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X-Ray Equipment as a Possible Sources of Nosocomial Infection due to Equipment Designs

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Abstract

The central imaging Department is the zone within the hospital where the diagnosis of illness and disease are faced by the numerous challenges posed by nosocomial infections. These infections can be transferred from the patient to the radiographer or other patients through the equipment used in the department or through other means. This study aims at determining the prevalence of nosocomial infections from the X-ray tube handle and the control console flat buttons/knobs, the impact of daily departmental workflow to the significance of these infections and the contribution of the different control panel designs (flat-button and knobs) to the prevalence of nosocomial infection recorded in two radiology centers studied within Enugu metropolis. Wet Sterile swab sticks were used to swab the surfaces of selected x-ray equipment parts after its disinfection before the start of work and subsequently after each patient. The swab samples were then taken to the microbiology laboratory for culturing and identification of bacteria growth. After incubation, the culture plates were examined microscopically under a bright light to identify the isolated microorganisms based on their colonial characteristics. The result of the analyzed data show that out of the total 60 swab samples (100%) collected from the surface of control console buttons and tube handles of both equipment, 24 swab samples (40%) were isolated to harbor significant growth of nosocomial infection. Amongst the strains of pathogens recorded from the designated equipment, staphylococcus aureus (17)70.8% was the commonest seen with the highest significance followed by klebsiella sp (6)25%. While E. coli (1) 4.2% shows the least significance. The result gotten also show that nosocomial infection, accumulated at a lower rate in control console with knob designs when compared to the one of flat button. This study established that truly x-ray equipment harbors nosocomial infection, and in essence, serve as a potential source of nosocomial infection spread. Also, that the flat button design of the x-ray control console has been identified to serve as a more potent source of nosocomial infection because its large surface area enabled it to accumulate infection at a faster rate than the knob designs.

Kaywords: Nosocomial Infection, X-Ray, Medical Imaging, Radiographer, Knob Designs

Introduction

The history of nosocomial infections can be traced to the origin of hospitals themselves and have been defined by the WHO as infections that develop in a patient during his/her stay in a hospital or other types of clinical facilities which were not present at the time of admission [1]. Eze et al., defined nosocomial infections as those infections which were not present at the time of their admission and usually manifest 48 hours or more after hospital admission, or within 30 days after discharge [2]. These infections usually become clinically apparent either during hospitalization or after discharge and as such, organisms that cause these infections are termed nosocomial pathogens [3]. It is also reported that infections acquired by staff or visitors to the hospital or other healthcare settings may also be considered as nosocomial [4]. Nosocomial infections first appear between 48 and 72 hours after a patient is admitted to a hospital or a health care facility [5]. These infections can be endogenous, i.e., arising from an infectious agent present within a patient's body, or exogenous i.e, transmitted or acquired from another source within the hospital settings. It could be from patients, health officials, and/or hospital equipment. It is any systemic or localized conditions that result from the reaction by an infectious agent or toxin [6].

Developing countries are reported to have up to 20 times the risk of contracting a nosocomial infection when compared with developed countries [1]. The British Medical Association (BMA) in 2006 recognizes that the occurrence of nosocomial infections, while not new, is to some degree inevitable in any primary, community or secondary healthcare setting [7]. The importance of nosocomial infection lies not solely on its ability to largely alter its proportion of spread and death rate, but also in its economic inferences. Nosocomial infection extends the duration of hospital stay, increases the cost of health care delivered and decreases the chances of recovery from ill-health. It poses a great challenge globally to health care, and the hospital environment has proven to be a notable means of transmitting these infections because of the existence of a suitable pathogen-to-host relationship. Statistics from many nations show that at any point in time, a tangible number of hospitalized patients tends to develop infections which were not present at the point when the patients were admitted to a hospital setting [8]. Now, it has become so remarkable that such infections acquired in clinics add greatly to its prevalence and economic challenges it poses. Having realized the economic implications of nosocomial infections, several agencies of world health; World Health Organization, the United Nations Environment and so many countries have made significant efforts in check-mating the prevalence of these infections.

