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Original Article

Radiology imaging equipment and accessories as possible fomites of nosocomial pathogens

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Abstract

Introduction: Radiology is a technical service that provides medical imaging for all sectors of healthcare. Hospital-acquired infections (HAIs) is a major challenge in radiology and this is exacerbated in contexts where the healthcare system is unable to provide adequate funding and attention to effective infection control measures. The objectives of this study were to audit current cleaning procedures through the observation of practices in a radiology department, and to determine the types and numbers of nosocomial pathogens present on selected radiology imaging equipment and accessories before and after decontamination.

Methodology: In phase one we observed seven radiographers to audit cleaning procedures and practices. In phase two we collected swab samples from selected radiology imaging equipment and accessories and then cultured them for identification of microbes.

Results: It was observed that radiographers partially practiced infection control measures. This was due to the absence of documented protocol for infection control procedures. Our results indicated that all the selected equipment and accessories were contaminated with microorganisms pre- and post-cleaning. The identified microbes were *Staphylococcus aureus*, Coagulase negative *Staphylococci* (CoNS), *Bacillus* species (spp.), *Shigella* spp., *Shigella sonnei*., *Klebsiella* spp., *Salmonella paratyphi* A (*S. paratyphi* A), *Salmonella typhi* (*S. typhi*), *Providencia rettgeri*, *Enterobacter* spp. and *Citrobacter* spp. and Methicillin resistant strains of *Staphylococcus aureus* (MRSA).

Conclusions: The research concluded that the recommended cleaning agents did not effectively reduce the number of microorganisms making the selected equipment and accessories fomites for nosocomial pathogens.

Key words: radiographer; fomites; infection control; nosocomial infections; cleaning; equipment.

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Introduction

Provision for adequate infection control measures in the healthcare facilities to prevent and reduce the spread of infectious diseases in the hospital environment is essential. When done effectively these measures secure the safety of patients, staff and the public by protecting them against infection contracted directly or indirectly during any hospital exposure.

Hospital-acquired infection (HAI) is the fourth highest cause of infections in developed countries, and is a major challenge in health-care [1]. Although funding and time are continually invested to eradicate HAIs, the problem remains [2]. In financially constrained sub-Saharan African countries such as Ghana, nosocomial infections contribute to the imbalance of resources available for the management of hospitals [3]. Globally, healthcare services are also affected by escalating financial burdens that are linked to increased patient morbidity and mortality resulting from HAIs [4,5]. About a decade ago, the reported annual spending of the United Kingdom National Health Service on HAIs was one million pounds sterling [6]. In the same period, one million seven hundred inpatients in the United States of America acquired HAIs contributing to 98,987 deaths [7]. The increasing bacterial resistance to antibiotics associated with HAIs has further contributed to the challenge [8,9].

In the last two decades, nosocomial infections have become a chronic problem in Ghana. This has affected the quality of care and cost to patients at healthcare facilities, and the national budget. The reasons for this chronic problem include the fact that healthcare professionals do not have knowledge of and do not comply with guidelines on disinfection due to inadequate information and understanding of infection prevention and control procedures [10]. Resource

constrained countries suffer greater effects of HAIs because of lack of sufficient surveillance programs required to curb the repercussion of these infections [11,12]. According to Saint *et al.*, although many publications address the identification and description of the various types of infections and prescribed methods for prevention, healthcare practitioners pay little attention to the use of preventative measures for nosocomial infections [13]. This scenario is common in developing countries like Ghana where very limited resources are available relative to the high patient volume [14].

The radiology department provides medical imaging service to patients from various units within the hospital such as wards, trauma, orthopedics and outpatient clinics [6,15]. It is documented that the radiology department facilitates the transfer of various healthcare associated pathogens including Vancomycin-resistant *Enterococci* (VRE), *Clostridium difficile*, *Acinetobacter* species, Methicillin resistant strains of *Staphylococcus aureus* (MRSA) and Norovirus [16]. For example, Tohidnia *et al.* confirmed the presence of a significant number of Coagulase negative *Staphylococci* (CoNS), *Escherichia coli* and *Pseudomonas aeruginosa* on radiology equipment and accessories [17]. Dancer *et al.* noted that *Staphylococci*, coliform bacteria, and moulds are capable of contaminating the surfaces of diagnostic radiology equipment such as the radiographic table and accessories such as cassettes [18]. Therefore, radiology contributes substantially to the potential for the spread of nosocomial infections.

