An-Najah National University

Faculty of Graduate Studies

RADIOLOGY DEPARTMENT: A POTENTIAL SOURCE OF MULTIDRUG-RESISTANT MICROORGANISMS, A CROSS-SECTIONAL STUDY AT TERTIARY CARE HOSPITAL, PALESTINE

By

Zena Mohammad Saleem Odeh

Supervisor

Dr. Mohammad Qadi

This Thesis is Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Infection Diseases Prevention and Control, Faculty of Graduate Studies, An-Najah National University, Nablus, Palestine.

2023

RADIOLOGY DEPARTMENT: A POTENTIAL SOURCE OF MULTIDRUG-RESISTANT MICROORGANISMS, A CROSS-SECTIONAL STUDY AT TERTIARY CARE HOSPITAL, PALESTINE

By

Zena Mohammad Saleem Odeh

This Thesis was Defended Successfully on 22/03/2023 and approved by

Dr. Mohammad Qadi	
Supervisor	Signature
Dr. Rasmi Abu-Helu	
External Examiner	Signature
Dr. Adham Abu Taha	
Internal Examiner	Signature

Dedication

I dedicate this work to my mother and my beautiful family, which is the source of love and support. I also dedicate this work to the soul of my late father; may God have mercy on him.

To my life partner Obida who supported me in every possible way.

To my dear friends from the medical field in the hospital who are on the job, who are doing the impossible to save a person’s life, and to all those who helped me accomplish this work.

For those who are always in my heart and who give me the strength to continue my dream to succeed.

To all the martyrs and injuries in Palestine. In addition, to all sieged cities of Palestine, from Jenin AL-Qassam to Gaza Hashim.

Finally, I thank everyone who helped me finish this work.

Acknowledgements

Primarily, I want to thank Allah, who will always be the most important source of strength and direction. Through numerous disappointments, his guidance kept me going, and when my frustrations tended to lead me astray, his direction helped me get back on track.

I want to appreciate unique folks who always gave me everything needed or asked for. They always found the time, no matter what the work was or how busy they were. These appreciations are sent to my parents, who provided the assistance in making this effort a success.

I would like also to thank An-Najah National University represented by the university president Prof. Abdel Naser Zaid. Special thanks for the dean of the college of graduate studies, and I would like to extend my sincere gratitude to the thesis' advisor, Dr. Mohammad Qadi, for his efforts and support during the experiments and writing of this thesis. His expertise and unending assistance were a terrific asset from which I gained a lot of knowledge. He expressed great enthusiasm for the thesis, which encouraged me to keep working hard.

Finally, I owe a huge debt of gratitude to my family, co-workers and friends for helping me get through college and making those years the happiest of my life.

Declaration

I, the undersigned, declare that I submitted the thesis entitled:

RADIOLOGY DEPARTMENT: A POTENTIAL SOURCE OF MULTIDRUG-RESISTANT MICROORGANISMS, A CROSS-SECTIONAL STUDY AT TERTIARY CARE HOSPITAL, PALESTINE

I declare that the work provided in this thesis, unless otherwise referenced, is the researcher's own work, and has not been submitted elsewhere for any other degree or qualification.

Student's Name: Zena Mohammad Saleem Odeh

Signature: _____

Date: 22/03/2023

List of Contents

Dedication iii
Acknowledgements iv
Declaration v
List of Contents vi
List of Tables viii
List of Appendices ix
Abstract x
Chapter One: Introduction and Theoretical Background 1
Introduction 1
Literature review 4
Chapter Two: Methods 9
2.1 Study Design 9
2.2 Study Population 9
2.3 Study time 13
2.4 Study sample and settings 13
2.5 Bacterial Culture and Detection 13
2.6 Vancomycin resistance 14
2.7 Contamination rate calculation 14
2.8 Ethical Approval 14
Chapter Three: Results 15
3.1 Bacterial Detection 15
3.2 Total Bacterial Contamination 39
3.3 Gram-positive: *Staphylococcus* (MSA-growth) 42
3.4 Gram-positive: MRS 44
3.5 Gram-positive: Vancomycin Resistant *Staphylococcus* VRS 45
3.6 Gram-positive: (VRE) 45
3.7 Gram-Negatives 46
3.8 Gram-negative: ESBL and CRE 46
3.9 Contamination rate 47
Chapter Four: Discussions 48
Chapter Five: Conclusion 52
List of Abbreviations 53
References 54

Appendices 64
الملخص .... ب

List of Tables

Table 1: Commonly Hand-Touched sites 10

Table 2**:** Calculated contamination rate (CFUs/cm2) during the two months on both Blood and Chocolate agar from each sample source 16

Table 3: Shows sample source and number of colonies on each plate during May 23

Table 4**:** Shows sample source and number of colonies on each plate during June 31

Table 5: Sites with contamination rate of ≥1CFU/cm2, either on Blood or on Chocolate agar 39

Table 6**:** Sites contaminated with bacteria that can grow on MSA agar during two months 42

Table 7: Sites contaminated with MRS, on Mannitol Salt agar with Oxacillin 44

Table 8**:** Sites harbors VRE in the radiology department, on Bile Esculine agar with Vancomycin 45

Table 9**:** Samples with growth of gram-negative bacteria 46

Table 10: Isolated Organisms in May and June 46

Table 11: Compression with other studies for MRSA contamination 67

List of Appendices

Appendix A: Approval from the Faculty of Higher education 64
Appendix B: IRB 65
Appendix C: Facilitation of a Researcher's Mission 66
Appendix D: Tables 67

RADIOLOGY DEPARTMENT: A POTENTIAL SOURCE OF MULTIDRUG-RESISTANT MICROORGANISMS, A CROSS-SECTIONAL STUDY AT TERTIARY CARE HOSPITAL, PALESTINE

By
Zena Mohammad Saleem Odeh
Supervisor
Dr. Mohammad Qadi

Abstract

Globally, healthcare facilities face a great challenge in the form of hospital-acquired infections (HAIs). Aside from the morbidity and mortality they cause, these illnesses are also extremely costly. Research on infection transmission in the medical area has been considerable, but not so much in the radiology department.

This study aims to identify the presence of multidrug-resistant (MDR) microbes on surfaces that are frequently touched in Computed Tomography (CT), Magnetic Resonance Imaging (MRI), Ultrasound (US), plain X-ray examination rooms, and portable radiography that are susceptible to contamination, as well as to investigate the potential dangers of contracting MDR organisms to patients and healthcare providers.

In this study, 160 swab samples were collected from the radiology department at a tertiary care hospital in Palestine during May and June 2022. Samples were obtained from 80 predefined surfaces twice within and outside of CT and MRI examination rooms, as well as from US and Plain X-ray machines and portable X-ray machines. Samples were taken at 7:00 a.m. using cotton swabs following the regular cleaning procedure. Bacterial colony-forming units (CFUs) per square centimeter (cm^2) were calculated after swabbing a 100 cm^2 surface.

Nearly all of the surfaces tested had bacterial CFUs. The highest contamination rate was found on keyboards ranging from (1.2-8) CFU/cm^2, the sides of patient tables (1.2-20) CFU/cm^2, knee coil (2.4-3) CFU/cm^2, and patient leg supports (1.2-8) CFU/cm^2. Noticeable increase in the contamination was noticed in June comparing to May and this was consistent with the increase in: number of isolated patients in the hospital, the workload in the radiology department and number of patients referred to the hospital. In our study, none of the examined sites showed contamination with MDR gram negative

bacteria like Extended-Spectrum Beta-lactamases producing *Enterobacterales* (ESPL) or Carbapenemase-Producing *Enterobacterales* (CPE). On the other hand, methicillin resistant *Staphylococcus aureus* (MRSA), vancomycin resistant *Staphylococcus aureus* (VRSA) and vancomycin resistant *Enterococcus* (VRE) were detected. All of the radiology department equipment and sites could be a source of bacterial infection including MDR; so, obligatory and committed disinfection protocol must be revised and implemented in the morning and between patients.

Keywords: Radiology Department, MDR, Hospital-acquired infection, Bacterial nosocomial infection, Contamination.

Chapter One
Introduction and Theoretical Background

1.1 Introduction

Surfaces in the hospitals are often contaminated with microorganisms. Surfaces that have been contaminated with germs can serve as a possible source of healthcare-associated infections (HAIs). It has been believed that bacteria on contaminated surfaces cause HAIs, but there are missed points about how transmission of these bacteria to the patient occurs (1).

In intensive care units (ICUs), HAIs pose a major threat to patient health. As a result, more than 30 percent of all ICU admissions are affected with these HAIs. Medical procedures, the presence of several invasive devices that disrupt anatomical and immunological protective barriers, and medication administration all put ICU patients at risk for infection.

These factors combine to decrease the body's ability to fight off infection. The rise of Multidrug-resistant organisms (MDROs) has also been attributed to the widespread usage of broad-spectrum antibacterial medicines (2). MDROs were found on hospital room surfaces despite the use of terminal disinfection (3).

The radiology department is critical in medical diagnosis and treatment since it receives a wide spectrum of in-patients and out-patients on a daily basis (4, 5). Dealing with patients with various diseases and the use of different radiological equipment (Computed Tomography (CT), Magnetic Resonance Imaging (MRI), Ultrasound (US), plain X-Ray, and portable X-Ray machine), results in intense traffic in the radiology department, and this combined with loss of cleaning and disinfecting of modalities results in the transmission and dissemination of nosocomial infection between patients (5), and from HealthCare Workers (HCWs) to patients by direct or indirect way (6).

In recent years, the rate of HAIs from radiology departments has grown, harming HCWs and patients during treatment and complicating any radiographic investigation/intervention (7, 8).

Nosocomial infections, also known as healthcare-associated infections (HAI), are illnesses that develop after a patient is admitted to the hospital but were not present upon admission. These infections are typically picked up during a hospital stay and become noticeable within the first 48 hours of being admitted (8, 9).

Previous literature has shown that the CDC has classified nosocomial infection sites into 13 types with 50 infection sites (10). They cause significant morbidity and mortality in hospitalized patients (6), specifically in low-income countries rather than in high income countries around the world (9-11).

In contrast to community-acquired infections (CAIs), these infections usually occur as a result of pathogens taking advantage of patients whose normal defenses against infection are contravened (5).

A range of microbes could cause nosocomial infection. As mentioned in the previous research, the worst scenario will happen when this infection is caused by MDROs (8, 9). The problem of MDROs first emerged in 1940, and has since become more difficult to treat (10, 12), and a threat to global health, hospitalized patients, and HCWs (13). MDROs impose a significant economic burden due to unnecessary longer hospital stays, a higher risk of readmissions, and additional disease costs (7) (14). Poor hand hygiene and environmental cleaning have the ability to transfer MDROs and colonize them in patients (13-15).

The prevalence of MDR bacteria in hospitals may lead to the empiric selection of antibiotics that target MDR bacteria, and intravenous antibiotic use within the past 90 days is a key risk factor for the emergence of resistance to various antimicrobial medicines (16). Despite the importance of hospitalizations in the care of acute illnesses, they also increase the chance of susceptible patients contracting a wide variety of nosocomial infections, many of which are resistant to antibiotics. The infected person may have contracted the disease from another patient, from a hospital worker, or from the hospital itself (17).

High-touch surfaces in patient rooms, such as bed controls, bed rallies, call buttons, and bedside tray tables, represent a critically important MDROs reservoir and increase the

risk of acquisition by other patients, visitors, and hospital staff who are exposed to them (4, 18, 19).

Several studies suggest that disinfection is an important technique that helps control microbial carriage in people who already have MDROs. In addition to the mentioned techniques, there are several crucial infection prevention methods. Most infection prevention techniques (e.g., environmental cleaning, hand hygiene, contact precautions, active screening) are intended to prevent MDROs (or other Microbes) from spreading to individuals who do not already have them. Disinfection offers a universal solution by safeguarding both MDROs carriers and non-carriers (20).

Disinfection is becoming increasingly significant in most hospitals, because the number of patients harbouring MDROs asymptomatically is growing over time (21).Increased research on MDROs persistence in the hospital environment and subsequent transmission recently resulted in a greater emphasis on hospital environmental hygiene (22-24).

One of the most prevalent causes of nosocomial infections is central-line-associated bloodstream infection (CLABSI) (25). MDROs account for 20% to 67% of all CLABSIs. CLABSI MDROs are difficult to treat and the indwelling catheter is difficult to remove, making it critical to understand the best management strategy for critically ill hospitalized patients (23).

Drug resistant and MDROs include Methicillin-resistant *Staphylococcus aureus* (MRSA), Methicillin resistant *Staphylococcus epidermis* (MRSE), Vancomycin-resistant *Staphylococcus aureus* (VRSA),Vancomycin resistant *Enterococcus* (VRE), extended-spectrum Beta-lactamases producing *Enterobacterales* (ESPL), Carbapenemase-producing *Enterobacterales* (CPE)., Carbapenem resistant *Acinetobacter baumannii* (CR-AB), and Carbapenem-resistant *Pseudomonas aeruginosa* (CR-PA) (7, 24, 26).

MDROs implications are measured depending on examining patients' medical records. It also looks into their medical expenses, such as bed, nursing, medication, antimicrobial, operation, therapy, laboratory, and inspection charge (18).

Multifaceted infection strategies make acquisition and infection with MDROs challenging to avoid. It was found in the literature that it is difficult to avoid due to

multiple potential transmission routes (transmission from patient to HCWs, transmission from patient to hospital environment, transmission from HCWs to patient, transmission from environment to HCWs, and overall patient-to-patient transmission) (22).