Eze et al., found that x-ray equipment and accessories in a government hospital in Anambra state were adequately contaminated to be a potential source of infection [2]. Similar conclusions were reached by Ochie and Ohagwu, in south-eastern hospitals and in northern hospitals [5,9]. Apart from the contact between the equipment and the patient, the control panel knobs, exposure buttons, x-ray tube handles, and the tube release buttons are frequently handled by the radiographer, and the radiographer may constantly transmit pathogenic organisms from the patients to the equipment. It has been observed by the researchers that some radiographers who attend to patients on duty have a high potential for hand-contamination either from open wounds, diabetic foot ulcers, etc, while many may use non-sterile gloves to position the patient, and do not take care of disinfection procedures like removing the gloves prior to handling the x-ray equipment. This increases the chances of nosocomial infection for the next patient that will arrive. Also, some older equipment designs come with control knobs and grooves modification, which make them difficult to disinfect after use, when compared to newer equipment that comes in flat button designs with a larger surface area that are easier to clean. Studies that have been carried out on nosocomial infection have not yet considered the contributions of the different equipment designs to the prevalence of nosocomial infection in the radiography department, and this study hopes to some extent, fill up this lacuna.

Fox and Harvey, on their research to investigate if X-ray cassettes could be a possible source of pathogens capable of causing nosocomial infections, and if they could be a possible vector for cross-infection within the imaging department in a big hospital in East England, established that, x-ray cassettes harbor nosocomial pathogens making them a potential source of cross-infection [10]. In their experiment, they swabbed X-ray cassettes used for mobile radiography, accident and emergency and inpatient. A total of forty cassettes were swabbed specifically to access general levels of bacterial contamination, and also for the presence or absence of methicillin-resistant Staphylococcus aureus. The result of their research demonstrated that there were large levels of growth of the samples taken from cassettes and developed in the Microbiology Department. Coagulase-negative Staphylococcus, Micrococci, Diptheroids and species of Bacillus were all identified.

In another research carried out by Chimamanda and Chidakwa at Zimbabwean hospital to investigate whether the radiology equipment could be a reservoir for microorganisms which aid the spread of infection to patients swab samples were collected from selected X-ray equipment and accessories and sent to the microbiology laboratory for culturing and identification using standard laboratory procedure [11]. Bacteria were isolated in 38 swabs representing 42% of all the swab samples. Staphylococcus aureus, lactose fermenting coliforms, Staphylococcus saprophyticus, Pseudomonas aeruginosa and coagulase-negative staphylococcus were the bacteria isolated from the swab samples. Lactose-fermenting coliforms were isolated the most. namely 17 times (45%); Pseudomonas aeruginosa were only isolated once. X-ray cassettes recorded the highest number of times that bacteria were isolated (55%) with coliform being isolated most often (52%). This led to their conclusion that x-ray equipment harbors nosocomial pathogens.

Kim et al., performed surveillance cultures of the surfaces of x-ray cassettes in 2012, to assess contamination with methicillin-resistant Staphylococcus aureus (MRSA) at Hallym University College of Medicine Seoul, Korea. In their work, surfaces of 37 x-ray cassettes stored in a radiology department were cultured using mannitol salt agar containing 6 µg/mL oxacillin [12]. Suspected methicillin-resistant staphylococcal colonies were isolated and identified by biochemical testing and pulsed-field gel electrophoresis (PFGE) analysis was performed to determine the clonal relationships of the contaminants. The result of their investigation shows that six x-ray cassettes (16.2%) were contaminated with MRSA. During the isolation procedure, we also detected 19 x-ray cassettes (51.4%) contaminated with methicillin-resistant Staphylococcus haemolyticus (MRSH), identified as yellow colonies resembling MRSA on mannitol salt agar. PFGE analysis of the MRSA and MRSH isolates revealed that most isolates of each organism were identical or closely related to each other, suggesting a common source of contamination.