The objectives of this study were to: audit current cleaning procedures through the observation of practices in a radiology department, determine the types and numbers of nosocomial pathogens present on selected radiology equipment and accessories before decontamination and ascertain the presence of nosocomial pathogens following decontamination of selected radiology imaging equipment and accessories with the two preferred departmental disinfectant chemical agents.

Methodology

This research involved a two-phase approach with an observational study followed by an experimental component.

Study site

The site for the study was the radiology department of a teaching hospital (TH) in Ghana. The hospital has approximately 2000 beds with 250 new admissions daily and an outpatient attendance of 1500 per day.

Sample

The selected sample of items included radiology equipment and accessories from two general rooms which were named Room A and B respectively. These rooms were selected because they were the two functioning rooms at the time of the study and both had a high turnover of outpatients, ward patients, accident and emergency cases.

In addition, seven radiographers from the department were selected since they were working in the selected general rooms during the data collection period. The observation period was from 1st of June 2017 to 30th June 2017. These radiographers worked morning, afternoon and night shifts in the two rooms on a rotational schedule.

Phase 1: Observational study

The seven radiographers who worked on a rotational schedule in the two rooms were observed by the researcher for one month in order to audit the applied routine cleaning procedures of radiology equipment and accessories. Damp dusting and cleaning of equipment and accessories using methylated spirits or chlorine bleach, and hand washing using water and liquid soap were observed and recorded.

Phase 2: Experimental study

Swab samples were taken by the researcher after clinical training and under the supervision of two qualified microbiologists from the University of Ghana. A standardized method of data collection was used by the researcher. To assure the quality and integrity of the research, this study adhered to the Good Laboratory Practice (GLP) standards of the department, informed by the World Health Organization guidelines. These standards include requirements for adequate equipment and accessories handling and proper documentation of research results and record keeping.

The use of swab sticks enabled a total of 128 swabs to be taken over three weeks from 10th-28th July 2017 in Rooms A and B. Thirty-two (32) swabs were taken from each room at 08:00 in the morning. This was after the night shift and before the equipment and accessories were used or cleaned by the day shift staff (pre-cleaning). This sample collection method was used because evidence in literature suggests that radiographers' workload is higher during the night shift and thus they have less time to clean the equipment and accessories [6,15]. This early morning swabbing also

avoided disturbing the patient flow, as well as the work of the healthcare professionals in the radiology department. Another thirty-two (32) swabs were taken per room after cleaning with one of the chemical disinfectant agents routinely used in this radiology department (post-cleaning).

The researcher and the biomedical scientists wore sterile hand gloves during the swabbing process, to reduce the possibility of cross-infection between the swabbed items and from the hands to the swab. Samples were placed in bijoux bottles containing peptone broth. These were packed into brain heart infusion (a nutrient rich medium) and then incubated in peptone water overnight at 37 °C to promote bacterial growth. Growth in peptone water was observed and then streaked on the surface of MacConkey and Blood agar (gelatinous substances) plate and incubated for 18-24 hours for growth of microorganisms. A standard technique was employed for isolation of bacterial colonies. The isolated colonies were identified based on their morphological characteristics, Gram stain and biomedical reactions.

Methicillin sensitivity tests were performed to determine which of the identified *Staphylococcus aureus* and CoNS were resistant or sensitive to methicillin.

Data analysis

A comprehensive description was documented based on the observations of the radiographer's routine protocols with regards to departmental infection control. Baseline comparisons, where appropriate, were made using a Chi-square (χ^2) test to identify the significance of association between two experimental variables and to help determine the significance of the data. Statistical significance level was determined as $p < 0.05$. All statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS) Statistics, version 25 [19].

Ethical issues

Prior to commencement of this study, ethics approval was granted by the research ethics committees of the university and the teaching hospital. Written informed consent was sought from radiographers before the observation of how they practiced infection control at work but with sufficient time delay to avoid special procedures being done because of the study.

Results

The objectives of this study were to observe current cleaning procedures and practices in a radiology department, determine the types and number of nosocomial pathogens present on selected radiology imaging equipment and accessories before cleaning and ascertain the presence of nosocomial pathogens following cleaning of the selected items with departmental disinfectant chemical agents.

