRIVATE EMRGENCY SERVICES

Pending date

Dear Sir,

Re: Permission to conduct research

I am conducting a research project in order to complete a Masters degree in Emergency Medical Care through the Department of Emergency Medical Care and Rescue, Durban University of Technology.

Title of research:

An investigation into ambulance Laryngoscopes as a potential source of infection in a private ambulance service in the eThekwini district of KwaZulu-Natal.

Names of research students	: Mr S Pillay
Contact No	: 0784807872
Name of supervisor	: Mr S. Naguaran
Contact No	: 031 373 5336/ 083 786 3376
Name of Co-Supervisor	: Dr AM Folami
Contact No.	: 031-3732689/ 0662002880
Name of institution	: Durban University of Technology Department of Emergency Medical Care and Rescue

The purpose of this study is to determine the infection prevention and control practices regarding laryngoscope blades and handles amongst Emergency Medical Service personnel in a private ambulance service in the eThekwini district of KwaZulu-Natal, and to evaluate the current knowledge on infection control and whether they would like the implementation of a formalised infection control policy.

All interested staff in the private emergency medical services of the eThekwini district, KwaZulu-Natal would be chosen for the study. This district has been chosen as it has an adequate sample size of staff for a study of this size. There are also no clear protocols existing regarding infection control, particularly cleaning and decontamination of laryngoscope blades and handles

Procedure: The study consists of two parts. The first part requires you to complete a simple fifteen minute questionnaire and requires your honest response. It is concerned with your knowledge and decontamination practices of laryngoscope blades and handles infection control. This will be completed while you are at the base, at shift change. You are not required to state your name or address and all information will be treated in the strictest confidence. There will be no way of identifying you from the returned questionnaires. The second part of the study aims to find out if there are any potentially dangerous bacteria and fungi on laryngoscope blades and handles. Neither the ambulances nor the staff who work on them will be able to be identified from the results of the study. The objectives of the study are as follows:

1. To identify and quantify the prevalence of bacteria and fungi on laryngoscope blades and handles used by Emergency Medical Services (EMS).
2. To evaluate the current decontamination practices of EMS personnel for the disinfection of laryngoscope blades and handles.
3. To establish the minimum concentration of disinfectants and protocol required to inhibit the growth of microorganisms during prehospital cleaning and disinfection.

All data will be coded and handled confidentially to ensure anonymity. The name of the ambulance service, the bases in the district and the staff will not be identified. Participation in the study is voluntary and participants will be required to complete a consent form. Collection of data will take place at shift change. The researcher will be responsible for all data collection. The study will not impact on the normal operations of the service as data collection will occur at bases before handover. This study hopes to contribute to reducing healthcare associated infection for patients, Emergency Medical Care staff and their families. A report containing the findings of the study will be forwarded to you. You are free to use the findings to implement a protocol.

A copy of the research proposal is attached. Do not hesitate to contact us if you require any information regarding my research study.

Thank You

Sugan Pillay
Research Student

Annexure 6: Questionnaire

Title

To evaluate current decontamination practices of EMS personnel regarding the disinfection of laryngoscope blades and handles.

Ambulance base Code:

Thank you for agreeing to participate in this study. Remember that your answers will be kept confidential. Nobody else, apart from the researcher, will be able to identify who completed this questionnaire.

Instructions: Please complete details below.

1. Please give your age (in years) : _____
2. How many years have you worked in an EMS? _____
3. How long have you been an advanced life support paramedic/emergency care practitioner? ----------
   ----

Instructions: Please tick the appropriate answer.

4. What is your understanding of the word decontaminate or disinfection?

A process that eliminates many or all pathogenic microorganisms, except bacterial spores, on inanimate objects.	
Removal of visible soil from objects and surfaces that is normally accomplished manually or mechanically using water with detergents or enzymatic products.	

A process that destroys or eliminates all forms of microbial life and is carried out in health-care facilities by physical or chemical methods	
Don't know	
Unsure	

5. What is your understanding of the term infection control in the emergency medical services?

Infection control prevents or stops the spread of diseases in healthcare settings	
Is the ability to regulate all possible infections	
Infection control refers to policies and procedures used to minimize the rate of diseases transmission, especially in hospitals and human or animal health care facilities.	
Don't know	
Unsure	

6. Do you feel that you have sufficient knowledge about infection control practices regarding the laryngoscope blade and handles?

