INFECTION CONTROL PRACTICES AND MICROBIAL LOAD OF IMAGING RECEPTORS USED BY A DIAGNOSTIC IMAGING DEPARTMENT AT AN ACADEMIC HOSPITAL

by

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DECLARATION OF INDEPENDENT WORK

I, Tanya Wainwright (student No. _____), hereby declare that this research project, submitted to the Central University of Technology, Free State, for the degree Master of Radiography (Diagnostic), is my own, independent work. This research project was conducted at the Central University of Technology, Free State, under the supervision of Dr B. van der Merwe, co-supervised by Dr I. Sebelego.

Tanya Wainwright

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GLOSSARY OF TERMS

Colonised	Bacteria have settled on an item (Ehrlich and Coakes, 2017).
Microbial load	Number of microbes on an item (Russotto et al., 2015).
Reservoir	Habitat where a pathogen can live (Auffermann et al., 2015).
Route	A identified path an item moved from point A to point B and back to point A (Burbridge, 2012).
Trip	When an imaging receptor or imaging receptors left the department (Anderson *et al.*, 2023).
Fomite	Non-living object that can be contaminated with a pathogen and then carry the pathogen and transfer it to another item (Burbridge, 2012).
Nosocomial pathogens	Pathogen acquired within a hospital (Sukumar and Yadav, 2012).

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LIST OF ABBREVIATIONS

CFU/mL	Colony-forming units per millilitre
COVID-19	Coronavirus disease 2019
CRE	Carbapenem-resistant Enterobacteriaceae
DNA	Deoxyribonucleic acid
ESKAPE	*Enterococcus faecium, Staphylococcus aureus, Klebsiella pneumoniae, Acinetobacter baumannii, Pseudomonas aeruginosa and Enterobacter* species
ICU	Intensive care unit
IR	Imaging receptor
MDR	Multi-drug-resistant
mL	Millilitres
MRSA	Methicillin-resistant *Staphylococcus aureus*
NICU	Neonatal intensive care unit
PICU	Paediatric intensive care unit
spp.	Species
VRE	Vancomycin-resistant *Enterococcus*
WHO	World Health Organization

CHAPTER 1
OVERVIEW OF THE STUDY

1.1 INTRODUCTION

Mobile radiography machines have made it easy to travel around a hospital and take radiographs in departments or wards when patients are unable to visit the imaging department itself. Imaging Receptors are intended to be used in any place where there is a radiography machine that can expose it. After the exposure has been done, the IR must be taken to a processor to read out the image that was acquired. The combination of the mobile radiography machine and IRs that can move around freely opened a new world of assisting patients in need and with ease (Taher et al., 2025).

Digital mobile radiography machines differ from conventional mobile radiography machines; in the former, a dedicated IR is referred to as a digital detector. A digital radiography machine is more efficient than the conventional mobile radiography machine because no external processing of the exposed image is required (Bwanga et al., 2023). A digital radiography machine has a display interface on which the readout of the image is immediate. The physician can view the radiograph within seconds on the mobile radiography machine screen in the ward. Only one digital detector is needed for all radiographs. Once the exposure has been made, the image is created and the digital detector no longer stores the image, in contrast to an IR (Almojadah et al., 2023). An added advantage is that double-exposure images cannot be created. Thus, there is a lower exposure dose for the patient, because double exposures to IRs can happen in the absence of proper precautions to mark the IRs that were already exposed (Crest + Oral-B Dentalcare, n.d.).

Infection control protocols in health care settings vary across the world; however, a few key aspects are addressed in most countries' protocols, such as hand hygiene and sterile procedures. Current infection control practices in South Africa and listed by the Department of Health include the hand hygiene steps of the World Health Organization (WHO), which provide information on pre- and post-patient contact, sterile practices and making use of personal protective equipment such like masks and gowns

(Department of Health, 2017). Infection control protocols are important because of the consistent worldwide threat of contamination of patients and healthcare workers with nosocomial pathogens (Sukumar and Yadav, 2012). The effects of contamination can be devastating and, all over the world, researchers are searching for solutions to this problem. Russotto et al. (2015) investigated the involvement of medical equipment in cross-contamination in health care settings. They found that the immediate environment around the patient was likely to be colonised by bacteria, and that hand hygiene can be a concern if it is not performed properly, or performed inadequately.

In the radiology setting, inanimate objects such as imaging receptors (IRs) have the ability to act as a fomite (Burbridge, 2012), which means infection/pathogens can be transmitted through equipment that comes in contact with patients. IRs are the instruments used to capture the image which is created after an exposure with X-rays are made of an anatomical area (AGFA HealthCare, 2010). When IRs are not disinfected after patient contact, any possible infectious agent may be transmitted to another patient as a possible susceptible host (Ehrlich and Coakes, 2017). IRs travel through hospitals when equipment is used for mobile radiography and, thus, contribute to the risk of spreading infectious agents on the routes travelled through the hospital (Burbridge, 2012; Nyirenda et al., 2018).

ESKAPE (*Enterococcus faecium, Staphylococcus aureus, Klebsiella pneumoniae, Acinetobacter baumannii, Pseudomonas aeruginosa* and *Enterobacter* species) pathogens are examples of infectious agents that pose a great risk in the hospital environment. Infection control methods need to be enforced to prevent spread of infectious agents (Santajit and Indrawattana, 2016).

The WHO (2017) classifies the ESKAPE pathogens according to priority, namely critical, high and medium. However, not all the ESKAPE group pathogens are prioritised by the WHO. *Klebsiella* (K) *pneumoniae* is not identified as one of the prioritised pathogens; nevertheless, it is included in this study because research reports on several cases involving K. *pneumoniae* (WHO, 2017). However, the following pathogens were included in the study to allow full spectrum of cover regarding the ESKAPE pathogens namely *Enterococcus faecium, Staphylococcus aureus,*

Klebsiella pneumoniae, Acinetobacter baumannii, Pseudomonas aeruginosa and *Enterobacter* species.

The importance of the study relates to evidence that many patients are infected with nosocomial pathogens, of which the source could be any number of items/people within the hospital setting (Jayasinghe and Weerakoon, 2014). By taking swab samples and observing if the infection control recommendations were followed, possible areas/actions that could cause contamination and colonisation could be identified in the implementation of current protocols.

1.2 BACKGROUND TO THE RESEARCH PROBLEM

Research indicates that the IRs used in intensive care units (ICUs) and the imaging department in this study served as reservoirs/fomites for nosocomial pathogens (Kim et al., 2012; Eze, 2014; Auffermann et al., 2015). When radiographers visit different wards or ICUs in the hospital to take mobile radiographs, they come into contact with many different micro-organisms. Upon returning to the imaging department, the IR has already come into contact with patients who may have been contaminated with pathogens. These pathogens that can come into contact with the IR form part of the infection cycle. The infection cycle (see Figure 2.2) starts with the infectious agent, and is followed by a reservoir, the exit of a substance from the human body, methods of transmission, entry of substances into the human body and, lastly, a susceptible host (Ehrlich and Coakes, 2017). An infectious agent that came into contact with an IR that had not been properly disinfected can complete the infection cycle if the IR comes into contact with a susceptible host (Ehrlich and Coakes, 2017). In this study, the researcher investigated the infection control practices and microbial load of the IRs of a diagnostic imaging department at an academic hospital.

1.3 PROBLEM STATEMENT

Research indicates that the IRs used in ICUs, as well as the imaging department under investigation, served as reservoirs/fomites for nosocomial pathogens. At any given time when an inanimate object, such as the IRs in this study is used consistently, there is a possibility that nosocomial pathogens can spread. The spread can only occur if

there was contamination of a pathogen and a new host is colonised. Therefore, infection control needs to be applied in as many forms as possible, for example cleaning the IR, washing hands when making contact with an IR or a patient. Infection control can be determined by observation as well as testing for the most common and current types of pathogens discussed in peer reviewed literature. In this study, the researcher investigated whether infection control practices were applied by radiographers during mobile radiography examination procedures. Furthermore, the researcher investigated the microbial load on the surfaces of the IRs.

1.4 RESEARCH QUESTIONS

What are current infection control practices and microbial load on the surfaces of the IRs used in the diagnostic imaging department during mobile radiography examinations at an academic hospital?

Subsidiary questions of this investigation were as follows:

- Is the infection control protocol executed, namely disinfecting radiography equipment before and after patient contact, hand washing before and after patient contact, as well as utilising plastic covers for all IRs?
- What is the movement of an IR within the hospital during an identified day?
- What are the current microbial loads of the IRs?
- Are any of the microbes members of the ESKAPE group of pathogens and do they harbour antibiotic resistance characteristics?

1.5 OVERALL GOAL

The goal of the study was to determine if the current infection control practices of the imaging department, such as hand hygiene, cleaning of IRs, placing IRs in waterproof barriers like a plastic bag and disposing of contaminated items like gloves during and during mobile radiographic examinations, were effective in limiting the spread of nosocomial pathogens.

1.6 AIM OF THE STUDY

The study aimed to investigate the current infection control practices and microbial loads on the surfaces of the IRs used in a diagnostic imaging department and during mobile X-ray examinations at an academic hospital.

1.7 OBJECTIVES

To achieve the aim, the following objectives were formulated:

- To contextualise the effects of nosocomial infections and standard infection control practices via a literature review, to compile observational notes;
- To observe, using observational notes, whether correct infection control protocol/practices were applied in relation to IRs and the handling of IRs (notes were not taken in front of the radiographers);
- To observe the various daily routes/processes of the IR during imaging in the department and during mobile X-ray examinations. The observation was captured on an observational note (see Appendix A); and
- To test IR surfaces for the presence of selected microbes and analyse antibiotic resistance capabilities when members of the ESKAPE group were detected.

To correctly capture the observed data, an observation tool was designed. The tool enabled the researcher to capture infection control practices and the movement of the IRs consistently (see Appendix A). In addition to the observation tool, the researcher made use of a microbial sample tracking sheet to capture data for the microbiology part of the study. The sampling tracking sheet enabled the researcher to document whether all the necessary steps were taken to ensure that the correct sampling procedure was followed (see Appendix B).

1.8 DEMARCATION OF THE INVESTIGATION

This study was conducted at the Department of Clinical Imaging Sciences of an academic hospital. The analysis of the swabs taken took place at the laboratory facilities at the Central University of Technology in Bloemfontein, South Africa.

The study was conducted from October 2019 to December 2023. The data collection started in October 2019, but the Coronavirus pandemic of 2019 (COVID-19) created a countrywide lockdown that interrupted sampling for two years. In 2022, the sampling commenced when some of the lab sampling material needed to be replaced because it had expired during the two years of lockdown, and sampling was completed in 2023. However, by then, a new digital X-ray machine had been introduced to the department and the researcher had to determine how to fit the new machine into the study. Research was undertaken on the machine routes and it was determined that the study could continue.

1.9 RESEARCH DESIGN OF THE STUDY

The study design for this research study was prospective, quantitative and observational. All the data were collected prospectively in numerical format, which made statistical analysis possible (Shuttleworth, 2015). Prospective research involves for the observation of participants and precisely documenting the observations (StatsDirect, 2018). The observation was documented by noting actions taken in a numerical format per action taken. Observation of the routes travelled by the IRs allowed for unmediated feedback (Merriam, 2016). The research paradigm for this study is a positivist paradigm. A positivist paradigm relies on quantitative study design with comparable data in numerical format and being able to perform statistical analysis of the collected data. A positivist paradigm allows for observational data to be collected as well (Park, Konge and Artino, 2020).

1.10 STUDY POPULATION AND SAMPLING METHOD

The study sample involved all 12 available conventional 35 × 43 cm X-ray machine IRs and a digital X-ray machine detector (only the 35 × 43 cm digital detector was sampled, for the sake of consistency, in turn, the 24 × 30 cm digital detect was not sampled because it was not routinely used like the conventional IRs) used in the imaging department, as well as during mobile X-ray examinations at the participating academic hospital. The IRs were labelled to enable the researcher to keep track of the movement of each individual IR circulating through the hospital. Physical swabs were taken in the

morning before the day shift started at 07:00 and again at 16:00 when the day shift ended. The swabs were taken individually for each IR pre- and post-disinfection with 70% ethanol. The sampled swabs were transferred to the laboratory for cultivation.

The sampling method used was observing the routes travelled by the IRs throughout the hospital and documenting the data with observational notes (see Appendix A). Before and after the observational process, swab samples were taken of all 35 × 43 cm IRs.

1.11 RESEARCH TOOLS

The researcher utilised a microbial sample tracking sheet (see Appendix B) and observational notes for documentation purposes. The observational notes contained observational criteria. Observational notes were used to document and guide the observation of the movement of the IRs (see Appendix A). According to a particular situation, a specific criterion was selected, which was numerically calculated as a percentage, for example, how many students performed mobile radiographs in the ICU or how many IRs were transported, either by hand or by the mobile machine.

A microbial sample tracking sheet was used to document all surface areas that were disinfected and swabbed (see Appendix B). The swabs were taken in the imaging department, in a room where the researcher was not visible to the radiographers. The samples were taken with a special sterile swab; the samples were taken to the laboratory. The swabs were analysed in the laboratory by the microbiologist, who compiled a detailed report on all the findings. The researcher processed the information obtained and will report on it in this dissertation.

1.12 TRUSTWORTHINESS, VALIDITY, RELIABILITY AND CREDIBILITY

Trustworthy research is defined as valid and reliable research (Statistics Solutions, 2018). Validity was achieved by accurately planned steps to acquire the samples (Durand et al., 2015). Validity and the reliability of a research study can be defined as the accurate measurement of the data that was collected and intended to be measured (Andersson, Boateng and Abos, 2024). To establish the validity and the reliability of

the sample, following a proper infection control process was of great importance. Proper infection control meant the samples could be preserved (Durand et al., 2015).

Reliability can be defined for a research study by how consistent the data collection was (Durand et al., 2015). Reliability of the samples and research were achieved by planning the sampling process. Moreover, the sampling and observations were well documented and guided by checklists (Statistics Solutions, 2018).

Credibility can be defined as being able to trust the content that was found or studied (Statistics Solutions, 2018). Credibility was achieved by making use of triangulation during the sampling phase. Triangulation of data was achieved by documenting the routes the IRs travelled, and comparing the sampling data obtained from the IRs (Statistics Solutions, 2018). Thus, the findings of the microbial sampling were supported by observational data.

1.13 ETHICAL CONSIDERATIONS

Approval to conduct the study was obtained from the Health Science Research Ethics Committee of the Faculty of Health Sciences at the University of the Free State (ethics No. UFS-HSD2018/1466/2506-0002). The hospital in question will not be named, nor will any personal information of the radiographers observed in this research study be revealed. The researcher and supervisors are the only people with access to the population data collected. The participants of the study all signed informed consent forms that had guided them through the process and provided them with a choice to participate if they felt secure to do so (see Appendix C). This study was conducted with approval from the Free State Department of Health (see Appendix D).

1.14 SIGNIFICANCE AND VALUE OF THE STUDY

This study is significant because of the high risk of cross-contamination in ICUs and medical imaging departments and when mobile X-ray examinations are done. The results from the swabs could indicate if the current infection control process is adequate or if a new plan/method should be designed. This study has the potential to improve infection control practices to limit the spread of nosocomial pathogens. Due

to radiographers being required to do Continuous Professional Development, there could be increased possibilities to educate radiographers and student radiographers on what is the best practice for infection control on mobile radiography in addition to standard infection control in the department like hand washing. By continuously testing, the efficacy of certain infection control practices and monitoring infection control practices and behaviours without intervention, the possibility exist that a highly effective infection control practice can be established.

1.15 ARRANGEMENT OF THE REPORT

The report consists of five chapters. Chapter 1 provided the background to the research study. Chapter 2 will provide a detailed discussion of the relevant literature and supports the study with guidance from the literature and previous research performed in relation to the topic. The methodology of the study will be discussed in Chapter 3, including all aspects of sampling. The results of the study will be discussed in Chapter 4. To conclude the report, Chapter 5 will present recommendations and limitations of the study.

1.16 CONCLUSION

Nosocomial infections present a great risk for patients, especially patients in ICU who have compromised immune systems. The ESKAPE group of pathogens currently present as a critical issue in health care facilities.

The focus of this study was to identify the routes that IRs follow and to determine whether pathogens of the ESKAPE group were present on the IRs. The results may indicate whether IRs contribute to the transmission of pathogens on the routes the equipment travels through the hospital.

CHAPTER 2
LITERATURE REVIEW

2.1 INTRODUCTION

Medical imaging has made diagnosis of pathologies and subsequent treatment easier with high rate of patient interaction within a medical imaging department and mobile radiography (Sukumar and Yadav, 2012). To be able to create a radiograph an IR is used to capture the interaction of the radiation through the relevant anatomy. Thus, the IR plays a very important role in creating a radiograph. The IR however can come into contact with pathogens on a regular basis and that contributes to the infection cycle (Sukumar and Yadav, 2012).

Through the review of the literature, a clear understanding will be gained of the infection cycle pertaining to IRs that are used in mobile radiography. The infection cycle starts when an infectious agent contaminates the IR, which serves as the reservoir for the infectious agent (see Figure 2.2). From there, the IRs travel and could be contaminated further during the process of moving about and, finally, the infectious agent has the opportunity to enter a susceptible host (Ehrlich and Coakes, 2017). IRs are used in radiology to capture radiographs via ionising radiation exposure to the anatomical part of interest and transferring the images to a computer. IRs served as the main focus of the study, because IRs travel through a hospital, including ICUs.

Little research has been undertaken on the possibility that IRs form part of the infection cycle. No previous association has been made to indicate that the movement of IRs within a hospital helps to spread nosocomial pathogens. Thus, observing how IRs travel through a hospital and observing the hygiene actions that are taken, and comparing that data to the presence of selected microbes, were expected to provide the researcher with data to determine the connection between IR handling actions and hygiene practices. The literature informs, guides and gives rise to new questions on infection control and/or prevention (Russotto et al., 2015). The review of literature in this chapter served the purpose of guiding the researcher to perform relevant research (see Figure 2.1). Section 2.2 will discuss the cycle of infection and the human body's

reaction to being infected, nosocomial infections and the radiographer, IRs as a confirmed fomite, and infection control protocols.

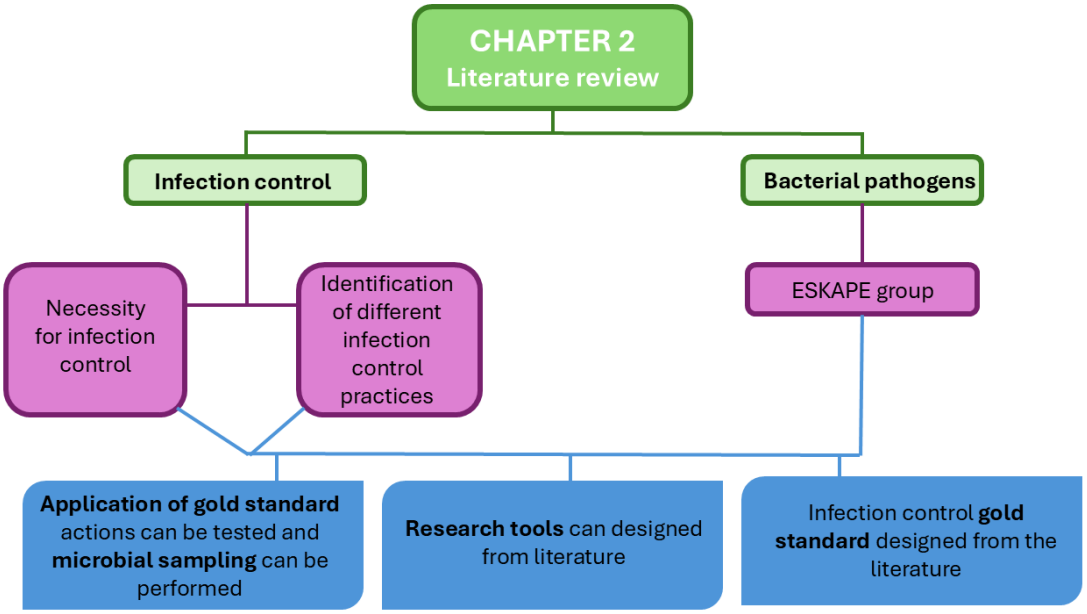

Figure 2.1: Theoretical framework

2.2 THE INFECTION CYCLE

A pathogenic organism will, in certain circumstances, colonise a surface area or susceptible host (Ehrlich and Coakes, 2017). A host can only be colonised by a pathogenic organism if the circumstances are ideal. The ideal environment requires moisture, a source of nutrients and the right temperature (Ehrlich and Coakes, 2017).

The infection cycle can be broken down into individual steps/sections, as illustrated in Figure 2.2. Each section is an entity on its own; however, when all the steps/sections align, the cycle of infection starts (Ehrlich and Coakes, 2017). The infection cycle continues until one of the favourable entities is removed/stopped (Ehrlich and Coakes, 2017). The steps/sections are the infectious agent, reservoirs, substances exiting the human body, transmission, entry of substances into the human body and a susceptible host.

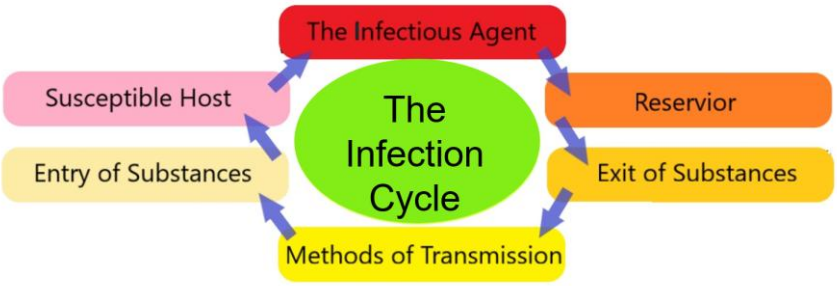

Figure 2.2: The infection cycle (Ehrlich and Coakes, 2017)

2.2.1 Infectious agent

An infectious agent is a micro-organism that can contaminate a susceptible host, thereby causing an inflammatory response. An inflammatory response is the way the body reacts when an infectious agent is introduced to the body. The body reacts by creating a physical response such as a fever and other symptoms (National Academy of Sciences, 2018). When an infection is acquired during a hospital stay or within three days of being admitted to a hospital, it is classified as a nosocomial infection. Thus, nosocomial infections are infections that were acquired within the hospital (Eze, 2014). Although viruses, fungi and parasites are recognised as sources of nosocomial infections, bacterial agents remain the most commonly recognised cause (Tobin and Zahra, 2025). The occurrence of nosocomial infection is related to several factors, including hospital environmental conditions, human occupancy and the characteristics of equipment. The occurrence of infectious agents in the clinical environment is a matter of concern and has generated several studies aimed at eliminating their presence (Dresch et al., 2018).

All bacterial nosocomial infections are either Gram-negative or positive. Patients who are admitted to ICUs have an increased risk of acquiring a Gram-negative bacteria infection (Bracco et al., 2013). Gram-negative bacteria cause a great deal of global concern, because the bacteria in this class are becoming increasingly more resistant to antibiotics (Zowawi et al., 2015). Figure 2.3 Illustrates how the Gram-negative Proteobacteria are organised into groups according to shared genetic characteristics. A bacterial tree is ranked from higher-order Phylum to Class, Order, Family, Genus and, finally, Species, as seen in Figure 2.3 (NCBI, n.d.).

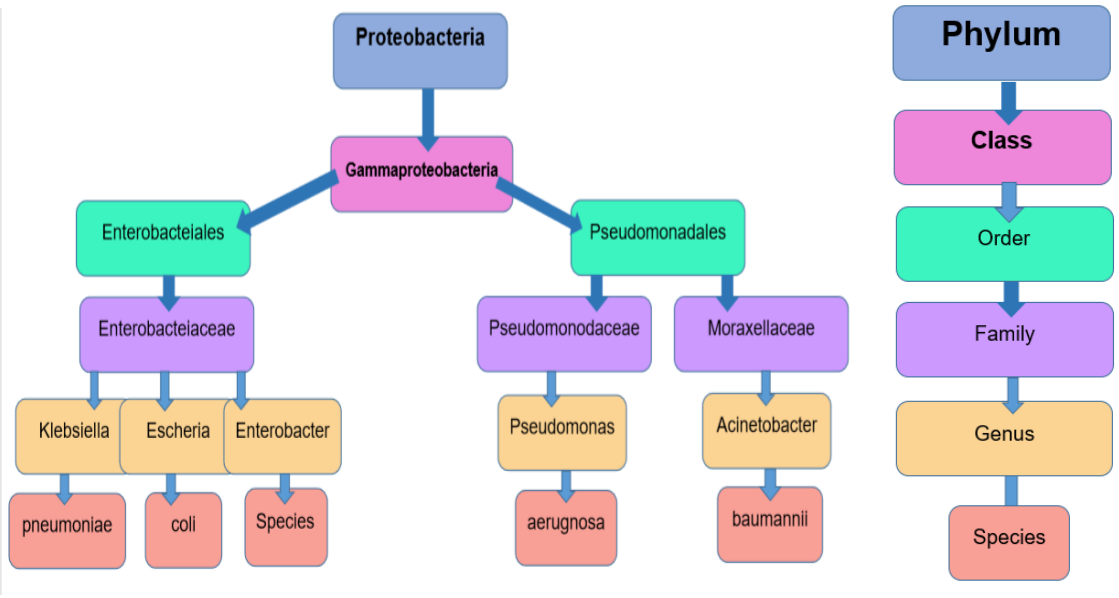

Figure 2.3: Relations between selected bacterial species in the Gram-negative Proteobacteria phylum

Members of the Enterobacteriaceae family are among the major causative agents of nosocomial infections (Hrabak et al., 2014). This family contains more than 100 species, which are typically found in the intestines of humans and animals. Coliforms are a group of Enterobacteriaceae (not a single species) that are considered hygiene indicators; they include *Escherichia coli*, *Klebsiella* species (spp), and *Enterobacter* spp. Coliforms are the most common pathogens in human adults, and account for 70% of infections, of which *E. coli* is the most common isolate and also the most capable of showing resistance to antibiotics (Maki et al., 2008; Braide et al., 2018). The second most common coliforms belong to the genus *Klebsiella*. In the early 1970s, *Klebsiella pneumonia* was established in the hospital environment and became the leading cause of nosocomial infections. It is found in high frequencies (80%) in the gastrointestinal tracts of patients, as well as in nasopharynges and on the hands. This considerable efficiency of colonisation, which is enhanced by acquired resistance to antibiotics, enables *Klebsiella* spp. to persist and spread rapidly in health care settings (Tzouvelekis et al., 2012). *Enterobacter* spp. is non-fastidious and can cause opportunistic infections in immunocompromised individuals (usually the infection is acquired during hospitalisation). Many strains of *Enterobacter* contain a wide range of

antibiotic resistance mechanisms and are resistant to almost all available antimicrobial drugs (Boucher et al., 2009).

Other Gram-negative bacteria that are generally associated with nosocomial infections are *Pseudomonas* and *Acinetobacter* (Khan et al., 2015). *Pseudomonas aeruginosa* is part of the normal gut flora and infection usually takes place through direct/indirect contact with the environment. *P. aeruginosa* is one of the leading antibiotic-resistant bacterium, and plays an important role in the inception of nosocomial infections worldwide (Ghamgosha et al., 2015). *Acinetobacter* species are widely distributed in the environment and readily contaminate the hospital environment. The most important human pathogen is *A. baumannii*, which has a relatively long survival time on human hands. Cross-contamination and infections at various sites, such as respiratory and urinary tracts, are common in the health care environment. Strains are often antibiotic-resistant, which is a particular problem in surgical wards and ICUs (Santajit and Indrawattana, 2016).

Gram-positive *Enterococcus* spp. are present in large numbers in the lower gastrointestinal tracts of humans. Two common species, *E. faecalis* and *E. faecium,* account for > 85% of the enterococci present in the intestine. They are hardy organisms that are able to survive on environmental surfaces for extended periods (Santajit and Indrawattana, 2016). Over the past decade, a rise in ampicillin- and vancomycin-resistant enterococcal infections in health care facilities have been reported (Santajit and Indrawattana, 2016). *Staphylococcus* is part of the normal skin flora, especially of the nose and perineum of humans and animals. Carriage rates are high in the general population, and transmission can occur by direct contact or airborne routes. Out of many species of *Staphylococcus* genus, *S. aureus* is considered one of the most important pathogens responsible for nosocomial infections (Khan et al., 2015). Reports of methicillin-resistant *S. aureus* (MRSA) emerged in the 1960s, and currently, MRSA isolates are estimated to account for 25% of *S. aureus* isolates. Tackling the problem of MRSA is a top priority for public health systems worldwide (Santajit and Indrawattana, 2016). Both *Enterococcus* and *Staphylocuccus* belong the phylum Firmicutes. A diagram of how these two Gram-positive genera are related is presented in Figure 2.4.

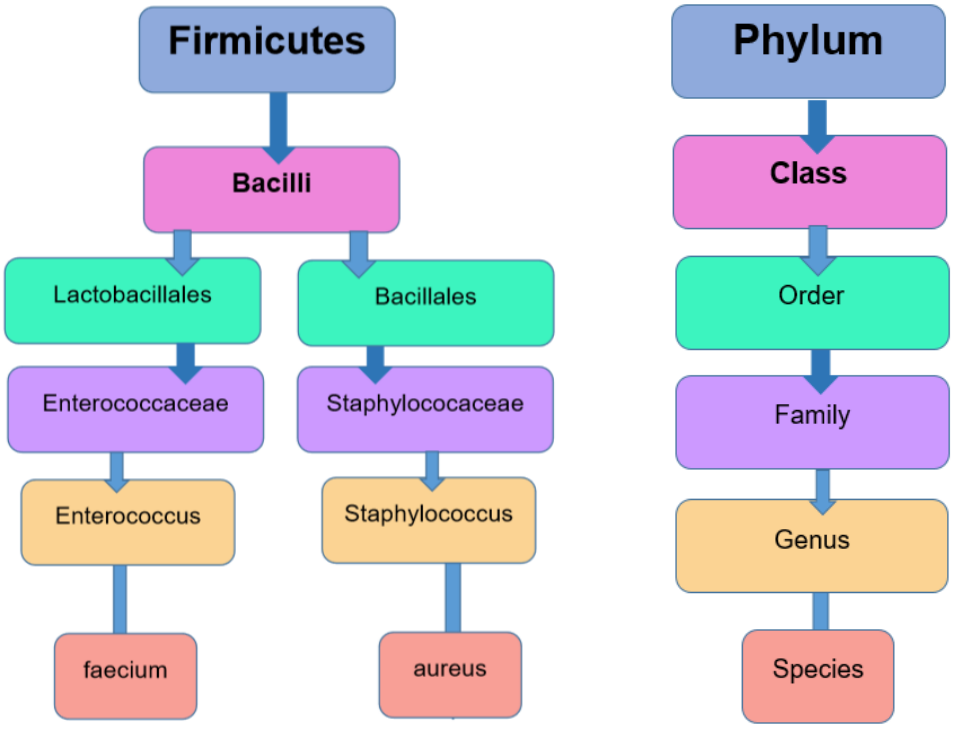

Figure 2.4: Relations between selected bacterial species in the Gram-positive Firmicutes phylum

There are more role players causing infections than just viruses and bacteria – yeast and mould should also be considered as possible infectious agents. Yeast and mould are classified as fungi and have been identified as opportunistic infectious agents in health care systems, although virus and bacterial infections are best known types of infections. The occurrence of yeast and mould infections is increasing steadily (de Pauw, 2011). There are an estimated 200 types of fungi that can cause infections in humans (Orlowski et al., 2017). Of the 200 fungal species that can cause infections, candida is the most common infectious agent (de Pauw, 2011; Schmiedel and Zimmerli, 2016; Orlowski et al., 2017).