Phase 1. Observational study: current cleaning procedures and practices

It was observed that four of the seven radiographers (57%) practiced damp dusting of equipment and accessories when it was evident that these items were dusty, while three (43%) did not practice damp dusting at any time during the observation period. It was however identified that all seven radiographers (100%) cleaned in between patient procedures whenever equipment or accessories were soiled through contact with blood or other body fluid. It was further observed that six radiographers (86%) did not wash their hands after each patient whereas one radiographer (14%) washed his/her hands after completing each patient procedure.

Prepared chlorine bleach, one liter to nine volumes of clean water, was used over many days and only replenished when it was finished. This practice is contrary to the recommendation that in order to be an effective disinfectant a fresh chlorine solution must be prepared daily.

There were storage challenges in both rooms under study. One example is that there were no hangers or rails for lead aprons, leaving them to be hung on tables, tops of cupboards or other available surfaces and they often fell off on to the floor. Another issue was that the X-ray cassettes were stored on the floor due to the unavailability of a suitable storage such as shelves or a box.

No radiographer wore gloves except in cases where it was evident that body fluid was present. Although no radiographer washed his/her hands before gloves were worn, all radiographers washed their hands after the use and disposal of gloves.

In addition, the department had no documented infection control measures for daily, weekly, or monthly cleaning of equipment and accessories.

Phase 2. Experimental: nosocomial pathogens present on selected radiology equipment and accessories before cleaning

Pathogenic and non-pathogenic isolates were present in both rooms before cleaning of the equipment and accessories (Figure 1). A total of eleven types of bacterial isolates were found in the two rooms. Four out

of eleven (36%) pathogens were identified in Room A whereas all eleven pathogens were identified in Room B. *Bacillus* spp. was the only (1/11) non-pathogenic isolate identified. The remaining (91%) were pathogenic isolates. Therefore, there was a significant difference in number ($p = 0.0267$) between pathogenic and non-pathogenic isolates identified before cleaning. *Bacillus* spp. had the highest number of isolates identified: 23 and 14 isolates in Room A and Room B respectively. *Staphylococcus aureus* (n = 12) and *Citrobacter* spp. (n = 7) were the predominant pathogenic isolates identified. The majority of CoNS (80%) and *Staphylococcus aureus* (67%) isolated pre-cleaning were resistant to methicillin (Figure 2).

Table 1 lists the equipment and accessories and their respective bacterial growths prior to cleaning in Room A. All the items selected for this study in Room A were found to be contaminated with more than one bacterial growth before cleaning and there was a total of 34 bacterial isolates. The x-ray cassettes and the horizontal Bucky surface (table top) had the most (n = 4) bacterial isolates. The horizontal Bucky surface had two isolates each of *Bacillus* spp. and *Citrobacter* spp. There were three *Bacillus* spp. and one *Citrobacter* spp. isolates on each of the two cassettes. There were no pathogenic isolates (*Staphylococcus aureus*, *Citrobacter* spp. and CoNS) identified on the control buttons, the erect Bucky handle, the tube head handles and collimators, or the horizontal Bucky knobs. Almost all items (except the exposure button and the horizontal Bucky handle) were contaminated with the non-pathogenic isolate *Bacillus* spp. (n = 23). *Citrobacter* spp. was the most commonly (n = 5) identified pathogenic isolate.

Table 2 lists the equipment and accessories and their respective bacterial growths prior to cleaning in Room B. All items selected for this study in Room B were contaminated with more than one bacterial isolate before cleaning, and there was a total occurrence of 38 bacterial isolates. The horizontal Bucky surface and the erect Bucky surface had the most (n = 4) bacterial growths. The horizontal Bucky surface had one growth each of *Bacillus* spp. and *Providencia rettgeri*, and two of *Staphylococcus aureus*.

Figure 1. Number of bacterial growths identified from Room A and B pre-cleaning.

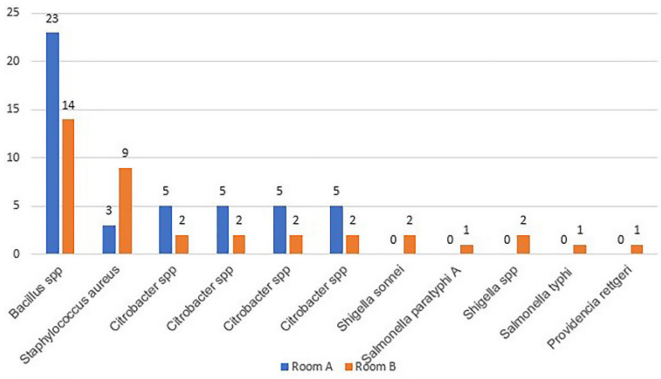

Figure 2. Reaction of CoNS and Staphylococcus aureus to methicillin.