Ochie and Ohagwu, carried out a study in south-eastern hospitals in Nigeria, to identify the nosocomial bacteria commonly found on x-ray equipment and accessories in this locality and also to assess the effectiveness of some common chemical disinfectants used in x-ray units [9]. Swab samples were collected from selected x-ray equipment and accessories. The swabbing procedure was carried out using sterile Evepon-swab sticks. The selected surfaces were first swabbed before being cleaned with the chemical disinfectant of appropriate dilution. The surfaces were then cleaned with chemical disinfectant and swabbed again. A short time interval was allowed before the second swabbing for the disinfectant solution to dry. The swab samples were then taken to the microbiology laboratory for culturing and identification using standard laboratory procedure. Cystine lactose electrolyte deficient (CLED) and blood agar media were used to prepare the culture samples. The prepared samples were put in Petri dishes and incubated for 24 hours at a temperature of 37°C. At the end of the incubation period, the samples were viewed under the microscope to identify the bacteria. Bacteria were isolated in 142 swabs representing 47.2% of all the swab samples. Staphylococcus aureus, Klebsiella spp, coliform and coagulase-negative Staphylococcus epidermidis were the bacteria isolated from the swab samples. Klebsiella spp were isolated most often (49 times; 34.5%) and coagulase-negative Staphylococcus epidermidis was isolated the least number of times (18 times; 12.7%). The x-ray cassettes recorded the highest number of times bacteria were isolated (54 times; 38%) with coliform being isolated most often (45 times; 31.7%). Sodium hypochlorite was the most effective chemical disinfectant. No bacterial isolates were seen in the swab samples collected after its use.

Eze et al., in the same vein, carried out an investigation within healthcare delivery institutions in government and private hospitals in Anambra State Nigeria, basically to investigate whether x-ray equipment and accessories harbor nosocomial pathogens and their potential role in causing nosocomial infection [2]. Wet sterile swab sticks were used to swab the surfaces of selected x-ray equipment and accessories, at the close of work. The swab samples were then taken to the microbiology laboratory for culturing and identification. MacConkey and Blood agar media (inhibitor) were used to prepare culture media. The prepared media were put in Petri dishes and swab samples were inoculated onto the culture plates. Culture plates were then incubated for 24 hours, at a temperature of 37ºc. At the end of the incubation period, the culture plates were viewed macroscopically under bright light, to identify the bacteria, according to their colonial characteristics. Data were analyzed using frequency and percentage. Their results showed that Bacteria were isolated in 182 samples (86%), out of the 200 samples collected. Bacteria isolated were Staphylococcus aureus (140), Pseudomonas aeruginosa (88), Proteus spp (28), Streptococcus (52), and Coliform spp (80) Staphylococcus aureus was the bacterium isolated most often (140 times), while

Proteus spp. was isolated the least number of times (28 times). But the largest number of samples was recorded on cassettes (60 times), for both government and private institutions. Bacterial isolates had a higher prevalence in government institutions (96), except Coliform spp. which had a higher prevalence in private institutions, this research made him agree with a similar work carried out by Ochie and Ohagwu [9].

Nevertheless, Suleiman et al., carried out research to identify the nosocomial bacteria associated with imaging equipment and accessories in Aminu Kano Teaching Hospital Kano, Nigeria [5]. Four different conventional x-ray units, fluoroscopy, computed tomography, angiography, and ultrasound units were selected. Swabs were collected from the surfaces of the selected parts of the equipment and accessories after working hours in each unit. The swabs were taken to the microbiology laboratory for culturing and identification using standard laboratory procedure. A total of 200 cultured samples were used in the study. The collected data was analyzed using SPSS version 16.0 software. Their result showed that bacteria were isolated in 43.5 % (n = 87) of all the swab samples with an ultrasound transducer as a major culture. Specific bacteria isolated were Staphylococcus aureus (n = 65; 74.7 %), Pseudomonas aeruginosa (n = 14; 16.1 %), Bacillus spp (n = 6; 6.9 %), Klebsiella spp (n = 1; 1.1 %) and Proteus spp (n = 1; 1.1 %). Methylated spirit was the most effective chemical disinfectant.