Several recent trials of universal disinfection involving the daily mouth, nose and skin Chlorhexidine(CHG) bathing (low cost to implement with few adverse events) with and without nasal mupirocin had also prompted widespread adoption of this practice in hospitalized ICU patients (21, 27). This adoption is mainly due to evidence that universal disinfection strategies reduce: 1- device-associated bacteremia (e.g. urinary catheter and central line) 2- other causes of bacteremia such as surgical site infection, and bed sores. The mentioned infection that can be avoided could be due to drug-resistant organisms. Contact precautions are intended to reduce direct or indirect contact with carriers of drug-resistant bacteria (20, 23) or their surroundings (22, 26). They extensively used it to inhibit the spread of drug-resistant and MDROs in the hospital context (24).

1.2 Literature review

Increase in environmental contamination with various types of the most common microorganisms will increase the rate of antimicrobial resistance and infection spread because of multiple risk factors such as temperature and humidity (23), that already have been found to increase the incidence of HAIs. In addition to other factors as the prevalence of colonization of MDROs in the overall population and the incidence of bacterial infection in the hospital (23). On the surfaces, the limit for microorganisms to be significantly infectious and require concerns and control is 1 CFU/cm^2 (9).

S. aureus is both a commensal bacterium and a human pathogen. Approximately 20%-30% of the human population is colonized with *S. aureus* (28-30). Also, inanimate surfaces are well known to be colonized with *Staphylococcus* and this can contribute to their transmission in the nosocomial setting (31). *S. aureus* can be divided into methicillin-sensitive *S. aureus* (MSSA) and MRSA (30). Interestingly, a recent study shows that it is 125 times less likely that a patient with a *S. aureus* infection is infected with MRSA if he is a MSSA carrier (32).

S. epidermidis has long been thought to be a harmless commensal due to its widespread colonization of human skin (33). *S. epidermidis* may be isolated from various types of

skin microenvironments, including dry, wet, sebaceous, and foot areas (34). Prior research suggests that *S. epidermidis* is the most researched member of the Coagulase negative *Staphylococcus* (CoNS) family. The same study found that it was formerly employed as a commensal comparator to its more pathogenic relative, *S. aureus* (35). Previous studies have emphasized that the *S. epidermidis* has emerged as the predominant pathogen of sepsis in preterm infants (36).

There are numerous studies about MRSA and it is well known that MRSA is a major cause of skin and soft tissue infection, respiratory and cardiovascular illness, and the leading cause of nosocomial infection (37).

The presence of an indwelling catheter, prior antibiotic therapy (within the last 30 days), in-hospital exposure time of five or more days, underlying Chronic Obstructive Pulmonary Disease (COPD), and recent hospitalization all are important risk factors for MRSA infection (38). MRSA is ubiquitous in both human body and in the environment and has the ability to survive the inanimate objects. All of these give this bacterium ability to be a potential health threat that results in increased morbidity, mortality, and prolonged hospitalization (32, 38).

In a review article, the conclusion was drawn from previous investigation, intervention studies, epidemiological studies and microbiological studies that the surfaces can be a potential source of hospital-associated microorganism transmission (39). This validates the critical need to enhance and optimize prevention, control, timely detection, and effective treatment strategies for multidrug-resistant *S. aureus* strains (32, 38), including the importance of ongoing surveillance of local antimicrobial resistance in *S. aureus* to guide empiric antimicrobial therapy(40).

In a recent study, when cleaning surfaces by using a sodium-lauryl-sulfate-based detergent can prevent MRSA transmission in health-care settings and reduce the risk of surface contamination at hospital in general and radiology department in particular (41). In a previous investigation involving bacterial detection, samples were obtained from CT equipment, and the results indicated that the CT wrap was the most contaminated with germs, prompting the development of a novel cleaning procedure (8).

Antimicrobial resistance (AMR) remains a global issue in the control of prevalent bacterial infectious diseases in both developing and developed countries (42). The resistance mechanisms of *S. aureus* are incredibly complicated, especially for MRSA(30). Among HIV positive individuals, methicillin resistance was widespread in 2017 (86%) and the percentage of MRSA significantly increased from 51.8 % in 2012 to 86 % in 2017. Also, in 2016, there was a significant increase in *S. aureus* infections (35%; $p<0.001$) and a (76%; $p=0.0007$)increase in MRSA infections (43).

There exists a considerable body of literature on antimicrobial resistance. In the literature, intrinsic and acquired mechanisms of MRSA of antibiotic resistance was documented in detail. Overall, MRSA has weak resistance to mupirocin, fusidic acid, and retapamulin (44). This indicates the necessity to apply antibiotic surveillance and make sensitivity testing of *S. aureus* before treatment and reduce use of broad-spectrum antibiotics to significantly decrease the spread of MRSA and MSSA at hospital.

Radiological markers (38)and x-ray cassettes can serve as a bacterial reservoir including is MRSA (19). To some extent, the subject of whether inanimate items in the radiography department can induce cross-contamination among patients has been investigated, in one investigation of lead aprons, bacterial samples were collected from various places on the aprons before and after disinfection(4). There was a significant difference after cleaning in the presence of the bacterial contamination. A similar study was carried out on protective lead aprons (thyroid shields, shoulder-vests, and wrap-around skirts) in surgical operating units, 88 out of 109 apron samples was contaminated (45).

Enterococci are part of the normal gastrointestinal flora (46), the most common aerobic Gram-positive *cocci* in the intestines and lower female genital tract(47), have become the second most common agents of nosocomial diseases (48), and are now ranked after *staphylococci* (49).

Vancomycin-resistant *Enterococci* (VRE) have emerged as important nosocomial pathogens. Drug resistant bacteria is commonly transmitted within healthcare settings including patient-to-patient transmission (50-52),VRE environmental contamination accounts for approximately 42% of VRE infected patients (23), and has been declared a serious public health threat due to its high level of antibiotic resistance (52). While hospital outbreaks are being reported (47, 52), commensal gut bacteria are commonly

detected in the hospital and community environments, these bacteria developed as nosocomial and community-acquired pathogens due to their ability to develop high-level resistance to antibiotics (53).

VRE may persist for extended periods of time on hands, gloves, and environmental surfaces (54), and also has the ability to develop antimicrobial resistance these factors contribute to its ability to cause nosocomial illness (49).The emergence of VRE has become a major public health concern, despite rising rates of VRE infections elsewhere in the world(55). In-hospital morbidity and mortality due to *Enterococci* Blood Stream Infection (BSI) is affected more by *Enterococcus* species and underlying diseases than by vancomycin resistance itself (46).

Antibiotic-mediated microbiota destruction and the consequent loss of balanced bacterial colonization can result in intestinal VRE colonization, and lead to bloodstream infection in hospitalized patients (52). VRE isolates can be resistant to multiple antibiotics(56, 57).

Patients colonized with these VRE strains should be prevented from contact with other patients, as prevention and control measure. If such a strain is cultured from a clinical sample, contact with patients should be monitored, and barrier measures (hand hygiene) should be applied(47, 54, 58, 59). Therefore, it is critical to fight VRE and specially *Enterococcus faecium* transmission in high-risk patients (60). There are limited data about VRE surface contamination in radiology departments, this study investigated its presents.

The real pandemic outbreak of COVID-19, which killed several million people and had major global economic consequences, is an indication that much more work is necessary to tackle infectious diseases and the growing global issue of antibiotic resistance (61).In case of hospitalized patients, the case-fatality rate linked with bacteraemia ranges from 35% to 50% and is usually associated with MDR gram-negative bacteria as ESBL and CRE (62). The rise of CRE mediated by hydrolytic enzymes known as carbapenemases has become a major global problem (61, 63).

Infection with either ESBL or CPE is linked to higher death rates, delay to successful therapy, increase in length of stay and total healthcare expenses (64). CRE isolates have been found in nosocomial and community-acquired infections (61, 65).

Carbapenems are a potent class of broad-spectrum antibiotics that are often the final line of defense against MDR bacterial infections, Carbapenems are lactam antibiotics that vary from penicillin by substituting a carbon atom for a sulfur atom and adding a double bond to the penicillin nucleus's five-membered ring(61).

Globally, prevalent carbapenemases are found in *Enterobacteriaceae* including *Klebsiella pneumoniae* carbapenemases (KPC)(66). *K. pneumoniae* that produces KPC is a worldwide threat (67).In a recent study, bacterial contamination was found on almost all selected areas in the radiology department including MRI and CT equipment, fortunately no MDROs such as MRSA , ESPL, or CPE were detected(9).

The possibility that items in the radiology department can cause cross-contamination among patients investigated is this research. The goal of this study is to determine the presence of multidrug resistant organisms on high touched surfaces in the radiology department, as well as to investigate the potential danger of contracting multidrug resistant organisms to patients and healthcare workers.

Chapter Two
Methods

Materials and Methods

2.1 Study Design

A cross-sectional study design carried over at radiology department at Tertiary Hospital: An-Najah National University Hospital, Palestine.

2.2 Study Population

The commonly hand-touched sites were assessed according to the previous studies (9)**,** and an adapted flow chart was created. Briefly, swab samples targeted the surfaces inside and outside: plain X-Ray, CT, MRI, US and portable X-Ray instruments, in addition to examination rooms, as shown in Table 1

Table 1

Commonly Hand-Touched sites

MRI	CT CANON (1)	CT SEMENS (2)	Interventional US (1)	US for general use (2)	X-Ray	Portable X-Ray primax (1)	Portable X-Ray care stream (2)
Canter of patient table 1	Head pillow	Head support	Linear probe	Linear probe	X-Ray cassette	X-Ray cassette	X-Ray cassette
Head support	RT side edge of patient table	RT side edge of patient table	Curve linear probe	Curve linear probe	Wall Bucky control panel	Touch screen	Touch screen
Head coil 1	Centre of patient table	Centre of patient table	Key board of US	US keyboard	Wall Bucky	Hands of machine	Hand of machine
Anaesthesia machine	Injector control panel	Another table in the CT room	Touch screen of US	Small touch screen	Touch screen of x-ray tube		
RT side gantry control panel	CT Keyboard	Leg support	-	Table in control room	Prep medication table		
X-Ray cassette	RT side gantry control panel	RT side gantry control panel	-	Door of examination room	Centre of patient table		

Leg support 2	LT side gantry control panel	LT side gantry control panel	-	Table of US tools	RT side edge of patient table		
Centre of gantry	Centre of gantry	Centre of gantry	-	Hand of US	LT side edge of patient table	-	-
Ear support (Headphone)	Surface of Emergency trolley	Prep medication table	-	Head pillow	Key board in control room	-	-
Surface coil 1	Control room keyboard	Keyboard in control room	-	Mouse in the control room	Mouse	-	-
RT side edge of patient table 1	LT side edge of the patient table	LT side edge of the patient table	-	Keyboard in control room	x-ray keyboard	-	-
Surface coil 2	Injector touch screen	Another table in the CT room	-	Large touch screen	-	-	-
Head coil 2	CT mouse	CT Mouse	-	Patient table	-	-	-
Knee coil	Mouse in the Control room	-	-	-	-	-	-

Centre of patient table 2	-	-	-	-	-	-	-
RT side edge of patient table 2	-	-	-	-	-	-	-
LT side edge of patient table 2	-	-	-	-	-	-	-
Leg support 1	-	-	-	-	-	-	-

2.3 Study time

The sample swabs were collected in two separate time periods, first one was during May/2022 and the other one was in June/2022. The same sites were investigated and these sites are described in Table 1.

2.4 Study sample and settings

160 swab samples were collected as described in Table 1. Each swab sample covered an area of 100 cm^2 (around 10 cm*10 cm). Samples were taken during each month, every other day.

Sampling was carried out with a sterile swab. The sterile swab was pre-soaked in sterile normal saline and inserted directly after swabbing into a falcon tube with 2 ml Phosphate Buffer Saline (PBS) and transported immediately to the microbiology lab at Faculty of Medicine and Health Sciences at An-Najah National University.

2.5 Bacterial Culture and Detection

Each tube was vortexed for one minute and 100 µl were cultured into each of the following agar plates:

1- Blood agar.
2- Chocolate agar.
3- MacConkey agar.
4-Mannitol salt agar (MSA).
5-MSA + Oxacillin (6 µg/ml) ➔ Methicillin Resistant *Staphylococcus* (MRS) detection.
6-MacConkey agar + Meropenem (1 µg/ml) ➔ CRE detection.
7-MacConkey agar + Cefotaxime (1 µg/ml) ➔ ESBL detection.
8-Bile esculin +Vancomycin (6 µg/ml) ➔ VRE detection.

Antibiotics used in this study were purchased from Sigma Aldrich, while the media were purchased from Oxoid. Media with antibiotics were prepared as described in the Clinical & Laboratory Standard Institute (CLSI) 2021, and as described in the literature (68, 69).

All plates were incubated at 37 degree / 24 hours aerobically, while Chocolate agar plates were incubated in 5% CO_2 .

American Type Culture Collection (ATCC) strains (*E. coli* ATCC 25922 *and S. aureus* ATCC 25923) and clinically confirmed isolates (MRSA, ESBL, CRE and VRE) that obtained from laboratory department at An- Najah National University Hospital were used as control for the prepared media in each preparation.