Patients presenting with pneumonia-related symptoms and chronic cough are advised to consider chest X-ray as a first-line method of diagnosis (Scott et al., 2014). Patients who are sent for chest radiographs might have fungal, bacterial or viral infections, which could possibly contaminate X-ray equipment (Kalu et al., 2009; Scott et al., 2014). When mobile radiographs are taken, a patient can come into contact with an IR, which could involve cross-contamination (Dresch et al., 2018). Furthermore,

diagnostic imaging equipment such as computed tomography and magnetic resonance imaging scanners can be used on patients with active fungal infections, thus providing a route for fungi to enter the imaging department (Orlowski et al., 2017).

Clearly, the mere occurrence of specific pathogens is no longer the only concern; infectious agents that are resistant to antibiotic treatments are a current and recurring issue that is recognised by hospitals all over the world. The presence of antibiotic resistance continues to increase globally and is posing a greater threat every day because of treatment difficulty (Burbridge, 2012; Kon and Rai, 2016). The WHO (2017: 13) classifies bacterial pathogens into three tiers (critical, high, and medium priority) according to a critical assessment of mortality, healthcare burden, community burden, the prevalence of resistance, 10-year trend of resistance, transmissibility, preventability in the community setting, preventability in the healthcare setting, treatability, and pipeline (see Figure 2.5). Critical-priority bacteria include *A. baumannii* and *P. aeruginosa*, and Enterobacteriaceae such as K. *pneumoniae*, *E. coli* as well as *Enterobacter* species (WHO, 2017). The highest-ranked Gram-positive bacteria (high priority) are E. *faecium* and *Staphylococcus aureus*; medium priority bacteria are not bacteria of interest (Tacconelli et al., 2018).

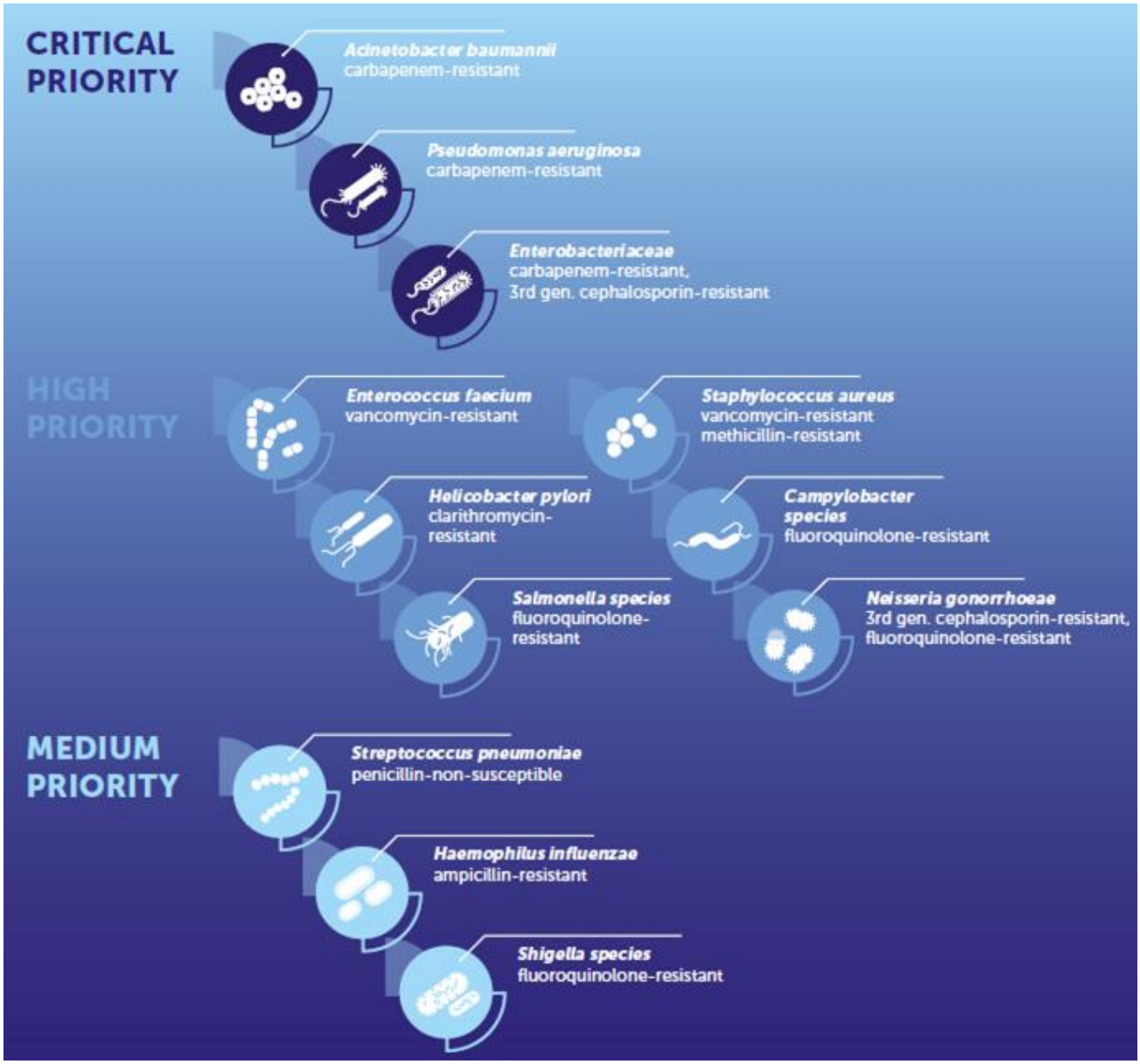

Figure 2.5: WHO prioritisation of pathogens to guide research and development of new antibiotics (WHO, 2017)

There is a link between the well-established research of the *Enterococcus faecium Staphylococcus aureus, Klebsiella pneumoniae, Acinetobacter baumannii*, *Pseudomonas aeruginosa* and *Enterobacter* species (ESKAPE) group of (see Section 3.2). and the WHO-prioritised pathogens. The ESKAPE group is identified as being a collection of bacteria that can cause serious bacterial infections, and most have the genetic mutation for antibiotic resistance. Both Gram-negative and positive species are represented in the ESKAPE group (Elhosseiny and Attia, 2018). The WHO classifies

Acinetobacter baumannii, *Pseudomonas aeruginosa* and Enterobacteriaceae as critical-priority pathogens, in addition to *Enterococcus faecium* and *Staphylococcus aureus,* which is a high priority pathogen. None of the medium priority pathogens are within the identified ESKAPE group. However, the remaining pathogen that is linked to the ESKAPE pathogens is *Klebsiella pneumoniae*.

In this study, ***E**nterococcus faecium **S**taphylococcus aureus, **K**lebsiella pneumoniae, **A**cinetobacter baumannii*, ***P**seudomonas aeruginosa* and ***E**nterobacter* species made up the **ESKAPE** group of pathogens and thus, formed the focus of the study when the IRs were sampled.

2.2.2 Reservoirs

A reservoir serves as a physical space or surface area that has favourable environmental conditions for pathogens to thrive. These favourable conditions include specific temperatures that are considered warm to hot, moisture and nutrients to feed on (Ehrlich and Coakes, 2017). A reservoir can include anything from a plastic surface to a healthy human; in the latter case, the healthy human body acts as a carrier for a pathogen (Ehrlich and Coakes, 2017). The human body has all the favourable conditions needed for a reservoir: The body has a relatively high temperature, it creates moisture and there are nutrients available on the body that enable pathogens survive and multiply. For example, all humans have normal flora that will not affect a healthy person; however, the normal flora can cause severe infections in patients who are immuno-compromised (Ehrlich and Coakes, 2017). An inanimate object such as an IR, or the human body, which contains normal flora, can act as a carrier or reservoir. When a contaminated IR or human comes into contact with an immune-compromised patient, an infection can be acquired via the transmission of a pathogen from the carrier or reservoir (Ehrlich and Coakes, 2017).

Various surfaces in hospitals tend to act as reservoirs for pathogenic bacteria, for example, keyboards, the buttons of lifts and bathroom surfaces (Pereira da Fonseca et al., 2016); other surfaces in the hospital that have a tendency to act as reservoirs include items such as chairs, blood pressure cuffs, equipment used for physical therapy, wheelchairs and patient-lifting equipment (Cadnum et al., 2015).

Radiographic imaging equipment, namely IRs, form part of the contact fomite/reservoirs (Burbridge, 2012). When a mobile X-ray image is acquired of a patient, the IR, which acts as a reservoir for pathogenic organisms, comes into contact with a patient during the X-ray procedure. When we refer to an IR as a fomite, it means that the IR can carry a pathogenic organism (Rollins, 2000). An investigation performed in Nigeria on 200 items of radiographic equipment found that IRs had the highest percentage of contamination in both government and private hospital settings (Eze, 2014). The contamination of IRs may be the result of the different sites from which patients are referred for X-ray examinations (Eze, 2014).

Pathogenic organisms normally need some form of a vector or fomite for transmission to take place. During X-ray examinations, the IRs come into contact with the patient as well as the radiographer and X-ray equipment, which may lead to cross-contamination from the IRs (Eze, 2014; Wainwright, 2015). Pathogenic organisms were identified on IRs in Africa, and studies clearly demonstrate that pathogenic organisms were able to survive on IRs (Eze, 2014; Wainwright, 2015). When pathogenic organisms are able to survive on an innate object, for example, IRs, the object will fulfil the role of a fomite for the micro-organisms. Some of the pathogenic organisms that were identified by studies performed in Africa include *Staphylococcus aureus*, *Pseudomonas aeruginosa*, Coliforms, *Streptococcus* spp., *Klebsiella pneumoniae* and Enterobacteriaceae (Eze, 2014; Wainwright, 2015). Radiographic equipment such as mobile machines and IRs are intended to move around throughout the hospital, thus allowing radiographers to travel to patients in different wards and acquire radiographs at the bedsides of patients. If equipment moves around the hospital, cross-contamination is possible (Russotto et al., 2015).

The outside covering of IRs is made of acrylonitryl butadiene styrene, which is a type of polymer (plastic) (AGFA HealthCare, 2010; Nugent, 2011), which could be made to have a porous surface (Nugent, 2011). IR surfaces can vary in ‘smoothness’. IRs do not have smooth surfaces; the surface irregularity can be between 10 to 60 microns, which has the disadvantage of creating ‘attachment points’ for bacteria (Van Landeghem et al., 1983; Tuson and Weibel, 2013). The current owner of the patent for IRs is AGFA (AGFA HealthCare, 2010).

The possibility of the surface of IRs creating a point of attachment is a disadvantage, because this point is an opportune surface for a biofilm to form (Van Landeghem et al., 1983; Tuson and Weibel, 2013). Biofilm is a community of micro-organisms that forms a layer on surfaces of items. The biofilm creates a medium called an 'extracellular polymeric substance', which is medium that can colonise a variety of surfaces (Surgers et al., 2019). Biofilm has been found on dry surfaces in ICUs; these dry surfaces indicate the presence of multi-drug-resistant (MDR) organisms (Hu et al., 2015)

Enterocossus faecium and Enterobacter spp. (species) (ESBL) producing microbes can exist within the biofilm, as can Enterobacteriaceae, which can be resistant to a multitude of drugs, and more common bacteria such as *Staphylococcus aureus*, *Pseudomonas aeruginosa*, *Acinetobacter* baumannii, and *Klebsiella pneumoniae* (Santajit and Indrawattana, 2016; Surgers et al., 2019). Biofilm has the ability to create security for the bacteria in the case of an immune response created by the host and serves as a shield against antibiotics as treatment (Surgers et al., 2019). Thus, biofilm is quite difficult to eradicate.

Bacteria, yeast and mould formed part of the focus of this study. Bacteria such as *E. faecium, S. aureus*, *K. pneumoniae*, *A. baumannii*, *P. aeruginosa,* and *Enterobacter spp.* (species) are the main bacteria indicated as important by the WHO and various authors (Boucher et al., 2009; Hu et al., 2015; Brindisi et al., 2016; WHO, 2017; Elhosseiny and Attia, 2018).

2.2.3 Exit of substances from the human body

The cycle of infection is dependent on there being a route for substances to exit the human body, called the portal of exit. The routes include exit points for fluids (blood and body fluids), as well as excretions/secretions (Burbridge, 2012). Substances may exit the human body via several routes. The bodily systems by which substances could leave the body are via the respiratory, urinary and gastrointestinal systems. Other routes that serve as portals for exiting the human body are the bloodstream and open wounds (Burbridge, 2012).

2.2.4 Methods of transmission

For micro-organisms to spread and cause new infections, there needs to be a way for the organism to be transferred to a new object or person, which refers to methods of transmission, which could be by direct transmission and indirect transmission (Kortenbout et al., 2015; Mirza et al., 2015).

An example of direct transmission is droplet transmission. Indirect transmission includes airborne transmission (which arises from droplet transmission), contaminated objects (fomites) as well as vectors (such as malaria via mosquitos) (Centers for Disease Control and Prevention, 2012). For the purposes of this study, the focus was on indirect contact, including fomite transmission, as these contact methods are the most relevant to the profession of radiography (Kortenbout et al., 2015; Mirza et al., 2015). Direct transmission occurs when body fluids, such as droplets, of an infected patient come into contact with, for instance, a paper cut on a radiographer's finger. Indirect transmission is commonly implicated when a contaminated object/surface is touched. Items that are related to indirect transmission include doorknobs, hospital linen and bedside tables, as well as diagnostic radiographic equipment (Kortenbout et al., 2015; Mirza et al., 2015).

A case study investigated two female cystic fibrosis patients who were infected via indirect transmission, which was well documented (Hansen et al., 2013). The first patient (Patient A) had been diagnosed with cystic fibrosis shortly after birth and had had several incidences with *Pseudomonas aeruginosa* between April 2006 and March 2007. Patient A lives in a small village on a remote island. Patient B, who had a chronic infection of a Danish strain of *Achromobacter rhulandii,* lived with her family, which included her twin sisters who did not suffer from cystic fibrosis. The three girls (the one girl who was new to the village (Patient A), who had cystic fibrosis, and the twin sisters, who did not have cystic fibrosis) became friends; however, the parents of both girls with cystic fibrosis made sure the two girls (the girl new to the village (Patient A) and the sister of the twins who was nine years older (Patient B), who also had cystic fibrosis) were never in the same room at the same time. A couple of weeks after meeting, Patient A experienced a decline in lung function and weight loss and sputum samples were taken (Hansen et al., 2013). After processing, the samples from Patient

A indicated infection with the same Danish strain of *A. rhulandii* as was identified in Patient B. This indicates that indirect cross-contamination took place between Patient A and Patient B, even though the two cystic fibrosis patients were never in the same room simultaneously (Hansen et al., 2013).

Droplet transmission, a form of direct transmission, occurs over short distances, and involves an infected patient coughing or sneezing. Micro-organisms can be trapped within a droplet and thus cause the pathogenic organism to spread over short distances (Kortenbout et al., 2015).

Fomite transmission is classified as a form of indirect transmission and involves transmission via non-living objects (LaMorte, 2016). These non-living or inanimate objects serve as instruments of contamination: Patient A contaminates the item, after which the item comes into contact with Patient B, thus possibly contaminating Patient B with bacteria from Patient A (LaMorte, 2016). During radiographic procedures such as ultrasound, the probe that is used can be a source of indirect transmission. The probe comes into contact with several patients and, unless it is properly disinfected, the probe can spread bacteria (Mirza et al., 2015). Fomite transmission is especially relevant when making use of IRs, where a patient comes into contact with the IR. It was found that IRs are possible fomites for indirect transmission of MRSA (Kim et al., 2012).

2.2.4.1 Imaging receptors as a fomite

The International Nosocomial Infection Control Consortium (2008) compiled a report on 'device-associated infections (DIA)' in ICUs. The report indicates that MRSA had a higher number of reported cases than Vancomycin-resistant *Enterococcus* (VRE). Devices associated with infections are elevator buttons, mobile communication devices, ventilators or urinary catheters, and these infections are more prevalent in third-world than in first-world countries (Rosenthal et al., 2008; Pereira da Fonseca et al., 2016)

Several studies that were performed over more than a decade indicate that X-ray equipment presents itself as fomites for pathogenic bacteria (Fox and Harvey, 2008; Kalu et al., 2009; Shelly et al., 2011; Kim et al., 2012; Eze, 2014; Domínguez Jiménez and Vergara-López, 2016; Pereira da Fonseca et al., 2016; Nyirenda et al., 2018). IRs

are hospital equipment that come in contact with several patients of different demographics within the hospital, as well as patients referred from other hospitals/general practitioners and outpatient clinics (Eze, 2014).

During diagnostic imaging of patients admitted to the ICU, there exists a gap in determining the effect radiographic equipment has on the spread of nosocomial infections (Levin et al., 2009). Due to this gap in research relating to evidence regarding the spread of nosocomial infections, it is important to continue research in this area.

2.2.5 Entry of substances into the human body

A susceptible host can only become infected with a micro-organism if a portal exists where micro-organisms can enter the host's system (Ehrlich and Coakes, 2017). The portals that allow entry to a susceptible host include the mucous membranes, any open wounds where there is a break in the skin, and the gastrointestinal tract. Other portals are the respiratory tract, especially when patients are intubated, and sites where catheters are placed within the patient, which grants direct access to favourable areas that are warm, moist and have some type of food source. Sites of infections where catheter placement is the norm include bloodstream infections where intravenous lines are placed, as well as urinary tract infections, where urinary catheters are inserted into the bladder (Ehrlich and Coakes, 2017).

During mobile as well as general radiography, radiographers come into contact with a variety of patients, the mobile machine, IRs, the bed rails, the catheters, ventilation tubes and intravenous lines. Thus, when performing imaging studies, cross-contamination is possible via main infection sites such as the urinary tract that is linked via the urinary catheter, bloodstream infections that can be linked to the intravenous lines because of contact during the positioning of the patient to acquire an image, as well as ventilation equipment (Dresch et al., 2018). Furthermore, when positioning for a post-operative series of imaging procedure/examination, radiographers can make contact with a surgical wound, leading to cross-contamination to the wound should a radiographer themselves have an open wound, even a needle prick could cause an infection or cross-contamination (Dresch et al., 2018).

2.2.6 Susceptible host

Being susceptible is defined as acquiring an infection by being exposed to a pathogen and not being able to effectively counteract the infection with a given pathogen (Centers for Disease Control and Prevention, 2012). In this case, the host would be human. The human being supplies the infectious organism/pathogen with sustenance or a secure habitat (UCLA, n.d.). A human being who is considered a susceptible host for a pathogen would not be able to create antibodies to fight the infection caused by a specific pathogen. Susceptible hosts usually have reduced immune systems.

Patients admitted to the ICU of a hospital have an increased risk of becoming infected and colonised by nosocomial pathogens (Burbridge, 2012). Patients in ICUs and neonatal intensive care units (NICUs) are more susceptible to nosocomial infections as a result of having depressed or decreased immune systems, caused by either a surgical procedure or unrelated pathology. Nosocomial infections are communicable diseases, thus there are safeguards that can be established to inhibit the spread of nosocomial pathogens (Burbridge, 2012).

Radiographers and health care workers who interact with patients daily face an increased risk of acquiring such infections. For radiographers, even slight fatigue or stress could cause an decreased immune response. Any decrease in immune response may contribute to acquiring an infection, in addition to being a host for possible infections (Ehrlich and Coakes, 2017).

2.3 ANTIBIOTIC RESISTANCE

When considering antibiotic resistance, the first step is to understand how antibiotics work. Antibiotics are chemicals that are designed to identify bacteria, on a cellular level, that present as harmful to an infected human (Khan Academy, 2019). The antibiotic then proceeds to infiltrate and break down/deactivate the bacteria. The interaction between the bacteria and the antibiotic will only take place if the bacteria are susceptible to the specific antibiotic, in which case, the susceptible bacteria will either stop growing or die (Khan Academy, 2019). Figure 2.6 illustrates the development of the process of antibiotic resistance.

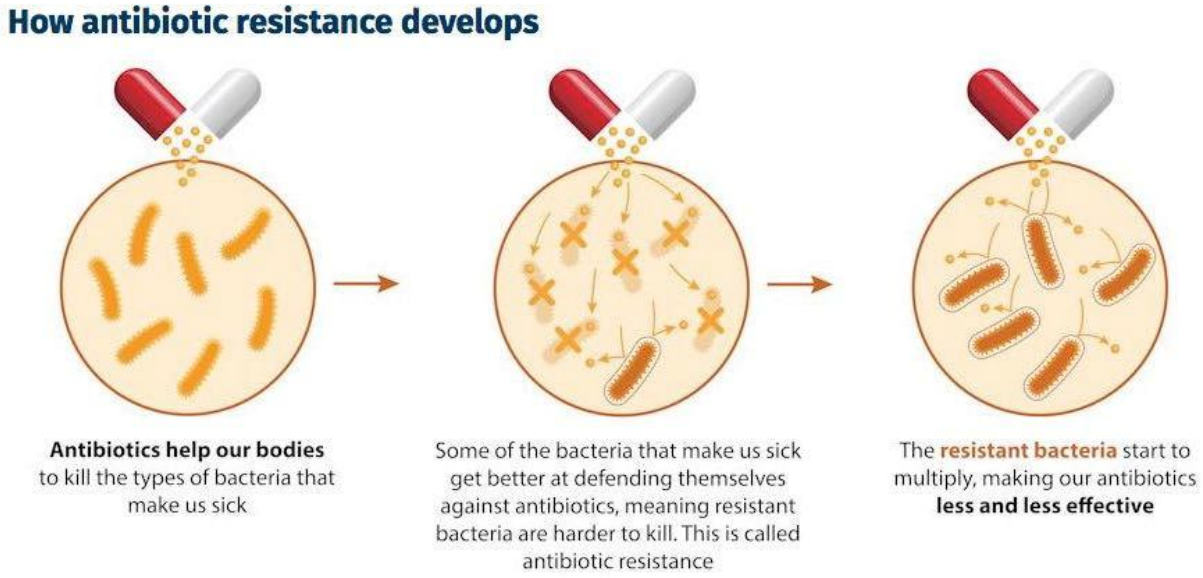

Figure 2.6: Development of antibiotic resistance (Health Navigator NZ, n.d.)

2.3.1 Deoxyribonucleic acid and gene transfer

Enzymes are responsible for making new bacterial deoxyribonucleic acid (DNA). Chromosomes are comprised of coiled strands of DNA. Chromosomes are shaped like rods (Alberts et al., 2002). The design of a chromosome is indicated in Figure 2.7.

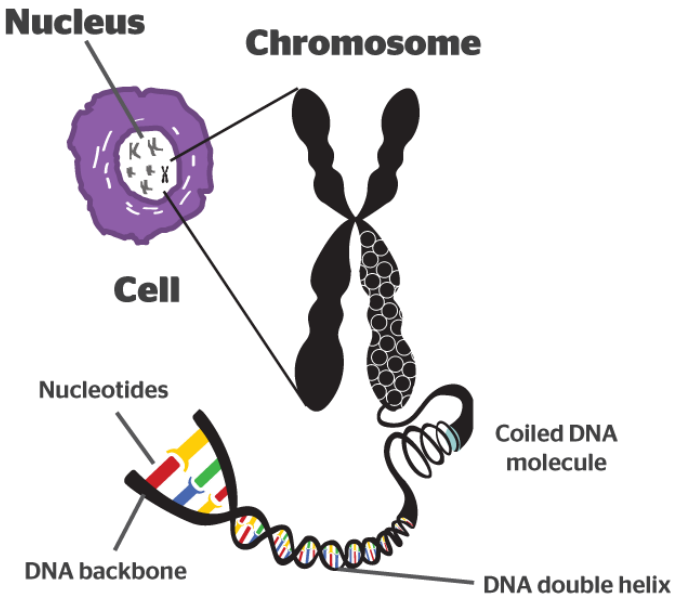

Figure 2.7: Chromosomal design (Biosciences for Farming in Africa, 2019)

A genome is a complete set of chromosomes, for example, the human genome has 23 pairs (US Department of Health and Human Services, 2019). The genome of bacteria includes all the genetic material of a specific bacterium (Alberts et al., 2002). The genetic material comprises different protein pairs (US Department of Health and Human Services, 2019). Genes are allocated on a chromosome to create cell functionality, in addition to the characteristics of an organism. If the organism, or bacteria, in this case, becomes more intricate, the bigger the genome will be (Alberts et al., 2002). Thus, in the case of antibiotic resistance, if the resistant gene is added to the bacteria, the bacterial chromosomes will become larger (Alberts et al., 2002).

When an antibiotic is prescribed, the antibiotic will incapacitate or eradicate the specific protein (gene) that is designed to be harmful. Bacterial species share DNA information. DNA can be shared through plasmids. A plasmid can be defined as a circle of DNA in a smaller form; it is identified externally to the bacterial chromosome. Several antibiotic resistance genes can be present on the same plasmid (Science Learning Hub, 2014). Recessive (inherited) genes are allocated on the plasmid itself. Thus, a recessive gene can be communicated between species through a lateral transfer of genetic material, for example, a resistant gene (Khan Academy, 2019), thus, making a greater number of species resistant to the same form of antibiotics (see Figure 2.8).

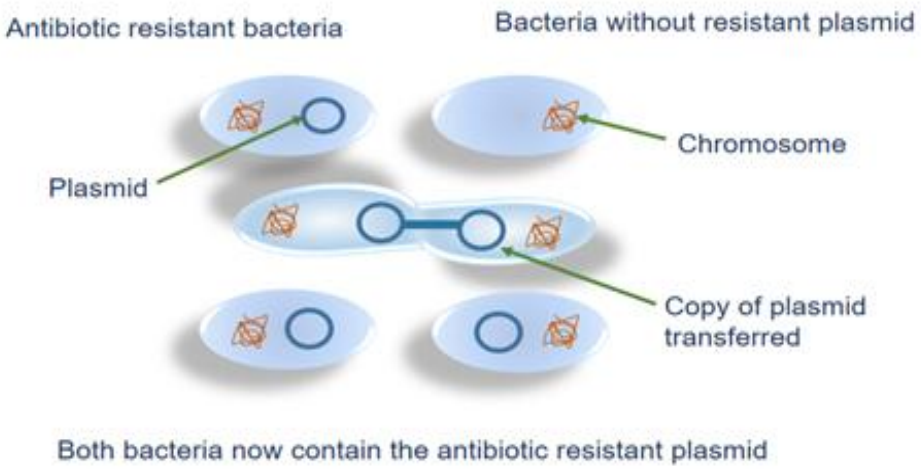

Figure 2.8: Lateral transfer of genetic material between bacteria (Caldwell and Lindberg, 2008)

Plasmids carry but a few genes ('Ji' Khalsa, 2010). Plasmids act independently and can be found outside of the nucleus (See Figure 2.7). Although plasmids are not found within the nucleus, plasmids still contribute to the DNA of the organisms/bacteria (Khalsa, 2010). Plasmids have the ability to transfer their genetic material through horizontal/lateral transfer, during which genetic material is shared between two bacteria from the same species, regardless how distant the relation might be (see Figure 2.8) (Enright et al., 2002). Plasmids also have the ability to carry more than one resistant gene at a time, as demonstrated in Figure 2.9.

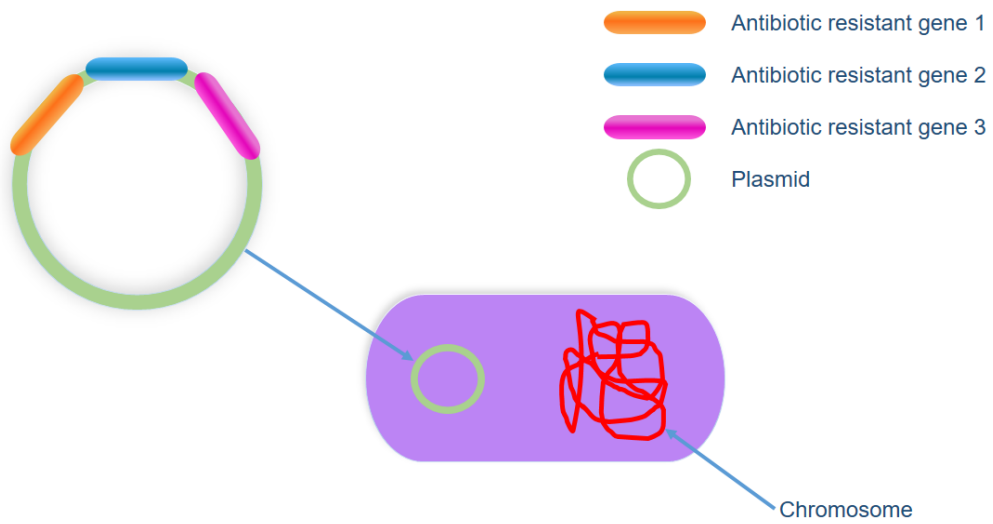

Figure 2.9: Plasmid with antibiotic-resistant gene(Science Learning Hub, 2014)

By making use of a broad-spectrum antibiotic, the chances of creating antibiotic resistance are increased (Ludden et al., 2015). Specialists advocate making use of narrow-spectrum antibiotics to limit the chance of resistance; however, the type of bacteria that caused an infection is not necessarily known to the health care practitioner (Khan Academy, 2019).

The main antibiotic-resistant enzymes that were the focus for this study are ESBLs and Carbapenem-resistant Enterobacteriaceae (CREs). Carbapenems are used as a 'last resort' antibiotic against Gram-positive and Gram-negative bacteria. The effectiveness of these broad-spectrum antibiotics is declining because of the increase in MDR bacteria. The resistance to carbapenems is creating a global crisis that has disastrous

effects for human health (Papp-Wallace *et al.,* 2011; Potter, D'Souza and Dantas, 2016).

Ambler classification is used to order and better understand the different beta-lactamases (β-Lactamases) due to the variety that exists. Ambler classification is used to divide β-Lactamases into four classes, namely A, B, C and D. The classification is made in relation to the sequence the β-lactamases amino acid falls in (Hall and Barlow, 2005). Figure 2.10 demonstrates the Ambler classification of β-lactamases.

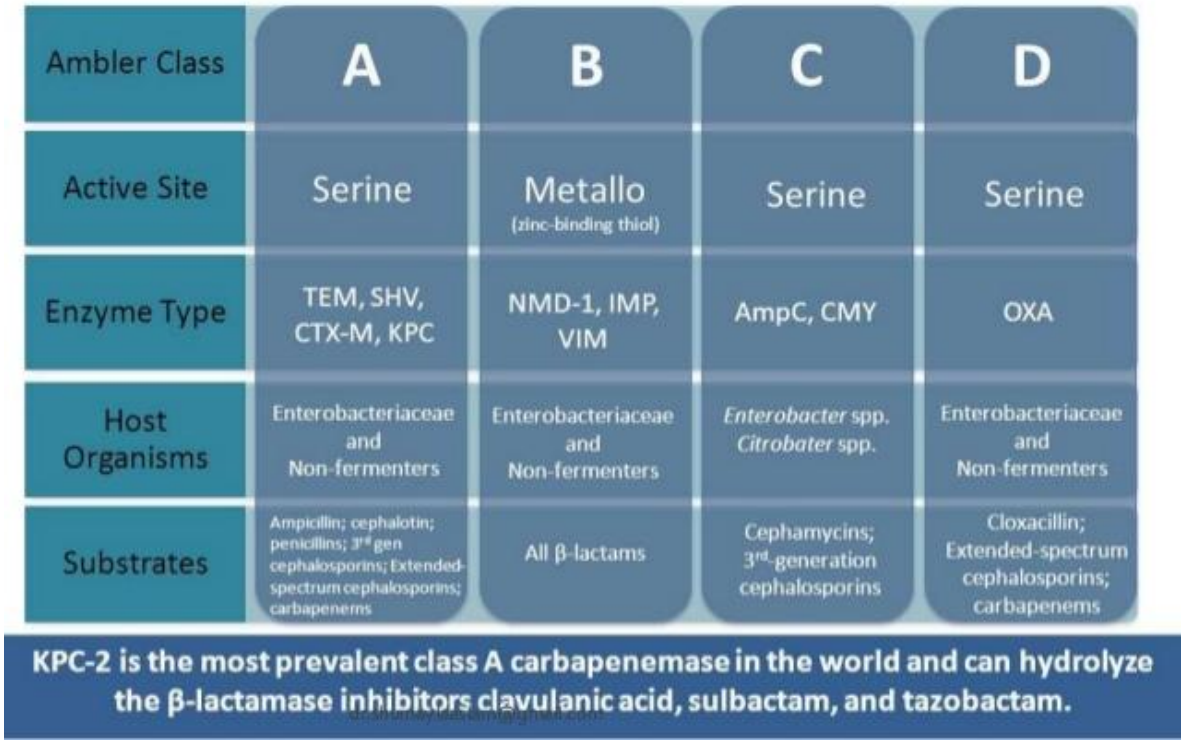

Figure 2.10: Ambler classification of β-lactamases (Murthy et al., 2018)

Ambler Class C β-lactamases fall under group 1 of the classification system. When the bacteria are exposed to β-lactamase antibiotics, an increase in the production of enzymes occurs. Group 1 enzymes originate from the Enterobacteriaceae family in addition to *Pseudomonas aeruginosa* (Ghafourian *et al.*, n.d.). There are studies that indicated that strains of *E. coli, as well as Klebsiella spp,* have a transference of enzymes; the transference takes place from chromosome to plasmid (Ghafourian et al., n.d.). Group 1 β-lactamases are found to be sensitive to carbapenems (Ghafourian et al., n.d.).

