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# Elevators and staircase handrails as potential sources of nosocomial pathogens at Ndola teaching hospital, Zambia

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**Abstract**
This study aimed to assess microbial colonization of elevators and the staircase handrail at Ndola Teaching Hospital. Swabs from elevators and staircase handrail were cultured on Blood, MacConkey and Mannitol Salt agar for 24-48h at 35-37$^{o}$C. All observed bacterial colonies where sub-cultured for identification. Data analysis was conducted with Microsoft excel 2010 and SPSS version 20 statistical software. A 2-tailed Pearson Correlation test was used to assess for significant differences in colonization prevalence between the two elevators and handrail. A total of 94 bacteria species were isolated, among which 75 (78.8%) were isolated from elevators while 19 (20.2%) were isolated from the staircase handrail. Most bacteria were isolated from exterior buttons followed by doors and interior of elevators whereas the basement, ground and sixth floor sections of the staircase handrail were largely contaminated with S. aureus, non-spore forming Gram positive bacilli, Klebsiella spp, coagulase negative Staphylococci and Enterobacter spp. Overall, the commonest isolated bacteria were S. aureus (33%) followed by non-spore forming Gram positive bacilli (16%), coagulase negative Staphylococci and endospore forming Gram positive bacilli (13.8% apiece), Streptococci (7.4%) and Klebsiella species (6.4%). Strong relationship existed on the prevalence of bacteria colonizers of elevators and staircase handrail ($p<0.01$). Therefore, the study showed that elevators and staircase handrail possess viable microorganisms and may act as potential sources of nosocomial infections especially to immune com promised patients in hospitals, and this calls for proper and effective infection control and prevention strategies to lessen microbial population from dry surfaces.

**Keywords:** elevators, handrail, Ndola teaching hospital, Microbial colonization, inanimate objects

## Introduction

The human community is surrounded by the environment that harbours a wide range of both pathogenic and non-pathogenic microorganisms. The hospital is no exception, if anything, it may harbour more pathogenic than non-pathogenic when infection control programs are not strengthened. Thanks to our bodies' immune system that controls and regulates the proliferation of these microbes. However, the hospital houses both immuno competent and immuno compromised individuals: and the latter are prone to contracting nosocomial and opportunistic infections [1]. In addition, microorganisms in hospital environment may be contracted from both wet and dry inanimate surfaces [2]. For this reason, it is important to setup deliberate policies on microbial monitoring of the inanimate environment to detect the presence of specific nosocomial pathogens which can be used to evaluate the efficacy of routine cleaning and disinfection practices [3].

Hospital acquired infections pose a great challenge to the welfare of patient management. This ultimately increases the length of stay for inpatients and further having a huge impact on hospital costs. Nosocomial infections usually affect immuno compromised patients due to age, underlying diseases, medical or surgical treatments and, antimicrobial use and long-term care in hospitals contribute to the emergence of nosocomial pathogens [4]. There is up to 70% chance for patients admitted to a room previously occupied by a patient with *Clostridium difficile*, *Pseudomonas aeruginosa*, methicillin-resistant *Staphylococcus aureus* (MRSA), *Acinetobacter baumannii* or vancomycin-resistant *enterococci* (VRE) to obtain these microbes during hospital stay [3, 5, 6]. Thus, microbial hygiene examinations may provide insights on how clean a surface is. During nosocomial outbreaks, various surfaces such as taps, sinks, toilets, beds, and floors are sampled for epidemiological investigations to assess the spread of nosocomial pathogens [7].

To mitigate these challenges, enhancing hospital surveillance programs for nosocomial pathogens is of utmost importance. Moreover, having a formidable infection control team that incorporate four key infection control components such as an effective hospital epidemiologist, one infection control practitioner, active surveillance mechanisms, and ongoing control efforts, have proven to reduce the rate of nosocomial infection [4, 8].