2.6 Vancomycin resistance

Screening method was used to detect vancomycin resistance. In short, bile esculin media was prepared with a concentration of 6 µg/ml, further confirmation was approached through E-test. E test was applied for those strains that need to be screened for vancomycin sensitivity; MRS detected using MSA + Oxacillin and colonies grown on bile esculin agar with vancomycin.

2.7 Contamination rate calculation

After the incubation period, colonies on each plate were counted and the results were presented after the calculations as CFU/cm^2 (calculation CFU/cm^2: counted colonies number * 0.2) as shown in Table 2.

2.8 Ethical Approval

Ethical approval was taken from institutional review board (IRB) at An-Najah National University and An-Najah National University Hospital.

Chapter Three

Results

3.1 Bacterial Detection

Bacterial growth was nearly detected in all targeted sites. Regarding samples collected in May, bacterial growth was detected in 49/80 sites. Samples collected in June showed growth in 52/80 sites. Interestingly, in total 60/80 sites showed bacterial growth as shown in Table 2 and 3.

In the radiology department as well as all other inanimate objects, gram-positive bacteria are predominant in and out of CT, MRI, Plain X-Ray, US rooms, and Portable X-Ray, while gram-negative was only detected in four sites as shown in Table 3 and 4.

Table 2

Calculated contamination rate (CFUs/cm^2) during the two months on both Blood and Chocolate agar from each sample source

		May- Experiment		June-Experiment	
Sample Number	Sample Source	Contamination rate chocolate agar	Contamination rate blood agar	Contamination rate chocolate agar	Contamination rate blood agar
1	Center of patient table MRI 1	0.6	0.2	0	0
2	MRI head support	0.6	2	0.4	0.2
3	Wall Bucky	0	0	0	0
4	Head pillow of CT CANON	0.6	0	2.2	0.4
5	RT side edge of patient table CT CANON	0	0	0.4	0.4
6	Center of patient table CT CANON	1.6	0.4	8.8	10
7	Head coil MRI 1	0.2	0.2	0	0
8	Control panel for contrast media injector	0	0	0	0
9	Wall Bucky x-ray control panel	0	0	0	0
10	X-Ray cassette	0	0	0	0.2
11	Keyboard of CT CANON	2	0.6	6	4

		May- Experiment		June-Experiment	
Sample Number	Sample Source	Contamination rate chocolate agar	Contamination rate blood agar	Contamination rate chocolate agar	Contamination rate blood agar
12	RT side gantry control panel CT CANON	0	0	0	0
13	X-Ray cassette of primax X-Ray portable	0	0	0	0
14	LT side gantry control panel CT CANON	0.4	1	0	0
15	Primax X-Ray portable touch screen	0	0.6	1	6
16	CT CANON gantry	0	0	0	0
17	Hand of primax X-Ray portable	0	0	0	0
18	Anesthesia Machine	0.4	0.2	0	0
19	RT side of control panel of MRI gantry	0.2	0	0	0
20	Table of MRI control Room	0	0	0.8	0.8
21	LT side of control panel MRI gantry	0	0	0	0
22	Touch screen of X-Ray tube	0	0	0	0
23	Core of MRI gantry	0	0	0	0
24	Table of prep medication in X-Ray room	0	0	0.8	0.2

		May- Experiment		June-Experiment	
Sample Number	Sample Source	Contamination rate chocolate agar	Contamination rate blood agar	Contamination rate chocolate agar	Contamination rate blood agar
25	Keyboard of US for general use	1.2	1.4	2.4	1.2
26	Patient table od US for general use	0.2	0	0	0
27	Earplug of MRI	0.2	0.2	0.8	0.4
28	Center of patient table X-Ray	0	0	0.2	0
29	MRI surface coil 1	0.2	0	0.2	0.2
30	RT side of MRI patient table	4.8	1	0	0
31	LT side of MRI patient table 1	0.4	0.6	20	20
32	Trolley emergency in CT CANON room	0.4	0	0.8	0.4
33	keyboard in CT CANON control room	3	0	0.6	1.6
34	CT Siemens Keyboard control room	4	8	6	6
35	CT Siemens mouse control room	0.8	0.4	0.6	0.4
36	CT Siemens inside gantry	0	0	0	0
37	CT Siemens center of patient table	0	0	0	0.4

		May- Experiment		June-Experiment	
Sample Number	Sample Source	Contamination rate chocolate agar	Contamination rate blood agar	Contamination rate chocolate agar	Contamination rate blood agar
38	RT side edge of CT Siemens Patient table	0.2	0	0.6	0.4
39	CT Siemens head support	0.8	0.6	0	0.8
40	RT side CT Siemens gantry control panel	0	0	0	0
41	LT side CT Siemens gantry control panel	0	0	0	0
42	linear probe for interventional US	0	0	0	0
43	Curve linear probe for interventional US	0	0	0	0
44	The keyboard of interventional US	1	0.6	0.2	0
45	Touch screen of interventional US	0	0.2	0.2	0
46	Table of prep medication in CT Siemens room	0	0	0	0
47	Trolley emergency in CT Siemens room	0.2	0	0	0
48	Patient leg support of CT Siemens	0.2	0	0.6	1.2
49	Linear probe for US general use	0	0	2.8	0.6
50	Curve linear probe for US for general use	0.2	0	0.4	0.4

		May- Experiment		June-Experiment	
Sample Number	Sample Source	Contamination rate chocolate agar	Contamination rate blood agar	Contamination rate chocolate agar	Contamination rate blood agar
51	Large touch screen for US for general use	0	0	12.8	0.4
52	Table of US for general use in control room	4.8	1.8	1.6	1.4
53	Door of US for general use examination room	0	0	0	0
54	Small touch screen for US general use	0.2	0	0.2	0.2
55	Patient tabel tools in US for general use room	0.8	0.2	0.6	0.4
56	Hand of US for general use	1	0.2	0.8	0.4
57	Patient Head pillow in US for general use room	0.6	0	0	0.6
58	Mouse of US for general use in control room	2.2	0.8	0.4	0.2
59	keyboard in control room of US for general use	3.4	0.6	1	0.2
60	RT side of X-Ray patient table	0.2	0	2.4	0.8
61	LT side of X-Ray patient table	0	0	0.2	0.4
62	Keyboard in control room od X-Ray	0	0.4	0.2	1
63	Hand of carestearm portable	8	0.2	0	0.8

		May- Experiment		June-Experiment	
Sample Number	Sample Source	Contamination rate chocolate agar	Contamination rate blood agar	Contamination rate chocolate agar	Contamination rate blood agar
64	Carestream touchscreen portable	0.2	0.2	5.2	5
65	X-Ray cassette of carestream portable	0	0	0.4	0
66	LT side of patient table CT CANON	8	8	1.6	1.2
67	Touch screen of injector in CT CANON control room	0.2	0	1.8	1.6
68	Mouse of CT CANON	0	0.2	0	0.6
69	Mouse in CT CANON control room	0	0	0	0
70	Surface coil MRI 2	0	0	0	0
71	Head coil MRI 2	0	0	0	0
72	Knee coil	2.4	3	0.6	0.4
73	Center of MRI patient table 2	1.4	0	2.8	2.4
74	RT side edge of MRI patient table 2	2.8	4.8	3	0.6
75	LT side edge of MRI patient table 2	5.8	4.2	8.4	6
76	LT side edge of CT Siemens patient table	0.8	0	0.8	0

		May- Experiment		June-Experiment	
Sample Number	Sample Source	Contamination rate chocolate agar	Contamination rate blood agar	Contamination rate chocolate agar	Contamination rate blood agar
77	Keyboard of X-Ray in control room	3.2	3.4	6	8
78	Mouse of X-Ray in control room	0	0	1	0.8
79	Patient leg support 1	2.2	2.4	0.4	0.4
80	Patient leg support 2 MRI	2	3.4	8	5.4

Table 3

Shows sample source and number of colonies on each plate during May.

Experiment 1: May	sample source	Blood Agar	Chocolate Agar	macConky Agar	Manetol Salt Agar	macConky with meropenem	macConky with cefotaxim	Manetol Salt Agar with oxacilline	Bile esculine Agar with vancomycin
1	Center of patient table MRI 1	1	3	0	0	0	0	0	0
2	MRI head support	10	3	0	0	0	0	0	0
3	Wall Bucky	0	0	0	0	0	0	0	0
4	Head pillow of CT CANON	0	3	0	1	0	0	0	0
5	RT side of patient table CT CANON	0	0	0	0	0	0	0	0
6	Center of patient table CT CANON	2	8	0	8	0	0	1	0
7	Head coil MRI 1	1	1	1	1	0	0	0	0
8	Control panel for contrast media injector	0	0	0	0	0	0	0	0
9	Wall Bucky control panel	0	0	0	0	0	0	0	0
10	X-Ray cassette	0	0	0	0	0	0	0	0
11	Keyboard of CT CANON	3	10	0	0	0	0	0	0

Experiment 1: May	sample source	Blood Agar	Chocolate Agar	macConky Agar	Manetol Salt Agar	macConky with meropenem	macConky with cefotaxim	Manetol Salt Agar with oxacilline	Bile esculine Agar with vancomycin
12	RT side gantry control panel CT CANON	0	0	0	0	0	0	0	0
13	X-Ray cassette of primax portable	0	0	0	0	0	0	0	0
14	LT side gantry control panel CT CANON	5	2	0	1	0	0	0	0
15	primax X-Ray portable touch screen	3	0	0	0	0	0	0	0
16	CT CANON gantry	0	0	0	0	0	0	0	0
17	Hand of primax X-Ray portable	0	0	0	0	0	0	0	0
18	Anasthesia Machine	1	2	0	0	0	0	0	0
19	RT side of control panel of MRI gantry	0	1	0	0	0	0	0	0
20	Table of MRI control Room	0	0	0	0	0	0	0	0
21	LT side of control panel MRI gantry	0	0	0	0	0	0	0	0
22	touch screen of X-Ray tube	0	0	0	0	0	0	0	0
23	inside gantry of MRI	0	0	0	0	0	0	0	0

Experiment 1: May	sample source	Blood Agar	Chocolate Agar	macConky Agar	Manetol Salt Agar	macConky with meropenem	macConky with cefotaxim	Manetol Salt Agar with oxacilline	Bile esculine Agar with vancomycin
24	Table of prep medication in X-Ray room	0	0	0	1	0	0	0	0
25	Keyboard of US for general use	7	6	0	5	0	0	0	0
26	Patient table od US for general use	0	1	0	1	0	0	0	1 no black colony
27	ear plugs of MRI	1	1	1	0	0	0	0	0
28	Center of patient table X-Ray	0	0	0	0	0	0	0	0
29	MRI surface coil 1	0	1	0	0	0	0	0	0
30	RT side of MRI patient table	5	24	0	11	0	0	0	0
31	LT side of MRI patient table 1	3	2	0	0	0	0	0	0
32	Trolley emergency in CT CANON room	0	2	0	0	0	0	0	0
33	Keyboard in CT CANON control room	0	15	0	0	0	0	0	0

Experiment 1: May	sample source	Blood Agar	Chocolate Agar	macConky Agar	Manetol Salt Agar	macConky with meropenem	macConky with cefotaxim	Manetol Salt Agar with oxacilline	Bile esculine Agar with vancomycin
34	CT Siemen’s Keyboard control room	40	20	0	0	0	0	2	0
35	CT Siemen’s mouse control room	2	4	0	0	0	0	0	0
36	CT Siemen’s inside gantry	0	0	0	0	0	0	0	0
37	CT Siemen’s center of patient table	0	0	0	0	0	0	0	0
38	RT side edge of CT Siemen’s Patient table	0	1	0	0	0	0	0	0
39	CT Siemen’s head support	3	4	0	0	0	0	0	0
40	RT side CT semen’s gantry control panel	0	0	0	0	0	0	0	0
41	LT side CT semen’s gantry control panel	0	0	0	0	0	0	0	0
42	linear probe for interventional US	0	0	0	0	0	0	0	0
43	Curve linear probe for interventional US	0	0	0	0	0	0	0	0
44	Keyboard of interventional US	3	5	0	2	0	0	0	0
45	Touch screen of interventional US	1	0	0	1	0	0	0	0

Experiment 1: May	sample source	Blood Agar	Chocolate Agar	macConky Agar	Manetol Salt Agar	macConky with meropenem	macConky with cefotaxim	Manetol Salt Agar with oxacilline	Bile esculine Agar with vancomycin
46	Table of prep medication in CT semen's room	0	0	0	0	0	0	0	0
47	Trolley emergency in CT semen's room	0	1	0	0	0	0	0	0
48	Patient leg support of CT semen's	0	1	0	3	0	0	0	0
49	Linear probe for US general use	0	0	0	0	0	0	0	0
50	Curve linear probe for US for general use	0	1	0	0	0	0	0	0
51	Large touch screen for US for general use	0	0	0	0	0	0	0	0
52	Table of US for general use in control room	9	24	0	9	0	0	0	0
53	Door of US for general use examination room	0	0	0	0	0	0	0	0
54	Small touch screen for US general use	0	1	0	1	0	0	0	0