Amber Class A enzymes fall under group 2. Group 2 enzymes are retained 'by plasmid'. Swift resistance to group 2 enzymes is a problem because of transmission 'into bacterial cells'. Clavulanic acid is a β-lactamase inhibitor and is also part of the original group 2 enzyme inhibitors. In 1965, enzymes were identified and named the main group 2 enzymes and forms part of the Enterobacteriaceae family. In 1979 it was found that the main group 2 enzymes spread to other bacteria. This indicates that the problem of resistance has been growing for many decades.

Ambler Class B enzymes fall under group 3 enzymes. These enzymes can destroy carbapenems and are found in *P. aeruginosa* in addition to being identified as metallo-enzymes. Other bacteria that can excrete are *Bacteriodes fragilis* as well as *Stenotrophomonas* (Ghafourian et al., n.d.). The group 4 β-lactamases (enzymes) contain enzymes that can inactivate penicillin (penicillinases) in addition to not being repressed by clavulanic acid. Carbenicillin and cloxacillin are two penicillin-based antibiotics that can chemically break down (hydrolyse) four of the group 4 enzymes. It is not sure whether the group 4 enzymes embody another molecular class of enzymes (Ghafourian et al., n.d.).

Extended-Spectrum β-lactamases (ESBL) producing *K. pneumoniae* has seen an increase in occurrence in South Africa. However, the amount of data and recorded research is scarce. During a study performed in Tanzania on neonatal blood samples, 25% of *E. coli* in addition to 17% of *K. pneumoniae* were found to produce ESBLs (Ghafourian et al., n.d.). In a second study performed in Tanzania on 377 samples, 29% of Gamma-negative bacteria produced ESBLs, with a 64% prevalence for *K. pneumoniae* as well as a 24% *E. coli* (Ghafourian et al., n.d.). However, not only hospitalised patients have ESBL producing bacteria. A study performed in Madagascar identified 10% of non-hospitalised patients as carriers of ESBL producing bacteria (Ghafourian *et al.,* n.d., 2015).

The last line of treatment for MDR infections is carbapenems, thus there is an increase in CRE (Potter et al., 2016). The Western Cape government (2019) reported an outbreak of CRE in neonates in a hospital in the province. The outbreak of CRE resulted in an increase in staff needed to ensure that the correct protocol of Tygerberg Hospital Neonatal Services was being followed, which subsequently resulted in a

greater risk of transmission of the infection (Western Cape Government, 2019). An analysis of reports for the period 2000 and 2016 regarding the presence of CRE in South Africa found more than 2 300 cases (Osei Sekyere, 2016). There was a mentionable increase in resistant cases in 2011, with no history of international travel that could have contributed to the increase. Thus, the presence of CRE indicates there was a local strain of carbapenem antibiotic resistance caused by overstimulation or use of carbapenem antibiotics (Osei Sekyere, 2016).

The following Ambler classifications are linked to CRE (Potter et al., 2016; Friedman et al., 2017; Magiorakos et al., 2017):

- Class A – *K. pneumoniae* carbapenemase (KPC)
- Class B – *metallo-β-lactamases (MBLs), imipenemase (IMP), Verona integrin-encoded MBL (VIM),* and *New Delhi MBL (NDM-1)*
- Class D – OXA-48-producing *K. pneumoniae*

Figure 2.10 presents a grammatical layout of the Ambler classification.

2.3.2 The ESKAPE group

Currently, according to the WHO, the most antibiotic-resistant group of bacteria is a collection of pathogenic bacteria called the ESKAPE group, which encompasses both Gram-positive and Gram-negative species and is made up of *E. faecium*, *S. aureus*, *K. pneumoniae*, *A. baumannii*, *P. aeruginosa*, and *Enterobacter* species. Most of them are MDR isolates and the most common causes of life-threatening nosocomial infections in, especially, immunocompromised and debilitated patients confined to ICUs (see Figure 2.10) (Elhosseiny and Attia, 2018).

Enterococcus faecium, Gram-positive bacteria, is the most clinically relevant of the 20 *Enterococcus* species, alongside *Enterococcus faecalis*. *Enterococcus faecium* is found within the gut and, thus, most infections are endogenous in origin. However, cross-contamination may occur among hospitalised patients. There is considerable concern regarding *Enterococcus* resistance. Globally, Vancomycin-resistant *enterococcus* is on the rise and is commonly associated with *E. faecium* (Santajit and Indrawattana, 2016).

Staphylococcus aureus has no specific growth requirements and forms part of the normal skin flora. *S. aureus* infections have responded well to treatment with penicillin; however, the overstimulation and use of antibiotics has led to β-lactamases producing *Staphylococcus* species. In the 1960s, MRSA infections were reported to be increasing and the consequences can be seen in the devastating effects this increase has globally (Santajit and Indrawattana, 2016).

Klebsiella pneumoniae is a Gram-negative bacteria of the Enterobacteriaceae family. *K. pneumoniae* is also non-fastidious in nature. Infections of the genus *Klebsiella* can be either endogenous or through contact with an infected host. β-lactam antibiotics such as penicillin, in addition to carbapenems, can be hydrolysed by β-lactamase enzymes. However, carbapenems are generally used to treat Gram-negative bacteria and has, therefore, resulted in *K. pneuminiae* carbapenem resistance (Santajit and Indrawattana, 2016).

Acinetobacter baumannii can survive for extended time periods on human hands, thus creating a situation where cross-contamination rates can increase significantly. *A. baumannii* is a Gram-negative bacterium and has a high frequency of resistance, with the recent emergence of carbapenemase (enzyme) production. β-lactamase production for imipenem and oxillinase serine strains has been identified. A double form of resistant genes against imipenem and colistin makes treatment for these genes with conventional treatment almost impossible (Santajit and Indrawattana, 2016).

Pseudomonas aeruginosa forms part of the normal gut flora and is also a Gram-negative bacterium. The prevalence of *P. aeruginosa* among the general public is significantly lower than that of hospitalised patients and much higher in immunocompromised hosts. The infectious source is exogenous, either by direct or indirect contact. However, the possibility of endogenous infection exists. *P. aeruginosa* has a natural inclination to resistance against antibacterial agents such as carbapenems (imipenem) and a low susceptibility to several antibacterial agents. *P. aeruginosa* strains are capable of producing ESBLs. Plasmid transfer is prevalent and thus, MDR is seen (Santajit and Indrawattana, 2016).

Enterobacter species can cause opportunistic infections in immune-compromised patients. *Enterobacter spp.* can consist of CRE and ESBLs (Santajit and Indrawattana, 2016).

2.4 THE HUMAN BODY'S REACTION TO BEING INFECTED

A patient that is admitted to a hospital may be colonised with pathogenic bacteria in a relatively short time (Samuel et al., 2010; Tobin and Zahra, 2025). When a patient is infected with a nosocomial pathogen, the severity of the infection can range between mild and severe (Samuel et al., 2010). The human body responds by producing an inflammatory reaction. The patient may present with symptoms such as fever, general discomfort and headache (National Academy of Sciences, 2018). Some bacteria that cause the infection can destroy the healthy cells of the human body, which may lead to a decrease in normal organ function (National Academy of Sciences, 2018). A severe immune reaction that is stimulated by an infection can be toxic to the human body and fatal to the patient (National Academy of Sciences, 2018).

2.5 NOSOCOMIAL INFECTIONS AND THE RADIOGRAPHER

According to Jayasinghe and Weerakroon (2014:10), a deficit exists regarding infection prevention control techniques of radiographers. In Jayasinghe and Weerakoon's study, data collection took place via a questionnaire, which had three focus areas: demographics, participant knowledge and practice, and standard precautions. The knowledge focus found that participants had relatively good knowledge, with more than 50% of participants indicating that the environment was a source of contamination. The study also revealed that radiographers did, in fact, possess knowledge of preventative measures. Although radiographers indicated that the environment was a source of contamination, when they were questioned about the origin of infections, it became evident that they had a limited understanding of the relevance of hand washing and wearing of masks and gloves and other measures (Jayasinghe and Weerakoon, 2014).

In countries where staff shortages in medical imaging departments are a constant concern, an increase in the workload per radiographer can have severe implications for patients, staff and medical imaging departments (Chingarande and Chidakwa,

2014). Thus, radiographers face an increased risk of acquiring occupational infections, as well as contributing to the spread of nosocomial pathogens (Jayasinghe and Weerakoon, 2014). To improve their knowledge of preventative measures, radiographers need to undergo education and training, for example, continuous professional development (Jayasinghe and Weerakoon, 2014; Zulu et al., 2024).

During the COVID-19 pandemic, radiographers' knowledge of infection control improved because medical imaging departments instituted training programmes to assist radiographers to create a safer environment for patients (Freihat et al., 2024).

During a research study that was performed in the Gaza Strip, radiographers and radiologists indicated that training was limited. Proper hand hygiene was not practiced and the recommendation is to provide training on a more regular basis to ensure that infection control is performed (Tabash et al., 2024).

2.5.1 Imaging receptor pathways

Russotto et al. (2015) identified different zones and/or areas in the health care setting. A patient zone was identified as the patient and their direct environment, thus creating a geographical zone that is linked to a specific patient. Moreover, a health care area was also identified, which comprises surfaces outside the patient zone (Russotto et al., 2015). By determining different zones and/or areas within the healthcare setting, a pathway is created in which researchers can determine where the highest frequency of contamination occurs. Hence, the conclusion is that radiographers should be included in infection control courses, which includes cleaning radiographic equipment before entering and after leaving the patient zone (Russotto et al., 2015).

Although there has been little research indicating detailed mapping of medical equipment routes, there is evidence that some form of tracking was done in China on patients with nosocomial infections (Wang et al., 2019). During the research process, patients were identified by making use of very specific inclusion criteria. The patients were followed, and all activities related to the patients were documented, one of which was that the patient underwent a chest X-ray. These patients were observed for several tests and any isolated pathogens that were present, until they were discharged or until death occurred (Wang et al., 2019).

A study performed in the Northern Cape province of South Africa found that no nosocomial infections could be traced back to imaging studies. However, the researchers relied on patient data documentation, laboratory reports and radiology reports (Nair et al., 2018). No physical sampling (microbiological sampling) of radiographic equipment was performed to determine if the equipment might have been a possible source of infection (Nair et al., 2018).

Medical professionals, for instance, radiographers, make direct contact with patients via their hands. Hand contamination is a well-known method of cross-contamination of pathogens that could be transferred to patients directly (Eze, 2014). Hand cross-contamination, which has been well researched and understood, stands in stark contrast to knowledge of cross-contamination from stethoscopes and other small medical equipment (Longtin et al., 2014). Stethoscopes are confirmed to be contaminated; however, further studies are needed to determine the relation between inanimate objects, such as stethoscopes, and cross-contamination (Fafliora et al., 2014; Longtin et al., 2014; Russotto et al., 2015). The importance of limiting the spread of nosocomial pathogens is a major issue that is not fully understood by all health care workers, including radiographers (Sukumar and Yadav, 2012). Radiographic equipment may contribute to the spread; however, knowledge seems to be lacking in the spread of nosocomial infections and infection control as it relates to radiographic equipment (Sukumar and Yadav, 2012).

2.5.2 Radiographers and breaking the infection cycle

Radiographers should be aware that, when handling a patient, any form of body fluid may contain pathogenic organisms. Standard methods that should be used by radiographers to reduce any chance of cross-contamination include proper application of hand hygiene techniques, wearing protective gear when necessary (gloves, masks and gowns), and ensuring that sharp objects are disposed of correctly (Burbridge, 2012). In addition to all of these measures, it is also important to make sure the IR is protected against any possible contamination, by covering the IR with a plastic bag (Auffermann et al., 2015).

A new way radiography practitioners are breaking the infection cycle is by creating antimicrobial layers for equipment. Some of the new digital equipment (a digital detector) now comes prepared with a layer that is identified as being antimicrobial; however, no specifications are provided regarding what the layer is made of. The antimicrobial layer provides a way to break the infection cycle when a pathogen comes into contact with the equipment, because the pathogen cannot survive on the antimicrobial layer (Siemens, n.d.).

2.6 INFECTION CONTROL PROTOCOLS

Protocols for infection control vary all over the world; however, the key aspects in relation to hand washing, for example, tend to be the same for most protocols, which could be considered as the 'gold standard' or actions taken to perform infection control for hand hygiene, or any other form of infection control. There is also a lack of agreement about what pathogens are the most likely to be present in certain circumstances/items, for example, hands that were not washed correctly, or on the uniforms and clothing of health care professionals (Tacconelli et al., 2014). Recommendations for typical safeguards include washing hands, wearing personal protective gear when it is indicated that a patient is colonised with pathogenic bacteria, disinfecting equipment after patient contact, and making use of single-use medical equipment (Tacconelli et al., 2014). A study performed in Ghana recommends that the same practices as mentioned by Tacconelli et al. should be implemented. However, the protocol used in Ghana was not adhered to by radiographers, especially washing hands after patient contact (Antwi et al., 2015).

The WHO (2004; 2016) published a guide on infection control that states that healthcare workers must, as a standard precaution, adopt the view that every patient's body fluids, including blood, can be a possible source of infection. A more recent guide, 12 years later, recommends the same standard precaution as the WHO guide, namely that any body fluid, in addition to blood, must be considered as a possible source of infectious material (NHS Foundation, 2018).

Various infection control guides and journal articles have the same emphasis on hand hygiene and several other infection control practices (WHO, 2004, 2016; Friedman et

al., 2017; Magiorakos et al., 2017; Ministry of Health and Long-Term care, 2018; NHS Foundation, 2018; Nyirenda et al., 2019). Taking into consideration the same emphasis on hand hygiene and several other infection control practices from various journal articles, it would be wise to consider a universally recommended protocol for infection control practices. A group of researchers that included the WHO Guidelines Development Group summarised the most common infection control practices globally because the same infection control and prevention occur in all countries, thus making prevention and control of infections a priority (Storr et al., 2017). The following were identified as among the core components that would to guide the effectiveness of an infection control programme (Storr et al., 2017):

- Provide infection control officers and staff support;
- Train infection control officers;
- Make a protocol for infection control and prevention available;
- Regularly identify and monitor outbreaks;
- Implement several methods to ensure best practices;
- Maintain record keeping and monitoring of infection control practices;
- Resolve understaffing issues;
- Distribute workload evenly among staff;
- Adapt or build the environment to apply infection control practices in an effective manner; and
- Adhere strictly to hand hygiene practices.

The Canadian standard for infection control and prevention that is applicable to medical devices and equipment indicates that health care professionals should, firstly, adhere to the manufacturer's instructions regarding cleaning/disinfecting or sterilising these items (Infection Prevention and Control Canada, 2016). The infection control guidelines indicate that items should be washed/cleaned and dried properly before the item is reassembled, equipment must be stored correctly, be inspected regularly, soap dispensers should not be topped up, no hand lotion should be used and hands must be washed before and after patient care (Infection Prevention and Control Canada, 2016). These basic standards are identified in most infection control protocols. Figure

2.11 contains a flow diagram for determining the type of precautions and actions to take for infection control when handling a patient (Alberta Health Services, 2013).

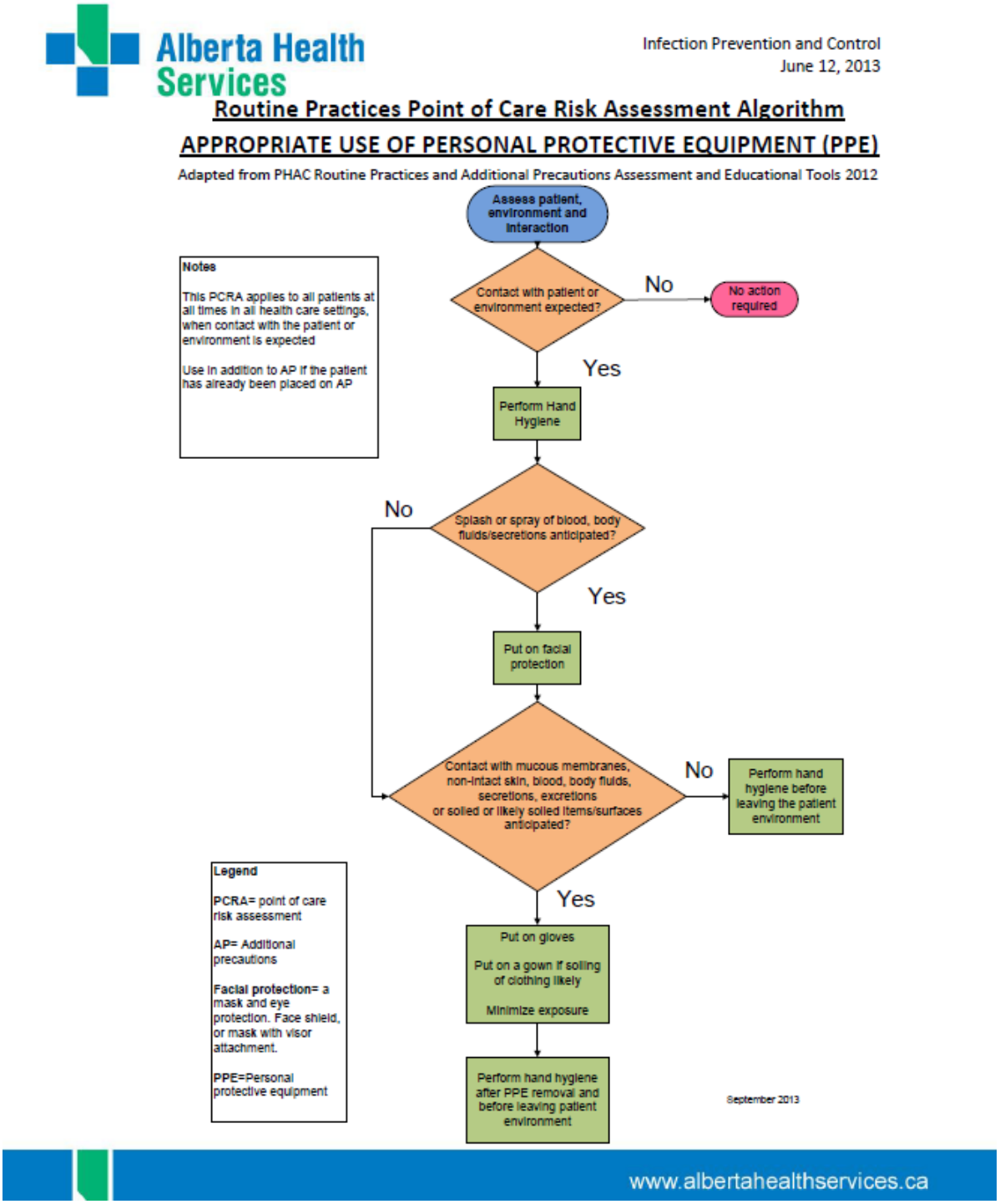

Figure 2.11: Appropriate use of personal protective equipment(Alberta Health Services, 2013)

The South African National Department of Health (2020) recommends, in a report on infection prevention and control methods, reducing reservoirs that cause infections in hospitals. The action plan includes designing health care facilities in a way that makes infection control measures easier, conducting surveillance of the infection risks, using protective gear when necessary, applying hand hygiene, doing quality management of the infection control plan and training cleaning staff on the use of cleaning agents.

The standard operating procedure for infection control used in the Free State province makes use of the WHO's 'My 5 Moments for Hand Hygiene' to indicate the appropriate steps to take when interacting with patients (Department of Health, 2017). It is divided into five events, namely before patient contact, before aseptic procedures, when there is a body fluid exposure risk, after patient contact and, lastly, after contact with a patient's surroundings. It is recommended that personal protective equipment is worn when there is a risk of exposure to body fluids and blood; masks and gowns must be worn when the risk of spray or splashes are eminent (Department of Health, 2017).

By implementing observation of possible routes that IRs can travel in the hospital, the researcher addressed the fact that limited research is available on pathways that medical equipment can travel through a hospital (see Appendix A). By identifying the routes that were travelled, the researcher combined observation with information of any pathogens that might have been identified. The observation started with a completely disinfected IR and, if any pathogens were present at the end of the sampling day, it served as an indication that an IR can act as a reservoir/fomite. The observational notes made it possible for the researcher to document small things, such as whether a lift or stairs were used, which lift or which stairs were used, which wards were entered and the bed number of a patient being X-rayed and other details steps that can be documented on the tool.

The protocols and infection control measures above were used to compile a criterion list that could be considered a gold standard of infection control measures. These infection control measures are not considered to be a perfect standard, but rather methods that were suggested as methods of high standards. The observational notes made provision for indicating the methods of hygiene that were applied during the acquisition of an X-ray image; they were compiled and referred to as the observational

note. When considering decontamination of items and surfaces, the recommendation is to follow manufacturer guidelines because decontamination or cleaning of surfaces falls under infection control (Department of Health, 2017). The following hygiene options are considered the gold standard documented on the observational notes:

- Hand washing pre-patient contact;
- Hand washing post-patient contact;
- Hand sanitiser pre-patient contact;
- Hand sanitiser post-patient contact; and
- Gloves donned post-hand washing and pre-patient contact (Tacconelli et al., 2014; Antwi et al., 2015; NHS Foundation, 2018).

Regarding IR hygiene, the following applied:

- Use a plastic bag (Auffermann et al., 2015);
- Use a pillowcase;
- No cover;
- Other (describe);
- Disinfect IR pre-patient contact (Alberta Health Services, 2013; Auffermann et al., 2015; Infection Prevention and Control Canada, 2016);
- Disinfect IR post-patient contact, (Alberta Health Services, 2013; Auffermann et al., 2015; Infection Prevention and Control Canada, 2016);
- Disinfect IR in department (Alberta Health Services, 2013; Auffermann et al., 2015; Infection Prevention and Control Canada, 2016); and
- No cleaning of IR was performed.

Disposal of hazardous waste:

- Dispose of plastic bag in hazards waste bag;
- Gloves placed in hazards waste bag;
- Pillowcase deposited in soiled linen bag; and
- Other method of disposal used (specify) (See Appendix A) (Department of Health, 2017).

Lastly, the recommendation of the WHO is that personal protective equipment must be removed correctly by following the following steps (Department of Health, 2017):

1. Remove gloves
2. Perform hand hygiene
3. Remove gown
4. Perform hand hygiene
5. Remove disposable cap
6. Perform hand hygiene
7. Remove eye protection
8. Perform hand hygiene
9. Remove mask/N95 respirator
10. Perform hand hygiene (Department of Health, 2017)

The decontamination of surfaces in the health care setting should, firstly, be executed according to manufacturer guidelines. The recommendation for decontaminating or cleaning surfaces that are not subject to manufacturer guidelines is to make use of household bleach diluted with water (Department of Health, 2017). The bleach and water solution should be applied to the surface and left for up to 15 minutes, whereafter it can be wiped clean with water and dried (Department of Health, 2017). When the disinfection process is complete, proper hand hygiene must be performed (Department of Health, 2017). During the observation process of this study, hand hygiene was documented when some form of hygiene was applied (see Appendix A). The WHO has a well-established hand washing technique that, when applied, will reduce cross-contamination from the hands of any person who comes into contact with a patient or other health care workers. Hand hygiene is always at the top of the list of infection control measures to stop the spread of possible pathogens, however, with IRs and digital detectors, which may act as fomites/reservoirs for pathogens, additional infection control measures need to be in place (Antwi et al., 2015).

Figure 2.12 illustrates the correct steps to take to ensure that the hands are clean before and after patient contact.

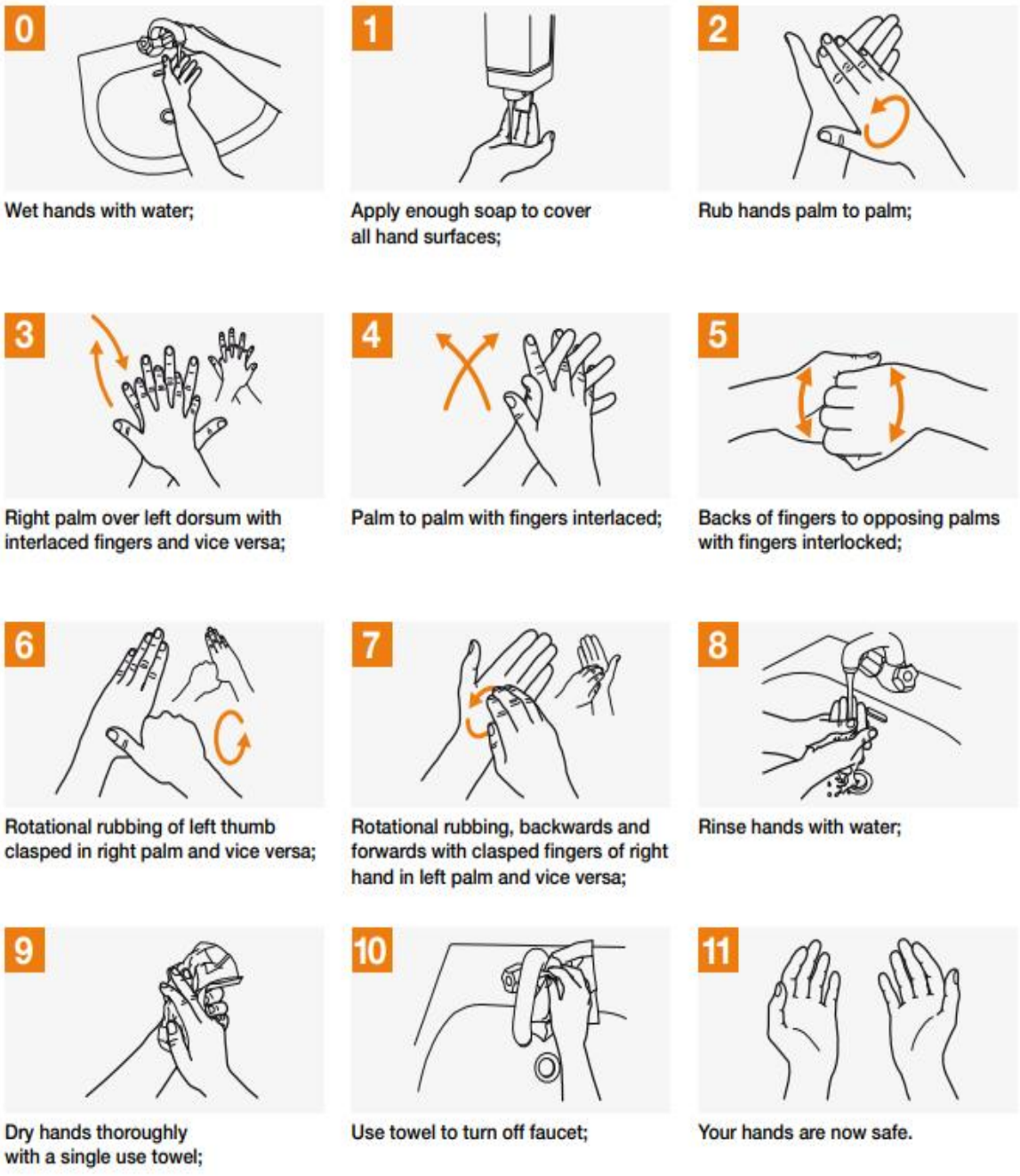

Figure 2.12: WHO's proper hand washing technique (WHO, 2009)

Standard safeguards are strengthened by creating awareness about additional safeguards. The additional safeguards include contact spread, as well as methods to inhibit spread via contact (Burbridge, 2012). Contact spread can be either direct or indirect, meaning that contact can be made with the patient or the surrounding environment, which induces the spread of the nosocomial pathogen (Burbridge, 2012).

A 2016 research study report included training material for the academic hospital where the current study was performed. In the report, the details regarding infection control and its importance was highlighted. The risks associated with failing to perform infection control is covered in the report (Wainwright, 2015). During this study, it was found that IRs were the most colonised out of all the items sampled. Thus, the decision was made to investigate further and design a study to better understand protocols for infection control.

2.7 CONCLUSION

When radiographers visit different wards or ICUs in the hospital to take mobile radiographs, they may come into contact with many different micro-organisms. When the radiographer returns to the imaging department, the IR has had contact with patients who may have been contaminated with pathogens. These pathogens can come into contact with the IR, which form part of the infection cycle. The infection cycle starts with the infectious agent, followed by a reservoir, exit of substance from the human body, methods of transmission, entry of substances into the human body and, lastly, a susceptible host (Ehrlich and Coakes, 2017:139).

Radiographic equipment such as IRs can act as a fomite/reservoir when mobile radiographs are taken (Burbridge, 2012:17). An infectious agent that came into contact with an IR that had not been properly disinfected can complete the infectious cycle if the IR comes into contact with a susceptible host, such as a patient in ICU (Ehrlich and Coakes, 2017:139). Radiographers need to be aware that body fluids may contain pathogenic organisms that could lead to cross-contamination. Using disinfection methods could inhibit the spread of pathogenic organisms. Because of the rotation of IRs through the hospital, carried or transported by radiographers, cross-contamination risks increase (Burbridge, 2012). To inhibit the spread or cross-contamination of these pathogenic organisms, infection control needs to be a priority (Sukumar and Yadav, 2012:152).

CHAPTER 3
METHODOLOGY

3.1 INTRODUCTION

The study was designed to determine the infection control practices and the microbial load of the IRs at an academic hospital. Several factors, such as inclusion criteria, exclusion criteria, which bacteria to test for and a protocol that was submitted to the relevant department, were all factors taken into consideration when the study was designed for sampling purposes.

To perform the study, planning needed to be meticulous, and sampling techniques had to be applied. By planning and practicing the sampling methods and techniques, the researcher was able to perform tasks with ease. The study could be performed accurately because it had been planned properly regarding study design, demarcation and study tools. Below the following will be discussed, design of the study, demarcation of the investigation, observational notes, study population and sample of the observation, study population, research tool for the observation, data collection method for the observation and finally data analysis for the observation.

3.1.1 Design of the study

The study design is defined as a systematic plan or framework to gather data (Merriam, 2016). The study design of this research study was prospective, quantitative and observational. All data were collected prospectively in numerical format, which enabled statistical analysis (Shuttleworth, 2015). Prospective research allows for the observation of participants to make precise documentation of the observations (StatsDirect, 2018). The observations were documented by indicating actions taken in a numerical format per action taken. Observation of the routes travelled by IRs allowed for unmediated feedback (Merriam, 2016).