However, the survival of microorganisms on surfaces is dependent on factors such temperature and moisture. For instance, it was observed that Gram negative bacteria persist longer on surfaces than Gram positive bacteria and, their survival was further enhanced with humidity [2]. In the same systemic review study, it was revealed that bacteria such as *Enterococcus* (including Vancomycin Resistant *Enterococci*), *Staphylococcus aureus* (including Methicillin Resistant *Staphylococcus aureus)*,

*Streptococcus pyogenes*, *Escherichia coli*, *Acinebacter spp*., *Klebsiella spp*., *Pseudomonas aeruginosa*, *Serratia marcescens* and *Shigella spp*., survived for months on dry surfaces while *Bordetella pertussis*, *Haemophilus influenza*, *Proteus vulgaris* and *Vibrio cholerae* survived only for few days. Despite various cleaning and disinfection practices that are performed in hospitals, complete elimination of bacterial colonization does not occur as MRSA and *Acinetobacter baumannii* have been detected on environmental surfaces after cleaning and disinfection of a hospital ward [9]. Thus, hospital environment surfaces should regularly be monitored for the presence of nosocomial pathogens. So, dry surfaces like hospital staircase rails and elevators that are frequently utilised may be potential reservoirs of bacteria, and may act as conduits for hospital acquired infections.

Ndola Teaching hospital (NTH) has two functional elevators: one runs from the ground floor to third floor while the other runs from basement level to seventh floor. Besides the hospital having two functional elevators, and/or when these elevators are down (non-functional), the staircases that runs from the basement level to the rooftop are an option. Moreover, the hospital elevators and staircases become busier during patient visiting hours. Since staircases and elevators are used by hospital staff, patients and visitors, and are a vehicle of transporting foods, hospital waste, biological specimens for laboratory examination and corpses to the mortuary: we hypothesized that the cleaning in these areas may not be effective to reduce bacterial presence, and hence may act as sources of hospital acquired infections and conduits of infection transmission. Also, it has been suggested that hospital surfaces with hand contact are contaminated with nosocomial pathogens and may act as vectors for cross contamination, posing a risk of pathogen transmission from inanimate surfaces to susceptible patients [2]. Therefore, this study aimed at assessing microbial colonization of elevators and the staircase handrail at NTH.

## Materials and Methods

### Study site and study design

This study was a prospective cross-section laboratory based study that focused on understanding the bacterial colonization of elevators and the staircase handrail at Ndola Teaching Hospital. The hospital is the second largest health institution in Zambia with a capacity of 851 beds and 97 baby cots. It is also a referral centre for Copperbelt, Luapula and North-western provinces of Zambia and serves a population of 503 649 of Ndola district. The hospital, at the time of the study, had two functional elevators: one elevator runs from ground floor to third floor and was designated as elevator 1 and the other one that runs from the basement to seventh floor was designated as elevator 2. Besides the two elevators, there is a staircase handrail that runs from the basement to the seventh floor.

### Sample collection, culture and inclusion criteria

The presence/absence of microorganisms on the dry steel surface of the elevator and staircase handrail was assessed using the pre-moistened swabbing method to increase the chances of isolating microorganisms as reviewed by Galvin et al 2012 [3]. Sterile cotton wool swabs were used to collect the specimens. Swabs pre-moistened in normal saline were used to scrub the interior buttons, exterior buttons, door walls and interior flat handrails and interior walls of both elevators. The staircase handrail was also swabbed with pre-moistened swabs. These swabs were then put back in the transport media tube and were immediately transported to microbiology laboratory within 20 minutes. Swabs were labelled with swabbing site, date and time of collection. However, samples without proper labelling and those exceeding 2h without being cultured were excluded from the study. Also, all specimens with suspicion of cross contamination were excluded from the study. To avoid cross contaminations, one specimen per time was processed in the Biosafety cabinet.

Upon arrival to the microbiology laboratory, each swab was inoculated on Blood Agar (BA: Himedia, India), Mannitol Salt Agar (MSA: Sigma, USA) and MacConkey Agar (MA: Himedia, India) and the plates were incubated for 24 hours at 35 - 37ºC. The plates were then checked for growth and all different colonies growing on any of the media were then subcultured on a new set of plates to obtain pure colonies for definitive identification. If no growth appeared, the same plates were further incubated for 24 more hours and dealt with in the same manner.

### Microbial processing and identification.

After 24h to 48h of microbial growth, a Gram stain was used to differentiate Gram positive bacteria from Gram negative bacterial cells. After Gram staining, Gram positive organisms were identified by assessing the catalase and coagulase production. Further identification of Coagulase negative *Staphylococci* (CNS) with novobiocin susceptibility testing was performed to rule out *Staphylococcus saprophiticus* (novobiocin resistant). In this testing, a pure colony suspension equivalent to a McFarland 0.5 opacity standard of an 18-24h culture was prepared and inoculated on Mueller-Hinton Agar [10] and novobiocin (5ug) disk aseptically placed onto the inoculated agar surface. The plate was then incubated for 18-24 hours at 35-37ºC. The diameter of the zone of inhibition around the novobiocin disk was measured (in millimetres) and the zone size <16 mm was considered resistance whereas the zone size greater or equal to 16 mm was regarded as sensitive.