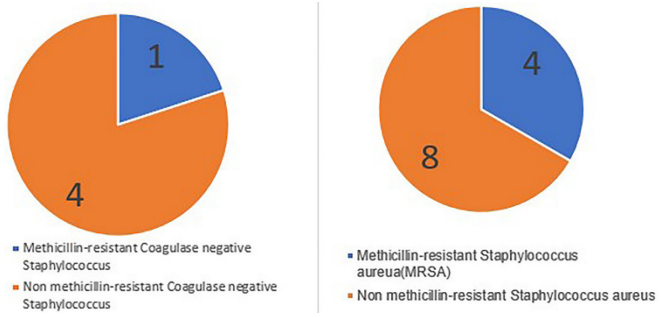

Table 1. Equipment/Accessories and their respective bacterial growth from Room A pre-cleaning.

Equipment/Accessories (item)	Bacterial growth per item				Total
	Bacillus spp.	*Staphylococcus aureus*	*Citrobacter* spp.	CoNS	
Exposure button	-	-	1	1	2
Horizontal Bucky surface (table top)	2	-	2	-	4
Cassette 35 cm × 43 cm	3	-	1	-	4
Cassette 24 cm × 30 cm	3	-	1	-	4
Control buttons	2	-	-	-	2
Door handles	1	1	-	-	2
Erect Bucky surface	2	1	-	-	3
Erect Bucky handle	2	-	-	-	2
Lead apron	2	1	-	-	3
Tube head handles	2	-	-	-	2
Tube head collimators	2	-	-	-	2
Horizontal Bucky handle	-	-	-	2	2
Horizontal Bucky knobs	2	-	-	-	2
Total	23	3	5	3	34

Table 2. Equipment/Accessories and their respective bacterial growth from Room B pre-cleaning.

Equipment/Accessories (item)	Bacterial growth per item											Total
	A	B	C	D	E	F	G	H	I	J	K	
Exposure button	1	1	-	-	1	-	-	-	-	-	-	3
Horizontal Bucky surface (table top)	1	2	-	-	-	-	-	-	-	-	1	4
Cassette 35 cm × 43 cm	3	-	-	-	-	-	-	-	-	-	-	3
Cassette 24 cm × 30 cm	2	-	-	-	-	-	-	-	-	1	-	3
Control buttons	1	1	-	-	-	-	-	-	-	-	-	2
Door handles	-	1	-	-	-	-	1	-	1	-	-	3
Erect Bucky surface	1	-	1	-	1	1	-	-	-	-	-	4
Erect Bucky handle	1	-	-	1	-	-	-	-	-	-	-	2
Lead apron	2	1	-	-	-	-	-	-	-	-	-	3
Tube head handles	-	1	1	-	-	1	-	-	-	-	-	3
Tube head collimators	1	1	-	-	-	-	-	-	1	-	-	3
Horizontal Bucky handle	1	-	-	-	-	-	1	-	-	-	-	2
Horizontal Bucky knobs	-	1	-	1	-	-	-	1	-	-	-	3
Total	14	9	2	2	2	2	2	1	2	1	1	38

A: *Bacillus* spp.; B*: Staphylococcus aureus*; C*: Citrobacter* spp.; D*: CoNS*; E*: Enterobacter* spp.; F: *Klebsiella* spp.; G: *Shigella sonnei*; H*: Salmonella paratyphi* A; I: *Shigella* spp.; J*: Salmonella typhi*; K*: Providencia rettgeri.*

Table 3. Bacterial growth from Room A post-cleaning with chlorine bleach.

Equipment/Accessories	Bacterial growth per item				Total
	Bacillus spp.	*Staphylococcus aureus*	CoNS	*Shigella* spp.	
Exposure button	1	-	-	-	1
Horizontal Bucky surface (table top)	1	1	1	-	3
Cassette 35cm × 43cm	1	-	-	-	1
Cassette 24cm × 30cm	1	1	-	-	2
Control buttons	2	-	-	-	2
Door handles	-	2	-	-	2
Erect Bucky surface	1	1	-	-	2
Erect Bucky handle	1	1	-	-	2
Lead apron	3	-	-	-	3
Tube head handles	-	1	1	-	2
Tube head collimators	-	1	-	-	1
Horizontal Bucky handle	-	-	1	1	2
Horizontal Bucky knobs	-	-	-	-	0
Total	11	8	3	1	23

Table 4. Bacterial growth from Room B post-cleaning with methylated spirits.