Yes	
No	
Neutral	

7. Are you confident in inspecting the response vehicle laryngoscope blade and handle with a bare hand

Yes	
No	

8. Do you wash your hands before disinfecting the laryngoscope blade and handle?

Yes	
No	

9. When preparing for ETI what hand hygiene methods do you use?

Washing of hands before setting up for ETI	
Use of sanitizer prior to setting up of ETI	
Washing of hands before and after setting up for ETI	
Sanitizing of hands before and after setting up for ETI	
Sanitizing hands donning of gloves setting up for ETI and putting on a new pair of gloves and then intubating	

10. Do you wear gloves when washing the laryngoscope blade and handles?

Yes	
No	

11. Do you have sufficient time to clean and disinfect the laryngoscope blade and handles on shift?

Yes	
No	

12. Is cleaning and disinfection equipment readily available at the Base?

Yes	
Do not know	
No	

13. Which would you prefer in your airway kit?

Reusable blades	
Disposable blades	

14. Is there a second pair of laryngoscope blades and handles at base/on board the response vehicle?

Yes	
Do not know	
No	

15. Were you ever in a situation whereby you needed a second pair of laryngoscope blades and handles to intubate due to the first pair of laryngoscope blade and handle being contaminated?

Yes	
No	

16. Would it be beneficial to have a second pair of laryngoscope blades and handles included in your airway kit?

Yes	
No	

17. Are you aware of what CSSD is?

Yes	
No	

Unsure	

18. How do you clean and disinfect the laryngoscope blade and handles on duty?

Soap and Water followed by disinfectant	
Soap and Water only	
Water only	
Water followed by Disinfectant only	
Wash with disinfectant and sent to CSSD	
Package as is and send to CSSD	
Unsure of what to do	

19. When are the laryngoscope blade and handle usually cleaned?

After every case where I have intubated a patient	
Beginning of shift	
End of shift	
I clean it upon every shift change	
When there is visible blood or secretions upon inspection	

‘

20. In terms of the disinfectant who prepares the solution?

Do not know	
Unsure	

I take the responsibility upon myself	
I ask my manager for assistance	
I use any amount of the solution available regardless of its strength	

21. Is there anything special that you use in terms of PPE when performing endotracheal intubation for suspected high risks patients such as: Covid 19, TB viral or bacterial, HIV and Cancer?

---

22. With Covid 19 restrictions are you allowed to use the hospitals sluice rooms to disinfect the laryngoscope blades and handles after hand over?

Yes	
Due to infection control , No	
Unsure	

23. Do you think it is possible for microorganisms/pathogens such as the Covid 19-virus to be transmitted from one patient to another without adequately disinfecting the laryngoscope blades and handles between patients/cases?

Yes	
No	
Unsure	

24. Does your emergency medical service base have its own sluice room designated for decontamination?

Yes	
No	
Unsure	

25. If no to the above question what do you do in terms of designated sight to decontaminate the laryngoscope blade and tool?

---

26. Do you think it is safer to decontaminate/ disinfect the laryngoscope blade in a controlled environment such as a designated sluice room?

Yes	
No	

27. In terms of arriving at a mass casualty where there were multiple red code patients requiring endo-tracheal intubation, what was your preparation between the patients in terms of the cleaning of the laryngoscope blades and handles?

---

28. What methods do you use to disinfect hidden corner places on the laryngoscope blade and handle during cleaning process? What are your methods?

---

29. In your service, are there currently formal policies on infection control practices regarding laryngoscope blades and handles?

Yes	
Do not know	
No	

30. Do you think that EMS should have a formalized infection control protocol with regarding the laryngoscope blade and handles disinfection?

Strongly Agree	
Agree	
Neutral	
Disagree	
Strongly Disagree	

31. Apart from what you have already stated in the above responses, are there any comments or problems regarding infection control that you would like to mention?

---

32. Would you be interested in learning more about decontamination and infection control regarding the laryngoscope blade and handles?

Yes	
Unsure	
No	

Annexure 7: Letter to the Head of Biotechnology and Food Technology

Letter to the Head of Biotechnology and Food Technology

Professor Feroz Mahomed Swalaha

Head of the Biotechnology Department

Department of Applied Sciences

Dear Prof. Swalaha

My name is Sugandran Pillay, I am an Emergency Medical Care student at the Durban University of Technology. In order to complete my Masters of Health Sciences in Emergency Medical, I must complete a research-based dissertation which require the use of Microbiology laboratory situated in your Department.

My research work involves the investigation of laryngoscope blades and handles that are frequently use in AM. It is used to insert a tube by bypassing the vocal cords to provide a definitive airway. Unfortunately, it comes in contact with various fluids such as blood vomitus and patients who maybe with holding dangerous diseases such as Covid 19 or multi-drug tuberculosis to name a few. This medical equipment has the potential to be the source and vehicle for transmission of various microorganisms. Therefore, I have chosen to evaluate the presence of bacteria on ambulance laryngoscope blades and handles. The study will be based on quantitative cross sectional experimental design, using non-probability sampling, which will be subdivided into three main objectives, namely:

1. To identify and quantify the prevalence of bacteria and fungi on laryngoscope blades and handles used by Emergency Medical Services (EMS).
2. To evaluate the current decontamination practices of EMS personnel for the disinfection of laryngoscope blades and handles.
3. To establish the minimum concentration of disinfectants and protocol required to inhibit the growth of microorganisms during prehospital cleaning and disinfection.