3.1.2 Demarcation of the investigation

This study was conducted at an academic hospital, in the Department of Clinical Imaging Sciences. The study was not limited to any specific part of the hospital, thus no restrictions on observational areas were made. The analysis of the swabs taken was done by the laboratory facilities of the Central University of Technology.

3.1.3 Observational notes

The observation of the routes and interactions of IRs was guided by observational notes (see Appendix A) which were piloted after ethics approval had been granted. The observational notes related to matters such as hand washing, making use of gloves and plastic cover, placement of IRs, as well as the route travelled by the equipment, which was recorded and documented. However, for the documentation of the swab samples, a separate sample tracking sheet was implemented. The phases of the research study are indicated in Figure 3.1.

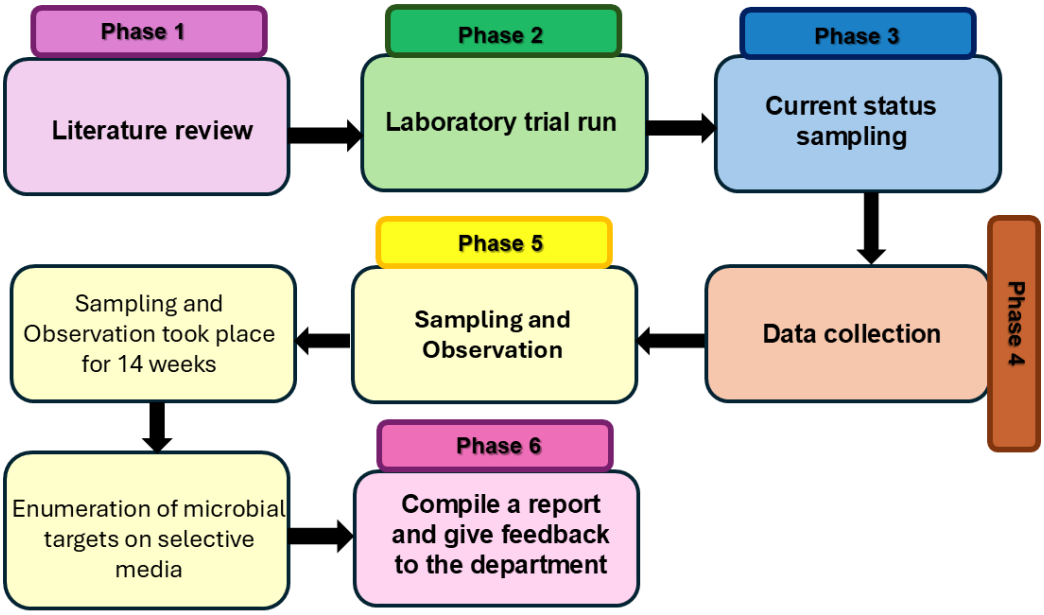

Figure 3.1: Phases of the research study

3.1.4 Study population and sample of the observation

The study sample included all 12 of the 35 × 43 cm IRs used in the imaging department and for mobile radiographic examinations. The digital mobile radiographic machine was also included with both the 35 × 43 cm (sampled for microbial testing) and the 24 × 30 cm (not sampled for microbial testing) digital detectors. The IRs were labelled to indicate which of them were circulating through the hospital at any time.

3.1.4.1 Study population

During the study, the observational portion was based on several criteria. The observation was executed by observing the travel of IRs, contact IRs make with either people or surfaces and documenting staff who interact with the IRs. During the study paediatric patients had radiographs taken of the chest and abdomens, however, that was performed using 24 cm × 30 cm size IR or the same size digital detector. The 24 cm × 30 cm size IR was part of the exclusion criteria. No extremities were performed during the study period, thus no need for a different size IR was needed.

The following were the inclusion criteria:

- IIRs that were 35 cm × 45 cm in size
- Siemens Digital Healthineers mobile with the detector 35 cm × 45 cm in size
- Radiographers, student radiographers and patient care assistants that worked with the IRs

The following were the exclusion criteria:

- IRs that were smaller than 35 cm × 45 cm in size
- Any other digital mobile unit that was not a Siemens Healthineers mobile unit
- Radiographers that were not able to perform mobile examinations

3.1.4.2 Research tool for the observation

The research tool that was used is an observational note (see Appendix A). The note enabled the researcher to document all aspects of the travel and contact made with the IR. Examples of actions that were documented are hygiene practices, because hygiene practices directly influence microbial load, and travelling to high-risk areas such as ICUs. Documenting the travel mechanism of IRs could indicate trends of other

reservoirs/fomites, such as an IR holder, that could be investigated further for possible cross-contamination.

3.1.4.3 Data collection method for the observation

All IRs that formed part of this study were identified, labelled and numbered, if needed. The total number of 35 × 43 cm IRs in circulation was 12 (subject to change without notice), which included the Siemens Digital Healthineers mobile with the 35×43 cm detector. Only 35 cm × 43 cm IRs were used, because they were the most likely to circulate through the hospital and as standard practice at the study site extremities are not routinely performed during mobile radiography, patients are rather transported to the department. Before the digital machine was introduced the paediatric patients' wards made use of their own mobile radiography machine and there was IRs at the ward that did not go to the department, which was the allocated starting point for the IRs. The IRs had to be identified; in this department the IRs were already numbered. Thus, the numbers already allocated to each IR were used for this study. Each IR already had a number written on it by the department for quality control purposes; that number was used for the identification of the IRs. Thus, if the number 8 was written on the IR, the number 8 was used as identifier and written on any observational note or data sampling sheet (see Appendices A and B). Data was recorded on the observational notes. The data collected were captured numerically per IR and the route travelled was recorded in full.

3.1.4.4 Data analysis for the observation

The analysis of the data was performed by the research team. The statistical analysis was completed using SPSS Version 28. Chi Square tests were performed for different participant groups for example, radiographers and student radiographers' amount of different hand hygiene actions. The tests indicated non-significance with *p*-values greater than 0.05. If there was a significant statistical difference the *p*-values would be less than 0.05.

3.2 DATA COLLECTION FOR SWABBING

The process was documented using a sample tracking sheet (see Appendix B). The sample tracking sheet served as a guide to indicate which IRs had been wet swabbed, and whether all six surface areas had been swabbed. The six surface areas were the front and back of the IRs, and the four narrow sides of the IRs. All the mentioned surfaces were wet swabbed at each sampling event for all the IRs. The sterilisation process was recorded with a similar sample tracking sheet, to allow accurate record keeping of the process (see Appendix B).

3.2.1 Study population of the swabbing

The study population is a group of objects that is selected or identified. The identified objects for this study were all the IRs 35 cm × 45 cm in size. These IRs were wet swabbed to determine the microbial loads of each IR. Discussed in full below are the items that was identified to be included or excluded for swabbing as the microbiology portion of the study. The same items were swabbed that was observed and this is where the link is made between the object and the infection control actions towards the objects or IRs.

3.2.1.1 Inclusion criteria

The IRs had to be 35 cm × 45 cm in size. The Siemens Digital Heatlhineers Mobile 35 cm × 45 cm detector was the only digital mobile X-ray machine that was included.

3.2.1.2 Exclusion criteria

IRs that were not 35 cm × 45 cm in size were not sampled. No other digital mobile machine was included for sampling.

3.2.2 Research tool

The tool that was used to capture the sampling data was the sample tracking sheet. The sample tracking sheet was used to document who was sampling, as well as the date and time. The sampling number as well as the type of sample was indicated on the sheet. The sheet was finally completed by indicating if all the sides of the IRs had

been swabbed.

3.2.3 Data collection process

The data were collected by swabbing all IRs. The IRs were swabbed to determine the current microbial load of the IRs, then, the IRs were disinfected and swabbed again. The swabs that were taken post-disinfection were intended to determine if the IR had been disinfected completely and had a microbial load of 0. All the information was recorded on a sample tracking sheet (see Appendix B).

3.2.4 Data analysis of the swabs

The data were analysed by recording the microbial analysis on an Excel spread sheet. For the data analysis sheet, the colony-forming units per millilitre (CFU/mL) was documented on the sheet for each individual type of cultivation media that was used. The Chi square test was performed for statistical significance.

3.3 LABORATORY TRIAL RUN FOR THE SWABS

The researcher tested the observational notes to determine if it was effective in accurately capturing the observational data. The researcher followed one IR for a day (04:30 to 16:00). By following an IR, the researcher was able to determine a basic pattern of the path travelled by the IR, as well as the different contact points made by the IR.

The chosen IR was disinfected with 70% ethanol and wet swabbed to confirm a microbial load of 0 (control). Then, the IR was placed back into the holding space to return it into circulation. At the end of the determined period of observation, the researcher swabbed the IR again and submitted both swabs to the laboratory for analysis. The researcher was trained in disinfection and wet swabbing techniques by the expert in microbiology. No changes needed to be made to the research tool or the swabbing process. The first three swabbing events took place under the same person's supervision.

3.4 METHOD OF MICROBIAL SWABBING OF IMAGING RECEPTORS AND DIGITAL DETECTOR

The IRs that were identified as being used in the department and which had circulated throughout the hospital for mobile X-ray examinations, were disinfected and swabbed and placed back into their holding space, from where the observation process started. The holding space forms part of the route that the IRs followed on a daily basis; thus, the holding space was also recorded on the checklist every time an IR was placed there. The peak time when the IRs were followed was from 07:00 to 16:00 of the same day. The researcher determined the peak time for IR circulation, to allow adequate sampling circumstances. For the observation to be successful, the researcher used observational notes (see Appendix A) to guide the observation; thus, allowing the researcher to document all observational data.

The radiographers in the department were not sensitised about the study. The consent form indicated that the purpose of the study was to observe the routes IRs travel through the hospital on certain days (see Appendix C) to enable the researcher to determine a possible pattern of movement for each IR. The letters of consent for the observational part of the study did not contain information on the sampling process; the letters only informed the radiographers about the observational part of the study (see Appendix C). By doing so, participants were not sensitised to adapt their behaviour.

The samples were labelled according to the number allocated to the IR. A sample tracking sheet was used to record the swab samples. The researcher delivered each set of swabs to the laboratory immediately after sampling was completed, to preserve the sample. At the lab, the researcher observed the cultivation and enumeration of selected microbes, which always took place within 24 hours of collection.

All information that was received from the laboratory was recorded on an Excel spreadsheet. The data included pre-exposure swabs and post-exposure swabs. Each swab sample – pre- and post-exposure swabs – was analysed using the same protocol. Figure 3.2 illustrates the flow of the sampling and observational process.

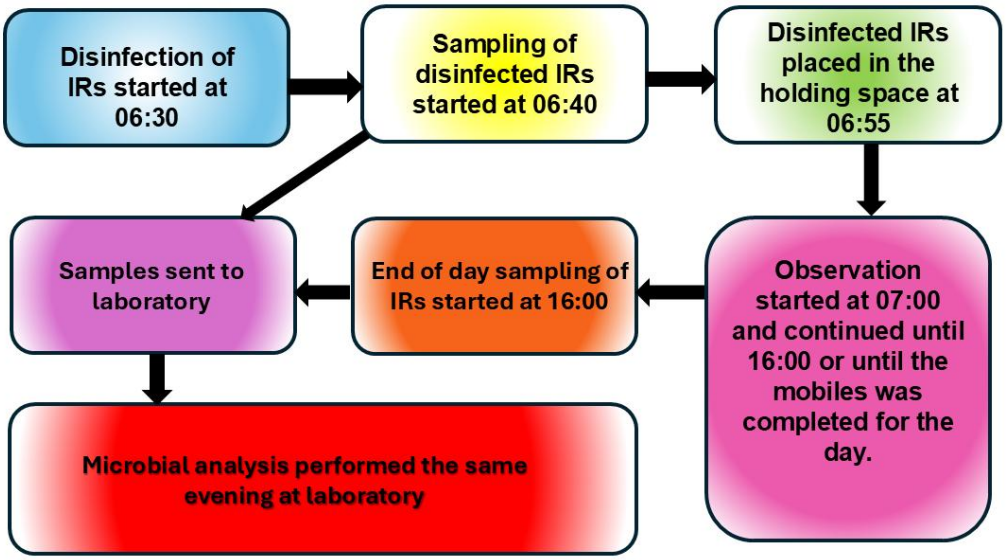

Figure 3.2: Sampling and observational process

3.5 DISINFECTION PROTOCOL FOR THE SAMPLER (RESEARCHER)

The researcher started disinfection by spraying 70% ethanol on their hands and forearms. The researcher put on sterile gloves after the disinfection. The gloves were disposed of after each sample was taken, correctly, as prescribed by hospital policy.

This process applied to both pre-exposure sampling and post-exposure sampling. By making use of a standardised method for the researcher to apply infection control, many variables were eliminated from the study.

3.6 THE OBSERVATIONAL PROCESS

The Swedish Association of Local Authorities and Regions (2016) indicate important preventative measures against possible infection of patients. Several methods can be utilised to create a safe environment for patients who are susceptible to nosocomial infections (Swedish Association of Local Authorities and Regions, 2016). The comparative study recommends that health care workers create a safe environment for the patients by ensuring the availability of hand sanitiser, disposable gloves, gowns and clean uniforms (Swedish Association of Local Authorities and Regions, 2016).

When attending to patients who are known to be infected with an infectious agent, strict hygiene precautions must be applied. Auffermann et al. (2015) describe a protocol for obtaining chest radiographs without spreading the infectious agent. During the process of acquiring a chest X-ray image, several steps have to be followed, such as wearing gloves and disposable gowns, sanitising equipment and placing the IR in a clear bag that is sealed and then in a second bag that is not sealed, for safe removal of the IR. Finally, disposable gowns, gloves should be disposed of safely and, as a last step, hands should be sanitised (Auffermann et al., 2015). All the steps mentioned above relate back to the designed gold standard for infection control applicable for this study.

During the process of observation, a daily pattern of what happens to an IR was created. By tracking the IRs through the hospital during peak times, the researcher was able to determine how much an IR travels, as well as the types of interaction that take place during an average day, and whether these activities have an impact on the microbial load of the IR.

The researcher followed the IRs during the hours of 07:00 to 16:00 one to two days a week for 14 weeks, giving a total of 14 sampling sessions. The radiographers who had agreed to be observed signed informed consent forms (see Appendix C). The observation was guided by observational notes. Thus, a clear pattern of the interactions with the IR was identified (see Appendix A). The researcher did not assist the radiographers during mobile X-ray examinations, and every action was documented as it happened. When a mobile X-ray examination form was received, the radiographers or student radiographers approached the researcher to indicate that a mobile X-ray examination was going to be performed. Then, the researcher took an observational note on which simple letters, such as G for ground, were written and on which any extra short notes could be made. The time of departure was written down, as was the method of travel of the IR and how many radiographers did the mobile X-ray examination. Thereafter it was documented if the lift or stairs were taken, the floor visited, as well as if the type of lift that was used (service lift or public use lift). When the radiographer(s) exited the floor, the ward, room or unit and/or bed number was documented. When the radiographer was busy with patient positioning and placement of the IR, careful notes were made about where the IR was placed before the IR was placed for exposure, where the IR made contact with the patient and how the IR was

protected or cleaned. Details of infection control measures taken, such as hand hygiene before and after patient contact, were also meticulously noted. After the exposure, the same process of note taking was followed, until the IR was finally processed and the radiographers or student radiographers left the IR when they had completed the X-ray. Then, the place where the IR was left was noted, for example, on the processor. This step-by-step procedure represents the way the researcher observed the IR and made the notes accordingly.

The observational notes were compiled by making use of the infection control protocol of the Free State Department of Health (see Appendix E). The observational note allows for observations to be made on the activities of student radiographers, qualified radiographers or patient care assistants. In this way, the researcher could record actions such as hand washing, cleaning of the IRs and whether gloves were worn on the observational notes. The observational note is compiled in such a way that each action taken can be be captured in numerical format. The actions indicated on the observational notes allow for a box to be ticked. The total number of ticks was counted to assign a numerical value to the observations.

For the observation process to be successful, the IRs were followed step by step, from the department where the IR was left until the time the IR was back in the department and returned for the next use. When an IR was going to be used, the notes started by recording the unique number of the IR, the time the IR left the department and the persons who were responsible for using the IR.

The next step was to document the floor, ward, room and bed of the desired destination. During the travel process, it was documented how the IR was carried (either by hand, trolley or mobile IR holder) and whether a lift or stairs were taken to reach the desired destination. While the IR was enroute, each action was documented, such as if an IR was placed on the floor or on a patient bed trolley. Infection control was also recorded, such as if hands were washed or sanitiser and personal protective equipment was used before patient contact was made; disposal of these items was also recorded. During the positioning portion of the mobile examination, the points of contact with the patient were documented, for instance, whether a sheet was placed over the IR or if it was in direct contact with the skin of the patient. Once the

examination was completed, the whole process was documented again, but in reverse, from infection control post-patient contact and all the activities all the way back to the department, ending with the time and the final placement of the IR (see Appendix A).

The data were originally recorded on the observation note, which was then combined into both a text format and numerical format on Excel (see Appendix A). For example, IR 8 travelled six times via the lift and seven times via the stairs, compared to IR 2, which travelled via the stairs only, nine times in total over the 14 sampling sessions. Thus, statistics were developed to determine the normal routes travelled. By linking all the data from the observation notes to the microbiology swab sample data, a comparison was done between routes travelled and microbial loads, which could indicate a likelihood of contamination at particular sites that were travelled to.

SPSS 28 was used to perform the statistical analysis. The test used to determine statistical significance was the Chi square test.

3.7 SWABBING PROTOCOL

Each IR was swabbed on all six of its surfaces using a sponge stick with 20 ml sterile saline, according to the manufacturer's instructions (3M). After the bag was sealed, a label that correlated with the number on the IR was placed on it. Each sample was packaged. The package included a sample tracking sheet (see Appendix B) and a list of the infection control steps radiographers applied (which were also labelled with the correlating number of the IR that was observed). The procedure was performed pre-exposure (immediately after disinfection) and post-exposure. The labels of the containers and the infection control checklist indicated whether the swabs were taken pre-exposure or post-exposure.

3.8 LABORATORY PROCEDURES

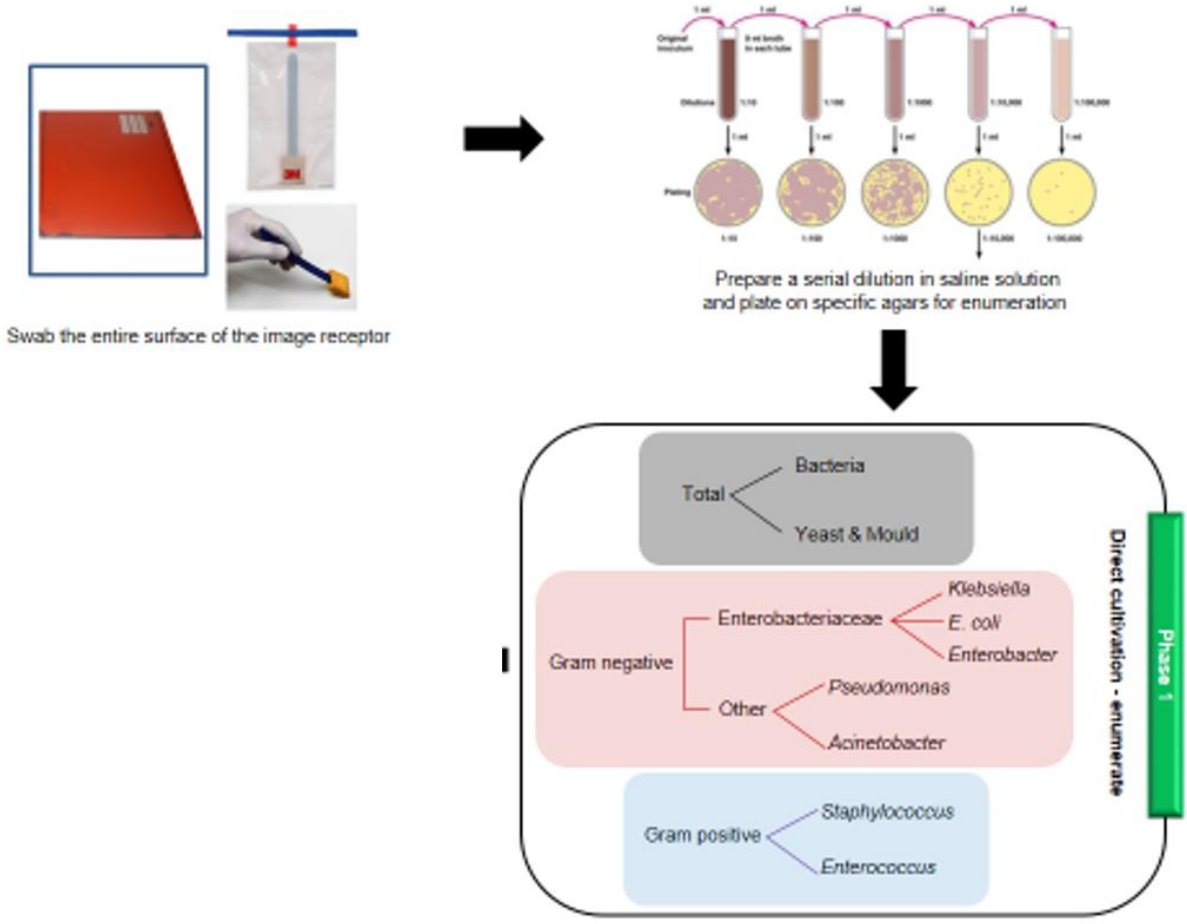

Figure 3.3: Laboratory procedure

Figure 3.3 illustrates the microbial testing experimental design. Microbes were collected from the surface of the IR using a stick swab. The swab was placed in a sterile bag containing 10 ml saline. The mixture was serially diluted and plated onto different agars (Table 3.2) for enumeration. If growth was present, colonies were transferred to chromogenic screening plates using replica plating to detect various antibiotic resistances. Gram-negatives were screened for carbapenem and extended β-lactamase and Gram-positives for methicillin and vancomycin resistance.

3.8.1 Day of sampling

On the day of sampling, several actions were taken to ensure the accuracy and consistency of the sampling process. On the morning of sampling, which started at

06:30, all IRs were recovered from the wards. Two people were needed to complete the sampling process: the first person (P1) disinfected their hands or wore gloves as a precaution because they did not touch the items that were sampled; P1 did come into contact with the sterile sampling bags. The second person (P2) disinfected their hands and wore sterile gloves. The observation part of the sampling started once the physical samples had been obtained. Table 3.1 lists the actions and steps that were taken.

Table 3.1: Actions taken during sampling

Step	Action
1	Spray surface with 70% ethanol and wipe with a paper towel
2	Place masking tape in a square on surface for IRs and gloves. (This ensured the researcher did not stray from the disinfected area.) (see Figure 3.4)
3	P1 prepares the sampling sheet (see Appendix B)
	P2 cleans the surface within the masking tape lines
4	P1 dispenses 20 ml saline in the sponge stick bag
	P2 sprays hands with 70% ethanol and put on sterile gloves
5	Surface swabs taken by P2
6	P1 opens bag for swab stick
	P2 places swab stick in bag
7	P2 retrieves IR with sterile gloves on
8	P1 hands new bag with 20 ml saline to P2
9	P2 takes sponge stick from P1 and sampled the IR.
10	P1 places sponge stick in bag – just the top in the bag. P1 breaks off the stick.
11	P1 seals sample and puts it on ice
12	P2 cleans the surface after each IR was sampled, using 70% ethanol

Steps 3 to 12 were repeated for all IRs that needed to be sampled. The samples were taken to the laboratory after sampling by P1. All the steps were repeated during the afternoon sampling at 16:00.

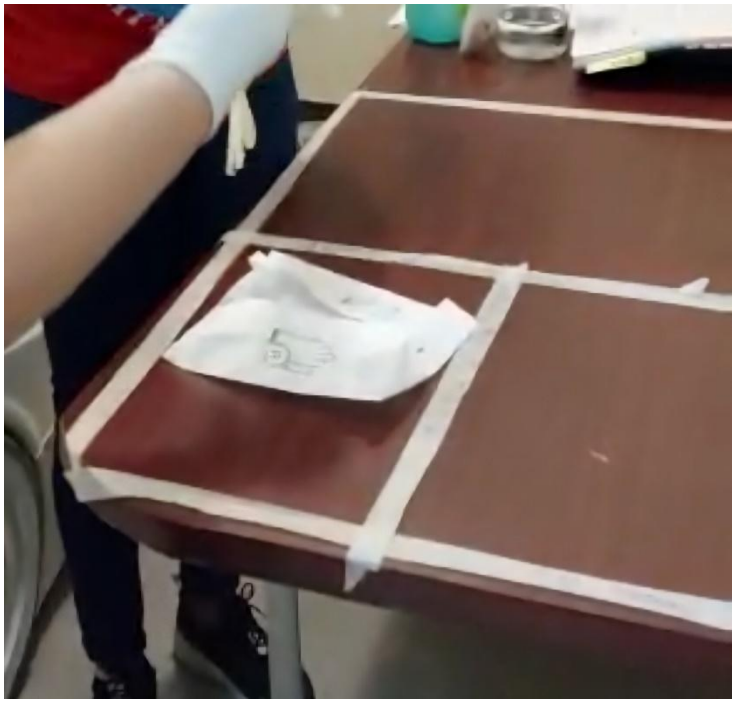

Figure 3.4: Taped off sampling space (Photo credit Dr B. van der Merwe)

3.8.2 Lab processing, plating and enumeration

The cold chain was maintained by keeping samples on ice. Sample processing took place in a Class II biological safety cabinet (Biobase). Swabs were processed immediately or within 24 hours of the time sampled. Each bagged sample was placed in the stomacher individually at 260 rpm (Tufts et al., 2014). The sponge in each sample bag was compressed with a specially designed device (EzSqz) to remove as much of the saline from the sponge as possible. The saline that was pressed out of the sponge was collected using a sterile serological pipette, the volume was recorded, and the liquid transferred to a sterile 15 ml Falcon tube. Falcon tubes were placed in an ice box to ensure that each sample was kept viable when the samples were moved between different equipment. Tubes were centrifuged at 5 000 rpm for 7 minutes at a temperature of 4°C. The samples were moved back to the biosafety cabinet to drain the supernatant from the Falcon tubes. The cells that were lifted from the IR were collected at the bottom of the tube as a visible pellet. After the supernatant had been drained, 9 ml of sterile saline was dispensed into the Falcon tube making use of the 3 ml dispenser. The cells were resuspended in the saline by gentle mixing on the Rotarix 270-degree rotating mixer for one minute.

Each sample was plated on different commercially available selective/differential agars to detect heterotrophic bacteria, yeast and mould, as well as selected Gram-negative and Gram-positive bacterial families, groups, genera or species. The agars, target and how a presumptive positive was visualised are presented in Table 3.2. (Hoyos-Mallecot et al., 2017; Bracco et. al, 2013; Brindisi et al., 2016; Gouliouris et al., 2016; Latifpour et al., 2016; Soares et al., 2017). A volume of 0.1 ml was evenly distributed on each agar plate using the EasySpiral Pro automatic plater (Intersience). Plated samples were incubated according to the supplier recommendations. Plate count agar and Rose bengal chloramphenicol plates were incubated at 30ºC. RAPID'Enterobacteriaceae, Cetrimide and Slanetz and Bartley plates were incubated at 35ºC and Harlequin coliform, CHROMagar *Acinetobacter*, Baird-Parker and *Klebsiella* ChromoSelect placed at 37ºC. Growth was assessed every 12 hours for up to 48 hours. However, Rose bengal chloramphenicol plates were incubated for up to 7 days and assessed every 24 hours. Growth was captured and colonies enumerated using the Scan 1200 HD automatic colony counter (Interscience).

Table 3.2: Microbial selection for determining microbial load on image receptors. Details include agar information, colony visualisation and antibiotic resistance targets

Target	Selective/differential agars	Visual	Antibiotic resistance*	Visual
Total counts				
Bacteria	Plate count	White/cream		
Yeast and mould	Rose bengal chloramphenicol	White/pink/red		
Gram negatives				
Enterobacteriaceae	RAPID'*Enterobacteriaceae*	Pink to red	CRE	Clear/cream; pale pink; blue
Coliforms	Harlequin *E. coli*/coliform	Blue-green/rose-pink		
Klebsiella	*Klebsiella* ChromoSelect	Purple/magenta	CRE	Steel blue
			ESBL	Green
E. coli	Harlequin *E. coli*/coliform	Blue-green	CRE	Pale pink
			ESBL	Blue or pink
Enterobacter	Harlequin *E. coli*/coliform	Rose-pink colonies	CRE	Sea green
Other Gram negatives				
Pseudomonas	Cetrimide	Green/yellow under UV	CRE	Light brown
Acinetobacter	CHROMagar Acinetobacter	Red	CRE	Clear/cream
Gram positives				
Staphylococcus	Baird-Parker	Black/with halo (*S. aureus*)	MRSA	Blue
Enterococcus	Slanetz and Bartley	Red	VRE	Blue and purple

Note. **Brilliance*™ agar = chromogenic screening plates for the detection of various antibiotic-resistant isolates; CRE = carbapenem-resistant Enterobacteriaceae; ESBL = extended spectrum β-lactamase, MRSA = methicillin-resistant *S. aureus*; VRE = vancomycin-resistant enterococci

3.9 CONCLUSION

A variety of factors need to be taken into consideration when two fields of study are combined. During this study, the radiography portion was very specifically designed to allow a microbiology portion to be added. Two fields of study provided a new perspective on the main field, which is radiography.

The study was made possible by planning and working with supervisors who are specialists in each field of study. This study was made possible by referencing the literature to plan and create effective research tools and consulting expert supervisors.

CHAPTER 4
RESULTS AND DISCUSSION

4.1 INTRODUCTION

Both conventional and digital mobile radiography machines have advantages and disadvantages. However, tracking the movement of IRs or digital machines within a hospital are different for each. IRs can be moved and used separate from an radiography machine, but with the digital system everything must be used together. Thus, when mapping out a travel course for different systems, a unique pattern emerges regarding the digital system.

The study was performed to determine the current infection control process of the IRs used in the imaging department and the possible microbial load. In addition, the study provided data on the routes travelled by the IRs and the digital radiography machine. The study was performed prospectively, quantitatively and observationally. The observational portion of the study design was determined to be count data and can, therefore, be discussed as qualitative data (Shuttleworth, 2015). The data were sourced from observational notes and microbiological testing (see Appendices A and B). The observation was documented by marking the actions taken and then recording each action with a number for the number of times the action was performed. Thus, if an action was not performed, a 0 was allocated, or if it was performed twice, a 2 was recorded, thereby creating a numerical format per action taken. Observation of the routes travelled by IRs allowed for unmediated feedback (Merriam, 2016).

4.2 DESCRIPTION OF TOOLS AS DATA SOURCES

Data are always acquired by means of a source/tool. When a tool is designed in the form of an observational note and sample tracking tool, the data are extracted from said tools to formulate data patterns that can be evaluated and discussed. The tools used also allow for statistical analysis that can provide confidence values and visual figures of the statistics. Therefore, it is important to understand the tools used for the study.

4.2.1 Observational notes

Recording data representing the routes taken by the IRs was done with a specifically designed recording sheet, in the form of observational notes (Appendix A). To accurately record what happened during the time an IR travelled, the researcher had to determine key points of interest to log in the observational notes. Due to the nature of mobile X-ray examination requests, which requires X-ray examinations to be performed almost anywhere within the hospital, the first item to be checked off is the method used to carry the IRs and its placement while the radiographers and student radiographers were in the room/ward. Thereafter, any possible means of transfer, via a lift or stairs, had to be indicated as the first part of the physical path the IR took to reach the requested destination. Secondly, it was crucial to document and record different floors as well as wards to which the IRs travelled. Lastly, within the wards, the room number, if it was not an open ward, and bed number was also recorded to be as specific as possible.