Equipment/Accessories (item)	Bacterial growth per item				Total
	Bacillus spp.	*Staphylococcus aureus*	*Citrobacter* spp.	*Salmonella paratyphi* A.	
Exposure button	1	-	-	1	2
Horizontal Bucky surface (table top)	3	-	-	1	4
Cassette 35cm × 43cm	2	-	-	1	3
Cassette 24cm × 30cm	2	1	-	-	3
Control buttons	-	-	1	-	1
Door handles	2	-	-	-	2
Erect Bucky surface	3	-	-	-	3
Erect Bucky handle	1				1
Lead apron	-	2	-	1	3
Tube head handles	2	-	-	-	2
Tube head collimators	1	-	-	-	1
Horizontal Bucky handle	-	-	-	-	0
Horizontal Bucky knobs	-	1	-	-	1
Total	17	4	1	4	26

The erect Bucky surface recorded one growth each of *Bacillus* spp., *Citrobacter* spp., *Enterobacter* spp. and *Klebsiella* spp. There were no pathogenic isolates (B-K) identified on one of the cassettes. Almost all items (except the door handles, the tube head handles and the horizontal Bucky knobs) were contaminated with the non-pathogenic isolate *Bacillus* spp. (n = 14). *Staphylococcus aureus* was the most common (n = 9) pathogenic isolate which contaminated the majority of the equipment and accessories (except the cassettes, the erect Bucky surface, and the erect and horizontal Bucky handles).

Nosocomial pathogens present on selected radiology equipment and accessories after cleaning

Pathogenic and non-pathogenic isolates were present after cleaning of equipment and accessories with methylated spirits or chlorine bleach (Figure 3). Only four types of bacterial growths were present in each room. *Citrobacter* spp., was not identified after cleaning with the detergent chlorine bleach in Room A. Seven pathogens were absent following use of the detergent methylated spirits in Room B; namely CoNS, *Enterobacter* spp., *Klebsiella* spp., *Shigella sonnei*, *Shigella* spp., *S. typhi* and *Providencia rettgeri*.

Staphylococcus aureus was the most common pathogen (n = 12) identified in both the rooms. There was no significant difference ($p = 0.5835$) between the total number of bacterial isolates in the two rooms after decontamination (Room A = 23, Room B = 26). An unexpected finding was that after decontamination, Room A recorded a higher number of pathogenic bacterial isolates (n = 12). *Staphylococcus aureus* increased from three growths before cleaning to eight growths after cleaning and *Shigella* spp. (n = 1) was only present after cleaning in Room A. The number of CoNS (n = 3) was the same after cleaning in Room A. The only non-pathogenic isolate, *Bacillus* spp. had the highest number of isolates; 11 and 17 isolates identified in Room A and Room B respectively (Figure 3). Another unexpected finding was that *Bacillus* spp. increased from before cleaning (n = 14) to after cleaning (n = 17) in Room B. The number of isolates of *S. paratyphi* A also increased from before cleaning (n = 1) to after cleaning (n = 4) in Room B while *Staphylococcus aureus* decreased from before cleaning (n = 9) to after cleaning (n = 4).

Figure 3. Number of bacterial growths identified post-cleaning with bleach (Room A) and methylate spirits (Room B).