In order to achieve this, I humbly request to use Microbiology Laboratory situated in your Department for microbial analysis of samples that will be collected from the ambulance laryngoscope blades and handles.

Your assistance will be highly appreciated.

Regards,

Submitted by:

_
Mr. S. Pillay

Date:

Approved / Not Approved

……...
Prof F.M. Swalaha
Head of the Biotechnology Department

Date: _____

Annexure 8: Data collection sheet one

DATA COLLECTION SHEET ONE:

DATE:	BASE CODE:

Laryngoscope handles

Swab Label	Base	Base Code	Response vehicle Code	Site	Site Code	Date	Time

Laryngoscope blades

Swab Label	Base	Base Code	Response vehicle Code	Site	Site Code	Date	Time

Annexure 9: Data collection sheet two

DATA COLLECTION SHEET TWO:

DATE:	BASE CODE:

Laryngoscope handles/Blades

Swab Label	Base	Base Code	Response vehicle Code	Site	Site Code	Date	Time

Colony morphology:

Size:

Shape (form):

Colour:

Elevation:

Margin:

Surface Appearance

Odour:

Gram Stain	
Positive	Negative
Genus:	
Specie:	
Morphological Shape:	
Selective Media:	

Annexure 10: Data collection sheet three

DATA COLLECITON SHEET 3

Modified Kirby Bauer Assay

Sanchlor HF				
Organism	Zone of Inhibition 1	Zone of Inhibition 2	Zone of Inhibition 3	Average zone of inhibition
Staphylococcus				
Streptococcus				
Coliforms – E. Coli, Klebsiella, Proteus etc.				
Bacillus Species				
Diphtheroids				
Pseudomonas				
Mycobacteria				

Angiosyme Synergy 5				
Organism	Zone of Inhibition 1	Zone of Inhibition 2	Zone of Inhibition 3	Average zone of inhibition
Staphylococcus				
Streptococcus				
Coliforms – E. Coli, Klebsiella, Proteus etc.				
Bacillus Species				
Diphtheroids				
Pseudomonas				
Mycobacteria				

D-Germ hand disinfectant				
Organism	Zone of Inhibition 1	Zone of Inhibition 2	Zone of Inhibition 3	Average zone of inhibition
Staphylococcus				
Streptococcus				
Coliforms – E. Coli, Klebsiella, Proteus etc.				
Bacillus Species				
Diphtheroids				
Pseudomonas				
Mycobacteria				

Bio scrub soap				
Organism	Zone of Inhibition 1	Zone of Inhibition 2	Zone of Inhibition 3	Average zone of inhibition
Staphylococcus				
Streptococcus				
Coliforms – E. Coli, Klebsiella, Proteus etc.				
Bacillus Species				
Diphtheroids				
Pseudomonas				
Mycobacteria				

Control:

	Positive Control: Ciprofloxacin (Antibiotic)				Antimicrobial Susceptibility		
Organism	Zone of Inhibition 1 (mm)	Zone of Inhibition 2 (mm)	Zone of Inhibition 3 (mm)	Average zone of inhibition (mm)	Susceptible	Intermediate	Resistant
Staphylococcus							
Streptococcus							
Coliforms – E. Coli, Klebsiella, Proteus etc.							
Bacillus Species							
Diphtheroids							
Pseudomonas							
Mycobacteria							

Adapted from (Amod 2018)

Annexure 11: Editing certificate

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EDITING CERTIFICATE

Re: **Sugandran Pillay**
DUT master's dissertation: **An Investigation into Ambulance Laryngoscopes as a Potential Source of Infection Amongst Emergency Medical Service Personnel in a Private Ambulance Service in the Ethekwini Municipality of KwaZulu-Natal**

I confirm that I have edited this dissertation and the references for clarity, language and layout. I returned the document to the author with track changes so correct implementation of the changes and clarifications requested in the text and references is the responsibility of the author. The intellectual content of the document is the responsibility of the author. I am a freelance editor specialising in proofreading and editing academic documents. My original tertiary degree which I obtained at the University of Cape Town was a B.A. with English as a major and I went on to complete an H.D.E. (P.G.) Sec. with English as my teaching subject. I was a part-time lecturer in the Department of Homoeopathy at the Durban University of Technology for 13 years and supervised many master's degree dissertations during that period.

Dr Richard Steele
15 November 2023
per email