When the IR was allocated to the bed all actions taken were recorded, such as whether the IR was cleaned with ethanol or soap or whether a cover was put over it. A detailed record of any interaction with the IR allowed the researcher to create detailed travel routes as well as infection control habits in relation to the IRs.

At the end of each trip, the IR was placed or left somewhere and was recorded as the end of the trip for the specific IR. The end-of-trip place that was ideal was the IR station next to the processor, however the IRs were left on the processor or placed in the mobile machine's IR holder for a possible next trip. At the end of each day, the IRs were collected from all the places they had been left and sampled for the last time. The last sample gave an indication of what bacteria, if any, had cross-contaminated or had been 'picked up' during the day. The final bacterial counts indicated microbial loads that could be linked to different actions taken during the day.

4.2.2 Microbiology sample tracking tool

Physical samples of any item for microbiological processing and testing/cultivation had to be tracked meticulously. Meticulous tracking enabled the researcher to

determine if the sample was viable when it arrived for processing and testing/cultivation. On the sample tracking sheet, identifiers were marked, such as the date, IR number and the person(s) who were responsible for sampling. The sample tracking tool was completed three times for every sample taken, once for the current status sample, once for the disinfected sample (0) and, finally, for the end-of-the-day sample (1). The time was noted on the tool, as were comments on the appearance of the IR, or if anything was visible on the IR, for example, remnants of a sticker, blood or even soap. The swab was marked complete if all surface areas were swabbed, with the time included; there was also a place for comments (see Appendix B). The samples were kept on ice and refrigerated until the plating took place on the evening of the day the samples were taken. Keeping the samples on ice and refrigerated limited changes to the samples, because the bacteria the researcher tested for grew in warm environments, thus, the colder the environment (not freezing because that might damage the sample), the better the sample could be preserved.

4.3 INFECTION CONTROL OBSERVATIONS AND PRACTICES

Infection control is important during any radiographic examination; however, during mobile radiographic examinations, the importance increases. Infection control was especially relevant during the Coronavirus disease 2019 (COVID-19) pandemic (Abuzaid et al., 2022). Any type of infection control can make the difference between halting the spread of pathogens at the source or becoming a vector for it.

Additional observations included whether gloves, hand sanitisers and covers for the IRs/digital detector were used, as per the gold standard for infection control documented in the design of the observational notes and literature (see Appendix A and Chapter 2). Cleaning the IRs and digital detector is also recommended, even if a cover is used. Many infection control measures were skipped during the period of the entire study and, as a result, cross-contamination and spread of pathogens were possible. There is evidence supporting proper infection control for various medical items and instruments and an increase in research on IRs and digital detectors because they present as a risk (Chingarande and Chidakwa, 2014; Wainwright, 2015).

Manufacturers of IRs and digital detectors have designed materials that act as antimicrobial barriers. If the antimicrobial materials are introduced and tested extensively, they could assist in decreasing cross-contamination from patients to equipment or equipment to patients. As for the IR system used at the participating imaging department, it was easy to clean, as was the digital detector. The digital detector that was used is marketed as having an antimicrobial layer (Siemens, n.d.).

4.4 RESULTS: LINKING RADIOGRAPHY AND MICROBIOLOGY

4.4.1 Gold standard behaviours

Each trip taken by the IR was documented on the observational notes (see Appendix A). Tracking was done by making a tick on the observational notes for each action taken. The actions that fulfil the designed gold standard of infection control are the mechanism of travel, hand hygiene, IR cover and IR cleaning. The same set of gold standards was applied for qualified and student radiographers. Additionally, the infection control behaviours of the two types of radiographers were highlighted, because student radiographers are still in training. Comparing qualified radiographers and student radiographers was never a goal of the study; however, valuable information could possibly be deduced from the data.

The gold standard was not designed as a method to determine the ‘perfect’ infection control actions, but rather to determine what actions were taken to perform infection control. For mechanism of travel, hand hygiene, IR cover and IR cleaning, a percentage of 100% was allocated to each. Thus, the grouping of mechanism of travel comprised three actions, namely carrying the IR by hand, carrying it against the body and carrying it in the IR holder. The total of 100% was then divided by three for each of the actions, which equals 33.3% per action. For example, if the IR was carried only once by hand for an entire trip and no other action was used (out of the identified three possibilities), out of the 100%, only 33.3% of actions (by hand) was utilised during the identified trip.

Hand hygiene had the most actions that could be performed and each action counted towards a total of 100%. The number of actions that could be taken for hand hygiene was six actions in total, which lead to each action counting 16.67%.

Thus, 16.67% was allocated for each of the following actions: hand washing pre-patient contact, hand washing post-patient contact, hand sanitiser pre-patient contact, hand sanitiser post-patient contact, gloves used and using gloves post-hand washing and pre-patient contact. The 100% total was divided equally between the six actions.

Concerning protection of the IR or digital detector, three options were provided for the grouping out of 100%. Each of the following three actions was allocated a percentage of 33.3%: plastic bag, pillowcase, and any other method.

Lastly, IR cleaning or disinfecting also comprised three actions, and the 100% was divided equally (33.3% each) between cleaning in the department, cleaning before patient contact, and cleaning after patient contact. Thus, all the different groupings counted for 100%, and the 100% was equally divided between actions to give a percentage per action taken.

4.4.1.1 Mechanism of travel

To perform mobile X-ray examinations, some form travel must always take place. This study investigated how and where the IR had to be transported to reach the site where the radiographs were to be taken. Transportation of IRs can be done in several ways. The IRs can be placed in the IR holder and carried by hand or against the body. The digital detector of the digital mobile X-ray machine will always be transported in the docking station (which doubles as an IR holder) of the machine. The decision about how to transport the IRs is normally based on how many radiographers/student radiographers are going to perform the mobile X-ray examination together; sometimes there are more hands to carry, or if someone does not want to carry it by hand, and needs to push the mobile X-ray machine, it is best to place the IR in the IR holder.

Three possible mechanisms of travel (IR trips n = 43), one trip was not followed but documented), the digital X-ray machine always travelled in the docking station or IR holder, which means 100% for the digital X-ray machine) were identified and are listed below as follows:

- Carried in the hand

- Carried against the body
- Transported in the IR holder

When the participants were identified to determine the actions taken in relation to mechanism of travel, a total of 30 qualified radiographer participants and 12 student radiographers where identified. Each radiographer (n = 30) and student radiographer (n = 12) usually had a pattern according to which they preferred to perform a task. The manner in which a participant performed the task can vary from participant to participant. The graph in Figure 4.1 indicates how qualified radiographers and student radiographers applied the mechanism of travel according to the gold standard, which makes up a total percentage of 100 for each action taken.

When travelling, 23.3% of qualified radiographers carried the IR in their hands (n = 7 out of 30 actions), compared to 14.1% of student radiographers (n = 4 out of 28 actions). It is important to note that IR can be transported in more than one way during a route, as it might be carried by hand to a ward and in the IR holder back to the imaging department. There could be various reasons for the slightly higher percentage of qualified radiographers who carried the IR by hand – the reasons could be determined by further investigation. In this study, some sampling sessions took place when the students were not in clinical practice, but on campus, or no students were available to perform or accompany the mobile X-ray examinations. For every action, an investigation can be performed to determine the reason behind the choice of action.

When a comparison was made in relation to carrying the IR against the body, 3.5% of qualified radiographers (n = 1 out of 30 actions) chose this action, while 0% of students (n = 0 out of 28 actions) chose to carry IRs against their bodies.

Lastly, there was the option to transport the IR in the IR holder of the mobile X-ray machine. The qualified radiographers (n = 9 out of 43 actions) opted to let the IR travel in the IR holder at a rate of 20.9%, whereas the students (n = 4 out of 31 actions) used the IR holder only 12.9% of the time (see Figure 4.1).

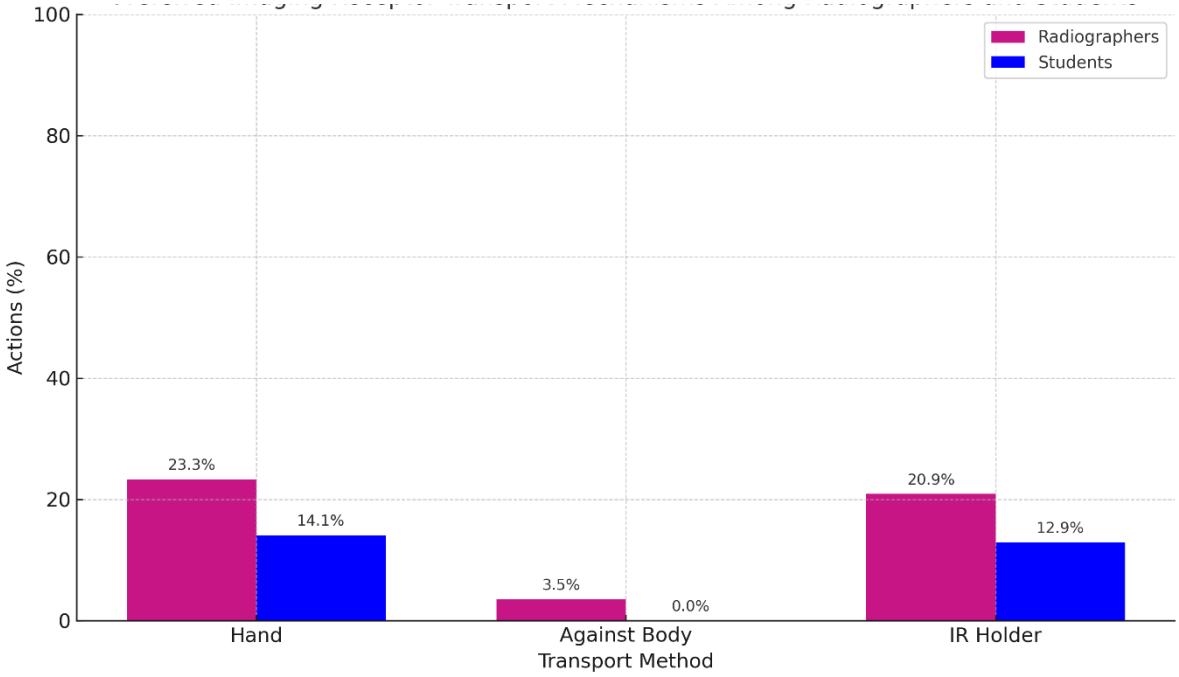

Figure 4.1 Preferred imaging receptor transport mechanisms of radiographers and students

The qualified radiographers (n = 30) made use of the preferred mechanisms of travel 47.7% of the time (combined total for all three mechanisms of travel). Student radiographers (n = 28) used the three identified gold standard actions for transporting an IR 27% of the time in total. There is no statistically significant difference between the behaviours of the qualified radiographers and the students (*p*-value of .4133, thus *p*-value > .05) when a Chi square test was performed (See Table 4.1). Mechanisms of travel mostly presented as a personal choice; no strange or out of the ordinary behaviour was observed by the researcher. The remaining 25.3% was allocated to the digital X-ray machine; the digital detector always travelled in the holder (docking station) because this is where the digital detector was charged.

Table 4.1: Statistical significance between qualified radiographers and student radiographers

Mechanism of travel	Qualified radiographers	Student radiographers	*p*-value
3 types namely: By hand Against the body In the IR holder	N=30	N=12	0.4133 (>0.05)

4.4.1.2 Hand hygiene

Propper hand hygiene is always required and the focus on hand hygiene increased during and after the COVID-19 pandemic (Alwan et al., 2023). Hand washing is greatly beneficial; however hand sanitiser became increasingly more popular from 2020 onward. Below is a list of possible ways and times to use hand hygiene:

- Hand washing pre-patient contact
- Hand washing post-patient contact
- Using hand sanitiser pre-patient contact
- Using hand sanitiser post-patient contact
- Using gloves
- Using gloves with post-hand washing and pre-patient contact (Tacconelli et al., 2014; Antwi et al., 2015; NHS Foundation, 2018)

To measure application of the gold standard, the preference for hand hygiene, out of 100% for the total trips taken (n = 86), each of the actions was allocated a preference percentage of 16.67%. The 16.67% for each action (six in total) accumulated per participant (either a qualified radiographer or student) to a rounded 100%. The highest percentage was for radiographers (n = 60) washing their hands post-patient contact, which amounted to a 31.7% preference. In comparison, the student radiographers (n = 26) had a preference of 29.5% for washing their hands post-patient contact. The lowest compliance rate was for wearing gloves post hand washing and pre-patient contact, at 2.4% for qualified radiographers and 6.8% for

student radiographers. Hand hygiene was not greatly prioritised in any of the provided actions and are all below 40% for actions taken (see Figure 4.2).

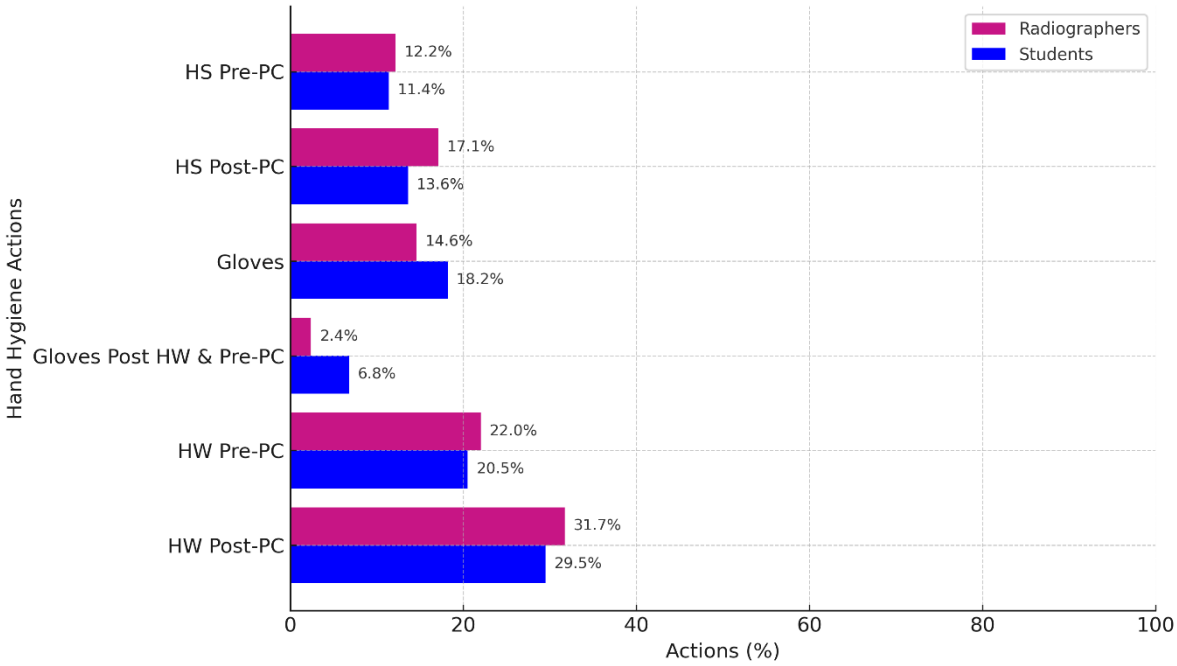

Figure 4.2 Preferred hand hygiene methods used by radiographers and students

Note. HW = hand washing, PC = patient contact, HS = hand sanitiser

Hand hygiene is a well-known practice as a preventative measure for cross-contamination (Antwi et al., 2015). The low percentages noted for hand hygiene in this study means cross-contamination could be possible. Hand hygiene is extremely important for limiting spread and cross-contamination because, in this study, the participants consistently touched the patient and the IR or digital detector. If hand hygiene is not practiced as recommended in the literature, the risk of cross-contamination and spread of bacteria increases (Tacconelli et al., 2014; Antwi et al., 2015; NHS Foundation, 2018). A further study could be performed to determine how to improve qualified radiographers' and student radiographers' understanding and effectively use of personal protective equipment.

4.4.1.3 Imaging receptor cover

In this study, two main options were marked as acceptable, and another category was available for 'other' if any attempt was made to cover the IR during an X-ray examination. These were the three options:

- Plastic bag
- Pillowcase
- Other (describe) (Auffermann et al., 2015)

Creating a waterproof barrier is a way of preventing cross-contamination from the IR to any possible pathogen it comes into contact with (Auffermann et al., 2015). The preference to create a barrier between the patient and the IR or digital detector is extremely low: 0% preference for all three options for student radiographers. Qualified radiographers made use of a plastic bag at 2.3% and 1.2% had a preference for making use of a pillowcase (n = 86 trips).

4.4.1.4 Cleaning imaging receptor

IRs should be kept clean because they are a known fomite/reservoir for pathogens. The three main places/times indicated as the gold standard for cleaning are:

- Clean in the department;
- Clean before patient contact; and
- Clean after patient contact (Alberta Health Services, 2013; Auffermann et al., 2015; Infection Prevention and Control Canada, 2016).

As can be seen in Figure 4.3, the highest preference rate was for cleaning the IR after patient contact (n = 86 trips) for both qualified radiographers (n = 22 trips), at 25.6%, and for student radiographers (n = 24), at 27.9%. It was excellent that the IR was cleaned after patient contact; however, if there were pathogens on the IR before it came into contact with the patient, cross-contamination could have occurred. Thus, cleaning the IR before it comes into contact with the patient is beneficial too; however, qualified radiographers only did it 10.5% of the time (n = 9); student radiographers had an even lower compliance rate, of 3.5% of the time (n = 3). The last line of protection for a department is to clean the IR while it is in the department. The qualified radiographers complied at a low rate of only 1.2% (n = 1 trip); no student radiographers executed this protective action.

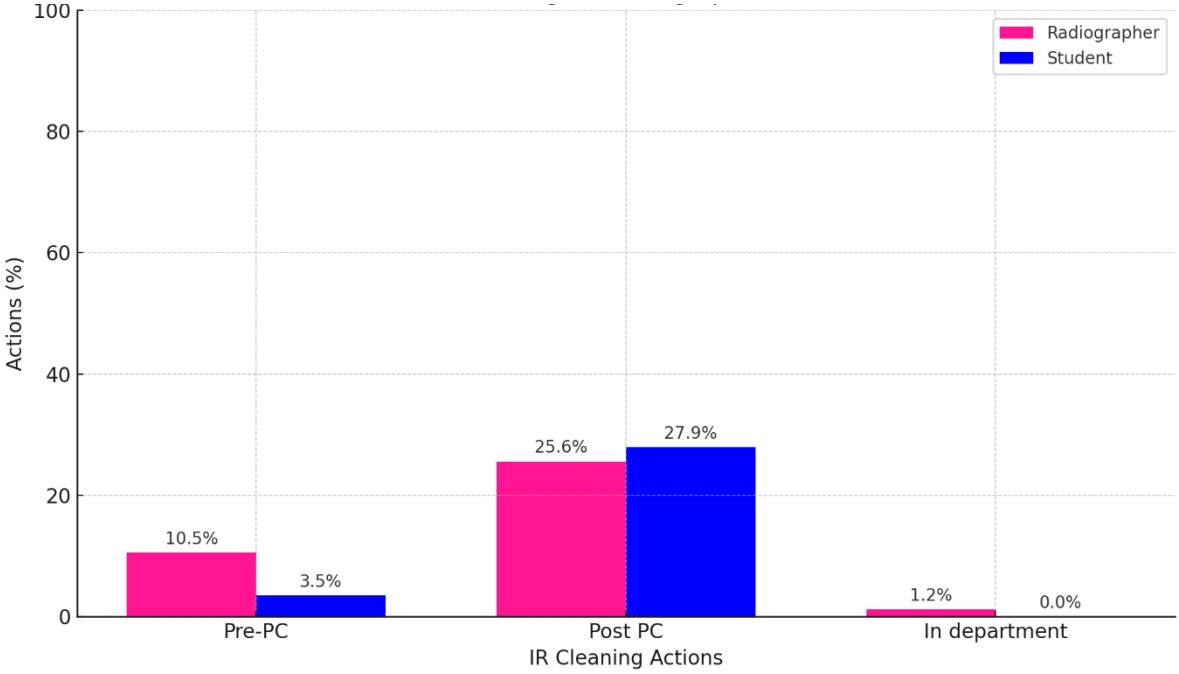

Figure 4.3: Preferred IR cleaning by radiographers and students

Note. PC = patient contact; IR = imaging receptor; In department = cleaning took place in the imaging department

4.4.1.5 Disposal of contaminated items

The items used during mobile X-ray imaging, such as gloves, plastic bag and pillowcase, all need to be disposed of correctly. Correct disposal ensures that no cross-contamination can take place. Disposal can be done as follows:

- Depositing in a hazardous waste bag (gloves and plastic bag)
- Depositing in slush room (pillowcase)
- Other (describe)

Like the trend of hand hygiene, where gloves were used most frequently, when it came to disposal, placing the soiled gloves in a hazardous waste bag had the highest preference, with 19.8% for student radiographers and 14% for qualified radiographers; a cover was disposed of in a normal waste bin once by a qualified radiographer. Using the hazardous waste bag to dispose of a plastic bag that had been used, and a linen saver (other), both had compliance of 2.3% for qualified radiographers; no student radiographers made use of such items. The almost 0%

use of disposable items (except for gloves) means the compliance rate for disposal is low and, therefore, this gold standard could not be adequately tested.

4.4.2 Trips and routes

A total number of 51 trips were made over the course of the study, with 86 routes. In total 43 of the routes were with the conventional mobile X-ray machine IRs and 43 routes were with the digital mobile X-ray machine. However, several more IRs and exposures were made than the 51 trips. IRs can only be exposed once and then needs to be read out, leading to the radiographers taking more than one IR on a trip. The digital X-ray machine has a docking station/digital detector holder (similar to the IR holder) for both a 35 cm × 43 cm and a 24 cm × 30 cm digital detector, right behind each other. When the digital X-ray machine was taken out on a trip, even if only the 24 cm × 30 cm digital detector was used, the trip was documented. The documentation of each trip was paramount because the possibility existed that the 35 cm × 43 cm digital detector could be used.

During the first part of the study, when the IRs were followed and observed, the routes were relatively consistent. However, after the introduction of the digital X-ray machine, a few new routes were introduced. The digital X-ray machine was also used in the maternity wards, NICU and private referral rooms. The maternity ward, NICU and private referral rooms were located on the basement level of the hospital and, therefore, a new route was established, which was not included during the first part of the study. The total number of trips for IRs and digital detector when no exposure was made was 9 trips in relation to 77 exposures made, which indicates a highly significant chance of an exposure being made during a trip (p-value < .0001) when a Chi square test was performed (See Table 4.2). The high significance value of taking an extra IR on a trip and the IR likely being exposed, seems to reinforce the tendency of radiographers taking extra IRs on a trip or the digital machine being used more often than the official requested examinations that were scheduled.

Table 4.2: Statistical significance between exposures made and no exposure made during a trip

Exposures made	No exposure made	*p*-value
N=77	N=30	<0.0001

4.4.2.1 How a day was started for sampling

Each day was started in the laboratory by gathering all the necessary sampling equipment and freshly made ice for the samples. The sampling items were transported to the hospital and into the imaging department, to an identified area where a sampling station was set up.

At the sampling station, the counter was disinfected and taped off into areas where the IR or digital detector were to be sampled and disinfected, and an area for preparing the sterile gloves the researcher had to wear. After the sampling station had been prepared and all the IRs and digital detector had been placed at the sampling station, the sampling started and was completed within a few hours. The samples were then preserved on ice and immediately taken to the laboratory by an assistant. After the researcher had spoken to the participants, each participant decided whether they were willing to take part in the study by completing an informed consent letter (see Appendix C). As soon as the informed consent form was signed and the first mobile X-ray examination request was received, the observational part of the study commenced. At the end of each sampling day, the sampling station was set up again to take samples of the IRs and digital detector to determine the presence of bacteria.

4.4.2.2 Fully documented trip on the first day of sampling

Below is a typed transcription of the observational notes from each trip, which were physically recorded by the researcher. The observational trip data are presented in a simplified manner to guide the reader through the notes and to provide a clear overview of the information briefly documented during each observation.

Trip 1 – Leaving the department at 10:05 (IR 8 and 10 used) back by 10:38. (Two small IRs travelled with). One qualified and one patient care assistant went on the mobile.

IR 8 – Travelling to floor 2 (Coronary unit) by taking the lift on the service side and exited at floor 10 to take images of paediatric patients. Not related to the big IRs, as this was just part of the trip. After completion at floor 10, the lift was taken on the service side exiting at floor to ward B.

One qualified and patient care assistant was working together. The qualified carried the IRs against his body with his hands and placed the IR in the mobile IR holder. No form of infection control was performed. IRs travelled to the 10th floor and was placed on the floor. Thereafter the IRs was placed in the IR holder of the mobile machine. The 2 small IRs that was used on floor 10 was placed against the large IRs that was going to be used on floor 2. The IR was placed against the skin of the patient with the patient ID sticker placed on the IR to mark the patient ID to the IR used. The IR was placed on the table by the computer station.

The lift on the service side was used to return to the department on the ground floor. No infection control was performed when the IR came back to the department. The IR 8 was left on the processor in the department.

IR 10 –Travelled the same route as IR 8, however, no exposure was made. The IR was left in the IR holder to be used later.

Time unknown. IR2 - New trip not followed at a later time, the IR was not followed. The qualified radiographer left without informing the researcher that he was leaving. The IR travelled to ICU P. ICU P is on the same level of the imaging department, and normally the mobile machine from the department is used. The IR is normally carried by hand or in the IR holder of the mobile machine.

Trip 2 – Time leaving department at 14:53 (IR 2 and 8 was used) and returned at 15:08. (1 small IR travelled with). One qualified and a patient care assistant was on the mobile.

IRs 2 and 8 were both used for the second time during trip 2 on that day.

IR 2 – Traveling to floor two. Took the lift and exited at floor 2 via the service side to ward A, Bed 5. One qualified radiographer and a patient care assistant went on the mobile. The patient care assistant carried the IR by hand. No hand hygiene was performed, no IR cover, no IR cleaning and no disposal of items due to no use of covers.

The IR was placed behind the bed sheet for exposure. IR was placed against bed and the bed rail, while a sticker was placed on the IR for ID purposes. The IR was then carried by hand to exit floor to via the lift to the detour to floor 4 ward A and exited at floor 4 via the service side.

On the fourth floor, IR 2 was placed on a chair while the 24 cm × 30 cm (which did not form part of the inclusion criteria) IR was in contact with IR 2. From floor 4 the IR was taken back to the department via the lift and was carried by hand and the IR was placed in the table next to the processor. After processing the IR was left in the processor.

IR 8 – Traveling to floor 2. Took the lift and exited at floor 2 via the service side to ward A, Bed 3. The plate count agar carried the IR by hand. No hand hygiene was performed, no IR cover, no IR cleaning as well as no disposal of items due to no use of covers.

The IR was placed behind the bed sheet for exposure. IR was placed against bed and the bed rail, while a sticker was placed on the IR for ID purposes. The IR was then carried by hand to exit floor to via the lift to the detour to floor 4 ward A and exited at floor 4 via the service side.

On the fourth floor, IR 8 was placed on a chair while the small IR was placed on top of IR 8. From floor 4 the IR was taken back to the department via the lift and was carried by hand and the IR was placed in the table next to the processor. After processing the IR was left in the processor.

Trip 3 – Time leaving department at 15:23 (IR 3, 4 and 5 was used) and returned at 15:36. One qualified and a student was on the mobile. It was clear

that the student followed the qualified radiographer's infection control measures, or the lack thereof.

IR 3 – Traveling to floor 2. Took the lift and exited at floor 2 via the service side to ward A (Multi ICU), Bed 7. The student carried the IR by hand and placed it in IR holder. No hand hygiene was performed, no IR cover, no IR cleaning and no disposal of items due to no use of covers.

The IR was placed behind the bed sheet after exposure the IR was place on the bed where a sticker was added for identification. IR was carried back to the department by hand by the qualified radiographer. The IR was placed in the holder back in the department after processing.

IR 4 - Traveling to floor 2. Took the lift and exited at floor 2 via the service side to ward A (Multi ICU), Bed 7. The student carried the IR by hand and placed it in IR holder. No hand hygiene was performed, no IR cover, no IR cleaning and no disposal of items due to no use of covers.

The IR was placed behind the bed sheet after exposure the IR was placed on the table where a sticker was added for ID. IR was carried back to the department by hand by the student. The IR was placed in the holder back in the department after processing.

NOTE: IR cassette reader of IR 4 was not working. IR plate of 4 changed with IR plate of 10 for processing. Afterwards the imaging plates was swopped again. IR cassette 4 was placed on the table while IR 10 was being processed.

IR 5 – Traveling to floor 2. Took the lift and exited at floor 2 via the service side to ward A (Multi ICU), Bed 4. The student carried the IR by hand and placed it in IR holder. No hand hygiene was performed, no IR cover, no IR cleaning as well as no disposal of items due to no use of covers.

The IR was placed behind the bed sheet after exposure the IR was place on the table by bed 7 where a sticker was added for identification. IR was carried back to the department by hand by the qualified radiographer. The IR was placed in the holder back in the department after processing. The qualified

washed his hands in the department. However, cross-contamination could already have occurred anywhere in the hospital. A visual representation of what a full day of trips look like can be seen in figure 4.4. The final results of the trip data are divided into each section of results under the gold standards for example hand hygiene and methods of travel, among others.

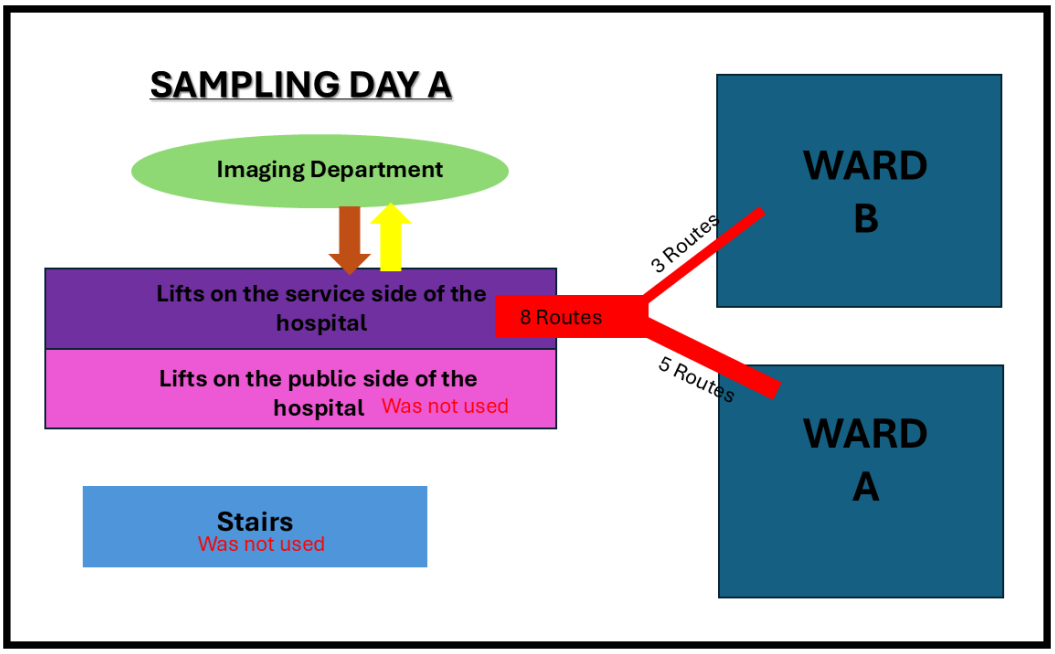

Figure 4.4: Sampling day A: Trip and route representation

4.4.2.3 Imaging receptor placement

During a trip, the IRs are placed on various surfaces. One of the concerns was that IRs were being placed on the floor. The IR/digital detector was placed on the floor 11 times on 86 routes, that is 12.79% of the time. Placing the IR or digital detector on the floor allows the IR or digital detector to come into contact with an area that is designated for walking, and the possibility exists that cross-contamination could take place. However, it is important to note that, for the digital detector, it was placed on the ground much less often – only 6.98% (n = 3 out of 43 digital detector trips), compared to 18.6% (n = 8 out of 43 trips) for the IR. This is a decrease in frequency from IRs to digital detectors and could lead to less cross-contamination when the digital detector is used.