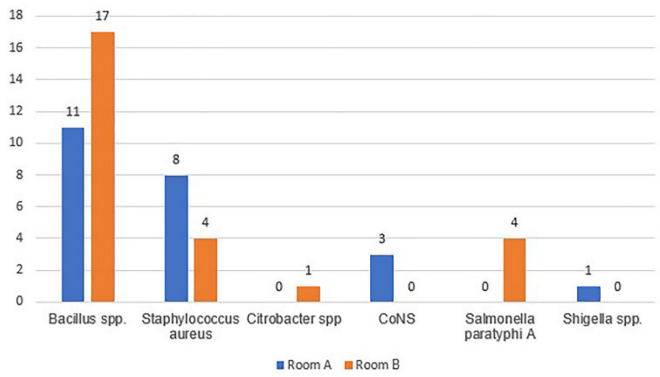

Table 3 lists the equipment and accessories in Room A and their respective bacterial growths post-cleaning. Most items in Room A were found to be contaminated with at least one bacterial isolate except for the horizontal Bucky knobs. The total number of isolates decreased from 34 before cleaning to 23 after cleaning with chlorine bleach. *Staphylococcus aureus* was the most common (n = 8) pathogenic isolate which contaminated the majority of equipment and accessories (except the exposure and control buttons, the lead apron, the horizontal Bucky handle and knobs) in Room A. The door handles were mainly contaminated with *Staphylococcus aureus* (n = 2). Most items (except the door handles, the tube head handles and collimators, the horizontal Bucky handle and knobs) were contaminated by the non-pathogenic isolate *Bacillus* spp. (n = 11). *Shigella* spp. was the least identified pathogen (n = 1) and was found on the horizontal Bucky handle.

Table 4 lists the equipment and accessories and their respective bacterial isolates post-cleaning in Room B. Most of the items in Room B were contaminated with at least one bacterial isolate except for the horizontal Bucky handle. The total number of isolates decreased from 38 before cleaning to 26 after cleaning with methylated spirits. *Staphylococcus aureus* and *S. paratyphi* A. were the most common pathogens identified after cleaning, accounting for four bacterial isolates per pathogen. The horizontal Bucky surface was the most contaminated item (n = 4) with three *Bacillus* spp. isolates and one *S. paratyphi* A isolate identified on the surface. Most items (except the control buttons, the lead apron and the horizontal Bucky handle and knobs) were contaminated by the non-pathogenic isolate *Bacillus* spp. (n = 17).

In summary the radiographers practiced partial infection control measures. Therefore, pathogens were identified on selected imaging equipment and accessories before and after cleaning. The majority of CoNS and *Staphylococcus aureus* isolated pre-cleaning were resistant to methicillin. *Bacillus* spp. was the only non-pathogenic isolate identified and was also the most predominant bacterial isolate identified.

Staphylococcus aureus was the most predominant pathogenic isolate identified.

Discussion

Phase 1. Observation: current cleaning procedures and practices

The observational data from the audit indicated that not all radiographers clean equipment and accessories regularly in between patients or have a daily, weekly or monthly cleaning routine. This was in line with a similar study by Antwi *et al.* which indicated that radiographers do not clean equipment and accessories regularly [20]. This phenomenon could be attributed to a high work load [6] or the absence of strict departmental monitoring of infection control practices [21]. The observational data revealed that the department had no documented infection control measures to guide practice or facilitate the monitoring of practice. Thus, the contaminated Buckys, cassettes and lead aprons (Table 1 and Table 2) could be the result of radiographers not cleaning the equipment and accessories adequately.

The most significant and effective method to prevent infection within the healthcare system, including the radiology department, is appropriate application of hand hygiene by radiographers. It was however observed that only one radiographer washed his/her hands after each patient procedure. This is in congruence with the findings of the Ghana Ministry of Health which stated that healthcare professionals practice inadequate washing of their hands [10]. The contaminated Bucky handles and exposure buttons could be the result of radiographers not practicing proper hand hygiene.

The inappropriate storage of cassettes and lead aprons could have led to them being predominately contaminated by *Bacillus* spp. All lead aprons used in Room A and B were contaminated with *Bacillus* spp. and *Staphylococcus aureus*. These bacteria are found in soil and dust [22] and are likely to be present on the floor of the department. Numerous studies have identified *Staphylococcus aureus* as a major contaminant of lead aprons and radiology equipment [6,23]. It was found that even when lead aprons were properly stored, they were inadequately cleaned by radiographers, causing them to accumulate dust which then presented them as possible fomites of nosocomial pathogens [6].

It was observed that radiographers wore gloves only in cases where it was evident that body fluid was present and, with the exception of one radiographer, they washed their hands only after the use and disposal of gloves. It is very important to wash hands before and after wearing gloves. Healthcare professionals can acquire MRSA after touching surfaces of gloves which were contaminated by patients colonized with MRSA [24].