Onwuzu et al., had to examine the efficacy of the widespread practice of the use of plain non-sterile tissue paper in some low-cost private ultrasound centres in Enugu as a method of disinfecting ultrasound transducers after each use and its potential impact on nosocomial infection management in clinical practice [13]. Swab samples from convex ultrasound transducers before and after transabdominal scanning of three consecutive patients were obtained from 10 different ultrasound centres in urban and rural areas of Enugu state. Ultrasound coupling gel samples were equally obtained, and all samples cultured for bacteria growth which was quantified in colony forming units per ml (cfu/ml) and reported in 1000/ml. Paired sampled t-test was used to check for significance in the reduction in the bacterial load before and after the transducer was cleaned. The result they obtained showed that nine different bacterial strains were isolated. Staphylococcus aureus and Klebsiella spp had the highest percentage of occurrence in all centers. Significant bacteria growth was recorded in the morning before the examination, and plain tissue paper significantly reduced the bacterial load in the ultrasound transducer.

Materials and Methods

A total number of 60 swab samples was collected using a sterile swab stick from the surface of the control console buttons and tube handles in both hospitals under study; out of the 60 swab samples, 30 were collected from Life Chart medical Diagnosis Centre (Centre 1) while the other 30 were collected from NOHE (Centre 2). The surfaces of the equipment parts under study; (i) The control panel buttons and (ii) The x-ray tube handles, were effectively disinfected with chlorine or iodine-based disinfectant before the start of work for the day. Immediately after disinfecting the equipment parts our first swab sample was taken with a wet sterile swab stick. A second swab sample was then taken after a patient has been attended to with the equipment, the same pattern follows for successive patients until 15 swab samples were collected each from the two parts of the equipment under study making it a total of 30 swab samples from each hospital. Swab samples were labeled appropriately and taken to a microbiology laboratory for culture in order to identify bacterial growth; the culture media MacConkey agar was prepared according to the manufacturer's instructions. After incubation, the culture plates were examined microscopically under a bright light in order to identify the isolated microorganisms based on their colonial characteristics.

The collected data were analyzed using both descriptive and inferential statistics and presented in tables and charts. The descriptive statistics – frequency and percentage were used to summarize data. The inferential statistics – Chi-Square Test and Fishers Exact Test were used to compare the different and same equipment types. The Fishers Test was used when data failed to meet the Chi-Square assumption (that not more than 20% of the expected frequency should less than 5). These tests were done at 5% level of significance. Significance difference hence existed if p-value is less than .05, ($p < .05$); otherwise, no significance. These statistics were done with the aid of the Statistical Package for Social Science (SPSS) version 25 and Microsoft Excel 2016.

Results

Table 1 shows total number of samples collected from both Centers and the number of samples with significant infection growth. Figure 1 presents the prevalence of nosocomial infections in the x-ray control console and tube handle. Prevalence of infection in Control Console was 20.0% for Centre 1 (knob design) and 26.7% for Centre 2 (flat button design). For tube handle, the prevalence was 46.7% for Centre 1 and 66.7% for Centre 2. Generally, the prevalence for control console was 23.3% while that for tube handle was 56.7%.

Figure 2 and 3, are graph/chart showing the significance of nosocomial infection on the Y-axis and exam progress/workflow on the X-axis for both the control console and tube handles of both centers. From Figure 2, above, it highlighted that the prevalence of infection in the control console of Centre 1 (knob design) accumulates nosocomial infection at a slower rate, as its first significant growth of the pathogen in the swab culture resulted from the 10th swab sample. The control console of Centre 2 (Flat button design), in comparison, accumulates nosocomial infections at a faster rate as its first significant growth of the pathogen in the swab culture resulted from the 6th swab sample. Figure 3 above, highlighted that the prevalence of infection recorded from the tube handle of the x-ray equipment in center 1, accumulates nosocomial infection at a slower rate, as its first significant growth of pathogens in the swab culture resulted from the 6th swab sample. The tube handle of x-ray equipment of Centre 2 in comparison accumulates nosocomial infections faster as the first growth was recorded from the 3rd swab sample.