Experiment 1: May	sample source	Blood Agar	Chocolate Agar	macConky Agar	Manetol Salt Agar	macConky with meropenem	macConky with cefotaxim	Manetol Salt Agar with oxacilline	Bile esculine Agar with vancomycin
55	Patient table tools in US for general use room	1	4	0	3	0	0	0	0
56	Hand of US for general use	1	5	0	3	0	0	0	0
57	patient Head pillow in US for general use room	0	3	0	0	0	0	0	0
58	Mouse of US for general use in control room	4	11	0	3	0	0	0	0
59	Keyboard in control room of US for general use	3	17	0	8	0	0	0	0
60	RT side of X-Ray patient table	0	1	0	0	0	0	0	0
61	LT side of X-Ray patient table	0	0	0	0	0	0	0	0
62	Keyboard in control room od X-Ray	2	0	0	0	0	0	0	0
63	Hand of carestearm portable	1	40	0	0	0	0	0	0

Experiment 1: May	sample source	Blood Agar	Chocolate Agar	macConky Agar	Manetol Salt Agar	macConky with meropenem	macConky with cefotaxim	Manetol Salt Agar with oxacilline	Bile esculine Agar with vancomycin
64	carestream touchscreen portable	1	1	0	0	0	0	0	0
65	X-Ray cassette of carestream portable	0	0	0	0	0	0	0	0
66	LT side of patient table CT CANON	40	40	0	18	0	0	3	0
67	Touch screen of injector in CT CANON control room	0	1	0	0	0	0	0	0
68	Mouse of CT CANON	1	0	0	0	0	0	0	0
69	Mouse in CT CANON control room	0	0	0	0	0	0	0	0
70	Surface coil MRI 2	0	0	0	0	0	0	0	0
71	Head coil MRI 2	0	0	0	0	0	0	0	0
72	Knee coil	15	12	0	0	0	0	1	0
73	Center of MRI patient table 2	0	7	0	0	0	0	0	0
74	RT side of MRI patient table 2	24	14	0	11	0	0	1	0

Experiment 1: May	sample source	Blood Agar	Chocolate Agar	macConky Agar	Manetol Salt Agar	macConky with meropenem	macConky with cefotaxim	Manetol Salt Agar with oxacilline	Bile esculine Agar with vancomycin
75	LT side of MRI patient table 2	21	29	1	6	0	0	0	0
76	LT side of CT semen's patient table	0	4	0	0	0	0	0	0
77	Keyboard of X-Ray in control room	17	16	0	3	0	0	0	0
78	Mouse of X-Ray in control room	0	0	0		0	0	0	0
79	Patient leg support MRI 1	12	11	0	6	0	0	2	0
80	Patient leg support 2 MRI	17	10	0	1	0	0	0	0

Table 4

Shows sample source and number of colonies on each plate during June

Experiment 2: June	Sample Source	Blood Agar	chocolate Agar	macConky Agar	Manetol Salt Agar	macConky with Meropenem	macConky with cefotaxim	Manetol Salt Agar with oxacilline	Bile esculine Agar with vancomycin
1	Center of patient table MRI 1	0	0	0	0	0	0	0	0
2	MRI head support	1	2	0	0	0	0	0	0
3	Wall Bucky	0	0	0	0	0	0	0	0
4	Head pillow of CT CANON	2	11	0	2	0	0	2	30
5	RT side of patient table CT CANON	2	2	0	1	0	0	1	0
6	center of patient table CT CANON	50	44	7	20	0	0	7	40
7	Head coil MRI 1	0	0	0	0	0	0	0	0
8	control panel for contrast media injector	0	0	0	0	0	0	0	0
9	wall Bucky control panel	0	0	0	0	0	0	0	0
10	X-Ray cassette	1	0	0	0	0	0	0	0
11	Keyboard of CT CANON	20	30	0	17	0	0	1	0

Experiment 2: June	Sample Source	Blood Agar	chocolate Agar	macConky Agar	Manetol Salt Agar	macConky with Meropenem	macConky with cefotaxim	Manetol Salt Agar with oxacilline	Bile esculine Agar with vancomycin
12	RT side gantry control panel CT CANON	0	0	0	0	0	0	0	0
13	X-Ray cassette of primax portable	0	0	0	0	0	0	0	0
14	LT side gantry control panel CT CANON	0	0	0	0	0	0	0	0
15	primax X-Ray portable touch screen	30	5	0	20	0	0	2	10
16	CT CANON gantry	0	0	0	0	0	0	0	0
17	hand of primax X-Ray portable	0	0	0	0	0	0	0	0
18	Anesthesia Machine	0	0	0	0	0	0	0	0
19	RT side of control panel of MRI gantry	0	0	0	0	0	0	0	0
20	Table of MRI control Room	4	4	0	0	0	0	0	0
21	LT side of control panel MRI gantry	0	0	0	0	0	0	0	0
22	touch screen of X-Ray tube	0	0	0	0	0	0	0	0
23	inside gantry of MRI	0	0	0	0	0	0	0	0

Experiment 2: June	Sample Source	Blood Agar	chocolate Agar	macConky Agar	Manetol Salt Agar	macConky with Meropenem	macConky with cefotaxim	Manetol Salt Agar with oxacilline	Bile esculine Agar with vancomycin
24	Table of prep medication in X-Ray room	1	4	0	1	0	0	0	0
25	Keyboard of US for general use	6	12	0	7	0	0	0	0
26	Patient table od US for general use	0	0	0	0	0	0	0	0
27	ear plugs of MRI	2	4	0	4	0	0	0	0
28	center of patient table X-Ray	0	1	0	0	0	0	0	0
29	MRI surface coil 1	1	1	0	1	0	0	0	0
30	RT side of MRI patient table	0	0	0	0	0	0	0	0
31	LT side of MRI patient table 1	100	100	0	60	0	0	0	0
32	Trolley emergency in CT CANON room	2	4	0	2	0	0	0	0
33	keyboard in CT CANON control room	8	3	0	9	0	0	0	0
34	CT Siemens Keyboard control room	30	30	0	30	0	0	0	0

Experiment 2: June	Sample Source	Blood Agar	chocolate Agar	macConky Agar	Manetol Salt Agar	macConky with Meropenem	macConky with cefotaxim	Manetol Salt Agar with oxacilline	Bile esculine Agar with vancomycin
35	CT Siemens mouse control room	2	3	0	2	0	0	0	0
36	CT Siemens inside gantry	0	0	0	1	0	0	0	0
37	CT Siemens center of patient table	2	0	0	0	0	0	0	0
38	RT side edge of CT Siemens Patient table	2	3	0	1	0	0	0	0
39	CT Siemens head support	4	0	0	3	0	0	0	0
40	RT side CT Siemens gantry control panel	0	0	0	0	0	0	0	0
41	LT side CT Siemens gantry control panel	0	0	0	0	0	0	0	0
42	linear probe for interventional US	0	0	0	0	0	0	0	0
43	Curve linear probe for interventional US	0	0	0	0	0	0	0	0
44	Keyboard of interventional US	0	1	0	0	0	0	0	0
45	Touch screen of interventional US	0	1	0	0	0	0	0	0
46	Table of prep medication in CT Siemens room	0	0	0	0	0	0	0	0

Experiment 2: June	Sample Source	Blood Agar	chocolate Agar	macConky Agar	Manetol Salt Agar	macConky with Meropenem	macConky with cefotaxim	Manetol Salt Agar with oxacilline	Bile esculine Agar with vancomycin
47	Trolley emergency in CT Siemens room	0	0	0	0	0	0	0	0
48	Patient leg support of CT Siemens	6	3	0	1	0	0	0	0
49	Linear probe for US general use	3	14	0	6	0	0	0	0
50	Curve linear probe for US for general use	2	2	0	2	0	0	0	0
51	Large touch screen for US for general use	2	64	0	0	0	0	0	0
52	Table of US for general use in control room	7	8	0	8	0	0	0	0
53	Door of US for general use examination room	0	0	0	0	0	0	0	0
54	Small touch screen for US general use	1	1	0	1	0	0	0	0
55	Patient table tools in US for general use room	2	3	0	2	0	0	2	0
56	hand of US for general use	2	4	0	5	0	0	0	0

Experiment 2: June	Sample Source	Blood Agar	chocolate Agar	macConky Agar	Manetol Salt Agar	macConky with Meropenem	macConky with cefotaxim	Manetol Salt Agar with oxacilline	Bile esculine Agar with vancomycin
57	patient Head pillow in US for general use room	3	0	0	3	0	0	0	0
58	Mouse of US for general use in control room	1	2	0	0	0	0	0	0
59	keyboard in control room of US for general use	1	5	0	5	0	0	1	0
60	RT side of X-Ray patient table	4	12	0	4	0	0	0	0
61	LT side of X-Ray patient table	2	1	0	0	0	0	0	0
62	Keyboard in control room od X-Ray	5	1	0	2	0	0	0	0
63	hand of carestearm portable	4	0	0	1	0	0	0	0
64	carestream touchscreen portable	25	26	0	2	0	0	0	0
65	X-Ray cassette of carestream portable	0	2	0	0	0	0	0	0
66	LT side of patient table CT CANON	6	8	0	7	0	0	3	0

Experiment 2: June	Sample Source	Blood Agar	chocolate Agar	macConky Agar	Manetol Salt Agar	macConky with Meropenem	macConky with cefotaxim	Manetol Salt Agar with oxacilline	Bile esculine Agar with vancomycin
67	touch screen of injector in CT CANON control room	8	9	0	8	0	0	0	15
68	mouse of CT CANON	3	0	0	0	0	0	0	0
69	mouse in CT CANON control room	0	0	0	0	0	0	0	0
70	surface coil MRI 2	0	0	0	0	0	0	0	0
71	Head coil MRI 2	0	0	0	0	0	0	0	0
72	Knee coil	2	3	0	4	0	0	0	0
73	Center of MRI patient table 2	12	14	0	6	0	0	0	0
74	RT side of MRI patient table 2	3	15	0	8	0	0	0	0
75	LT side of MRI patient table 2	30	42	0	22	0	0	3	0
76	LT side of CT Siemens patient table	0	4	0	0	0	0	0	0
77	Keyboard of X-Ray in control room	40	30	0	28	0	0	0	0
78	Mouse of X-Ray in control room	4	5	0	4	0	0	0	0

Experiment 2: June	Sample Source	Blood Agar	chocolate Agar	macConky Agar	Manetol Salt Agar	macConky with Meropenem	macConky with cefotaxim	Manetol Salt Agar with oxacilline	Bile esculine Agar with vancomycin
79	patient leg support 1	2	2	0	2	0	0	0	0
80	leg support 2 MRI	27	40	0	27	0	0	0	0

3.2 Total Bacterial Contamination

Regarding bacterial contamination ≥ 1 CFUs/cm^2, in May, out of 80 sites examined, 21 sites (26%) had contamination, while in June, 22 sites (27%) were considered as contaminated. In total, 29 sites showed contamination of ≥ 1 CFUs/cm^2, as shown in Table 5.

Table 5

Sites with contamination rate of ≥1CFU/cm^2, either on Blood or on Chocolate agar

		May- Experiment		June-Experiment	
Sample Number	Sample Source	Contamination rate chocolate agar	Contamination rate blood agar	Contamination rate chocolate agar	Contamination rate blood agar
2	MRI head support	0.6	2	0.4	0.2
4	Head pillow of CT CANON	0.6	0	2.2	0.4
6	Center of patient table CT CANON	1.6	0.4	8.8	10
11	Keyboard of CT CANON	2	0.6	6	4
14	LT side gantry control panel CT CANON	0.4	1	0	0
15	primax X-Ray portable touch screen	0	0.6	1	6
25	Keyboard of US for general use	1.2	1.4	2.4	1.2
30	RT side of MRI patient table	4.8	1	0	0

		May- Experiment		June-Experiment	
Sample Number	Sample Source	Contamination rate chocolate agar	Contamination rate blood agar	Contamination rate chocolate agar	Contamination rate blood agar
33	Keyboard in CT CANON control room	3	0	0.6	1.6
34	CT Siemen's Keyboard control room	4	8	6	6
44	Keyboard of inteventional US	1	0.6	0.2	0
48	Patient leg support of CT semen's	0.2	0	0.6	1.2
51	Large touch screen for US for general use	0	0	12.8	0.4
52	Table of US for general use in control room	4.8	1.8	1.6	1.4
56	Hand of US for general use	1	0.2	0.8	0.4
58	Mouse of US for general use in control room	2.2	0.8	0.4	0.2
59	Keyboard in control room of US for general use	3.4	0.6	1	0.2
60	RT side of X-Ray patient tabel	0.2	0	2.4	0.8
63	Hand of carestearm portabel	8	0.2	0	0.8
64	carestream touchscreen portabel	0.2	0.2	5.2	5
66	LT side of patient table CT CANON	8	8	1.6	1.2

		May- Experiment		June-Experiment	
Sample Number	Sample Source	Contamination rate chocolate agar	Contamination rate blood agar	Contamination rate chocolate agar	Contamination rate blood agar
67	Touch screen of injecter in CT CANON control room	0.2	0	1.8	1.6
72	Knee coil	2.4	3	0.6	0.4
73	Center of MRI patient table 2	1.4	0	2.8	2.4
74	RT side of MRI patient table 2	2.8	4.8	3	0.6
75	LT side of MRI patient table 2	5.8	4.2	8.4	6
77	Keyboard of X-Ray in control room	3.2	3.4	6	8
79	patient leg support 1	2.2	2.4	0.4	0.4
80	patient leg support 2	2	3.4	8	5.4

3.3 Gram-positive: *Staphylococcus* (MSA-growth)

Concerning contamination with bacteria that can grow on MSA which is mainly *Staphylococcus*, in May, out of 80 sites examined, 9 sites have contamination rate of ≥ 1 CFUs/cm^2, while in June 18 sites considered as contaminated. In total, 20 sites showed contamination of ≥ 1 CFUs/cm^2, as shown in Table 6 and 10.