Phase 2. Experiment

Nosocomial pathogens present on selected radiology equipment and accessories before cleaning

Four types of bacteria were isolated from the 32 samples taken prior to cleaning of equipment and accessories from Room A; namely *Bacillus* spp., *Staphylococcus aureus*, *Citrobacter* spp. and CoNS. Similar research conducted in Canada identified *Bacillus* spp., *Staphylococcus aureus* and CoNS as major contaminants of hospital equipment and accessories [25]. Eleven types of bacteria were isolated from the 32 samples taken prior to cleaning of equipment and accessories from Room B; namely *Bacillus* spp., *Staphylococcus aureus*, *Citrobacter* spp., CoNS, *Enterobacter* spp., *Klebsiella* spp., *Shigella sonnei*, *S. paratyphi* A, *Shigella* spp., *S. typhi* and *Providencia rettgeri*. The higher number and types of bacterial isolates found in Room B could be attributed to the higher workload of this room. All items selected for this study in both the rooms were found to be contaminated with more than one bacterial growth before cleaning.

Bacillus spp. was the only non-pathogenic bacteria isolated and its distribution over the sampled surfaces (37 isolates) indicated that it was the most predominant organism colonizing the equipment and accessories. Previous studies have shown that *Bacillus* spp. is the major contaminant of hospital equipment and accessories [14]. Although most strains of *Bacillus* spp. are non-pathogenic to humans, some can cause serious infections like bacteremia, septicemia, pneumonia and meningitis in immuno-compromised patients [26]. The extent of colonization in both rooms could be explained by the fact that spores of *Bacillus* spp. are able to withstand certain chemical disinfectants for moderate periods [27].

Staphylococcus aureus, well-known for building resistance to antibiotics [28], was isolated from various items including the door handles, the erect and horizontal Bucky surfaces and the exposure button. Radiographers and patients who came into contact with those items risked contracting infection. This bacterium recorded the highest number of pathogenic isolates (n = 12) and is known to cause infections such as boils, post-operative wound infections, septicemia, osteomyelitis and pneumonia [29].

Seven bacterial isolates of *Citrobacter* were identified pre-cleaning (Figure 1). *Citrobacter freundi* is frequently found in the intestinal tract of human beings and has been identified to cause a variety of infections in hospitalized patients. These infections affect the respiratory tract, the urinary tract, the gastrointestinal tract and wounds, and are caused by contaminated medical equipment and accessories [30,31].

There were five isolates of Coagulase negative *Staphylococcus* prior to cleaning. The frequent use of medical devices and the practice of inadequate nursing procedures have increasingly resulted in in CoNS being one of the major nosocomial pathogens [32,33]. CoNS are more resistant to antibiotics than *Staphylococcus aureus* and accounts for foreign body-related infections and infections in preterm newborns [32].

There were two *Klebsiella* spp. isolates identified in Room B (Figure 1). A similar study by Ochie and Ohagwu identified *Klebsiella* spp. as a nosocomial pathogen [34]. Patients who suffer from chronic pneumonia caused by *Klebsiella pneumoniae* or *Klebsiella oxytoca* may visit the radiology department for chest X-ray examinations [35,36]. *Klebsiella* spp. was found on the erect Bucky surface and the tube head handles (Table 2). This indicates contamination of the erect Bucky surface due to contact with the patient as well as contamination of the handles due to transfer by the radiographers' hands. Contamination of the radiographers' hands often occurs as a result of contact with the patient or equipment while positioning these during imaging.

One bacterial isolate each of *S. paratyphi* A and *S. typhi* were identified in Room B. These bacteria are responsible for the deadly bacterial infection, typhoid fever. Approximately 13.5 million typhoid fever cases were reported globally in 2010 [32].

There were two bacterial isolates of *Shigella sonnei* and *Shigella* spp. in Room B. Both isolates cause diarrhoea which if not treated with urgency can result in morbidity and death in children. Diarrhoea kills 14000 Ghanaian children annually. There has also been an increasing resistance of *Shigella sonnei* to a variety of antimicrobials [37,38]. The occurrence of diarrhoea increases when there is inadequate cleaning of the work environment and related equipment and accessories [39].

One bacterial isolate for *Providencia rettgeri* was identified in Room B. *Providencia rettgeri* can develop a strong resistance to antibiotics. It is also the most common cause of catheter associated urinary tract infections (UTIs) in the elderly [40].

Two bacterial isolates of *Enterobacter* spp. were identified in Room B. *Enterobacter* spp. is well adapted for survival and can cause nosocomial infections such as bacteraemia, lower respiratory tract infections, intra-abdominal infections and UTIs. It can spread through the faecal-oral route or through blood products [41,42].

These results indicate that inadequate application of infection control measures by radiographers could have led to the equipment and accessories being fomites of nosocomial pathogens. Radiographers should wash their hands and clean equipment and accessories especially those that are in contact with either the patient's body or the radiographers' hands immediately after each examination. Effective cleaning methods are essential to break the cycle of infection.