For the Gram-negative organisms, besides using catalase and oxidase testing, the strains were exposed to different identification tests using in-house and/or commercialy prepared biochemical media such as Sulphur Indole Motility (SIM) agar (Becton, Dickinson and company (BD), USA), Triple Sugar Iron (TSI) agar (BD, USA), Lysine Iron Agar (BD, USA), Citrate agar (Mast Group Ltd, UK), urea media (BD, USA), oxidase reagent (Himedia, India), hydrogen sulphide (VYKing Pharmaceuticals Ltd, Zambia). Quality control was performed with *Staphylococcus aureus* (ATCC 25923), *Escherichia coli* (ATCC 25922) standard strains.

### Data processing and analysis

Data entry was done and managed in Microsoft excel 2010 and statistical analyses was performed by using SPSS version 20 statistical software. A 2-tailed Pearson Correlation test was used to assess for significant differences in colonization prevalence between the two elevators and handrail.

## Results

A total of 94 bacterial isolates were obtained from culture swabs of both elevators and the handrail. Out of 94 isolates, 28.7% (27)

bacteria were isolated from elevator 1, 51.1% (48) from elevator 2 and 20.2% (19) from the staircase handrail (Table 1).

**Table 1:** The distribution of bacteria isolates from staircase handrail and elevators

| Bacterial isolate | Elevator 1 %(n) | Elevator 2 %(n) | Handrail %(n) | Total %(n) |
|---|---|---|---|---|
| *S. aureus* | 19.4 (6) | 51.6 (16) | 29.0 (9) | 33.0 (31) |
| Endospore forming GPR | 38.5 (5) | 61.5 (8) | 0 | 13.8 (13) |
| CNS | 23.1 (3) | 53.8 (7) | 23.1 (3) | 13.8 (13) |
| *S. saprophyticus* | 66.7 (2) | 33.3 (1) | 0 | 3.2 (3) |
| Non spore forming GPR | 46.7 (7) | 26.7 (4) | 26.7 (4) | 16.0 (15) |
| *Streptococcus spp* | 28.6 (2) | 57.1 (4) | 14.3 (1) | 7.4 (7) |
| *Klebsiella* spp | 16.7 (1) | 66.7 (4) | 16.7 (1) | 6.4 (6) |
| *E. coli* | 33.3 (1) | 66.7 (2) | 0 | 3.2 (3) |
| *Enterobacter* spp | 0 | 50 (1) | 50 (1) | 2.1 (2) |
| *Providencia rettgeri* | 0 | 100 (1) | 0 | 1.1 (1) |
| Total | 28.7 (27) | 51.1 (48) | 20.2 (19) | 100 (94) |

%: percentage, n: number, GPR: Gram positive rods, spp: species, CNS: coagulase negative *Staphylococci*

Elevator 2 (E2) was highly conaminated followed by elevator 1(E1) then the staircase handrail (SHR). This was partly because the E2 runs from basement to seventh floor of the hospital building and people opt to use it more often as compared to E1 which only moves from ground floor to third floor: however the staircases are infrequently used as shown by less number of microbial isolates from the SHR. Among the bacterial isolates, *Staphylococcus aureus* (*S. aureus)* was more prevalent on SHR (47%) followed by E2 (33%) and E1 (22%): endospore forming Gram positive rods (EGPR) were more from SHR (21%) followed by E1 and E2 with 19% and 17%, respectively (Fig. 1A). Furthermore, coagulase negative *Staphylococci* (CNS) were mostly isolated from SHR (16%) followed by E2 (15%) then E1 (11%) whereas *Streptococci* were more from E2 (8%) followed by E1 (7%) then SHR (5%): but *Staphylococcus saprophyticus* (*S. saprophyticus*) and non-spore forming Gram positive rods (NGPR) were only isolated from the elevators (fig. 1A).