Table 1: Total number of samples collected from both Centers with significant infection growth

			Centre 1	Centre 2	Total
Infection Significance	No	Count	20	16	36
		% swab samples	66.7%	53.3%	60.0%
	Yes	Count	10	14	24
		% swab samples	33.3%	46.7%	40.0%
Total		Count	30	30	60
		% swab samples	100.0%	100.0%	100.0%

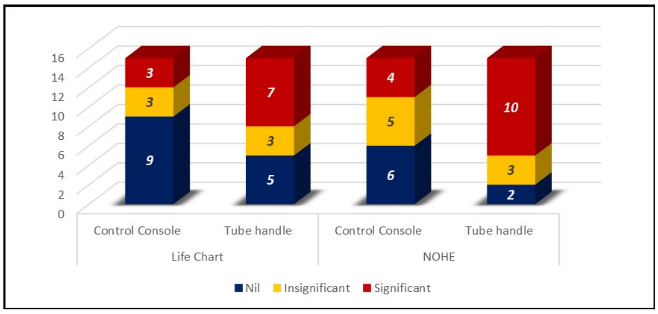

Figure 1: Showing the prevalence of Nosocomial Infections in X-ray Control Console and Tube Handle.

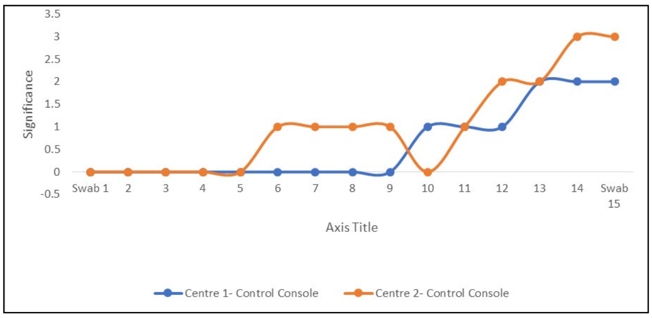

Figure 2: Prevalence of infection in the control console of Centre 1.

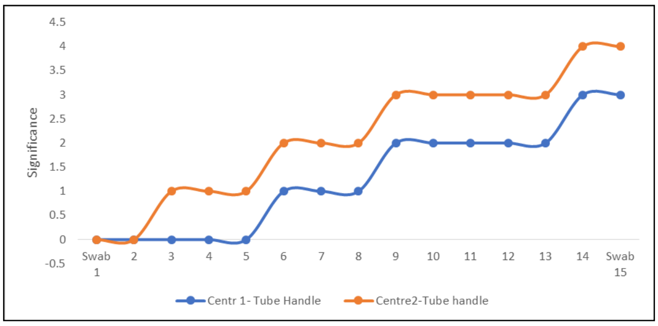

Figure 3: Prevalence of infection recorded from the tube handle of the x-ray equipment in center 1.