Nosocomial pathogens present on selected radiology equipment and accessories after cleaning

Results after cleaning with chlorine bleach in Room A show that four types of bacteria namely *Bacillus* spp., *Staphylococcus aureus*, CoNS and *Shigella* spp. were identified on the equipment and accessories. After cleaning with methylated spirits in Room B (Figure 3) four types of bacteria namely *Bacillus* spp., *Staphylococcus aureus*, *Citrobacter* spp. and *S. paratyphi* A were identified on the equipment and accessories. After cleaning, Room A recorded an unexpected higher number of pathogenic isolates (especially *Staphylococcus aureus*). It was identified that 12 out of 23 (52%) isolates from Room A were pathogenic compared to 9 out of 26 (35%) pathogenic isolates from Room B. Another unexpected finding was that the non-pathogenic isolate *Bacillus* spp. increased from 14 isolates before cleaning to 17 isolates after cleaning in Room B. *S. paratyphi* A also increased from one isolate before cleaning to four after cleaning in Room B.

Persistent bacterial contamination of items and especially those with higher numbers of certain types of bacterial isolates identified after cleaning could be attributed to various factors such as a difference in the effectiveness of the two cleaning agents. It is also noted that the time difference between the cleaning and testing processes, pre and post cleaning, in each room was too long and could have led to further growth of isolates or further contamination of equipment. The time gaps are a limitation of this study and further testing done on the same day is recommended.

It appeared that both chlorine bleach and methylated spirits did not effectively remove all bacterial isolates. These results are not in agreement with a study in Nigeria, where it was found that chlorine

bleach and methylated spirits were effective for removing pathogens [43]. The ineffectiveness of chlorine bleach in the research site could be attributed to the fact that the same mixture of chlorine was used for the cleaning processes over several days. Inappropriate use of disinfectants may also have introduced contamination. It is recommended that chlorine bleach be prepared for daily use because it loses its effectiveness over time [10]. Ideally radiology equipment and accessories should be pathogen-free because the presence of pathogens is sufficient to cause a significant threat to immuno-suppressed patients and overworked healthcare workers [44].

Nosocomial pathogens resistant to methicillin

It was also noted that the majority of CoNS and *Staphylococcus aureus* were resistant to methicillin. HAIs, particularly the ones involving resistant microorganisms, lead to difficult complications in contemporary medicine [45]. Antibiotic resistant strains represent serious healthcare complications [46,47].

Limitations of study

Due to the limitations of this study the effectiveness of the two cleaning agents could not be compared. These limitations were the difference in time frames used during the experimental study for the two cleaning agents as well as the occurrence of long periods of time between the swabbing and cleaning processes for both rooms. Furthermore, the chlorine bleach could have lost its potency since this cleaning agent was not prepared daily. Colony forming units were observed but were not documented in this study. Future studies should record colonies formed.

In addition, due to the informed consent process, the radiographers were aware of the observational study. Even with the time delay this could have influenced their behavior pertaining to the cleaning of equipment and the washing of hands.

Conclusions

It was observed that the radiographers practiced partial infection control measures and hand hygiene was applied inadequately. Nosocomial pathogens were identified on radiological imaging equipment and accessories, and therefore, these items are fomites of nosocomial pathogens which are potential causes of nosocomial infections. It appeared that both the disinfectants (chlorine bleach and methylated spirits) did not effectively remove all bacterial isolates. *Bacillus* spp. was the only non-pathogenic bacteria isolated and the most predominant organism colonizing the selected equipment and accessories. *Staphylococcus aureus* was the predominant pathogenic isolate identified. The majority of CoNS and *Staphylococcus aureus* were resistant to methicillin. HAIs, particularly the ones involving resistant microorganisms, represent one of the most difficult complications in contemporary medicine.

The focus of future research may be to determine which bacteria are resistant to specific detergents. Further chemical tests should be done on the *Bacillus* spp. to know whether *Bacillus cereus* and *Bacillus anthracis* are present on the equipment and accessories.

It is recommended that all radiology departments adopt effective communication regarding infection control procedures, implement an infection control protocol and enforce proper hand hygiene. Furthermore, departments should have proper storage of cassettes and lead aprons and also provide proper protection for equipment and accessories against body fluid. Periodic screening of the bacterial load, to assess the effectiveness of the cleaning processes, is also recommended.

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