Table 6

Sites contaminated with bacteria that can grow on MSA agar during two months

Sample Number/ Month	Sample source	Mannitol Salt Agar CFUs/cm^2
4/ May and June	Head pillow of CT CANON	0.2/0.4
5/June	RT side of patient table CT CANON	0.2
6/May and June	Center of patient tabel CT CANON	1.6/4
7/May	Head coil MRI 1	0.2
11/June	Keyboard of CT CANON	3.4
14/May	LT side gantry control panel CT CANON	0.2
15/June	primax X-Ray portable touch screen	4
24/May and June	Table of prep medication in X-Ray room	0.2/0.2
25/May and June	Keyboard of US for general use	1/1.4
26/May	Patient table of US for general use	0.2
27/June	ear plugs of MRI	0.8
29/June	MRI surface coil 1	0.2
30/May	RT side of MRI patient table	2.2
31/June	LT side of MRI patient table 1	3
32/June	Trolley emergency in CT CANON room	0.4
33/June	keyboard in CT CANON control room	1.8
34/June	CT Siemens Keyboard control room	6
35/June	CT siemens mouse control room	0.4

Sample Number/ Month	Sample source	Mannitol Salt Agar CFUs/cm^2
36/June	CT siemens inside gantry	0.2
38/June	RT side edge of CT siemens Patient table	0.2
39/June	CT siemens head support	0.6
44/May	Keyboard of interventional US	0.4
45/May	Touch screen of interventional US	0.2
48/May and June	Patient leg support of CT semens	0.6/0.2
49/June	Linear probe for US general use	1.2
50/June	Curve linear probe for US for general use	0.4
52/May and June	Table of US for general use in control room	1.8/1.6
54/May and June	Small touch screen for US general use	0.2/0.2
55/May and June	Patient table tools in US for general use room	0.6/0.4
56/May and June	Hand of US machine for general use	0.6/1
57/June	Patient Head pillow in US for general use room	0.6
58/May	Mouse of US for general use in control room	0.6
59/May and June	keyboard in control room of US for general use	1.6/1
60/June	RT side of X-Ray patient table	0.8
62/June	Keyboard in control room of X-Ray	0.4
63/June	Hand of carestearm portable	0.2
64/June	carestream touch screen portable	0.2
66/May and June	LT side of patient table CT CANON	3.6/1.4
67/June	Touch screen of injector in CT CANON control room	1.6
72/June	Knee coil	0.8
73/June	Center of MRI patient tabel 2	1.2
74/May and June	RT side of MRI patient tabel 2	2.2/1.6

Sample Number/ Month	Sample source	Mannitol Salt Agar CFUs/cm^2
75/May and June	LT side of MRI patient tabel 2	1.2/4.4
77/May and June	Keyboard of X-Ray in control room	0.6/5.6
78/June	Mouse of X-Ray in control room	0.8
79/May and June	Patient leg support MRI 1	1.2/0.4
80/May and June	Patient leg support MRI 2	0.2/5.4

3.4 Gram-positive: MRS

Regarding the surface contamination with MRS. Six sites in May and 9 sites in June, showed growth on MSA + Oxacillin, which means MRS is suspected to be present. Later on, all suspected colonies confirmed as MRS after subculture. Out of 13 sites, only one site has a contamination rate $\geqslant$1 CFUs/cm^2 in June, and none in May. However, the site with contamination rate $\geqslant$1 CFUs/cm^2 is the center of patient table of CT Canon with 1.4 CFUs/cm^2, as shown in table 7 and 10.

Table 7

Sites contaminated with MRS, on Mannitol Salt agar with Oxacillin.

Sample Number/Month	Sample Source	Mannitol Salt agar with Oxacillin
		CFUs/cm^2
4/June	Head pillow of CT CANON	0.4
5/June	RT side of patient table CT CANON	0.2
6/May and June	Center of patient table CT CANON	0.2/1.4
11/June	Keyboard of CT CANON	0.2
15/June	Primax X-RAY portable Touch screen	0.4
34/May	CT Siemens Keyboard control room	0.4
55/June	Patient table tools in US for general use room	0.4
59/June	Keyboard in control room of US for general use	0.2

66/May and June	LT side of patient table CT CANON	0.6/0.6
72/May	Knee coil	0.2
74/May	RT side of MRI patient table 2	0.2
75/June	LT side of MRI patient table 2	0.6
79/May	Patient leg support 1	0.4

3.5 Gram-positive: Vancomycin Resistant *Staphylococcus* VRS

After MRS detected and confirmed, all MRS isolates were tested for vancomycin sensitivity using E-test. In May, no VRS was detected, and all isolates were found to be vancomycin sensitive *Staphylococcus*. Surprisingly, in June, 7 out of 13 detected MRS were confirmed as VRS; namely, samples from Head pillow of CT Canon, center of patient table CT Canon, right side gantry control panel CT Canon, primax X-Ray portable touch screen, Patient table tools in US for general use room, keyboard in control room of US for general use, and left side of MRI patient Table 5 and 10.

3.6 Gram-positive: (VRE)

VRE were detected in five of the examined sites, one site in May with a contamination rate < 1 CFUs/cm^2, while the other four times were in June, with a contamination rate of ≥1 CFUs/cm^2, as showed in Table 8 and 10.

Table 8

Sites harbors VRE in the radiology department, on Bile Esculine agar with Vancomycin.

Sample number/month	Sample Source	Bile esculin Agar with vancomycin CFUs/cm^2
4/June	Head pillow of CT CANON	6
6/June	Center of patient table CT CANON	8
15/June	primax X-Ray portable touch screen	2
26/May	Patient table of US for general use	0.2
67/June	Touch screen of injector in CT CANON control room	3

3.7 Gram-Negatives

Our results showed that only four gram-negative bacteria were isolated from four different sites during the two cohorts done in May and June 2022. Three of these contaminated sites have contamination rate of < 1 CFUs/cm^2 during May, while the fourth contaminated site (center of patient table – CT cannon) has a contamination rate of 1.4 CFUs/cm^2 and this contamination was detected in June, as shown in Tables 3, 4and Table 9 and 10.

Table 9

Samples with growth of gram-negative bacteria

Sample number/month	Sample Source	CFU/cm^2
6/June	Center of patient table CT CANON	1.4
7/May	Head coil MRI 1	0.2
27/May	Ear plug of MRI	0.2
75/May	LT side of MRI patient table 2	0.2

3.8 Gram-negative: ESBL and CRE

None of the equipment sites from the radiology department that were tested showed growth of ESBL and CRE according to the data in Table 3,4, and Table 10 .

Table 10

Isolated Organisms in May and June

Isolated microorganisms	May	June	Collectively (May and June)
MRS	6	8	13
VRSA	0	7	7
VRE	1	4	5
CRE	0	0	0
ESBL	0	0	0

3.9 Contamination rate

Because of the increasing number of patients and an increased number of referred patients in June, the contamination rate average 1.3 CFUs/cm^2 is greater than in May 0.79 CFUs/cm^2, as shown in 3 and 4 Tables, while for the study period (May and June), no differences were noticed in the disinfectant materials used to disinfect the surfaces, the time, and frequency at which the surfaces are cleaned.

Growth conditions affect the contamination rate, as the data showed in table S3, contamination rate on chocolate agar was higher than contamination rate on blood agar for almost all sites during the two cohorts. Chocolate agar has a higher contamination rate than blood agar mostly because chocolate agar contains the lysed red blood cells with better growth for the fastidious organisms and due to the fact that chocolate agar plates were incubated in an anaerobic environment (70).

The results showed a contamination median value greater than 3 CFU/cm^2 from seven common surface sites tested in the CT, MRI, US, and Plain X-Ray; center and sides of the examination table X-Ray patient's table, knee coil, MRI patient legs support, and all of the radiology machine keyboards.

Alarming findings reveal that the highest contamination rate was found in: the CT Canon's core of patient table and the large touch screen of US for general use; with 10 CFUs/cm^2 and 12.8 CFUs/cm^2, respectively. Another alarming piece of data shows, the high contamination rate on the: Right and Left side of MRI patient table 2, MRI patient leg support 2, Keyboard in the X-Ray control room, Left side of patient table of CT Canon, CT Siemen's keyboard in the control room and Keyboard and table of US for general use; in both cohorts, as data shown in Table 2.

Chapter Four
Discussions

Gram-positive bacteria were more detected in the radiology department than gram-negative ones, and this was expected. This result is consistent with the previous investigations that have found that gram-positive were more common than gram-negative bacteria on inanimate surfaces of the radiology department (9). It was demonstrated that gram-positive bacteria have a stronger potential for surviving on inanimate surfaces and environment (71). Furthermore, gram-positive bacteria also make up a significant portion of the skin's microbiota (72). These are both possible explanations of: why gram-positive bacteria are more common.

In our study, MRS contamination rate on the inert surface is relatively high 13/80 (16%). On the other hand, in Sweden , swabs were taken from the bore, table, and wrap of two quaternary care inpatient CT scanners, wrap was the most contaminated item on a CT scanner and the prevalence of MRSA was significantly low (73). However, in another study in Irland, from 125 sample collected from the radiology department, MRSA was detected from one sample only, bore in the MRI gantry (12).

However, in earlier research on cassettes and lead aprons carried out in radiology departments across the United Kingdom, there was no evidence of MRSA (4). In our research, no MRS were detected from the MRI gantry, but the other 13 samples taken from different sites of the radiology department equipment’s were positive with MRS. MRSA was present on an X-ray cassette that had been utilized in the operation room (74). In addition, our investigation showed no evidence of MRS and bacterial contamination on X-Ray cassette as shown in Table 11 -see Appendix D-.

In general, the sample area makes up only a small portion of the overall surfaces, which may reduce the sensitivity of the test when attempting to identify resistant bacteria that are present in low numbers. In addition, the purpose of this investigation was to identify any contamination on the surfaces inside and outside the radiology examination rooms and equipment and whether they are more likely to be contaminated.

In the majority of the CT, X-Ray, and US examination rooms both inside and outside, as well as on the patient tables of the MRI machines, the keyboards contained a noticeable bacterial contamination rate that ranged 1-8 CFU/cm^2.

This has additionally been shown to be the case in other research, as they showed that workstation sites in the radiology department have 64.3% (9 of 14) contaminated with *S. aureus* and 21.4% (3 of 14) were contaminated with enteric organisms(9, 75). It is probable that this is because medical staff members do not adequately disinfect their hands after dealing with the patient within the examination room, or that they do not regularly disinfect the keyboards and patient tables. Both of these factors contribute to the spread of infection. There has been a lot of research on how important it is to practice good hand hygiene in order to prevent the spread of infection(76).

The simplest, most effective and least expensive strategy to prevent the spread of microorganisms is to practice strict hand cleanliness. In our study, a large number of CFU/cm^2 was found in most cases on LT side of MRI patient table 2, center of patient table CT CANON, and large touch screen for US for general use; with 8.4, 10, and 12.8 CFUs/cm^2; respectively. One possible explanation is that the patients' clothing had been in contact with their bodies for at least 15 minutes and HCWs hands when dealing with patients during examination. In addition, the examination tables' sides of MRI, CT and, X-Ray had contamination rate ranging 1-8.4 CFU/cm^2.

This may be due to the fact that patients set on the examination table with their skin in close contact with the side of the examination table. The examination table's sides and center, as well as the MRI knee coil and patient legs support, are most likely not thoroughly disinfected. In general, a large number of surfaces showed bacterial contamination that was higher than the permissible limit of one CFU/cm^2. Meanwhile, other studies showed low numbers of CFUs/cm^2 on the side of tunnel of MRI camera in the radiology department (9) and a decrease in bacterial growth presence in the magnetic field (77, 78).

The surfaces may have not been cleaned thoroughly enough and this may be a cause of the infection. This could be the result of, for instance, an insufficient amount of staff education on infection management, or it could be because the cleaning is not effective. When deciding on a cleaning procedure, there are many factors to take into consideration.

It should be efficient, but at the same time, it shouldn't have any negative effects on either humans or the environment, and it shouldn't be too expensive (79).

Alterations to cleaning procedures and the kind of materials used have varying effects on certain infections. A cleaning solution containing hydrogen peroxide is excellent against bacteria and viruses, but it is harmful to humans and cannot be used for continuous cleaning (80).

Self-disinfecting surfaces covered with copper and silver have also been studied, and this has been demonstrated to minimize HAI. For the pathogen, efficiency, the environment, and the economy to all benefit from disinfection procedures, further research is needed.

In the radiology department, fortunately, we detected a low number of CFU/cm^2 approximately near zero CFU/cm^2 on the side of the Siemens CT gantry , patient table of X-ray, head coil MRI, surface coils of MRI, and probes for interventional ultrasonography compared to other sites in MRI examination room , side of X-Ray patient table and probes of US for general use. Since patients contact this location practically every time they use these machines, it is highly unlikely that it is disinfected more regularly than other parts of the apparatus.

Concerning the effect that magnetic fields have on the number of bacteria present, additional research needs to be carried out. We were able to detect substantial differences in the contamination between months of May and June in the radiology department. In June, patient isolation, workload, and the number of referral of patients were all higher than in May. As reflection of that, average contamination rate from all sites in June was 1.3 CFUs/cm^2, while in May, it was 0.79 CFUs/cm^2. Moreover, six sites showed contamination with MRS in May compared to 9 sites in June, with only one site in June that had a contamination rate of $\geq$ 1 CFUs/cm^2.