Table 2. Presents the nosocomial findings in the x-ray equipment. For control console, the 3 significant samples in Centre 1 were only staphylococcus (100.0%) while the 4 samples of Centre 2 were 2 organisms: firstly, Staphylococcus (50.0%) and finally, Staphylococcus and Klebisella (50.0%). Generally, samples with 1 organism were 71.4% while that with 2 organisms were (28.6%). For the tube handle, the 7 significant samples in Centre 1 were 2 organisms: firstly, staphylococcus (71.4%) and finally, Staphylococcus and Klebisella (28.6%). The 10 samples in Centre 2 were 3 organisms: firstly, Staphylococcus (30.0%), then Staphylococcus and Klebisella (50.0%) and finally Staphylococcus, Klebisella and Escherichia coli (20.0%). Generally, samples with 1 organism were 47.1%; samples with 2 organisms were 41.2% while that with 3 organisms were 11.8%. Table 3 presents the contribution of equipment designs on the prevalence of nosocomial infections. Prevalence in knob design used in Centre 1, which is (20.0%) was slightly less than that of flat button design used in Centre 2, (26.7%); the difference was not statistically significant (p = 1.000). Hence, both designs have a nearly equal propensity of causing nosocomial infection when contaminated. Table 4 presents a comparison between the tube handle which has the same design in both centers for the prevalence of nosocomial infections. Prevalence in Centre 2 (66.7%) was higher than that of Centre 1 (46.7%); the difference was however not significant (p = .269) although due to the small number of observations. Hence, tube handle of Centre 2, was more associated with the prevalence of infection than that of Centre 1.

Table 2: Nosocomial infection findings in the X-rays Equipment

Control Console	**Centre 1**	**Centre 2**	**Total**
No. of Significant Samples	n = 3	n = 4	n = 7
Staphylococcus	3(100.0)	2(50.0)	5(71.4)
Staphylococcus & Klebisella	-	2(50.0)	2(28.6)
Tube handle			
No. of Significant Samples	n = 7	n = 10	n = 17
Staphylococcus	5(71.4)	3(30.0)	8(47.1)
Staphylococcus & Klebisella	2(28.6)	5(50.0)	7(41.2)
Staphylococcus, Klebisella & E.coli	0(0.0)	2(20.0)	2(11.7)

Table 3: Comparison of Nosocomial Infections between X-ray control console designs: Knob and Flat Button.

	Nosocomial Infection		**Total**	**Fishers**
Designs	**Yes**	**Nil**		**p-value**
Knob design-Centre1	3(20.0)	12(80.0)	15(100.0)	1.000
Flat button -Centre-2	4(26.7)	11(73.3)	15(100.0)	
Total	7(23.3)	23(76.7)	30(100.0)	

Table 4: Comparison of the prevalence of Nosocomial Infections between the tube handles (similar designs) in both Centers.

Tube handle	**Nosocomial Infection**			**Chi-Square**	**p-value**
	Yes	Nil	Total		
Centre 1.	7(46.7)	8(53.3)	15	1.222	.269
Centre 2.	10(66.7)	5(33.3)	15		
Total	17(56.7)	13(43.3)	30		

Discussion

The compliance with recommended hygiene standards among radiographers has been reported to be below internationally acceptable Malavaud et al., and Selwyn et al, in a study on hospital infection, concluded that improved methods in hospital hygiene help in a rapid decrease in the prevalence of nosocomial infection [14,15]. Bhari also highlighted that radiographers most times do not adhere to the recommended hygiene standard when handling equipment and in attending to patients Üstünsöz, thus increasing the possibilities of acquiring and spread of infection [16]. From Figures 1 to 3, it was highlighted that Centre 1 had a lower significant prevalence of nosocomial infections from control console and tube handle than Centre 2 which had a higher significant prevalence in both control console and tube handle. This high prevalence of nosocomial infection in Centre 2 might be attributed to poor methods in hospital hygiene standard or poor hygiene on the side of the Radiographers on duty, giving room for the growth of these pathogens thereby increasing their prevalence. This is in agreement with the findings of Floret et al. [17].

In Figure 2, It was shown that during the collection of each fifteen swab samples from the control console of Centre 1 and 2 i.e., knob and flat button designs respectively, nosocomial infection as highlighted, accumulated at a Slower rate in control console of Centre 1(knob design) than that of Centre 2 (flat button design), with the first significant pathogen growth resulting from swab samples of the 10th and 6th respectively. The above findings imply that the accumulation of nosocomial infection is faster while working with control console with flat button modification than when the knob design is adopted, owing to the fact that flat panel surfaces provided more surface area than the knob design type allowing a larger surface area to be infected by bacteria. The researchers suggest that the frequency with which the flat button control panel is disinfected in-between use should be more than that of the knob design types. Even though as at the time of this research, no literature exists to support or refute this finding, the researchers believe that this is a novel finding.