4.4.2.4 *Infection control compliance observed*

Items used for disinfection are not always available; this includes items such as soap, water, sanitiser of all types and paper towels to dry off or wipe off the items to be disinfected. The risk of not having these cleaning items is failure to practice infection control and, should the items be unavailable for long periods, it could lead to a permanent neglect of infection control, because the standard routine changes (Anderson et al., 2023).

4.4.2.5 *Pre-COVID and post-COVID and the new digital machine*

In 2019, the provided protocol (see Section 2.6) was, for the most part, not adhered to at all, as if infection control was not really a matter of priority for the participants (qualified radiographers) prior to the COVID-19 pandemic. For student radiographers, being observed by the researcher in itself made them rethink all aspects of performing a mobile X-ray examination, which includes infection control and, when students were extremely nervous/anxious, they forgot to execute certain steps, such as infection control or technical aspects of the mobile examination itself. Technical mistakes were not part of the study; however, it was observed several times that technical errors were made or not given the adequate attention.

COVID-19 had an impact on the mental preparedness for infection control. Participants automatically walked to sanitisers and places where they could wash their hands. Participants markedly searched for sanitisers and gloves. A very disappointing factor is that IRs were still not really covered, and it seemed acceptable to place IRs against the skin of the patient. A slightly different infection control routine was observed for individual sampling sessions and participants of all demographics (age ranges).

The new digital X-ray machine was implemented and markedly different attitudes regarding infection control of the digital detector (IR for a digital machine) were noted in comparison to the old IR system. The digital detector was cleaned on a more consistent basis. The more consistent cleaning could possibly have been due to the machine being new and the staff being informed to keep the digital machine clean; however, there are no documented data for this specific outcome other than that the action was observed. The new system had an additional size digital detector

(24 × 30 cm), which forms part of the machine in addition to the standard (35 × 43 cm) size. The digital detector works with a battery, and the battery was interchangeable between the two digital detectors. When a digital detector had to be used and the battery was not charged, the battery was changed between the two digital detectors to the preferred size of digital detector to be used for a patient. The interchangeable battery allowed for a new form of cross-contamination, which was not planned for in the original design of the study and observational notes. However, the researcher did take note of the battery exchanges made. The machine was also used in the NICU and maternity wards, while, at the start of the study, these units and wards made use of their own machine and IRs. The NICU and paediatric ICU wards present with patients with a higher risk of infection and, thus, this additional movement through the hospital posed an increased risk to these high-risk patients. It is important to note that the participants did take additional precautions, as per the guidelines of the matrons of the wards, to use the neonatal tray for examinations instead of placing the digital detector underneath the patient. Infection control practices of the participants improved during the time spent in the NICU wards and was limited to ‘timed visits’ and emergencies. Thus, these high-risk wards were not visited constantly.

The new machine also introduced new routes of travel because it was a closed system (the digital detector is stored in the machine itself to allow for charging of the battery). The digital detector allowed physicians to request X-ray examinations while the radiographers were in the ward and could review the radiographs immediately. This poses several risks, but also has benefits. Risks include that the digital detector is used immediately and, unless it was adequately disinfected, the next patient is exposed to the previous patients' pathogens/bacterial infections, if present. The benefit is that the machine and participants do not have to travel to various sites, thus lowering cross-contamination risk, and no microbes outside the unit or ward could possibly be introduced into the environment.

Physicians interacted with the digital machine, while they did not interact with the IRs and previous X-ray machine, which introduced a new form of interaction with the machine. Any new or additional interaction with the machine poses a risk of cross-contamination. If the physician failed to do adequate hand washing or apply

infection control standards, there could be an increased risk of cross-contamination, which could, in turn, cause infections if an infectious agent was present. The researcher could not determine if the physician interaction with the equipment had an impact on cross-contamination. Because of the possibility that the antimicrobial layer was effective, this might not be a problem for the physical digital detector, but regarding hand hygiene, there is a possibility of cross-contamination between patients from contact of hands alone; however, this study provided no evidence, because the counts were zero.

4.4.2.6 Influence of demographics of qualified radiographer, student radiographer and researcher

During the study, the researcher observed many qualified radiographers and student radiographers. Qualified radiographers have a subgroup of qualified radiographers, for instance, qualified radiographers who had been qualified for many years and who were considered senior radiographers when the researcher started to study radiography. There were qualified radiographers who had been newly qualified when the researcher was a student radiographer, as well as radiographers who had qualified at or around the same time as the researcher. The last group was the qualified radiographers who were newly qualified and some were former students of the researcher.

Each one of these groups was observed as having different attitudes towards the researcher being present. The senior radiographers continued as normal, as if the researcher was not there. The qualified radiographers who had qualified during the same timeframe as the researcher either asked for assistance or just continued as if the researcher was a colleague coming along for the trip; they were comfortable. The newly qualified radiographers were observed as being more nervous around the researcher, as if the researcher was assessing them during the mobile X-ray examinations.

The student radiographers were mostly very nervous, and it was observed that they tried hard to remember what they had been taught during their formal training. The students were also observed following the lead of whoever was the qualified radiographer working with them regarding infection control.

4.4.2.7 Trips, rooms and wards

All trips departed from the imaging department on the ground floor, because this is where the IRs and digital X-ray machine are stored. During a trip, several floors, wards, rooms and beds were visited and were documented as such. The lift was the most common method of travelling between floors because the IRs were heavy or because the mobile X-ray machine had to be taken from the department to another floor. The significance of using the lift instead of the stairs is very strong and indicative of the type of equipment used and observed during the study.

At the site where the study was performed, there are multiple lifts, including those used for service delivery, for patients and for visitors. During the observation process, notes were made on the lifts that were used. The observations of what type of lift was used relate to the best route to travel to increase efficiency and identify possible sites of contamination of X-ray equipment such as the mobile X-ray machine or IR. A visual representation of the most frequently visited wards is presented in Figure 4.5.

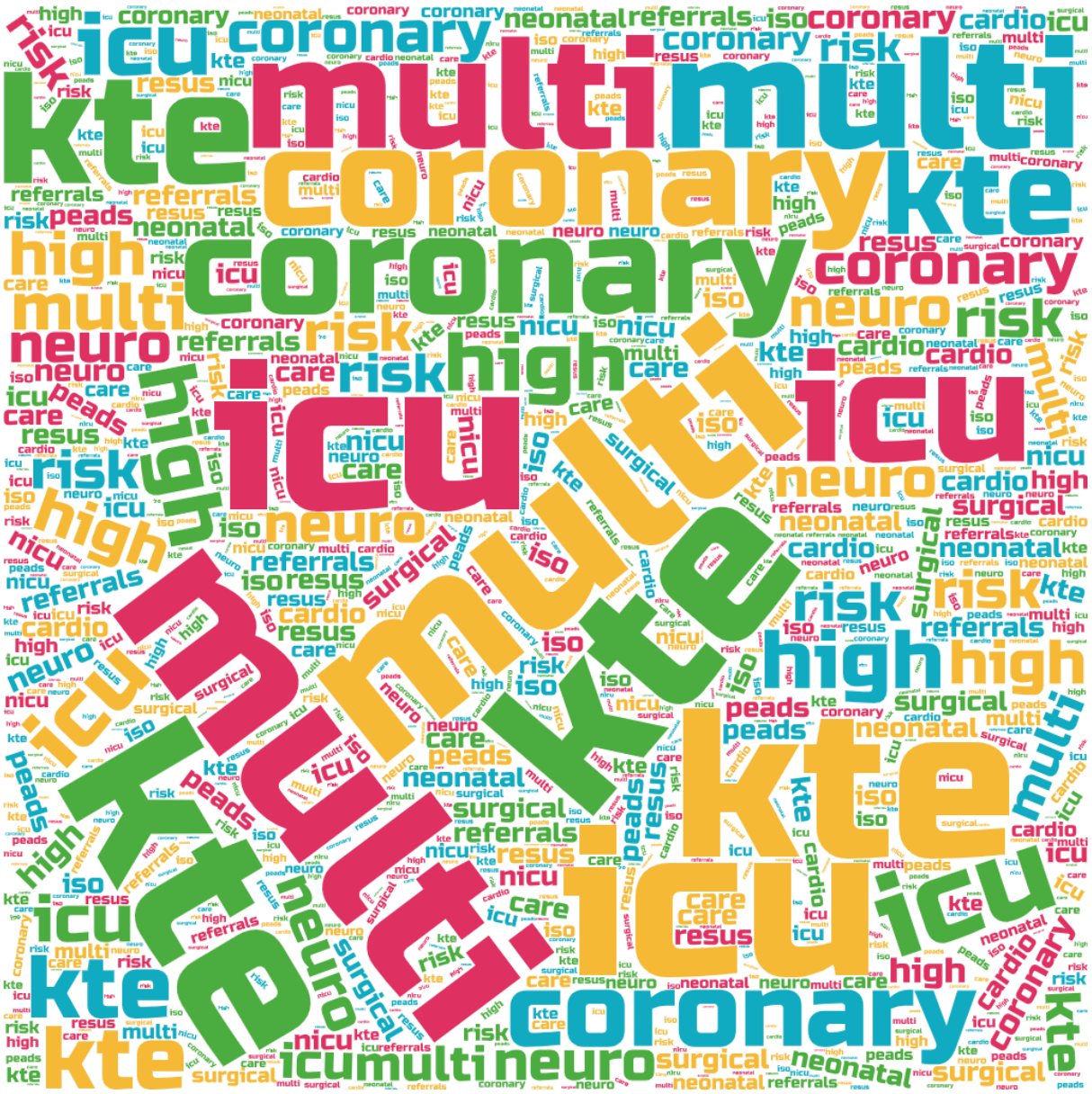

Figure 4.5: Word cloud: Room frequencies

The new digital X-ray machine was also used in the maternity ward, the NICU and the paediatric ICU. The study was designed to follow the identified 35 × 43 cm IRs. The NICU and paediatric ICU, specifically, pose higher risks to the patients who are admitted to these wards. Neonatal and paediatric patients have lower or almost no immune system support. Thus, if infection control standards are not upheld, neonatal and paediatric patients would be even more susceptible to infections and cross-contamination (Ehrlich and Coakes, 2017).

With the conventional mobile machine, the same IR was not necessarily used for different patients in succession. With the digital X-ray machine, the digital detector is used in succession and cross-contamination risks could possibly increase if infection control is not practiced (Levin et al., 2009). However, the specific digital X-ray machine that was used in this study was promoted on its brochure as having an antimicrobial layer with less than 2 CFU/mL (Siemens, n.d.). The data suggest that the antimicrobial layer is effective.

The digital mobile X-ray machine is a very quick system in terms of time that is saved by not having to process, as with a conventional mobile X-ray machine and the IRs used. However, for the digital mobile X-ray machine, it would be preferable to have several digital radiography system machines. If a hospital was financially capable of having a few of the systems to keep in the high-risk wards, for example the NICU, paediatric ICU and multidisciplinary unit. This was done previously with the CR system: The mobile unit was left on the floor and only the IRs were taken to the preferred ward. However, the IRs travelled constantly from the department and the wards. With the digital radiography system, this is not necessary and only a network cable and point are needed to send images to the picture archiving and communications system.

4.4.3 Microbiological findings in relation to the gold standard for infection control

Bacteria are present on/in any natural and/or man-made item. Due to the nature of bacteria, they multiply and spread. It is also true that the spread of bacteria can be prevented or limited/inhibited through various methods of infection control, or even treatment options, when a human host is involved (colonised). However, some natural items and man-made items have antibacterial or antimicrobial properties. Thus, the study of microbiology can be linked to many items in but not limited to a hospital setting. To determine what types of bacteria are present on an item, the bacteria need to be provided with a source of nutrients to grow, and an adequate environment (Ehrlich and Coakes, 2017).

Firstly, the microbiological screening aimed to determine total microbial load as total viable count and total yeast and mould using rich medium, plate count agar or

selective media, Rose bengal chloramphenicol, respectively. Secondly, specific groups, genera or species of interest were selectively enumerated using specialised media, as outlined in Table 3.2.

The gold standard of infection control was compared to any possible action that identified a link to specific bacteria in Table 3.2. Working with the gold standard consistently throughout the reporting process created a clear understanding of where improvements can be made and what risks can be associated with a specific or group of infection control actions.

4.4.3.1 Bacteria associated with mechanism of travel

During the travel, with each action associated with the gold standard for infection control, there is always an association between the type of action that could relate to different bacteria. Carrying the IR by hand (n = 16) resulted in a 64% association with presumptive *Staphylococcus aureus* (n = 25 contamination events), transportation via the IR holder (n = 6) in a 24% association; the lowest percentage for contamination was carrying the IR against the body (n = 3), at 12% (see Figure 4.6). No other multiple mechanisms of travel were associated with bacteria other that *Staphylococcus aureus*.

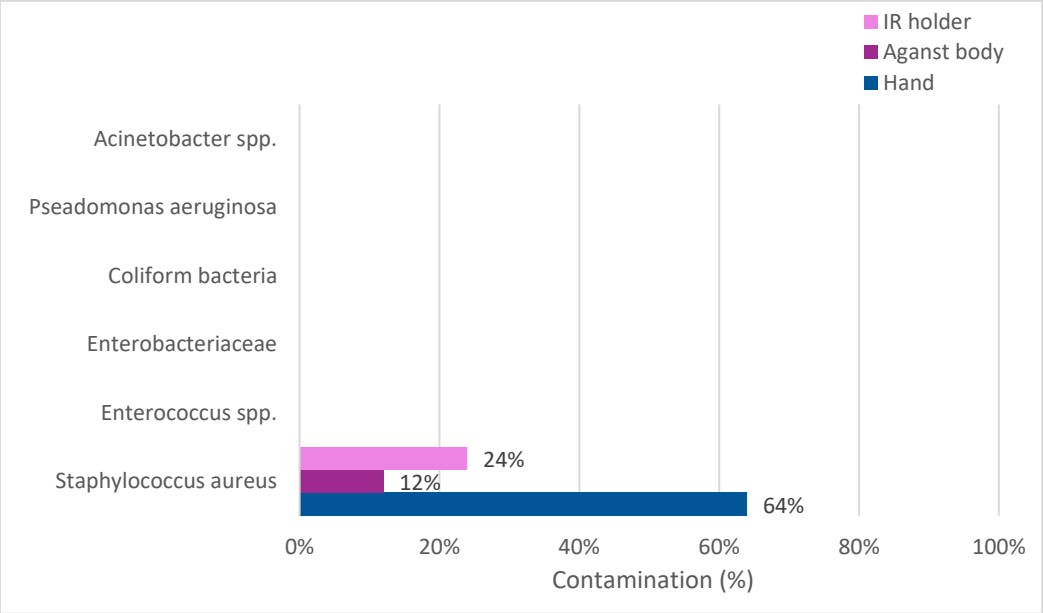

Figure 4.6: Mechanism of travel vs bacterial contamination

The data indicate that, although other methods, such as using the IR holder (20,9% for radiographers and 12.9% for student radiographers) posed a risk, it was lower than carrying the IR by hand in (see Figure 4.1) (23.3% for radiographers and 14.1% for student radiographers). Disinfecting and washing hands is highly recommended. Hand washing should be performed regularly, as often as possible.

4.4.3.2 Bacteria associated with hand hygiene

Hand hygiene always has a risk associated with cross-contamination and has been, on many occasions, been identified as a first line of defence. Hand sanitiser post patient contact was identified as increasing the risk of cross-contamination (n = 14 trips), by 42.9%, possibly with presumptive *Staphylococcus* aureus (n = 6 cases out of 14 trips) (see Figure 4.7). Hand washing post patient contact (n = 2 cases), as well as hand sanitiser pre-patient contact (n = 2 cases), by 14.3% each for *Staphylococcus* aureus. Hand washing pre-patient contact (n = 4 cases) had a 28.6% association. No other bacteria were associated with various actions.

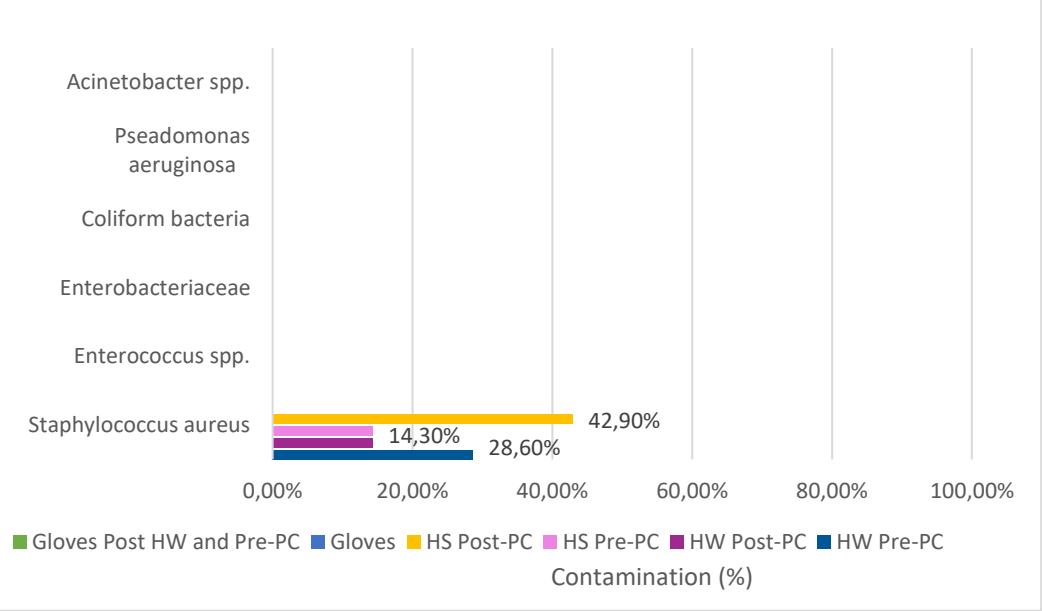

Figure 4.7: Hand hygiene vs bacteria contamination

This graph only indicates association and not causation, thus we cannot claim that the actions did not cause cross-contamination. However, an association between the hand hygiene actions and the presence of *Staphylococcus* aureus can be identified. There was no association between multiple combined hand hygiene

actions and other bacteria. The identification of the high percentages associated with hand sanitiser use post-patient contact could be the result of cross-contamination in cases where the IR or digital detector were not disinfected.

4.4.3.3 Bacteria associated with imaging receptor cover

The actions associated with covering the IR were not properly executed, at minimum. A plastic bag was used twice and a pillowcase was used once. This leads to a conclusion that it is statistically not relevant to relate any bacterial contamination to this action. The other way of investigating it and analysing what could be true is noting whether, if plastic bags or any form of a cover was used, a decrease in any IRs being contaminated was possible.

4.4.3.4 Bacteria associated with imaging receptor cleaning

There were no bacteria associated with IR cleaning, either pre-patient contact, post-patient contact or in the department. However, this cleaning is not to be confused with disinfecting of the IRs or digital detector at the start of each sampling session because these actions are associated with the participants. Thus, it could be concluded that any form of IR cleaning could, at a minimum, limit cross-contamination. IR cleaning, much like hand hygiene, should be routine and form part of every X-ray examination.

4.4.4 Disinfectants

Using disinfectants within the hospital setting is important, because it assists in decreasing the spread and cross-contamination of items used when working with patients (hand washing included). Prepared A 70% ethanol disinfectant that was made in the laboratory was used to disinfect the IRs before every sampling day commenced; however, several other types of disinfectants are used in the hospital, one of which is Steriscrub, which was observed in a bottle in a ward. The ethanol disinfectant that was made in the laboratory was able to disinfect the IRs and digital detector, as indicated by testing the microbial load, which showed that a zero microbial load could be achieved (see Appendix F). The three wards that were most visited were the multidisciplinary ICU, cardiothoracic unit or the cardio-thoracic unit and ICU Private. Individuals within the hospital have preferences for disinfectant

solutions. Some of the disinfectant solutions include chlorine, which can be abrasive and pose a risk to the pulmonary system if it is inhaled (Fontana et al., 2025).

4.5 SUMMARY

During the analysis of the data, it was found that infection control is not a priority for radiographers or student radiographers. Hand hygiene mostly had higher preference rates as a method of infection control, which is noteworthy

When the new digital X-ray machine with the antimicrobial layer was introduced, the study was changed; it is likely that antimicrobial layers will be the way forward and this possibility had to be investigated. In this study, no bacteria were detected at the end of a sampling day in which the digital X-ray machine was used, in comparison to the IRs, for which the participants had to take more care with cleaning and be aware of the placement of the IRs when travelling.

The infection control practices in the department or on mobile X-ray examinations were not consistently applied, even though the Department of Health, Free State, as well as the researcher, have developed adequate infection control protocols. Covers for the IRs were used only twice throughout 86 trips. By failing to cover an IR, there will be a form of contact in a patient's immediate area or bed. Any contact with a contaminated IR could lead to cross-contamination (Russotto et al., 2015; Wainwright, 2015). IRs move around frequently throughout the hospital for mobile radiography and the likelihood of exposure occurring is high, even if the participant takes along an extra IR to avoid walking back to the department when an extra mobile X-ray is requested.

As with each study, there are always new avenues to investigate and findings to refine. Recommendations can be made to create a gateway for further research, based on the findings of the current study. Lastly, it is advantageous to combine the two disciplines of radiography and microbiology to create an understanding about where infection control can be improved upon in the field of radiography.

CHAPTER 5
CONCLUSION

5.1 INTRODUCTION

Infection control is an integral part of protecting patients and staff against any possible infections. Nosocomial infections are infections that are acquired within the hospital and have the capability to cause severe harm to the patient – even death (Brito et al., 2010). Radiographers travel throughout the hospital while taking mobile X-ray examinations, thus an increased possible risk could be associated with patient contact, travel and inadequate infection control practices.

Every time a mobile X-ray examination is performed, and infection control protocols are not applied, either because of a shortage of cleaning items or a failure to practice infection control, the risk of cross-contamination rises. Cross-contamination is not the only reason for concern; however, it is the main motivation behind infection control. If the spread of bacteria can be inhibited or decreased the outcomes for patients will be improved.

In this study it was noted that none of the basic identified infection control measures were adhered to at a significant statistical level. The Chi square test was performed for mechanisms of travel, and trips. Microbial loads were associated with some of the IR routes and actions taken; however, when the digital mobile X-ray machine was introduced in 2023, the microbial loads decreased to 0. This finding suggests that there is a possibility that the antimicrobial layer of the digital machine was effective. The antimicrobial layer on the machine did, in fact, cause no microbial growth to be found on the digital detector.

5.2 LIMITATIONS

During the course of the study, several limitations came to the fore. Limitations can be used to improve a replication of the study or to determine a new avenue for a future study. The practical implications of failing to apply the gold standard or other

infection control practices may lead to nosocomial infections. Patients who can be affected include immune-compromised patients or patients with open wounds.

For an observational study, observer bias could be a factor. Observer bias could lead to the researcher expecting certain behaviour from participants and believing they did act in a certain way, though they did not necessarily see the action take place. This could lead to skewed data.

The relationship between the researcher and the participants who were observed played a role in behaviours. The researcher–participant relationship needs to be taken into account because the behaviour of the infection control process participant could change according to the perceived role of the researcher.

The COVID-19 pandemic had considerable implications for the progress of the study timeline. After the first round of sampling was completed, the pandemic broke out and sampling was put on hold for two years because the researcher was not permitted to enter the wards. Lastly, when the final sampling sessions were due to start, a new digital mobile X-ray machine was introduced. The sampling had to be checked to ensure that if it would work with this new machine, which also contributed to delaying the completion of the study.

5.3 RECOMMENDATIONS

Hand washing and overall hand hygiene should be performed with hospital-grade soaps and sanitisers. The disinfectants should also be allocated to cleaning equipment such as IRs and digital detectors. The availability of and proximity of disinfectants to the area where the disinfection/cleaning will be taking place will make it easier for radiographers to perform the tasks of cleaning and practicing hand hygiene.

Disinfection and cleaning forms a big part of preventing the spread of nosocomial pathogens and, unless the correct items to adequately disinfect and clean equipment are provided, staff disengage from infection control practices. Having access to disinfection and cleaning products enforces infection control practices and habits could be maintained and practiced correctly. For a ‘re-introduction’ of disinfectants and cleaning supplies, after a prolonged period of shortages, staff may

have to be instructed to change their behaviours back to a regular routine of infection control.

IR covers are very important and create a physical barrier between the patient and the IR. Physical barriers that are easy to use should be provided to radiographers. Training could be provided on the advantages of this method of infection control to decrease cross-contamination.

Further studies could be designed to investigate the antimicrobial layer. The manufacturers' guide mentions no specific material that the antimicrobial layer was created out of, however this could also be investigated. This barrier could play an important role in infection control in radiography and mobile radiography.

5.4 RESEARCH QUESTIONS AND OUTCOMES

In this study, the infection control protocols were not adhered to; participants failed to ensure that they washed their hands before and after patient contact, they did not regularly make use of hand sanitisers or wear gloves when a situation presented itself to do so, especially in ICU cases. Cleaning and covering IRs were also not frequently practiced, or barely at all, as far as covering the IR was concerned. The main purpose of an infection control protocol is to truly limit cross-contamination. The new digital machine with its antimicrobial layer on the digital detector proved to be effective in inhibiting bacterial spread from the digital detector itself (see Section 4.4).

Subsidiary questions, such as, what was the movement of an IR within the hospital during an identified day, could be answered with the observational notes. A full day is described in Section 4.4.2.1. Data on the final microbial loads are attached in Appendix F. The microbial loads for the IRs were prevalent. Except for an error with contaminated saline, the microbial loads of the digital detector were 0 CFU/mL. The antimicrobial testing was not performed for ESKAPE group pathogens because the first set of antibiotics had expired, and when the second set of antibiotics was ordered they arrived too late for replica plating and, finally, the last set of samples of the antibiotics expired again, thus, the tests were not performed.

5.5 CONCLUSION

Mobile radiography is an excellent and efficient method of assisting patients who are unable to visit the department for radiographs. Conventional mobile radiography with IRs showed colonisation with bacteria, while the digital mobile X-ray machine showed no colonisation. The brochure for the digital mobile machine indicates that, if colonisation occurred, it would be limited to 2 CFU/mL; the researcher noted none, regardless of any other IC measures taken.

Regardless of the routes or number of trips taken, the IRs showed colonisation if no form of infection control or cleaning were practiced. It was on rare to no occasions that no colonisation was identified, which posed a risk for patients and radiographers. Radiographers' knowledge of infection control should be revised consistently by means of continuous professional development, in-service training at their hospitals or revision of infection control protocols in the department and hospital. If at all possible, digital mobile X-ray machines with antimicrobial layers should be considered, though it should never replace general infection control.