Surprisingly, 7 sites showed contamination with VRS, and all were in June. Regarding contamination with gram-negative bacteria, a contamination rate of $\geq$ 1 CFUs/cm^2, was detected only from one site in June. In addition to that, VRE were detected in one site in May with a contamination rate of < 1 CFUs/cm^2, while it was detected from four sites in June, with a contamination rate of $\geq$1 CFUs/cm^2.

4.1 Limitation of this study:

As the surfaces, machines and places have varied designs, speeds, and workload, it is difficult to acquire samples with high consistency, so it is not easy to compare with other studies from other times, places and countries. However, for our study to be comparable as much as possible, we tried to be in alignment with similar research and other hygiene studies(5). Other point in the limitation: employees who were made aware that contamination would be monitored, may have increased their adherence to more hygienic practices. As another restriction, it cannot be ruled out that the results could have differed significantly if the trial was conducted during on-call hours and in the middle of the workday between patients.

Chapter Five
Conclusion

There is an ongoing debate all around the world regarding whether or not the setting of a hospital contributes to the spread of HAIs. However, there is evidence from research that supports the concept that hospitals can operate as a crucial reservoir of numerous nosocomial infections in a variety of environments. These environments include surfaces, medical equipment, and water systems.

In this investigation, it was concluded that:

1- Radiology department could be a source of healthcare acquired infection. Gram-positive bacteria were the most present bacteria and multidrug-resistant were detected from various sites with a contamination rate which exceeded the limit of 1 CFU/cm^2 in bacterial contamination.

2- Increasing in the work load, referred and isolated patient was proportional to the increase in the contamination rate, presence of gram-negative and multi drug resistant bacteria.

3- Surface cleaning and disinfecting must frequently focus on keyboards in the radiology department, examination patient table sides and centers, knee coil, US machine and patient legs support in particular.

4- Adapt a protocol for frequent testing of the contamination rate of the radiology departments' instruments to check the disinfectant is highly recommended.

List of Abbreviations

Abbreviation	Meaning
BSI	Blood Stream Infection
CRE	Carbapenemes- Resistance *Enterococci*
CT	Computed Tomography
CAI	Community-Acquired Infection
HAI	Healthcare Associated Infection
HCWs	Healthcare workers
MRI	Magnetic Resonance Imaging
MDROs	Multidrug Resistance Microorganisms
MSA	Mannitol Salt agar
MRS	Methicillin-Resistance *Staphylococcus*
MSSA	Methicillin-Sensitive *Staphylococcus aurues*
MRSA	Methicillin-Sensitive *Staphylococcus aurues*
US	Ultra Sound
VRSA	Vancomycin-Resistance *Staphylococcus aureus*
VRS	Vancomycin-Resistance *Staphylococcus*
VRE	Vancomycin-Resistance *Enterococci*
ESBL	Extended Spectrum Beta lactams

References

Weber DJ, Anderson D, Rutala WA. The role of the surface environment in healthcare-associated infections. Current opinion in infectious diseases. 2013;26(4):338-44.

Emine A, Nizam D. Healthcare-associated infections in Intensive Care Units: epidemiology and infection control in low-to-middle income countries. The Journal of Infection in Developing Countries. 2015;9.(10)

Chen LF, Knelson LP, Gergen MF, Better OM, Nicholson BP, Woods CW, et al. A prospective study of transmission of Multidrug-Resistant Organisms (MDROs) between environmental sites and hospitalized patients—the TransFER study. Infection Control & Hospital Epidemiology. 2018;40(1):47-52.

Boyle H, Strudwick RM. "Do lead rubber aprons pose an infection risk?". Radiography. 2010;16(4.303−297):

Giacometti M, Gualano MR, Bert F, Minniti D, Bistrot F, Grosso M, et al. Microbiological contamination of radiological equipment. Acta radiologica (Stockholm, Sweden : 1987). 2014;55(9):1099-103.

Picton-Barnes D, Pillay M. A Systematic Review of Healthcare-Associated Infectious Organisms in Medical Radiation Science Departments. 2020;8.(2)

Jia H, Li W, Hou T, Ma H, Yang Y, Wu A, et al. The Attributable Direct Medical Cost of Healthcare Associated Infection Caused by Multidrug Resistance Organisms in 68 Hospitals of China. BioMed Research International. 2019;2019:7634528.

Ilyas F, Burbridge B, Babyn P. Health Care-Associated Infections and the Radiology Department. Journal of medical imaging and radiation sciences. 2019;50(4):596-606.e1.

Palmqvist C, Samuelsson A, Fröding I, Giske C. Surface Contamination of CT and MRI Equipment—A Potential Source for Transmission of Hospital-Acquired Infections. Journal of Radiology Nursing. 2019;38.

Khan HA, Ahmad A, Mehboob R. Nosocomial infections and their control strategies. Asian Pacific Journal of Tropical Biomedicine. 2015;5(7):509-14.

Muradali D, Gold WL, Phillips A, Wilson S. Can ultrasound probes and coupling gel be a source of nosocomial infection in patients undergoing sonography? An in vivo and in vitro study. AJR American journal of roentgenology. 1995;164(6):1521-4.

Shelly MJ, Scanlon TG, Ruddy R, Hannan MM, Murray JG. Meticillin-resistant Staphylococcus aureus (MRSA) environmental contamination in a radiology department. Clinical Radiology. 2011;66(9):861-4.

Decker BK, Lau AF, Dekker JP, Spalding CD, Sinaii N, Conlan S, et al. Healthcare personnel intestinal colonization with multidrug-resistant organisms. Clinical microbiology and infection : the official publication of the European Society of Clinical Microbiology and Infectious Diseases. 2018;24(1):82.e1-.e4.

Lachiewicz AM, Hauck CG, Weber DJ, Cairns BA, van Duin D. Bacterial Infections After Burn Injuries: Impact of Multidrug Resistance. Clinical Infectious Diseases. 2017;65(12):2130-6.

Mody L, Washer LL, Kaye KS, Gibson K, Saint S, Reyes K, et al. Multidrug-resistant Organisms in Hospitals: What Is on Patient Hands and in Their Rooms? Clin Infect Dis. 2019;69(11):1837-44.

Sydnor ER, Perl TM. Hospital epidemiology and infection control in acute-care settings. Clin Microbiol Rev. 2011;24(1):141-73.

Metersky ML, Kalil AC. New guidelines for nosocomial pneumonia. Current opinion in pulmonary medicine. 2017;23(3):211-7.

Elliott TM, Hurst C, Doidge M, Hurst T, Harris PN, Gordon LG. Unexpected benefit of COVID-19 hospital restrictions: Reduction in patients isolating with multidrug resistant organisms after restrictions were lifted. Infection, disease & health. 2021.

Kim JS, Kim HS, Park JY ,Koo HS, Choi CS, Song W, et al. Contamination of X-ray cassettes with methicillin-resistant Staphylococcus aureus and methicillin-resistant Staphylococcus haemolyticus in a radiology department. Ann Lab Med. 2012;32 (3): 206-9.

Larrosa MN, Almirante B .Isolation strategy for controlling the spread of multidrug-resistant organisms: Is this still an essential option in hospitals? Enfermedades infecciosas y microbiologia clinica. 2021.

Huang SS. Chlorhexidine-based decolonization to reduce healthcare-associated infections and multidrug-resistant organisms (MDROs): who, what, where, when, and why? The Journal of hospital infection. 2019;103(3):235-43.

Blanco N, O'Hara LM, Harris AD. Transmission pathways of multidrug-resistant organisms in the hospital setting: a scoping review. Infection control and hospital epidemiology. 2019;40(4):447-56.

Saliba R, Ghelfenstein-Ferreira T, Lomont A, Pilmis B, Carbonnelle E, Seytre D, et al. Risk factors for the environmental spread of different multidrug-resistant organisms: a prospective cohort study. The Journal of hospital infection. 2021;111:155-61.

Chia PY, Sengupta S, Kukreja A, S.L. Ponnampalavanar S, Ng OT, Marimuthu K. The role of hospital environment in transmissions of multidrug-resistant gram−negative organisms. Antimicrobial Resistance & Infection Control. 2020;9(1):29.

Burnham JP, Rojek RP, Kollef MH. Catheter removal and outcomes of multidrug-resistant central-line-associated bloodstream infection. Medicine. 2018;97(42):e12782.

Anderson DJ, Chen LF, Weber DJ, Moehring RW, Lewis SS, Triplett PF, et al. Enhanced terminal room disinfection and acquisition and infection caused by multidrug-resistant organisms and Clostridium difficile (the Benefits of Enhanced Terminal

Room Disinfection study): a cluster-randomised, multicentre, crossover study. Lancet (London, England). 2017;389(10071):805-14.

Huang SS, Septimus E, Kleinman K, Moody J, Hickok J, Heim L, et al. Chlorhexidine versus routine bathing to prevent multidrug-resistant organisms and all-cause bloodstream infections in general medical and surgical units (ABATE Infection trial): a cluster-randomised trial. Lancet (London, England). 2019;393(10177):1205-15.

Tong SY, Davis JS, Eichenberger E, Holland TL, Fowler VG, Jr. Staphylococcus aureus infections: epidemiology, pathophysiology, clinical manifestations, and management. Clin Microbiol Rev. 2015;28(3):603-61.

Wertheim HF, Melles DC, Vos MC, van Leeuwen W, van Belkum A, Verbrugh HA, et al. The role of nasal carriage in Staphylococcus aureus infections. The Lancet Infectious diseases. 2005;5(12):751-62.

Guo Y, Song G, Sun M, Wang J, Wang Y. Prevalence and Therapies of Antibiotic-Resistance in Staphylococcus aureus. Frontiers in Cellular and Infection Microbiology. 2.(107)10;020

Suleyman G, Alangaden G, Bardossy AC. The Role of Environmental Contamination in the Transmission of Nosocomial Pathogens and Healthcare-Associated Infections. Current infectious disease reports. 2018;20(6):12.

da Silva AC, Rodrigues MX, Silva NCC. Methicillin-resistant Staphylococcus aureus in food and the prevalence in Brazil: a review. Brazilian journal of microbiology : [publication of the Brazilian Society for Microbiology]. 2020;51(1):347-56.

Dong Y, Speer CP. The role of Staphylococcus epidermidis in neonatal sepsis: guarding angel or pathogenic devil? International journal of medical microbiology : IJMM. 2014;304(5-6):513-20.

Byrd AL, Belkaid Y, Segre JA. The human skin microbiome. Nature reviews Microbiology. 2018;16.55−143:(3)

Otto M. Staphylococcus epidermidis--the 'accidental' pathogen. Nature reviews Microbiology. 2009;7(8):555-67.

Dong Y, Speer CP. Late-onset neonatal sepsis: recent developments. Archives of disease in childhood Fetal and neonatal edition:(3)100;2015 .F257-63.

Roberts S, Chambers S. Diagnosis and management of Staphylococcus aureus infections of the skin and soft tissue. Internal medicine journal. 2005;35 Suppl 2:S97-105.

Rodrigues R, Passadouro R, Gomes O, Castro R. Risk Factors ,Length of Stay and In-Hospital Mortality of Methicillin-Resistant Staphylococcus aureus Infections: A Case-Control Study. Acta medica portuguesa. 2020;33(3):174-82.

Otter JA, Yezli S, Salkeld JA, French GL. Evidence that contaminated surfaces contribute to the transmission of hospital pathogens and an overview of strategies to address contaminated surfaces in hospital settings. American journal of infection control. 2013;41(5 Suppl):S6-11.

Vicetti Miguel CP, Mejias A. A decade of antimicrobial resistance in Staphylococcus aureus: A single center experience. 2019;14(2):e0212029.

Petti S, Polimeni A, Dancer SJ. Effect of disposable barriers, disinfection, and cleaning on controlling methicillin-resistant Staphylococcus aureus environmental contamination. American journal of infection control. 2013;41(9):836-40.

Khanal A, G CS, Gaire A, Khanal A, Estrada R, Ghimire R, et al. Methicillin-resistant Staphylococcus aureus in Nepal: A systematic review and meta-analysis. International journal of infectious diseases : IJID : official publication of the International Society for Infectious Diseases. 2021;103:48-55.

Chinnambedu RS, Marimuthu RR, Sunil SS, Amrose P, Ramachandran V, Pachamuthu B. Changing antibiotic resistance profile of Staphylococcus aureus isolated from HIV patients (2012–2017) in Southern India. Journal of Infection and Public Health. 2020;13(1):75-9.

Chen W, He C, Yang H, Shu W, Cui Z, Tang R, et al. Prevalence and molecular characterization of methicillin-resistant Staphylococcus aureus with mupirocin, fusidic acid and/or retapamulin resistance. BMC microbiology. 2020;20(1):183.

La Fauci V, Riso R, Facciolà A, Merlina V, Squeri R. Surveillance of microbiological contamination and correct use of protective lead garments. Annali di igiene : medicina preventiva e di comunita. 2016;28(5):360-6.

Kramer TS, Remschmidt C, Werner S, Behnke M, Schwab F, Werner G, et al. The importance of adjusting for enterococcus species when assessing the burden of vancomycin resistance：a cohort study including over 1000 cases of enterococcal bloodstream infections. Antimicrob Resist Infect Control. 2018;7:133.