Table 3 also highlighted that out of the total swab samples collected from each control console of Centre 1and 2 (knob and flat button designs), 20% of the 15 swab samples collected from Centre 1(knob design) revealed significant growth of infection while in Centre 2(flat button), 26.7% of equal amount of swab samples also collected, show significant growth of pathogens. Although the percentage growth of pathogens recorded is slightly higher in Centre 2 (26.7%) when compared to Centre 1(20%), the difference between their percentage growths gives a P-value of 1.000 which is statistically not significant. A possible implication is that when both designs of the control console are exposed to infection, both have a nearly similar propensity to spreading nosocomial infection. However, after exhaustive literature search, no work has been done associating x-ray equipment designs (control console buttons) to the spread of nosocomial infection.

From the results obtained from testing the tube handles from both equipment as shown in Figure 3, both types of equipment tested has a similar design. However, the tube handle of Centre 1 accumulated nosocomial infection at a slower rate, with the first major significant growth resulting from the 6th swab sample. In Centre 2, the first major significant growth was recorded from the 3rd swab sample, which by implication is faster when compared to that of Centre 1. However, the prevalence of nosocomial infection in x-ray tube handle of Centre 2 has a higher association to causing nosocomial infections than that of Centre 1, this might be as a result of the larger throughput of patients associated with center 2 and the work pattern adopted. Also from Table 4, the prevalence of nosocomial infection in Centre 2 (66.7%) was higher than that of Centre 1 (46.7%); the difference was however not significant statistically with ($p = .269$). Hence, the tube handle of Centre 2, was more associated with the prevalence of infection than that of Centre 1.

From table 1, Out of the total 60 swab samples (100%) collected from the surface of control console buttons and tube handles of both equipment, 24 swab samples (40%) were isolated to harbor significant growth of nosocomial infection. From the isolated strains of bacteria it was established that the commonest strain of bacteria recorded from the different designs of the control console and the x-ray tube handle is Staphylococcus aureus, followed by Kleibisella sp and the lowest being E.coli which is in line with the work carried out by Ochie and Ohagwu in south-eastern hospitals in Nigeria, to identify the strains of nosocomial bacteria commonly found on x-ray equipment and accessories [9]. Nevertheless, it is clear from this study that the control console modification made of flat button accumulates nosocomial infection slightly faster than the knob design counterpart. However, this study was limited to just 60 swab samples, this quantity enabled the researcher to collect all the samples in a day. The reason why all samples were collected in a day was to prevent the bias that will be introduced by cleaning of the equipment the following day, which would not allow for the proper accumulation of bacterial infection to be accurately recorded. Had it been that it was possible for the researcher to collect a larger amount of swab samples all in one day, the culture result likely might have yielded a result with more significant difference statistically in the rate at which the different designs of control console buttons accumulate nosocomial pathogens than what we obtained.

Conclusion

Patients undergoing radiological examinations as well as the Radiology staff in the department can be victims of nosocomial infections. These infections can be contracted from radiographic equipment; control console (knob or flat panel design), which are areas frequently handled by the radiographers during the examination. When these two designs of the control console were studied and compared for the presence of nosocomial infection in the two centers, we thus established that the flat button design serves as a more potent source of nosocomial infection because, its large surface area enabled it to accumulate infection at a faster rate more than the knob design counterpart, thus making nosocomial infection to be more likely in departments with flat button design than in those with knob design. With the flat panel surfaces providing more surface area than the knob design type which allows a larger area to be infected by bacteria. The researchers thus suggest that the frequency with which the flat button control panel is disinfected in-between use should be more than that of the knob design types.

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