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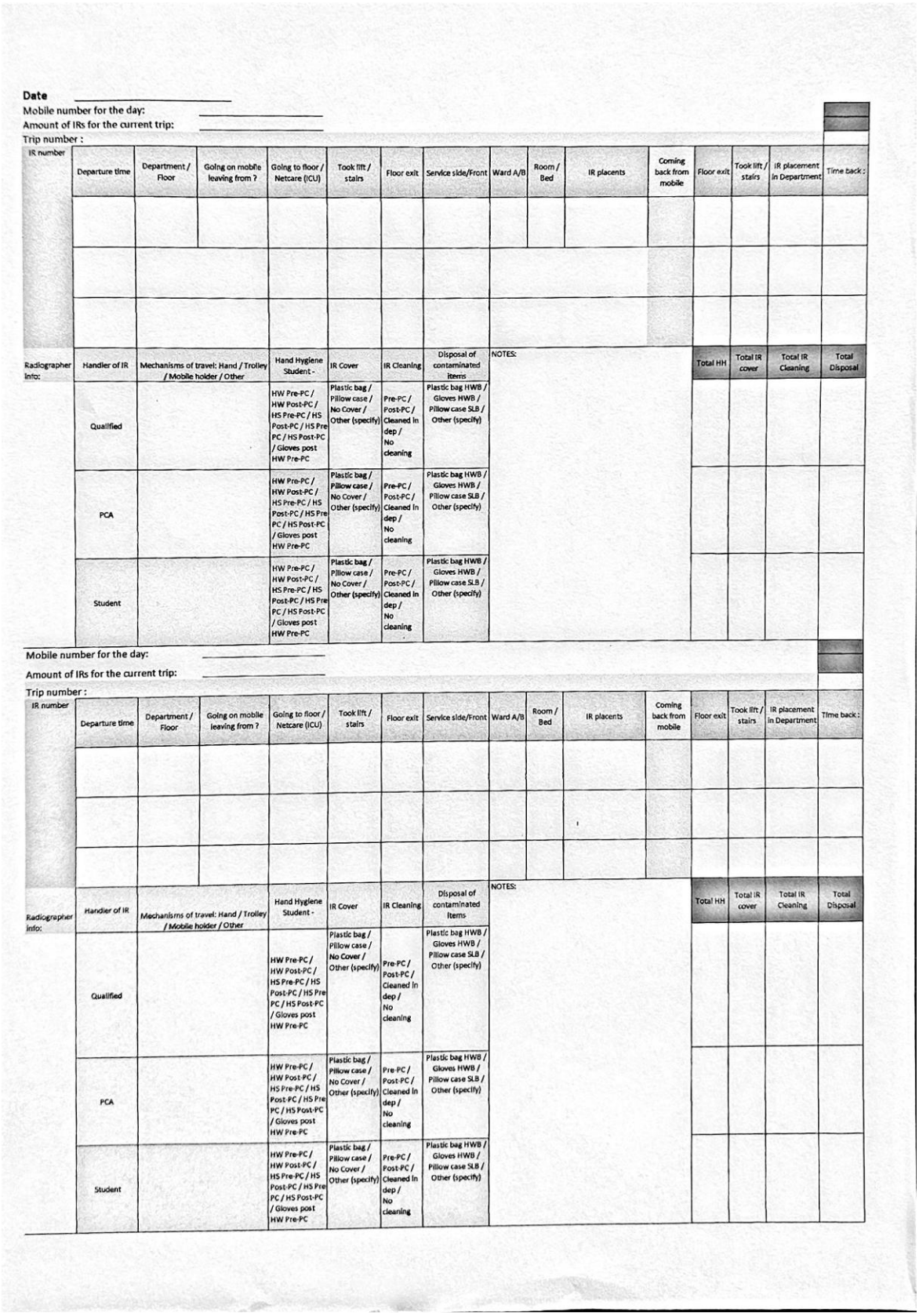
APPENDIX A: OBSERVATIONAL CHECKLIST



Date _____

Mobile number for the day: _____

Amount of IRs for the current trip: _____

Trip number :

IR number	Departure time	Department / Floor	Going on mobile leaving from ?	Going to floor / Netcare (ICU)	Took lift / stairs	Floor exit	Service side/Front	Ward A/B	Room / Bed	IR placents	Coming back from mobile	Floor exit	Took lift / stairs	IR placement in Department	Time back :

Radiographer info:	Handler of IR	Mechanisms of travel: Hand / Trolley / Mobile holder / Other	Hand Hygiene Student -	IR Cover	IR Cleaning	Disposal of contaminated items	NOTES:	Total HH	Total IR cover	Total IR Cleaning	Total Disposal
	Qualified		HW Pre-PC / HW Post-PC / HS Pre-PC / HS Post-PC / HS Pre PC / HS Post-PC / Gloves post HW Pre-PC	Plastic bag / Pillow case / No Cover / Other (specify)	Pre-PC / Post-PC / Cleaned in dep / No cleaning	Plastic bag HWB / Gloves HWB / Pillow case SLB / Other (specify)					
	PCA		HW Pre-PC / HW Post-PC / HS Pre-PC / HS Post-PC / HS Pre PC / HS Post-PC / Gloves post HW Pre-PC	Plastic bag / Pillow case / No Cover / Other (specify)	Pre-PC / Post-PC / Cleaned in dep / No cleaning	Plastic bag HWB / Gloves HWB / Pillow case SLB / Other (specify)					
	Student		HW Pre-PC / HW Post-PC / HS Pre-PC / HS Post-PC / HS Pre PC / HS Post-PC / Gloves post HW Pre-PC	Plastic bag / Pillow case / No Cover / Other (specify)	Pre-PC / Post-PC / Cleaned in dep / No cleaning	Plastic bag HWB / Gloves HWB / Pillow case SLB / Other (specify)					

Mobile number for the day: _____

Amount of IRs for the current trip: _____

Trip number :

IR number	Departure time	Department / Floor	Going on mobile leaving from ?	Going to floor / Netcare (ICU)	Took lift / stairs	Floor exit	Service side/Front	Ward A/B	Room / Bed	IR placents	Coming back from mobile	Floor exit	Took lift / stairs	IR placement in Department	Time back :

Radiographer info:	Handler of IR	Mechanisms of travel: Hand / Trolley / Mobile holder / Other	Hand Hygiene Student -	IR Cover	IR Cleaning	Disposal of contaminated Items	NOTES:	Total HH	Total IR cover	Total IR Cleaning	Total Disposal
	Qualified		HW Pre-PC / HW Post-PC / HS Pre-PC / HS Post-PC / HS Pre PC / HS Post-PC / Gloves post HW Pre-PC	Plastic bag / Pillow case / No Cover / Other (specify)	Pre-PC / Post-PC / Cleaned in dep / No cleaning	Plastic bag HWB / Gloves HWB / Pillow case SLB / Other (specify)					
	PCA		HW Pre-PC / HW Post-PC / HS Pre-PC / HS Post-PC / HS Pre PC / HS Post-PC / Gloves post HW Pre-PC	Plastic bag / Pillow case / No Cover / Other (specify)	Pre-PC / Post-PC / Cleaned in dep / No cleaning	Plastic bag HWB / Gloves HWB / Pillow case SLB / Other (specify)					
	Student		HW Pre-PC / HW Post-PC / HS Pre-PC / HS Post-PC / HS Pre PC / HS Post-PC / Gloves post HW Pre-PC	Plastic bag / Pillow case / No Cover / Other (specify)	Pre-PC / Post-PC / Cleaned in dep / No cleaning	Plastic bag HWB / Gloves HWB / Pillow case SLB / Other (specify)					

Central University of Technology, Free State

Date 25.07.19.
Mobile number for the day:
Amount of IRs for the current trip: 4 — 2 (Big) + 2 (small)
Trip number :

IR number	Departure time	Department / Floor	Going on mobile leaving from department	Going to floor / Netcare (ICU)	Took lift / stairs	Floor exit	Service side/Front	Ward A/B	Room / Bed	IR placents	Coming back from mobile	Floor exit	Took lift / stairs	IR placement in Department	Time back in Department:
8	10:05	D⁶		2 / 2	L / L	10 / 2	SS / SS	B				3	L	left on prep	10:38

Radiographer info:	Handler of IR	Mechanisms of travel: Hand / Trolley / Mobile holder / Other	Hand Hygiene Student -	IR Cover	IR Cleaning	Disposal of contaminated items	NOTES:	Total HH	Total IR cover	Total IR Cleaning	Total Disposal
Qualified	Q	Hand / Body IR holder in mobile PCA with Q; Q carry back	HW Pre-PC / HW Post-PC / HS Pre-PC / HS Post-PC / HS Pre-PC / HS Post-PC / Gloves post HW Pre-PC	Plastic bag / Pillow case / No Cover / Other (specify)	Pre-PC / Post-PC / Cleaned in dep / No cleaning — N	Plastic bag HWB / Gloves HWB / Pillow case SLB / Other (specify) — n/a	Went to 10th floor first. IRs placed on floor. Going back to 2nd floor. At Holding. Placed in IR holder on 2nd floor. Back to 10th floor. 2x small IRs placed against Big IRs. Pt skin against IR. Sticker placed on IR. IR placed on table by computer	none	no cover	none	none / n/a
Student	PCA	HW Pre-PC / HW Post-PC / HS Pre-PC / HS Post-PC / HS Pre-PC / HS Post-PC / Gloves post HW Pre-PC	Plastic bag / Pillow case / No Cover / Other (specify)	Pre-PC / Post-PC / Cleaned in dep / No cleaning	Plastic bag HWB / Gloves HWB / Pillow case SLB / Other (specify)						

Coronary (2) [redacted]

Add more rows ←

1st line

Trip number :

IR number	Departure time	Department / Floor	Going on mobile leaving from department	Going to floor / Netcare (ICU)	Took lift / stairs	Floor exit	Service side/Front	Ward A/B	Room / Bed	IR placents	Coming back from mobile	Floor exit	Took lift / stairs	IR placement in Department	Time back in Department:
10	10:05	D⁶	2 / 10	2 / 2	L / L	10 / 2	SS / SS								

Radiographer info:	Handler of IR	Mechanisms of travel: Hand / Trolley / Mobile holder / Other	Hand Hygiene Student -	IR Cover	IR Cleaning	Disposal of contaminated items	NOTES:	Total HH	Total IR cover	Total IR Cleaning	Total Disposal
Qualified	Q	Hand / Body IR holder in mobile PCA with Q	HW Pre-PC / HW Post-PC / HS Pre-PC / HS Post-PC / HS Pre-PC / HS Post-PC / Gloves post HW Pre-PC	Plastic bag / Pillow case / No Cover / Other (specify)	Pre-PC / Post-PC / Cleaned in dep / No cleaning	Plastic bag HWB / Gloves HWB / Pillow case SLB / Other (specify)	Went to 10th floor. IR placed on floor. Going back to 2nd floor, placed in IR holder on 2nd floor. Back to 10th floor. 2x small IR placed against big IR. No exposure → IR left in IR holder for later.	Travelled by IR holder			
Student	X	HW Pre-PC / HW Post-PC / HS Pre-PC / HS Post-PC / HS Pre-PC / HS Post-PC / Gloves post HW Pre-PC	Plastic bag / Pillow case / No Cover / Other (specify)	Pre-PC / Post-PC / Cleaned in dep / No cleaning	Plastic bag HWB / Gloves HWB / Pillow case SLB / Other (specify)						

Coronary (2) [redacted]

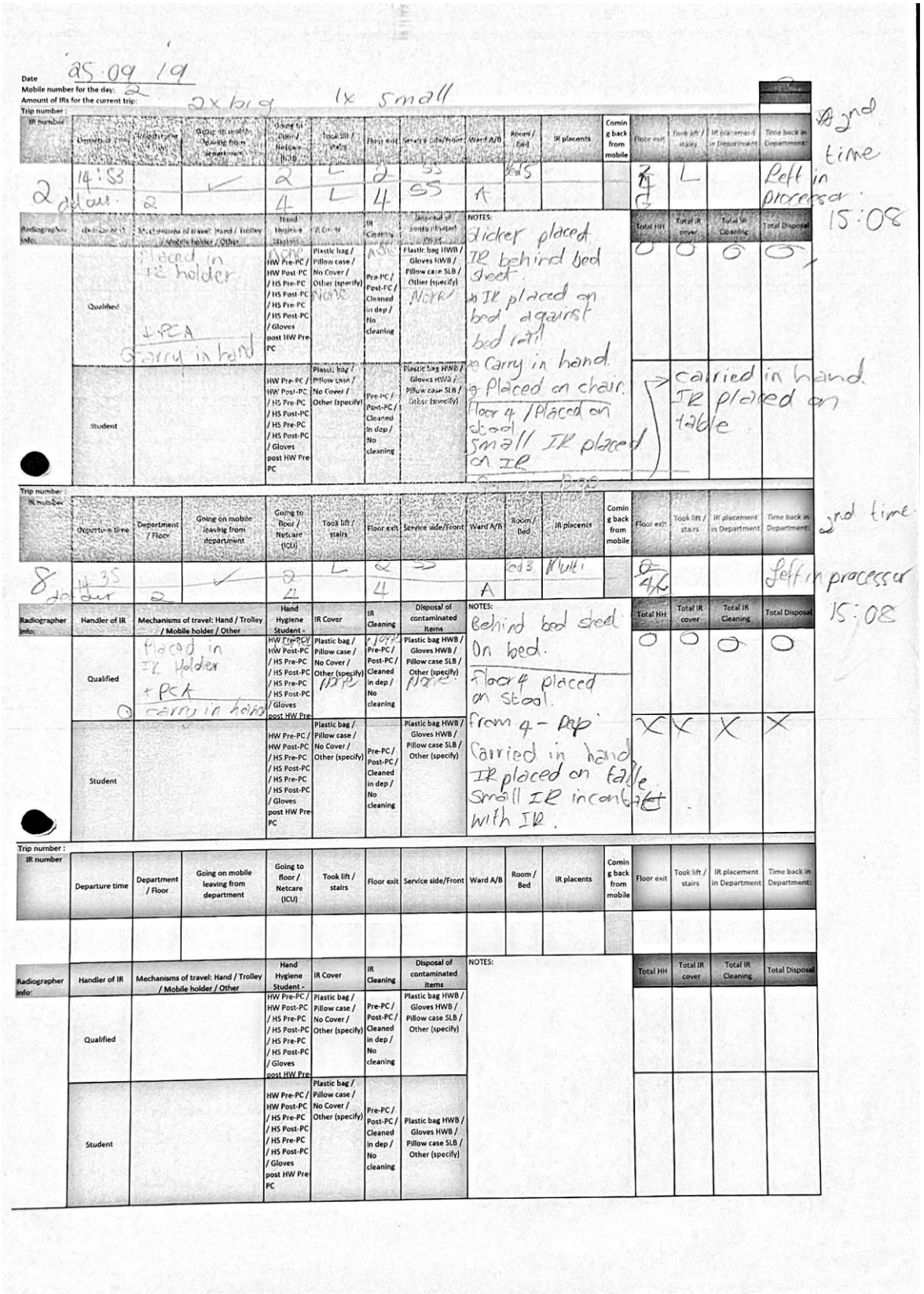
Back to dep without being exposed

Stop

Trip number :

IR number	Departure time	Department / Floor	Going on mobile leaving from department	Going to floor / Netcare (ICU)	Took lift / stairs	Floor exit	Service side/Front	Ward A/B	Room / Bed	IR placents	Coming back from mobile	Floor exit	Took lift / stairs	IR placement in Department	Time back in Department:
2	used	~~in dep~~	did	not	follow	→					to	Netcare			

Radiographer info:	Handler of IR	Mechanisms of travel: Hand / Trolley / Mobile holder / Other	Hand Hygiene Student -	IR Cover	IR Cleaning	Disposal of contaminated items	NOTES:	Total HH	Total IR cover	Total IR Cleaning	Total Disposal
Qualified			HW Pre-PC / HW Post-PC / HS Pre-PC / HS Post-PC / HS Pre-PC / HS Post-PC / Gloves post HW Pre-PC	Plastic bag / Pillow case / No Cover / Other (specify)	Pre-PC / Post-PC / Cleaned in dep / No cleaning	Plastic bag HWB / Gloves HWB / Pillow case SLB / Other (specify)					
Student			HW Pre-PC / HW Post-PC / HS Pre-PC / HS Post-PC / HS Pre-PC / HS Post-PC / Gloves post HW Pre-PC	Plastic bag / Pillow case / No Cover / Other (specify)	Pre-PC / Post-PC / Cleaned in dep / No cleaning	Plastic bag HWB / Gloves HWB / Pillow case SLB / Other (specify)					



Date 25.09.19
Mobile number for the day: 2
Amount of IRs for the current trip: 2x big 1x small
Trip number :

IR number	Departure time	Department / Floor	Going on mobile leaving from department	Going to floor / Netcare (ICU)	Took lift / stairs	Floor exit	Service side/Front	Ward A/B	Room / Bed	IR placents	Coming back from mobile	Floor exit	Took lift / stairs	IR placement in Department	Time back in Department:
2	14:33	2	✓	2 4	L L	2 4	SS SS	A	Beds			2 4	L		Left in processor 15:08

Radiographer info:	Handler of IR	Mechanisms of travel: Hand / Trolley / Mobile holder / Other	Hand Hygiene Student -	IR Cover	IR Cleaning	Disposal of contaminated items	NOTES:	Total HH	Total IR cover	Total IR Cleaning	Total Disposal
	Qualified	Placed in IR holder + PCA Carry in hand	HW Pre-PC / HW Post-PC / HS Pre-PC / HS Post-PC / HS Pre-PC / HS Post-PC / Gloves post HW Pre-PC	Plastic bag / Pillow case / No Cover / Other (specify) None	Pre-PC / Post-PC / Cleaned in dep / No cleaning	Plastic bag HWB / Gloves HWB / Pillow case SLB / Other (specify) None	Sticker placed IR behind bed sheet. IR placed on bed against bed rail. Carry in hand. Placed on chair. Floor 4 / Placed on stool Small IR placed on IR bag	0	0	0	0
	Student		HW Pre-PC / HW Post-PC / HS Pre-PC / HS Post-PC / HS Pre-PC / HS Post-PC / Gloves post HW Pre-PC	Plastic bag / Pillow case / No Cover / Other (specify)	Pre-PC / Post-PC / Cleaned in dep / No cleaning	Plastic bag HWB / Gloves HWB / Pillow case SLB / Other (specify)	→ carried in hand IR placed on table				

Trip number :

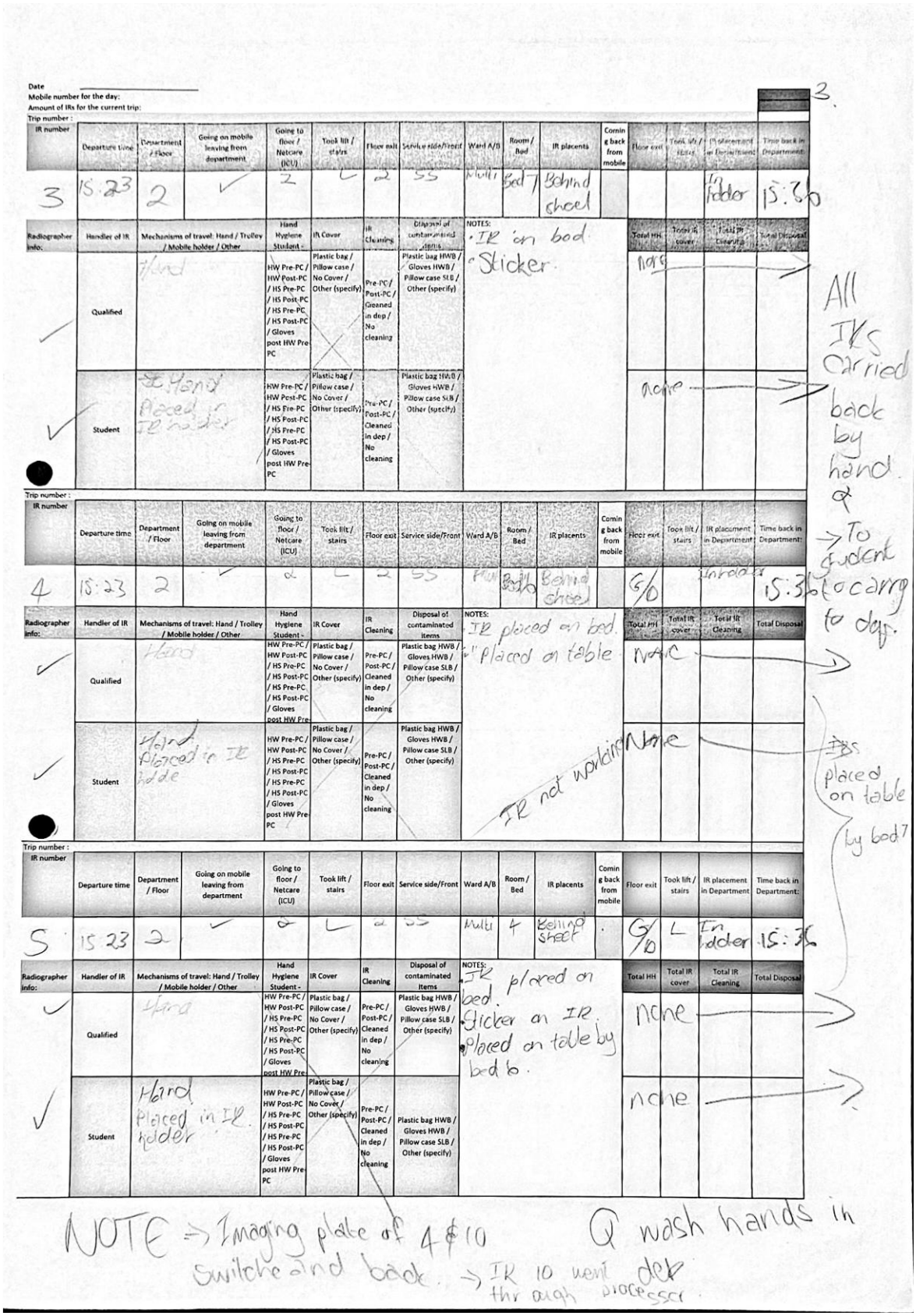
IR number	Departure time	Department / Floor	Going on mobile leaving from department	Going to floor / Netcare (ICU)	Took lift / stairs	Floor exit	Service side/Front	Ward A/B	Room / Bed	IR placents	Coming back from mobile	Floor exit	Took lift / stairs	IR placement in Department	Time back in Department:
8	14:35	2	✓	2 4	L	2 4	SS	A	Beds	Multi		2 4			Left in processor 15:08

Radiographer info:	Handler of IR	Mechanisms of travel: Hand / Trolley / Mobile holder / Other	Hand Hygiene Student -	IR Cover	IR Cleaning	Disposal of contaminated items	NOTES:	Total HH	Total IR cover	Total IR Cleaning	Total Disposal
	Qualified	Placed in IR Holder + PCA Carry in hand	HW Pre-PC / HW Post-PC / HS Pre-PC / HS Post-PC / HS Pre-PC / HS Post-PC / Gloves post HW Pre-PC	Plastic bag / Pillow case / No Cover / Other (specify) None	Pre-PC / Post-PC / Cleaned in dep / No cleaning	Plastic bag HWB / Gloves HWB / Pillow case SLB / Other (specify) None	Behind bed sheet On bed. Floor 4 placed on stool. From 4 - Dep Carried in hand IR placed on table Small IR in contact with IR.	0	0	0	0
	Student		HW Pre-PC / HW Post-PC / HS Pre-PC / HS Post-PC / HS Pre-PC / HS Post-PC / Gloves post HW Pre-PC	Plastic bag / Pillow case / No Cover / Other (specify)	Pre-PC / Post-PC / Cleaned in dep / No cleaning	Plastic bag HWB / Gloves HWB / Pillow case SLB / Other (specify)		X	X	X	X

Trip number :

IR number	Departure time	Department / Floor	Going on mobile leaving from department	Going to floor / Netcare (ICU)	Took lift / stairs	Floor exit	Service side/Front	Ward A/B	Room / Bed	IR placents	Coming back from mobile	Floor exit	Took lift / stairs	IR placement in Department	Time back in Department:

Radiographer info:	Handler of IR	Mechanisms of travel: Hand / Trolley / Mobile holder / Other	Hand Hygiene Student -	IR Cover	IR Cleaning	Disposal of contaminated items	NOTES:	Total HH	Total IR cover	Total IR Cleaning	Total Disposal
	Qualified		HW Pre-PC / HW Post-PC / HS Pre-PC / HS Post-PC / HS Pre-PC / HS Post-PC / Gloves post HW Pre-PC	Plastic bag / Pillow case / No Cover / Other (specify)	Pre-PC / Post-PC / Cleaned in dep / No cleaning	Plastic bag HWB / Gloves HWB / Pillow case SLB / Other (specify)					
	Student		HW Pre-PC / HW Post-PC / HS Pre-PC / HS Post-PC / HS Pre-PC / HS Post-PC / Gloves post HW Pre-PC	Plastic bag / Pillow case / No Cover / Other (specify)	Pre-PC / Post-PC / Cleaned in dep / No cleaning	Plastic bag HWB / Gloves HWB / Pillow case SLB / Other (specify)					



Date
Mobile number for the day:
Amount of IRs for the current trip:
Trip number :

IR number	Departure time	Department / Floor	Going on mobile leaving from department	Going to floor / Netcare (ICU)	Took lift / stairs	Floor exit	Service side/Front	Ward A/B	Room / Bed	IR placents	Coming back from mobile	Floor exit	Took lift / stairs	IR placement in Department	Time back in Department:
3	15:23	2	✓	2	L	2	SS	Multi	Bed 7	Behind sheet				In ladder	15:30

Radiographer info:	Handler of IR	Mechanisms of travel: Hand / Trolley / Mobile holder / Other	Hand Hygiene Student -	IR Cover	IR Cleaning	Disposal of contaminated items	NOTES:	Total HH	Total IR cover	Total IR Cleaning	Total Disposal
✓	Qualified	Hand	HW Pre-PC / HW Post-PC / HS Pre-PC / HS Post-PC / HS Pre-PC / HS Post-PC / Gloves post HW Pre-PC	Plastic bag / Pillow case / No Cover / Other (specify)	Pre-PC / Post-PC / Cleaned in dep / No cleaning	Plastic bag HWB / Gloves HWB / Pillow case SLB / Other (specify)	• IR on bed • Sticker.	none			
✓ ●	Student	Hand Placed IR in ladder	HW Pre-PC / HW Post-PC / HS Pre-PC / HS Post-PC / HS Pre-PC / HS Post-PC / Gloves post HW Pre-PC	Plastic bag / Pillow case / No Cover / Other (specify)	Pre-PC / Post-PC / Cleaned in dep / No cleaning	Plastic bag HWB / Gloves HWB / Pillow case SLB / Other (specify)		none			

Trip number :

IR number	Departure time	Department / Floor	Going on mobile leaving from department	Going to floor / Netcare (ICU)	Took lift / stairs	Floor exit	Service side/Front	Ward A/B	Room / Bed	IR placents	Coming back from mobile	Floor exit	Took lift / stairs	IR placement in Department	Time back in Department:
4	15:23	2	✓	2	L	2	SS	Multi	Bed 6	Behind sheet		G/D		In ladder	15:30

Radiographer info:	Handler of IR	Mechanisms of travel: Hand / Trolley / Mobile holder / Other	Hand Hygiene Student -	IR Cover	IR Cleaning	Disposal of contaminated items	NOTES:	Total HH	Total IR cover	Total IR Cleaning	Total Disposal
✓	Qualified	Hand	HW Pre-PC / HW Post-PC / HS Pre-PC / HS Post-PC / HS Pre-PC / HS Post-PC / Gloves post HW Pre-	Plastic bag / Pillow case / No Cover / Other (specify)	Pre-PC / Post-PC / Cleaned in dep / No cleaning	Plastic bag HWB / Gloves HWB / Pillow case SLB / Other (specify)	• IR placed on bed. • Placed on table	none			
✓ ●	Student	Hand Placed in IR ladder	HW Pre-PC / HW Post-PC / HS Pre-PC / HS Post-PC / HS Pre-PC / HS Post-PC / Gloves post HW Pre-PC	Plastic bag / Pillow case / No Cover / Other (specify)	Pre-PC / Post-PC / Cleaned in dep / No cleaning	Plastic bag HWB / Gloves HWB / Pillow case SLB / Other (specify)	IR not working	None			

Trip number :

IR number	Departure time	Department / Floor	Going on mobile leaving from department	Going to floor / Netcare (ICU)	Took lift / stairs	Floor exit	Service side/Front	Ward A/B	Room / Bed	IR placents	Coming back from mobile	Floor exit	Took lift / stairs	IR placement in Department	Time back in Department:
5	15:23	2	✓	2	L	2	SS	Multi	4	Behind sheet		G/D	L	In ladder	15:30

Radiographer info:	Handler of IR	Mechanisms of travel: Hand / Trolley / Mobile holder / Other	Hand Hygiene Student -	IR Cover	IR Cleaning	Disposal of contaminated Items	NOTES:	Total HH	Total IR cover	Total IR Cleaning	Total Disposal
✓	Qualified	Hand	HW Pre-PC / HW Post-PC / HS Pre-PC / HS Post-PC / HS Pre-PC / HS Post-PC / Gloves post HW Pre-	Plastic bag / Pillow case / No Cover / Other (specify)	Pre-PC / Post-PC / Cleaned in dep / No cleaning	Plastic bag HWB / Gloves HWB / Pillow case SLB / Other (specify)	• IR placed on bed. • Sticker on IR. • Placed on table by bed 6.	none			
✓	Student	Hand Placed in IR ladder.	HW Pre-PC / HW Post-PC / HS Pre-PC / HS Post-PC / HS Pre-PC / HS Post-PC / Gloves post HW Pre-PC	Plastic bag / Pillow case / No Cover / Other (specify)	Pre-PC / Post-PC / Cleaned in dep / No cleaning	Plastic bag HWB / Gloves HWB / Pillow case SLB / Other (specify)		none			

3.

All IRs carried back by hand & → To student to carry to dep.

~~IRs~~ placed on table by bed 7

NOTE => Imaging plate of 4 & 10 Q wash hands in switch and back. => IR 10 went dek through processor.

APPENDIX B: SAMPLING TRACKING SHEET

Sample tracking sheet

Date: | IR #:

Sampler Name:

Sterilization

Method:

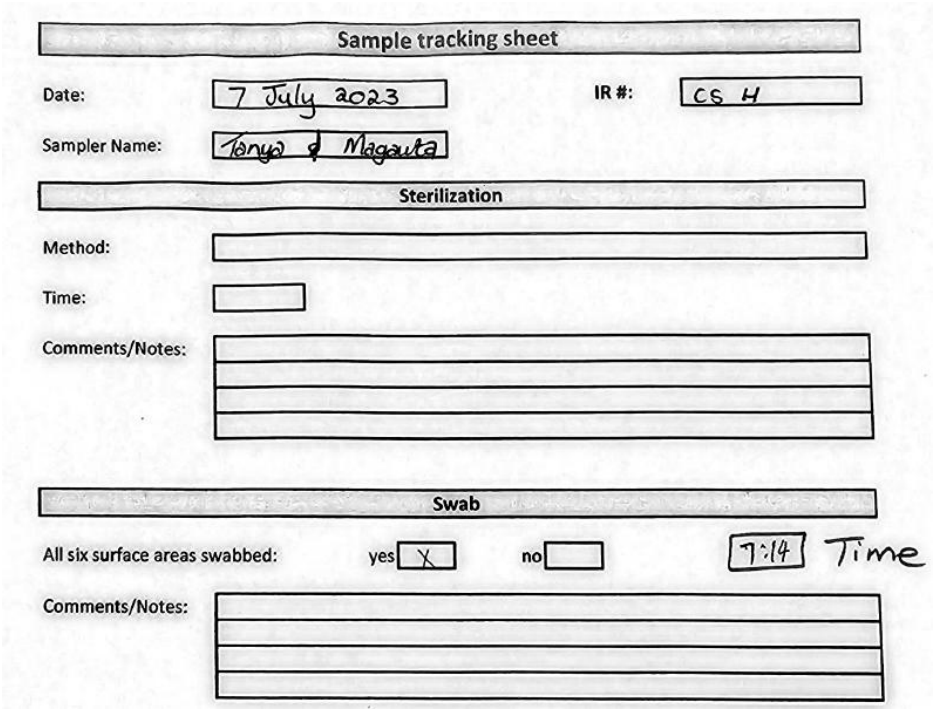
Time:

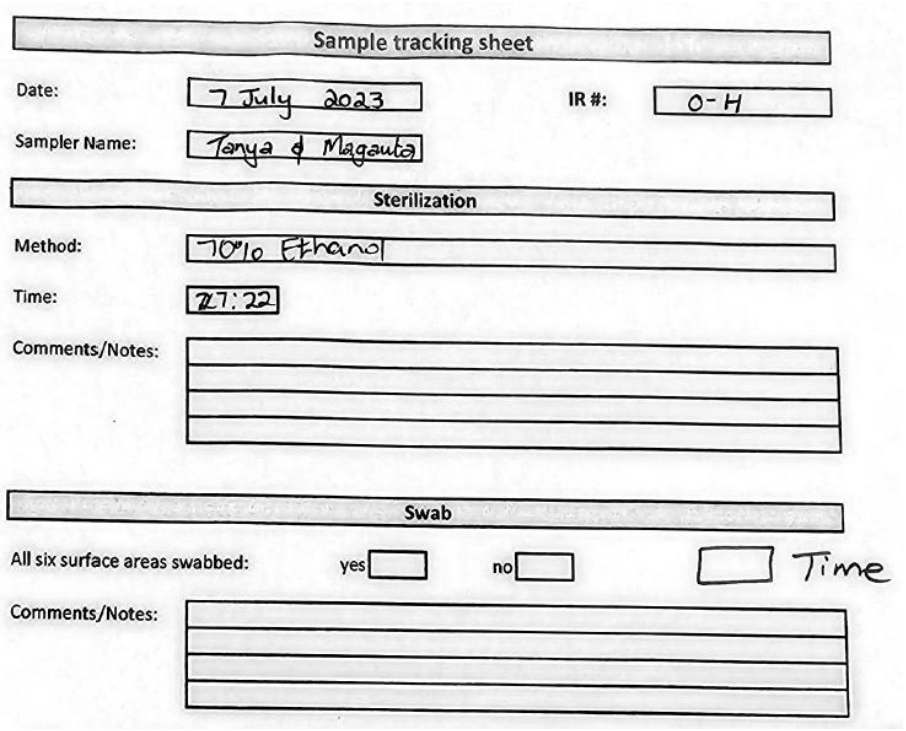
Comments/Notes:

Swab

All six surface areas swabbed: yes no

Comments/Notes:





Sample tracking sheet

Date: 7 July 2023 IR #: 0-H

Sampler Name: Tanya & Magauta

Sterilization

Method: 70% Ethanol

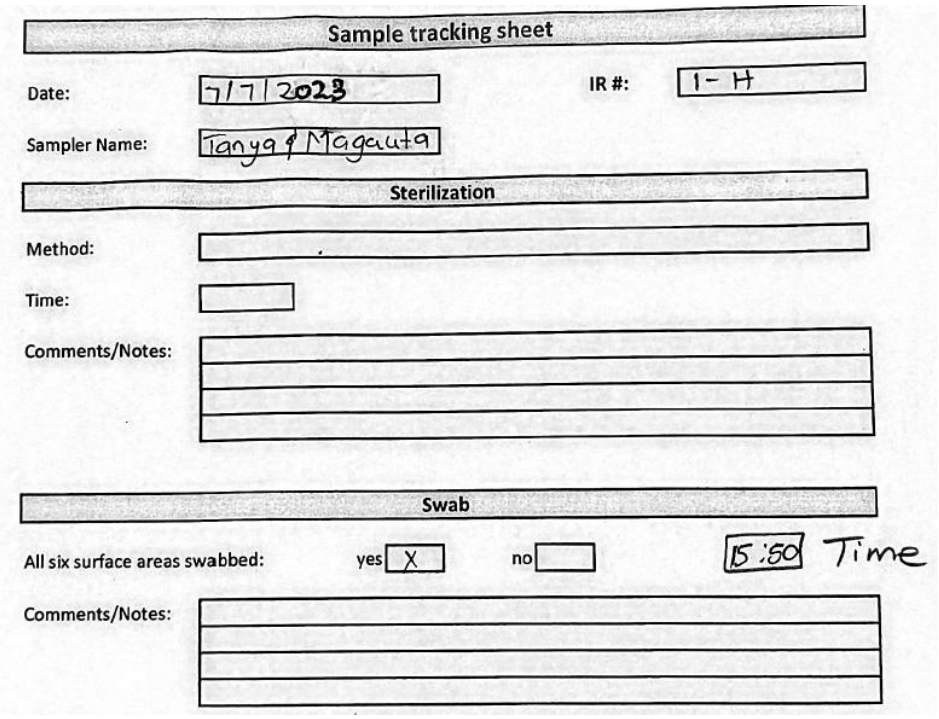
Time: 27:22

Comments/Notes:

Swab

All six surface areas swabbed: yes ☐ no ☐ ☐ Time

Comments/Notes:



Sample tracking sheet

Date: 7/7/2023 IR #: 1-H

Sampler Name: Tanya & Magauta

Sterilization

Method:

Time:

Comments/Notes:

Swab

All six surface areas swabbed: yes X no ☐ 15:50 Time

Comments/Notes:

APPENDIX C: INFORMED CONSENT LETTER FOR PARTICIPATION IN AN OBSERVATIONAL STUDY

Study title: Infection Control Practices And Microbial Load Of Imaging Receptors Used By A Diagnostic Imaging Department At An Academic Hospital.