Mascini EM, Bonten MJ. Vancomycin-resistant enterococci: consequences for therapy and infection control. Clinical microbiology and infection : the official publication of the European Society of Clinical Microbiology and Infectious Diseases. 2005;11 Suppl 4: 43-56.

Kampmeier S, Kossow A, Clausen LM, Knaack D, Ertmer C, Gottschalk A, et al. Hospital acquired vancomycin resistant enterococci in surgical intensive care patients – a prospective longitudinal study. Antimicrobial Resistance & Infection Control. 2018;7(1):103.

Růžičková M, Vítězová M, Kushkevych I. The Characterization of Enterococcus Genus: Resistance Mechanisms and Inflammatory Bowel Disease. Open medicine (Warsaw, Poland). 2020;15:211-24.

Mac S, Fitzpatrick T, Johnstone J, Sander B. Vancomycin-resistant enterococci (VRE) screening and isolation in the general medicine ward: a cost-effectiveness analysis. Antimicrob Resist Infect Control. 2019;8:168.−

Alemayehu T, Hailemariam M. Prevalence of vancomycin-resistant enterococcus in Africa in one health approach: a systematic review and meta-analysis. Scientific reports. 2020;10(1):20542.

Caballero S, Kim S, Carter RA, Leiner IM, Sušac B, Miller L, et al. Cooperating Commensals Restore Colonization Resistance to Vancomycin-Resistant Enterococcus faecium. Cell host & microbe. 2017;21(5):592-602.e4.

Iseppi R, Di Cerbo A, Messi P, Sabia C. Antibiotic Resistance and Virulence Traits in Vancomycin-Resistant Enterococci (VRE) and Extended-Spectrum β-Lactamase/AmpC-producing (ESBL/AmpC) Enterobacteriaceae from Humans and Pets. Antibiotics (Basel, Switzerland). 2020;9.(4)

Noskin GA, Stosor V, Cooper I, Peterson LR. Recovery of vancomycin-resistant enterococci on fingertips and environmental surfaces. Infection control and hospital epidemiology. 1995;16(10):577-81.

Melese A, Genet C, Andualem T. Prevalence of Vancomycin resistant enterococci (VRE) in Ethiopia: a systematic review and meta-analysis. BMC Infect Dis. 2020;20(1):124.

Arshadi M, Mahmoudi M, Motahar MS, Soltani S, Pourmand MR. Virulence Determinants and Antimicrobial Resistance Patterns of Vancomycin-resistant Enterococcus faecium Isolated from Different Sources in Southwest Iran. Iranian journal of public health. 2018;47(2):264-72.

Asgin N, Otlu B. Antibiotic Resistance and Molecular Epidemiology of Vancomycin-Resistant Enterococci in a Tertiary Care Hospital in Turkey. Infection and drug resistance. 2020;13:191-8.

Leclercq R. Epidemiological and resistance issues in multidrug-resistant staphylococci and enterococci. Clinical microbiology and infection : the official publication of the European Society of Clinical Microbiology and Infectious Diseases. 2009;15(3):224-31.

Häring A, Heudorf U, Exner M, Pitten F-A, Waidmann O, Hack D, et al. Impact of surface disinfection with hydrogen peroxide on the prevalence of vancomycin-resistant

enterococci (VRE) in hospital wards .GMS hygiene and infection control. 2020;15:Doc13-Doc.

Moemen D, Tawfeek D, Badawy W. Healthcare-associated vancomycin resistant Enterococcus faecium infections in the Mansoura University Hospitals intensive care units, Egypt. Brazilian journal of microbiology : [publication of the Brazilian Society for Microbiology]. 2015;46(3):777-83.

Taggar G, Attiq Rheman M. Molecular Epidemiology of Carbapenemases in Enterobacteriales from Humans, Animals, Food and the Environment. 2020;9.(10)

Quispe AM ,Soza G, Pons MJ. Multidrug resistance and its association with Enterobacteriales and age among pregnant Peruvian women with- bacteremia. Journal of infection in developing countries. 2020;14(12):1402-9.

Logan LK, Weinstein RA. The Epidemiology of Carbapenem-Resistant Enterobacteriaceae: The Impact and Evolution of a Global Menace. The Journal of infectious diseases. 2017;215(suppl_1):S28-s36.

Wilson H, Török ME. Extended-spectrum β-lactamase-producing and carbapenemase-producing Enterobacteriaceae. Microbial genomics. 2018;4.(7)

Bharadwaj AR, Daudu R, Singh NK, Wood JM. Draft Genome Sequences of Enterobacteriales Strains Isolated from the International Space Station. 2020;9.(37)

van Duin D, Doi Y. The global epidemiology of carbapenemase−producing Enterobacteriaceae. Virulence. 2017;8(4):460-9.

Cury AP, Girardello R, Duarte AJdS, Rossi F. KPC-producing Enterobacterales with uncommon carbapenem susceptibility profile in Vitek 2 system. International Journal of Infectious Diseases. 2020.20−93:118;

Kumar S, Vyas A, editors. Utilization of MacConkey-Meropenem screening Agar for the Detection of Carbapenem Resistanant Enterobacteriaceae in a tertiary care hospital2018.

Brown DFJ, Walpole E. Evaluation of selective and enrichment media for isolation of glycopeptide-resistant enterococci from faecal specimens. Journal of Antimicrobial Chemotherapy. 2003;51(2):289-96.

Calatrava E. Other Streptococcus Species and Enterococcus. In: Rezaei N, editor. Encyclopedia of Infection and Immunity. Oxford: Elsevier; 2022. p. 529-41.

Lemmen SW, Häfner H, Zolldann D, Stanzel S, Lütticken R. Distribution of multi-resistant Gram-negative versus Gram-positive bacteria in the hospital inanimate environment. Journal of Hospital Infection. 2004;5.7−191:(3)6

Chiller K, Selkin BA, Murakawa GJ. Skin Microflora and Bacterial Infections of the Skin. Journal of Investigative Dermatology Symposium Proceedings. 2001;6(3):170-4.

Childress J, Burch D, Kucharski C, Young C, Kazerooni EA, Davenport MS. Bacterial Contamination of CT Equipment: Use of ATP Detection and Culture Results to Target Quality Improvement. Academic Radiology. 2017;24(8):923-9.

Tugwell J, Maddison A. Radiographic markers – A reservoir for bacteria? Radiography. 2011;17(2):1.20−15

Duszak R, Lanier B, Tubbs JA, Ogilvie M, Thompson-Jaeger S. Bacterial Contamination of Radiologist Workstations: Results of a Pilot Study. Journal of the American College of Radiology. 2014;11(2):176-9.

Forrester LA, Bryce EA, Mediaa AK. Clean Hands for Life™: results of a large, multicentre, multifaceted, social marketing hand-hygiene campaign. Journal of Hospital Infection. 2010;74(3):225-31.

Fojt L, Strašák L, Vetterl Vr, Šmarda J. Comparison of the low-frequency magnetic field effects on bacteria Escherichia coli, Leclercia adecarboxylata and Staphylococcus aureus. Bioelectrochemistry. 2004;63(1):337-41.

Strašák L, Vetterl Vr, Šmarda J. Effects of low-frequency magnetic fields on bacteria Escherichia coli. Bioelectrochemistry. 2.4−161:(1)55;002

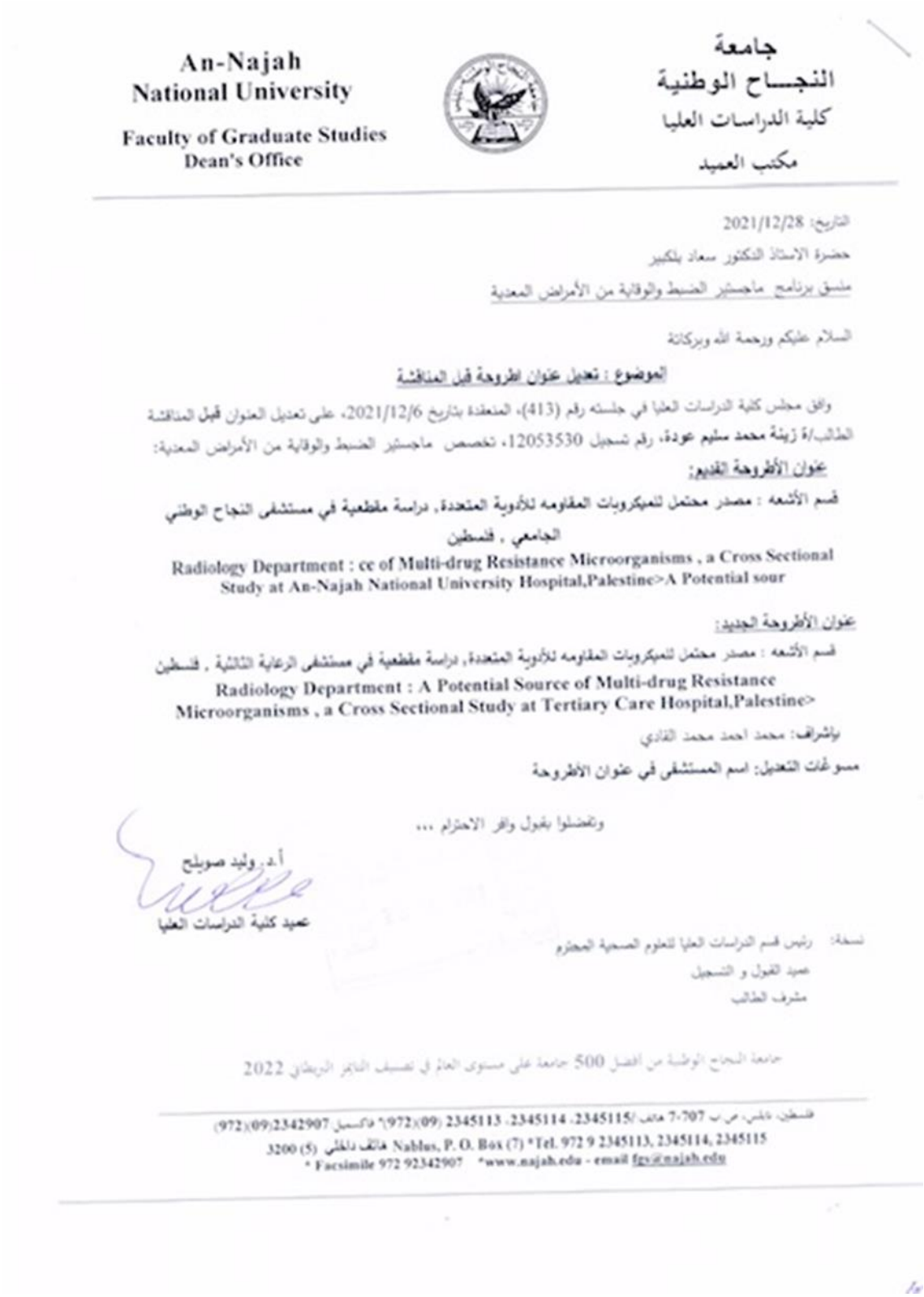
Dancer SJ. How do we assess hospital cleaning? A proposal for microbiological standards for surface hygiene in hospitals. Journal of Hospital Infection. 2004;56(1):10-5.

Rock C, Small BA, Thom KA, For the CDCPEP. Innovative Methods of Hospital Disinfection in Prevention of Healthcare-Associated Infections. Current Treatment Options in Infectious Diseases. 2018;10(1):65-77.

Appendices

Appendix A

Approval from the Faculty of Higher education



An-Najah
National University
Faculty of Graduate Studies
Dean's Office

جامعة
النجـــاح الوطنية
كلية الدراسات العليا
مكتب العميد

التاريخ: 2021/12/28

حضرة الأستاذ الدكتور سعاد بلكبير

منسق برنامج ماجستير الضبط والوقاية من الأمراض المعدية

السلام عليكم ورحمة الله وبركاتة

الموضوع : تعديل عنوان اطروحة قبل المناقشة

وافق مجلس كلية الدراسات العليا في جلسته رقم (413)، المنعقدة بتاريخ 2021/12/6، على تعديل العنوان قبل المناقشة الطالب/ة زينة محمد سليم عودة، رقم تسجيل 12053530، تخصص ماجستير الضبط والوقاية من الأمراض المعدية:

عنوان الأطروحة القديم:

قسم الأشعه : مصدر محتمل للميكروبات المقاومه للأدوية المتعددة، دراسة مقطعية في مستشفى النجاح الوطني الجامعي ، فلسطين

Radiology Department : ce of Multi-drug Resistance Microorganisms , a Cross Sectional Study at An-Najah National University Hospital,Palestine>A Potential sour

عنوان الأطروحة الجديد:

قسم الأشعه : مصدر محتمل للميكروبات المقاومه للأدوية المتعددة، دراسة مقطعية في مستشفى الرعاية الثالثية ، فلسطين

Radiology Department : A Potential Source of Multi-drug Resistance Microorganisms , a Cross Sectional Study at Tertiary Care Hospital,Palestine>

بإشراف: محمد احمد محمد القادي

مسوغات التعديل: اسم المستشفى في عنوان الأطروحة

وتفضلوا بقبول وافر الاحترام ...

أ.د. وليد صوبلح
عميد كلية الدراسات العليا

نسخة: رئيس قسم الدراسات العليا للعلوم الصحية المجزم
عميد القبول و التسجيل
مشرف الطالب

جامعة النجاح الوطنية من أفضل 500 جامعة على مستوى العالم في تصنيف التايمز البريطاني 2022

فلسطين، نابلس، ص.ب 7-707 هاتف /2345115، 2345114، 2345113 (09)(972)+ فاكسميل 2342907(09)(972)
Nablus, P. O. Box (7) *Tel. 972 9 2345113, 2345114, 2345115 هاتف داخلي (5) 3200
* Facsimile 972 92342907 *www.najah.edu - email fgs@najah.edu

Appendix B

IRB

An-Najah National University
Faculty of Medicine & Health Sciences
Institutional Review Board

جامعة النجاح الوطنية
كلية الطب وعلوم الصحة
لجنة اخلاقيات البحث العلمي

Ref :Mas. Dec. *2021/5*

IRB Approval Letter

Title of Research:

"Radiology Department: A Potential Source of Multidrug Resistant Microorganisms, a Cross Sectional Study at Tertiary Care Hospital, Palestinee"

Submitted by:
Zena odeh

Supervisor:
Mohammad Qadi

Approved:
6th Dec. 2021

Your Study **"Radiology Department: A Potential Source of Multidrug Resistant Microorganisms, a Cross Sectional Study at Tertiary Care Hospital, Palestinee"** reviewed by An-Najah National University IRB committee and was approved on 6th Dec. 2021

Hasan Fitian, MD

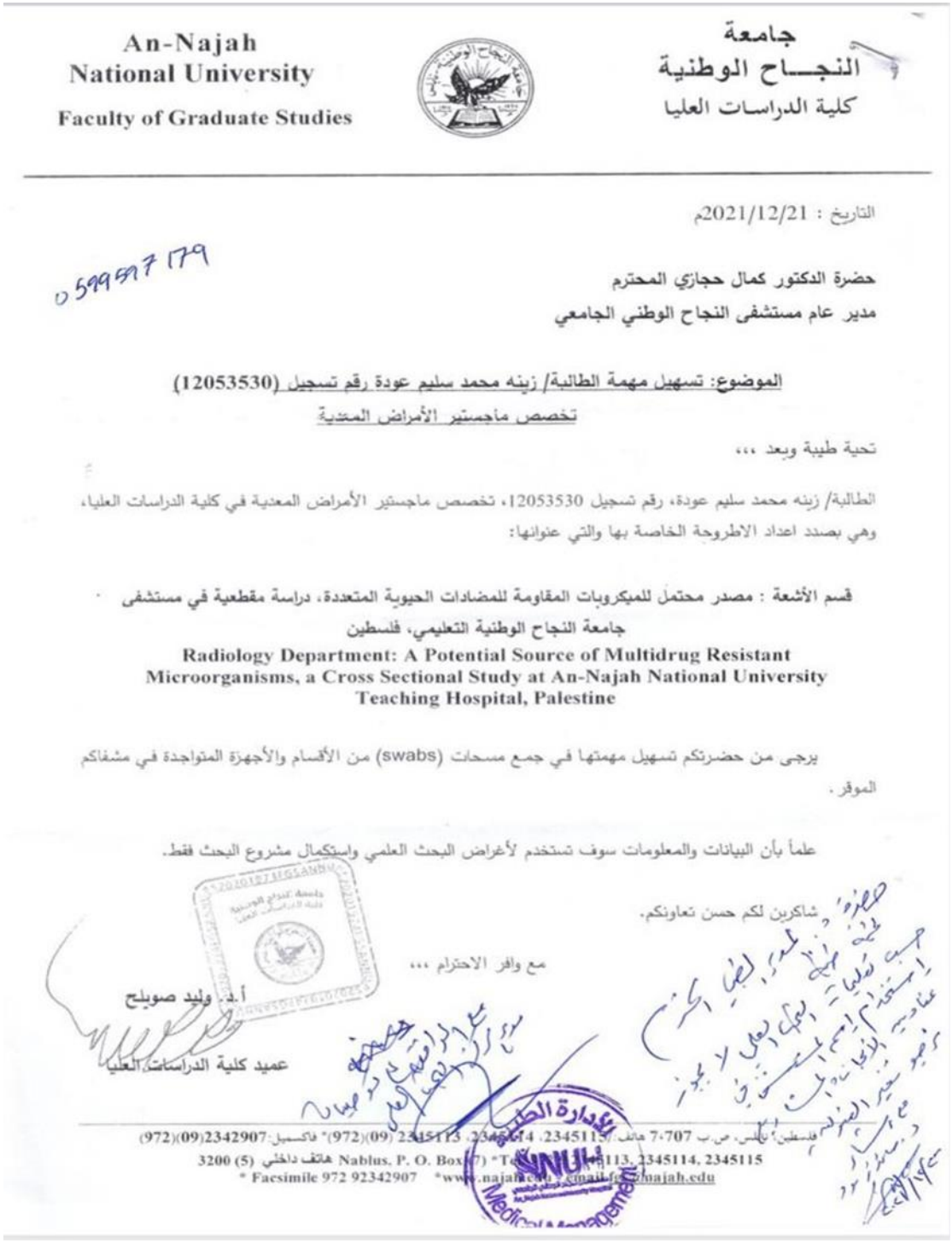
IRB Committee Chairman

IRB

Nablus - P.O Box :7 or 707 | Tel (970) (09) 2342902/4/7/8/14 | Faximile (970) (09) 2342910| E-mail : IRB@najah.edu

Appendix C

Facilitation of a Researcher's Mission



An-Najah
National University
Faculty of Graduate Studies

جامعة
النجـــاح الوطنية
كلية الدراسات العليا

التاريخ : 2021/12/21م

0599597179

حضرة الدكتور كمال حجازي المحترم
مدير عام مستشفى النجاح الوطني الجامعي

الموضوع: تسهيل مهمة الطالبة/ زينه محمد سليم عودة رقم تسجيل (12053530)
تخصص ماجستير الأمراض المعدية

تحية طيبة وبعد ،،،

الطالبة/ زينه محمد سليم عودة، رقم تسجيل 12053530، تخصص ماجستير الأمراض المعدية في كلية الدراسات العليا، وهي بصدد اعداد الاطروحة الخاصة بها والتي عنوانها:

قسم الأشعة : مصدر محتمل للميكروبات المقاومة للمضادات الحيوية المتعددة، دراسة مقطعية في مستشفى جامعة النجاح الوطنية التعليمي، فلسطين
Radiology Department: A Potential Source of Multidrug Resistant Microorganisms, a Cross Sectional Study at An-Najah National University Teaching Hospital, Palestine

يرجى من حضرتكم تسهيل مهمتها في جمع مسحات (swabs) من الأقسام والأجهزة المتواجدة في مشفاكم الموقر.

علماً بأن البيانات والمعلومات سوف تستخدم لأغراض البحث العلمي واستكمال مشروع البحث فقط.

شاكرين لكم حسن تعاونكم.

مع وافر الاحترام ،،،

أ.د. وليد صويلح
عميد كلية الدراسات العليا

فلسطين، نابلس، ص.ب 7707 هاتف (09)2345113, 2345114, 2345115 (972) فاكسميل (09)2342907 (972)
Nablus, P. O. Box (7) 7707 Tel. (09) 2345113, 2345114, 2345115 هاتف داخلي (5) 3200
* Facsimile 972 92342907 *www.najah.edu *e-mail:fgs@najah.edu

Appendix D

Tables

Table 11

Compression with other studies for MRSA contamination.

Study Site	Number of sample	country	Sample site	Refer
Ireland	1/125	Ireland	MRI gantry Bore	(12)
Palestine	13/80	Palestine	-Head pillow of CT CANON -RT side of patient CT CANON -Center of patient CT CANON -Keyboard of CT CANON -Primax portable touch screen -CT Siemns keyboard in control room -Patient table tool in US general room -Keyboard in control room US for general use -LT side patient table CT CANON -RT side of MRI patient table 2 -LT side of MRI patient table 2 -Knee coil -Patient leg support 1	This Study
Sweden	MRSA was significantly low according to RUL value	Sweden	CT Scanner (Table, Wrap, Bore).	([73])
United Kingdom	No evidence of MRSA	United Kingdom	X-Ray cassettes and Lead aprons	(4)

جامعة النجاح الوطنية

كلية الدراسات العليا

قسم الأشعة: مصدر محتمل للميكروبات المقاومة للأدوية المتعددة، دراسة مقطعية في مستشفى الرعاية الثالثة –فلسطين

إعداد

زينة محمد سليم عودة

إشراف

د. محمد القادي

قدمت هذه الرسالة استكمالا لمتطلبات الحصول علي درجة الماجستير في مكافحة وضبط العدوى، من كلية الدراسات العليا، في جامعة النجاح الوطنية، نابلس –فلسطين.

2023

قسم الأشعة: مصدر محتمل للميكروبات المقاومة للأدوية المتعددة، دراسة مقطعية في مستشفى الرعاية الثالثة –فلسطين

إعداد

زينة محمد سليم عودة

إشراف

د. محمد القادي

الملخص

تواجه مرافق الرعاية الصحية تحديا كبيرا للعدوى المكتسبة من المستشفيات، والتي تسبب بدورها الكثير من الوفيات والإعاقات، بالإضافة إلى هدر للأموال في علاج المرضى اللذين يعانون من البكتيريا المقاومة للمضادات الحيوية المتعددة. وعليه؛ فإن الكثير من الأبحاث تدور حول طرق انتقال العدوى والإصابة بها، ولكن القليل منها جرى عملها في قسم الأشعة لرصد البكتيريا المقاومة للمضادات الحيوية المتعددة.

تهدف هذه الدراسة إلى تحديد وجود بكتيريا مقاومة للمضادات الحيوية المتعددة على الأسطح التي كثيرا ما يتم لمسها في غرف قسم الأشعة وأجهزته، ما يجعلها معرضة للتلوث: التصوير الطبقي، والرنين المغناطيسي، والموجات الفوق صوتية، وكذلك غرفة وجهاز التصوير بالأشعة السينية، وجهاز الأشعة السينية المتنقل. بالإضافة إلى ذلك، تسعى الدراسة للتحقق من المخاطر المحتملة لانتقال البكتيريا المقاومة للمضادات الحيوية المتعددة للمرضى، ومقدمي الرعاية الصحية.

في هذه الدراسة، تم جمع 160 عينة من قسم الأشعة خلال شهري أيار وحزيران من سنة 2022. وتم الحصول على عينات من 80 سطحًا محددًا مسبقًا مرتين داخل غرف الفحص بالتصوير المقطعي والتصوير بالرنين المغناطيسي وخارجها، وكذلك من أجهزة الموجات فوق الصوتية، وأجهزة الأشعة السينية وأجهزة الأشعة السينية المتنقله. وقد جرى أخذ العينات في الساعة 7:00 صباحًا باستخدام مسحات قطنية بعد إجراء التنظيف الروتيني للأجهزة وغرف التصوير الطبي. وبعد ذلك، تم حساب وحدات تشكيل المستعمرات البكتيرية لكل سنتمتر مربع بعد مسح سطح بمساحه 100 سنتمتر مربع.

توصلت الدراسة إلى مجموعة من النتائج: جميع الأسطح التي تم أخذ العينات منها تحتوي على مستعمرات بكتيرية؛ فكان أعلى معدل لتلوث الأسطح على لوحات المفاتيح الخاصة بجميع الأجهزة في قسم الأشعة، حيث كانت النسبه بين 1.2−8 مستعمرة بكتيرية لكل سنتمتر مربع، تليها حواف الطاولات الخاصة بالمرضى، ونسبتها 1.2−20 مستعمرة بكتيرية لكل سنتمتر مربع، ثم الجهاز الخاص لتصوير الركبة بالرنين المغناطيسي، ونسبتها 2.4−3 مستعمرة بكتيرية لكل سنتمتر مربع، ثم المساند الخاصة لأرجل المرضى، وتحتوي على نسبه تلوث بمقدار 1.2−8 مستعمرة بكتيرية لكل سنتمتر مربع. وقد تبيّن أن هناك زيادة ملحوظة في التلوث في شهر حزيران مقارنة بشهر أيار، وكان هذا متسقًا مع الزيادة في: عدد المرضى المعزولين في المستشفى، وعبء العمل في قسم الأشعة، وعدد المرضى المحولين إلى المستشفى. وفي أثناء الدراسة، لم يظهر في المواقع التي تم فحصها تلوث بالبكتيريا سالبة غرام المقاومة للمضادات الحيوية المتعددة، مثل:

Extended-Spectrum Beta-lactamases producing Enterobacterales (ESPL) or Carbapenemase-Producing Enterobacterales (CPE).

من ناحية أخرى جرى رصد كل من:

methicillinresistantStaphylococcus aureus (MRSA), vancomycin resistant Staphylococcus aureus(VRSA) and vancomycinresistantEnterococcus (VRE).

من الممكن أن تكون الأجهزة والأسطح المتواجدة في قسم الأشعة مصدرا محتملا لنقل العدوى والبكتيريا وخاصة بكتيريا المقاومة للمضادات الحيوية المتعددة. لذلك؛ يجب مراجعة السياسات الخاصة بتنظيف الأسطح وكيفية تطبيق السياسة الخاصة لتنظيف الأسطح في الصباح وبين المرضى.

الكلمات المفتاحية: قسم الأشعة، البكتيريا المقاومة للمضادات الحيوية المتعددة، العدوى المكتسبة من المستشفيات، تلوث، عدوى المستشفى البكتيرية.