Thank you for the time spent on the information in this letter, and the pending decision of your participation. This letter is only provided in English, as it is a language commonly understood, and it is also the language of instruction at Central University of Technology, Free State. With this letter the researcher invites you to take part in the observational part of this study.

Information about the study:

The purpose of the study is to observe the route Image Receptors (IR) travel through the Hospital on certain days, thus allowing the researcher to determine a possible pattern of movement for each IR.

The researcher will observe the routes the Imaging Receptors travel throughout the Hospital from 04:30 (when routine rounds for mobiles start), until 16:00 (end of day shift). The participant will continue as normal, and the researcher will only observe and not intervene in any way.

The participation in the observation is voluntary, and the participant may withdraw at any time. Verbal withdrawal is also acceptable. Participation in this study will hold no costs for the participants. Furthermore, there will be no remuneration for participation in this study.

The researcher will answer any and all questions that participants may have with full confidentiality.

The researcher:

Tanya Wainwright

083 254 2232

twainwright@cut.ac.za

The participant:

Name and surname: _____

Contact number: _____

E-mail:_____

Contact details of Secretariat and Chair: Health Science Research Ethics Committee of the Faculty of Health Sciences (HSREC) at the University of the Free State (UFS) - for reporting of complaints/problems: telephone number (051) 405 2812.

Study title: INFECTION CONTROL PRACTICES AND MICROBIAL LOAD OF IMAGING RECEPTORS USED BY A DIAGNOSTIC IMAGING DEPARTMENT AT AN ACADEMIC HOSPITAL.

I (name and surname) _____ agree to participate in the observational part of the study. I fully understand what is expected, and that personal information will be kept private.

_____ _____

Participant's signature Date

_____ _____

Witness's signature Date

_____ _____

Researcher's signature Date

APPENDIX D: LETTER FROM THE DEPARTMENT OF HEALTH, FREE STATE

health
Department of Health
FREE STATE PROVINCE

15 May 2019

Ms. T Wainwright
Dept. of Radiography
CUT

Dear Mrs. T Wainwright

Subject: Investigation of the infection control practice and microbial load of imaging receptors used by a diagnostic imaging department at an Academic Hospital.

- Please ensure that you read the whole document, Permission is hereby granted for the amendment of the above – mentioned research on the following conditions:
- Participation in the study must be voluntary.
- A written consent by each participant must be obtained.
- Serious Adverse events to be reported to the Free State department of health and/ or termination of the study
- Ascertain that your data collection exercise neither interferes with the day to day running of the [redacted] nor the performance of duties by the respondents or health care workers.
- Confidentiality of information will be ensured and please do not obtain information regarding the identity of the participants.
- **Research results and a complete report should be made available to the Free State Department of Health on completion of the study (a hard copy plus a soft copy).**
- Progress report must be presented not later than one year after approval of the project to the Ethics Committee of the University of Free State and to Free State Department of Health.
- Any amendments, extension or other modifications to the protocol or investigators must be submitted to the Ethics Committee of the University of Free State and to Free State Department of Health.
- **Conditions stated in your Ethical Approval letter should be adhered to and a final copy of the Ethics Clearance Certificate should be submitted to** sebeelats@fshealth.gov.za or lithekom@fshealth.gov.za **before you commence with the study**
- No financial liability will be placed on the Free State Department of Health
- Please discuss your study with the institution manager/CEOs on commencement for logistical arrangements
- Department of Health to be fully indemnified from any harm that participants and staff experiences in the study
- Researchers will be required to enter in to a formal agreement with the Free State department of health regulating and formalizing the research relationship (document will follow)
- You are encouraged to present your study findings/results at the Free State Provincial health research day
- Future research will only be granted permission if correct procedures are followed see http://nhrd.hst.org.za

Trust you find the above in order.
Kind Regards

Dr D Motau
HEAD: HEALTH
Date: 14/05/19

APPENDIX E: EXTRACT OF THE DEPARTMENT OF HEALTH FREE STATE, INFECTION PREVENTION AND CONTROL MANUAL

health

Department of Health
FREE STATE PROVINCE

INFECTION PREVENTION AND CONTROL MANUAL

Compiled by : Standard Compliance Sub Directorate

Date: : 25 September 2008

5.1.2 PERSONAL PROTECTIVE EQUIPMENT (PPE) (FS DOH – 16/08/2004)

5.1.2.1 MASK

To protect mucus membranes of the nose and mouth during procedures that might generate splash or spray. A N95 high particulate respirator must be worn by the health care worker if a patient is a suspected or newly diagnosed TB patient or a defaulter until there is significant improvement (no cough & clinical response to treatment and two successive negative AFB smears)

5.1.2.2 EYE PROTECTION

Goggles or face shields/visors must be worn to protect mucus membranes of the eyes during procedures anticipated aerosolization or splashing of blood and/or body fluid, like suctioning, emptying of portovacs, lumber puncture, obstetric and surgical procedures

5.1.2.3 GOWNS / PLASTIC APRONS

To protect skin and soiling of clothing during activities or procedures that could generate splash or spray.

5.1.2.4 GLOVES

When touching or handling blood, secretions, body fluids and contaminated items, linen e.g.

5.4 HANDLING LINEN

Clean and used linen should be handled away from body and clothes to avoid contamination

Soiled linen with blood, body fluids, secretions, and excretions should be handled, transported and processed in a manner that prevents skin and mucous membranes exposures and contamination of clothing, and that avoids transfer of micro-organisms to other patients and environments.

Personnel must wear protective clothing while handling used linen

Used linen should be washed at temperatures according to guidelines

Color coding	**:**	**Bags**
Used linen	:	White canvas bag
Infectious linen	:	Yellow plastic bag
Soiled, wet linen	:	Blue plastic bag

5.6 APPROPRIATE HANDLING OF PATIENT CARE EQUIPMENT

5.6.1 MEDICAL DEVICES/CONSUMABLES

All hospital equipment is either single-use or reusable.

Single-use equipment should not be reused and should be discarded appropriately after use.

All reusable equipment must be decontaminated between patients to reduce the spread of infection via inadequately decontaminated equipment. Decontamination of items should be done according to the Equipment Instructions/manual or Internal policy.

5.6.2 MULTI DOSE VIALS

Avoid porcupine (leaving needles stick into the vial) by reducing the use of multiple dose vials, where used the vial should be discarded two hours after use. Smaller volumes of Saline & Dextrose 50% for example 50mls, 20mls should be used to prevent multi-dose. If multi dose vials must be used, use a closed-system device, (like a Clave) with it to avoid contamination of the contents

PHC Immunisations – according to protocols

5.7 ENVIRONMENTAL CLEANING AND SPILLS MANAGEMENT

Damp cleaning must be used in all areas, including high dusting

An appropriate detergent must be used

Spill management : Cover spill with paper towels

Put on unsterile latex gloves

Wipe spill up with paper towels

Discard paper towels in red plastic bag

Wash area with hypochlorite detergent and let dry

Discard used gloves in medical waste bin and wash hands

Glass spills : Scoop glass up with scoop/cardboard and discard in medical waste container or sharps container

5.8 EQUIPMENT FOR INVASIVE AND NON – INVASIVE PROCEDURES

5.8.1 INVASIVE PROCEDURES

Equipment for invasive procedures must be sterilized with either autoclaving, EO2 gas, Starred or cold sterilization, like Cidex OPA, methods

5.8.2 NON-INVASIVE PROCEDURES

Equipment must be surgically clean before use. If contaminated or visible soiled, first wash with soap and water and then use either pasteurization or with a hypochlorite – detergent at 5000 ppm

5.11.2 INFECTIONS WITH MULTIDRUG RESISTANT ORGANISMS

- Methicillin-resistant *Staphylococcus aureus* (MRSA)
  - Transmission is usually through the hands of health care staff.
  - The following precautions are required for the prevention of spread of epidemic MRSA:
  - Minimize ward transfers of staff and patients,
  - Ensure early detection of cases, especially if they are admitted from another hospital.
  - Screening of high risk patients will ensure early
  - Detection and appropriate precautions can be implemented,
  - isolate infected or colonized patients in a single room, isolation unit or cohorting in a larger ward,
  - Treat patients with MRSA pneumonias with airborne precautions in place,
  - Reinforce hand washing by staff after contact with infected or colonized patients
  - Consider using an antiseptic hand washing agent or alcohol hand-rub or hand gel,
  - Wear gloves when attending to the patient or when handling MRSA contaminated materials,
  - Wear a gown or apron when attending to the patient or when handling contaminated materials,
  - Develop protocols or guidelines for management of patients and staff during an outbreak,
  - Ensure that operating surgeons should not perform surgeries until declared negative for carriage.

❖ Vancomycin-resistant enterococcus (VRE)

- The major route of transmission of VRE within the health care facility is the hands of HCWs following contact with patients with VRE or their immediate environment. Usually this is associated with inadequate hand washing.
- *Infection control measures for VRE*
- Standard precautions with additional contact precautions should be applied.
- *Contact precautions* (See No 13)
- It is essential that all staff, visitors or any other person

entering the patient's room strictly follow standard and contact precautions.

- Daily environmental cleaning is essential.
- Patient must have his/her own patient care items.
- Any item must be disinfected after it is removed from the patient's room prior to being sent to another area in the hospital or being used on another patient.

❖ Multidrug-resistant tuberculosis (MDR-TB & XDR – TB)

Multidrug resistant TB is resistant to any combination of anti-TB drugs that includes Isoniazid and Rifampicin (the two most effective anti-TB drugs).

- TB is usually transmitted by exposure to airborne droplet nuclei produced by people with pulmonary or laryngeal disease, during expiratory efforts such as coughing and sneezing.
- Prolonged, close contact with such patients increases the risk of transmission.
- *Infection control measures for MDR-TB*

- Rapid detection,
- Immediate implementation of infection control precautions for all suspect or proven cases,
- Diagnosis and treatment of TB,
- Transport of patient – patient should wear a surgical mask, appropriate infection control precautions include standard precautions
- Plus additional precautions (airborne precautions).

5.13.3 METHODS OF SURVEILLANCE OF NOSOCOMIAL INFECTIONS:

- Kardex review
- Routine ward visits
- Microbiological data surveillance
- Hospital-wide surveillance
- Targeted surveillance
- Computer-generated surveillance
- Prevalence surveys :
  - Will provide Healthcare associated prevalence rates to individual hospitals
  - All the wards take part, specific time frames, each bed only counted once
  - Been done in three rounds – 9months apart
  - Data collection sheet is used
  - Focus on specific infections : surgical site infections, primary bloodstream infections, pneumonia and urinary tract infections.

MANAGEMENT: OCCUPATIONAL EXPOSURE TO HIV, HBV & HCV.

Please refer to the **GUIDELINES: MANAGEMENT OF OCCUPATIONAL EXPOSURES TO HIV, HBV, HCV AND RECOMMENDATIONS FOR PEP** for full details and for follow-up management.

1. PREVENTION:

1.1 Education and training of all staff at risk

1.2 HCWs to ensure they are vaccinated against Hep.B and immune.

1.3 Universal precautions. Wear goggles or visors - NB. Beware of recapping!!

1.4 HCW to place sharps bin next to him/her before the procedure. Discard sharps IMMEDIATELY. Do not walk around with exposed sharps. Always use the one hand technique when recapping.

1.5 Use only sharp bins for sharps.

1.6 The employer has to ensure that sharp bins are always readily available where required.

1.7 When working with any human material always concentrate, be patient and be careful.

1.8 Get assistance when working with any uncooperative patients.

12. Rinse, wash with running water and / or bleed the exposed area well.

13. Report the incident to the supervisor in the section,

14. Give **STAT OR WITHIN 2 HOURS**: (No Rx is given if HCW is known HIV positive)

    1. AZT (zidovudine) 300mg STAT and then 12 hourly

    2. 3TC (lamivudine) 150mg STAT and then 12 hourly

    3. **Take starter pack or enough** Rx to last until results are available and the final decision is made and / or until the main pharmacy opens.

    4. Get it from the person in charge of the AZT and 3TC – as arranged locally.

    5. **These tablets should ALWAYS be available.**

    6. Do not delay for the sake of a file. A file can be opened afterwards.

Protocol for handling of a patient with suspected of confirmed diagnosis of CCHF.

5.1 Get FED pack and supply equipment to staff nursing the patient.

5.6.1 Contents of FED pack : **For 6 people**

Waterproof long sleeve gowns

Plastic apron

Balaclava caps

N95 Respirator

Gloves – 2 pairs per person

Over shoes

Goggles

Red plastic bags large x 5

Red plastic bags medium x 10

Condemned linen

APPENDIX F: DATASET FOR OBSERVATIONAL NOTES AND MICROBIAL LOADS

Date	Sampling session	IR Unique number	IR number	Trip	Total trips per day	No exposure made	Used 24x30 IR of new machine	Departure time
25/09/2019	**A**	**A8-1**	8	1	5	0	0	10:05:00
25/09/2019		**A10-1**	10	1		1	0	10:05:00
25/09/2019		**A2-1**	2	2		0	0	14:00:00
25/09/2019		**A2-2**	2	3		0	0	14:53:00
25/09/2019		**A8-2**	8	4		0	0	14:53:00
25/09/2019		**A3-1**	3	5		0	0	15:23:00
25/09/2019		**A4-1**	4	5		0	0	15:23:00
25/09/2019		**A5-1**	5	5		0	0	15:23:00

Leaving from?	Going to	Lift	Stairs	Floor exit	Service side	Front	Ward A	Ward B	Room
G	2	1	0	2	1	0	0	1	Cornonary
G	2	1	0	10	1	0		1	0
G	Private P	0	0	G	0	0	0	0	0
G	2	1	0	2	1	0	1	0	MULTI
G	2	1	0	2	1	0	1	0	MULTI
G	2	1	0	2	1	0	1	0	MULTI
G	2	1	0	2	1	0	1	0	MULTI
G	2	1	0	2	1	0	1	0	MULTI

Leaving from?	Going to	Lift	Stairs	Floor exit	Service side	Front	Ward A	Ward B	Room
G	2	1	0	2	1	0	0	1	Cornanary
G	2	1	0	10	1	0		1	0
G	Private P	0	0	G	0	0	0	0	0
G	2	1	0	2	1	0	1	0	MULTI
G	2	1	0	2	1	0	1	0	MULTI
G	2	1	0	2	1	0	1	0	MULTI
G	2	1	0	2	1	0	1	0	MULTI
G	2	1	0	2	1	0	1	0	MULTI

Bed	Possible infection	IR placement	Placed in IR holder	Placed on table	Placed on bed	Placed on floor	Placed on chair	Behind sheet	Behind patient
0	0	3	1	0	0	1	0	0	0
	0	2	1	0	0	1	0	0	0
0	0	0	0	0	0	0	0	0	0
5	0	3	0	1	0	0	1	1	0
3	0	6	1	1	0	1	1	1	0
7	0	2	0	0	1	0	0	1	0
6	0	3	0	1	1	0	0	1	0
4	0	3	0	1	1	0	0	1	0

Behind linen saver/ Other	Skin contact	Sticker placed on IR	Docked IR (New Machine)	Coming back	Floor exit	Lift	Stairs	IR placement in department	Left on processor
0	1	1	0		G	1	0	1	1
0	0	0	0		G	1	0	1	0
0	0	0	0		G	0	0	1	0
0	0	1	0		2	1	0	1	1
0	0	0	0		G	1	0	1	1
0	0	1	0		G	1	0	1	0
0	0	0	0		G	1	0	1	0
0	0	1	0		G	1	0	1	0

Left in IR holder	Left on floor/OTHER	Digital Machine back in department	Time back	Handling data	Radiographer(s)	Mechanism of travel	Hand	Against body	IR holder
0	0	0	10:38:00		1	4	2	1	1
1	0	0	10:38:00		1	3	1	1	1
0	0	0	14:15:00		1	0	0	0	0
0	0	0	15:08:00		1	1	1	0	0
0	0	0	15:08:00		1	2	1	0	1
1	0	0	15:36:00		1	1	1	0	0
1	0	0	15:36:00		1	0	0	0	0
1	0	0	15:36:00		1	1	1	0	0

New machine used	Hand hygiene Total	HW Pre PC	HW Post PC	HS Pre PC	HS Post PC	Gloves	Gloves Post HW and Pre PC	Student(s)	Hand hygiene Total
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	1	0
0	0	0	0	0	0	0	0	1	0
0	1	0	1	0	0	0	0	1	0

HW Pre PC	HW Post PC	HS Pre PC	HS Post PC	Gloves	Gloves Post HW and Pre PC	(CS) PCA	(CS) RBC	(Post Cleaning AM)PCA	(Post Cleaning AM) RBC
0	0	0	0	0	0	n/a	n/a	n/a	n/a
0	0	0	0	0	0	n/a	n/a	n/a	n/a
0	0	0	0	0	0	n/a	n/a	n/a	n/a
0	0	0	0	0	0	n/a	n/a	n/a	n/a
0	0	0	0	0	0	n/a	n/a	n/a	n/a
0	0	0	0	0	0	n/a	n/a	n/a	n/a
0	0	0	0	0	0	n/a	n/a	n/a	n/a
0	0	0	0	0	0	n/a	n/a	n/a	n/a

Microbial loads in CFU/mL

Date	Sampling session	IR Unique number	(Post cleaning AM) PCA CFU/mL	(Post cleaning AM) RBC CFU/mL	(End of day PM) PCA CFU/mL	(End of day PM) RBC CFU/ml	(End of day PM) BPA CFU/mL	(End of day PM) S&B CFU/mL	(End of day PM) Rapid Entero CFU/mL	(End of day PM) Harlequin CFU/mL	(End of day PM) Cetrimide CFU/mL	(End of day PM) Acinetobacter CFU/mL
25/09/2019	**A**	**A8-1**	n/a	n/a	1185	9	1670	0	89	78	0	99
25/09/2019		**A10-1**	n/a	n/a	15850	59	21	0	2960	9715	0	15150
25/09/2019		**A2-1**	n/a	n/a	120	7	46	0	70	51	4	5
25/09/2019		**A2-2**	n/a	n/a	120	7	46	0	70	51	4	5
25/09/2019		**A8-2**	n/a	n/a	1185	9	1670	0	89	78	0	99
25/09/2019		**A3-1**	n/a	n/a	52	9	11	0	7	22	0	35
25/09/2019		**A4-1**	n/a	n/a	68	4	21	0	28	14	0	18
25/09/2019		**A5-1**	n/a	n/a	11	0	7	0	13	7	0	0
02/10/2019	**B**	**B8-1**	0	0	7	0	5	0	0	0	0	0
02/10/2019		**B7-1**	43	14	12	0	2	0	0	0	0	0
02/10/2019		**B8-2**	0	0	7	0	5	0	0	0	0	0
02/10/2019		**B7-2**	43	14	12	0	2	0	0	0	0	0
02/10/2019		**B8-3**	0	0	7	0	5	0	0	0	0	0
23/10/2019	**C**	**C10-1**	0	0	1	0	0	0	0	0	0	0
23/10/2019		**C10-2**	0	0	1	0	0	0	0	0	0	0
23/10/2019		**C8-1**	0	0	1	0	0	0	0	0	0	0

30/10/2019	D	D6-1	0	0	3	0	3	0	0	0	0	0
30/10/2019		D7-1	0	0	22	0	0	0	0	0	0	0
30/10/2019		D8-1	4	0	26	0	30	0	0	0	0	0
30/10/2019		D9-1	0	0	44	0	67	0	0	0	0	0
30/10/2019		D6-2	0	0	3	0	3	0	0	0	0	0
30/10/2019		D7-2	0	0	22	0	0	0	0	0	0	0
30/10/2019		D7-3	0	0	22	0	0	0	0	0	0	0
30/10/2019		D8-2	4	0	26	0	30	0	0	0	0	0
30/10/2019		D6-3	0	0	3	0	3	0	0	0	0	0
30/10/2019		D7-4	0	0	22	0	0	0	0	0	0	0
30/10/2019		D8-3	4	0	26	0	30	0	0	0	0	0
18/10/2022	E	E9-1	0	0	1	0	0	0	0	0	0	0
18/10/2022		E10-1	0	0	0	0	0	0	0	0	0	0
18/10/2022		E9-2	0	0	1	0	0	0	0	0	0	0
18/10/2022		E10-2	0	0	0	0	0	0	0	0	0	0
18/10/2022		E9-3	0	0	1	0	0	0	0	0	0	0
04/11/2022	F	F9-1	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
04/11/2022		F1-1	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

08/11/2022	G	G9-1	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
08/11/2022		G5-1	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
08/11/2022		G6-1	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
08/11/2022		G9-2	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
08/11/2022		G5-2	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
08/11/2022		G5-3	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
08/11/2022		G9-3	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
08/11/2022		G5-4	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
08/11/2022		G9-4	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
07/07/2023	H	H-NM	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
07/07/2023		H-NM	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
07/07/2023		H-NM	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
07/07/2023		H-NM	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
07/07/2023		H-NM	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
19/07/2023	I	I-NM										
19/07/2023		I-NM										
19/07/2023		I-NM										
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19/07/2023		I-NM										
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11/08/2023	J	J-NM										
11/08/2023		J-NM										
11/08/2023		J-NM										
11/08/2023		J-NM										
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11/08/2023		J-NM										
25/08/2023	K	K-NM										
25/08/2023		K-NM										
25/08/2023		K-NM										
25/08/2023		K-NM										
25/08/2023		K-NM										
25/08/2023		K-NM										
25/08/2023		K-NM										

08/09/2023	L	L-NM	0	0	0	0	0	0	0	0	0	0
08/09/2023		L-NM	0	0	0	0	0	0	0	0	0	0
08/09/2023		L-NM	0	0	0	0	0	0	0	0	0	0
08/09/2023		L-NM	0	0	0	0	0	0	0	0	0	0
08/09/2023		L-NM	0	0	0	0	0	0	0	0	0	0
12/09/2023	M	M-NM	0	0	0	0	0	0	0	0	0	0
12/09/2023		M-NM	0	0	0	0	0	0	0	0	0	0
12/09/2023		M-NM	0	0	0	0	0	0	0	0	0	0
12/09/2023		M-NM	0	0	0	0	0	0	0	0	0	0
12/09/2023		M-NM	0	0	0	0	0	0	0	0	0	0
12/09/2023		M-NM	0	0	0	0	0	0	0	0	0	0
15/09/2023	N	N-NM	0	0	0	0	0	0	0	0	0	0
15/09/2023		N-NM	0	0	0	0	0	0	0	0	0	0
15/09/2023		N-NM	0	0	0	0	0	0	0	0	0	0

APPENDIX G: LANGUAGE EDITOR

Declaration

24 September 2025

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Master's thesis: Infection control practices and microbial load of imaging receptors used by a diagnostic imaging department at an academic hospital

Student: T. Wainwright

I confirm that I edited and formatted the the thesis, ensured that sources cited in the text appear in the references and vice versa, and recommended changes to the text.

I did not actively check for plagiarism or whether the student used AI tools to write the text or suggest sources. If I noticed hallucinated sources, I indicated them to the student for replacement.

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MA Language Practice (UFS)

Hettie Human
EDITOR

APPENDIX H: STATISTICIAN

TECRO RESEARCH
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Tel: +27 51 412 4669 | Mobile: +27 82 881 3926

Attention: Ethics Committee Chairperson

Block D, Room 115
Francois Retief Building
Faculty of Health Sciences
University of the Free State

22 May 2018

Title: MICROBIAL LOAD ON IMAGING RECEPTORS USED BY A DIAGNOSTIC IMAGING DEPARTMENT AT AN ACADEMIC HOSPITAL

Researcher: Ms. T. Wainwright (Student number: 209006560)
Master of Radiography (Diagnostic)
Department of Clinical Sciences (Programme Radiography)
Faculty of Health and Environmental Sciences
Central University of Technology (Free State)

I have reviewed this protocol. I provided input and recommendations and will be the biostatistician responsible for the analysis of the data.

Cornea Venter
cornea.venter@tecro-research.com
082 881 3926

APPENDIX i: LETTER FROM THE HEALTH SCIENCES RESEARCH ETHICS COMMITTEE: FACULTY OF HEALTH SCIENCES, UFS

UNIVERSITY OF THE FREE STATE
UNIVERSITEIT VAN DIE VRYSTAAT
YUNIVESITHI YA FREISTATA

UFS·UV
HEALTH SCIENCES
GESONDHEIDSWETENSKAPPE

Health Sciences Research Ethics Committee

24-Apr-2023

Dear **Ms T Wainwright**

Ethics Number: UFS-HSD2018/1466/2506-0002

Ethics Clearance: **INVESTIGATION OF THE INFECTION CONTROL PRACTICES AND MICROBIAL LOAD OF IMAGING RECEPTORS USED BY A DIAGNOSTIC IMAGING DEPARTMENT AT AN ACADEMIC HOSPITAL**

Principal Investigator: **Ms T Wainwright**

Department: **Radiography - CUT**

Submission Page

SUBSEQUENT SUBMISSION APPROVED

With reference to your recent submission for ethical clearance from the Health Sciences Research Ethics Committee. I am pleased to inform you on behalf of the HSREC that you have been granted ethical clearance for your request as stipulated below:

- Annual re-approval: The ethical clearance of this project is extended to 23 April 2024.

The HSREC functions in compliance with, but not limited to, the following documents and guidelines: The SA National Health Act. No. 61 of 2003; Ethics in Health Research: Principles, Structures and Processes (2015); SA GCP(2020); Declaration of Helsinki; The Belmont Report; The US Office of Human Research Protections 45 CFR 461 (for non-exempt research with human participants conducted or supported by the US Department of Health and Human Services- (HHS), 21 CFR 50, 21 CFR 56; CIOMS; ICH-GCP-E6 Sections 1-4; International Council for Harmonisation (ICH) Harmonised Guideline, Integrated Addendum to ICH E6(R1), Guideline for Good Clinical Practice (GCP) E6(R2), 2016, SAHPRA Guidelines as well as Laws and Regulations with regard to the Control of Medicines, Constitution of the HSREC of the Faculty of Health Sciences.

The Principal Investigator (PI) bears final responsibility for the RIMS application. In the event of any misconduct or improper activities perpetuated by a third party, the PI will be held vicariously liable. The HSREC will bear no responsibility or liability for any actions of a PI and/or third party or breach of confidentiality caused by the PI and/or third party.

For any questions or concerns, please feel free to contact HSREC Administration: 051-4017794/5 or email EthicsFHS@ufs.ac.za.

Thank you for submitting this request for ethical clearance and we wish you continued success with your research.

Yours Sincerely

Prof. A. Sherriff
Chairperson : Health Sciences Research Ethics Committee

Health Sciences Research Ethics Committee
Office of the Dean: Health Sciences
T: +27 (0)51 401 7795/7794 | E: ethicsfhs@ufs.ac.za
IRB 00011992; REC 230408-011; IORG 0010096; FWA 00027947
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www.ufs.ac.za

APPENDIX J: TURNITIN REPORT

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APPENDIX K: ABSTRACT

Introduction: Infection control protocols in health care settings vary across the world; however, a few key aspects are addressed in most countries' protocols, such as hand hygiene and sterile procedures. Current infection control practices in South Africa and listed by the Department of Health include the hand hygiene steps of the World Health Organization (WHO), which provide information on pre- and post-patient contact, sterile practices and making use of personal protective equipment such like masks and gowns (Department of Health, 2017). Infection control protocols are important because of the consistent worldwide threat of contamination of patients and healthcare workers with nosocomial pathogens (Sukumar and Yadav, 2012). The effects of contamination can be devastating and, all over the world, researchers are searching for solutions to this problem.

In the radiology setting, inanimate objects such as imaging receptors (IRs) have the ability to act as a fomite (Burbridge, 2012), which means infection/pathogens can be transmitted through equipment that comes in contact with patients. When IRs are not disinfected after patient contact, any possible infectious agent may be transmitted to another patient (susceptible host) (Ehrlich and Coakes, 2017). IRs travel through hospitals when equipment is used for mobile radiography and, thus, contribute to the risk of spreading infectious agents on the routes travelled through the hospital (Burbridge, 2012).

Main research question:

What are current infection control practices and microbial load on the surfaces of the IRs used in the diagnostic imaging department during mobile X-ray examinations at an academic hospital?

Methods: The study sample involved all 12 available conventional 35 × 43 cm X-ray machine IRs and a digital X-ray machine detector (only the 35 × 43 cm digital detector was sampled, for the sake of consistency, in turn, the 24 × 30 cm digital detector was not sampled because it was not routinely used like the conventional IRs) used in the imaging department, as well as during mobile X-ray examinations at the participating academic hospital. The IRs were labelled to enable the researcher to keep track of the movement of each individual IR circulating through

the hospital. Physical swabs were taken in the morning before the day shift started at 07:00 and again at 16:00 when the day shift ended. The swabs were taken individually for each IR pre- and post-disinfection with 70% ethanol. The sampled swabs were transferred to the laboratory for cultivation.

Results: During the analysis of the data, it was found that infection control is not a priority for radiographers or student radiographers. Hand hygiene mostly had higher preference rates as a method of infection control, which is noteworthy.

When the new digital X-ray machine with the antimicrobial layer was introduced, the study was changed; it is likely that antimicrobial layers will be the way forward and this possibility had to be investigated. In this study, no bacteria were detected at the end of a sampling day in which the digital X-ray machine was used, in comparison to the IRs, for which the participants had to take more care with cleaning and be aware of the placement of the IRs when travelling.

The infection control practices in the department or on mobile X-ray examinations were not consistently applied, even though the Department of Health, Free State, as well as the researcher, have developed adequate infection control protocols. Covers for the IRs were used only twice throughout 86 trips. By failing to cover an IR, there will be a form of contact in a patient's immediate area or bed. Any contact with a contaminated IR could lead to cross-contamination (Russotto et al., 2015; Wainwright, 2015). IRs move around frequently throughout the hospital for mobile radiography and the likelihood of exposure occurring is high, even if the participant takes along an extra IR to avoid walking back to the department when an extra mobile X-ray is requested.

Significance: The importance of the study relates to evidence that many patients are infected with nosocomial pathogens, of which the source could be any number of items/people within the hospital setting (Jayasinghe and Weerakoon, 2014). By taking swab samples and observing if the infection control recommendations were followed, possible areas/actions that could cause contamination and colonisation could be identified in the implementation of current protocols.

Keywords: Infection control, imaging receptors, mobile radiography, bacteria, fomite, reservoir, patient contact, protocol