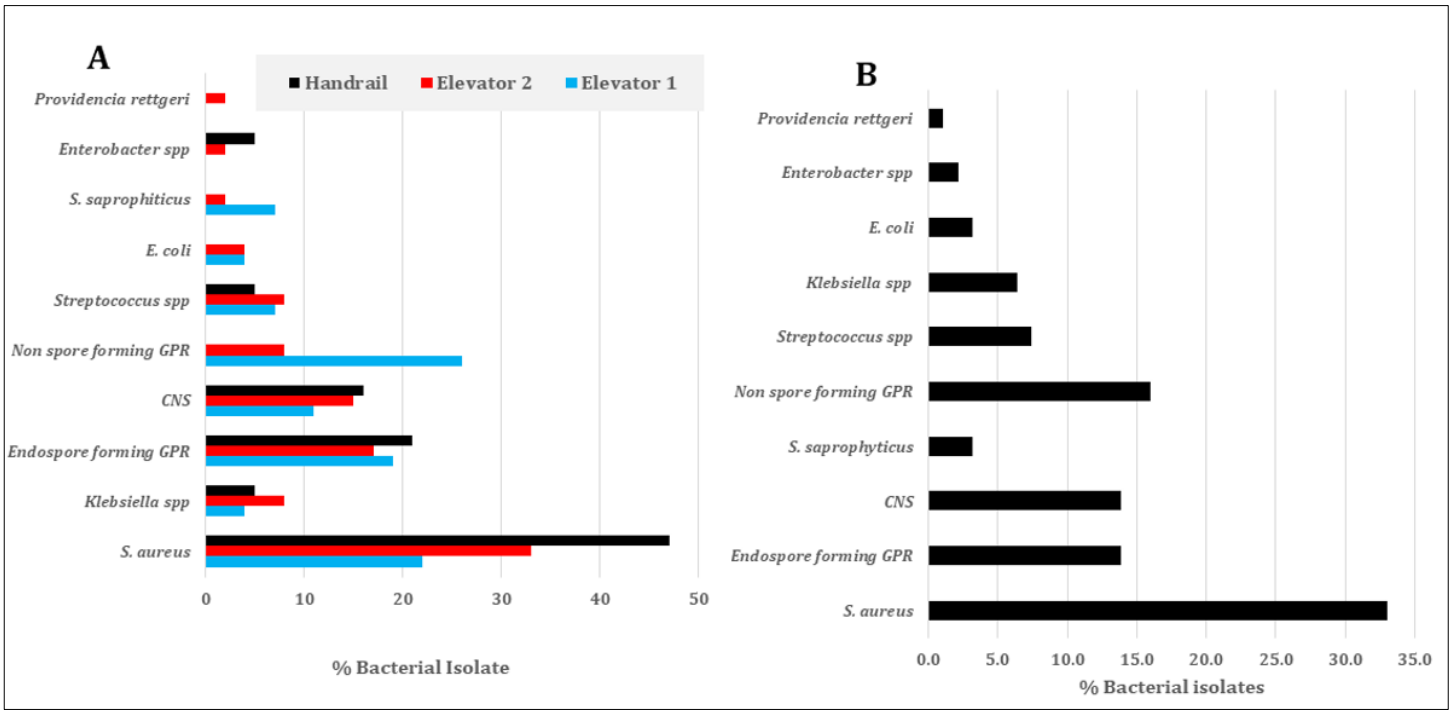


**Fig 1:** The percentage proportion (A) and prevalence (B) of bacterial isolates from elevators (1 and 2) and staircase handrail. CNS: coagulase negative Staphylococci, GPR: Gram positive rod, spp: species.

Overall, figure 1B (and Table 1) further revealed that the commonest colonizer amongst all isolated bacteria was *S. aureus* (33%) followed by NGPR (16%), CNS & EGPR (13.8% apiece), *Streptococci* (7.4%) and *Klebsiella* spp (6.4%). Yet, the commonest isolates from individual equipment were NGPR (26%: 7) followed by *S. aureus* (22%: 6), S. aureus (33%: 16) followed by EGPR (17%: 8), and S. aureus (47%: 9) followed by NGPR (21%: 4) for E1, E2 and SHR respectively (Table 1). Since elevators are widely used as shown by the highest number of isolates (Table 1), we hypothesized that elevator buttons (both interior and exterior) and interior doors, walls and rails could be heavily contaminated as they are frequently touched by people using elevators, and we wanted to identify the commonest contaminants. On average, *S. aureus* was identified as the commonest colonizer of exterior buttons, door walls, and interior handrail and walls of elevators followed by EGPR colonizing mostly the interior handrail and walls, door walls and interior buttons (Fig. 2).

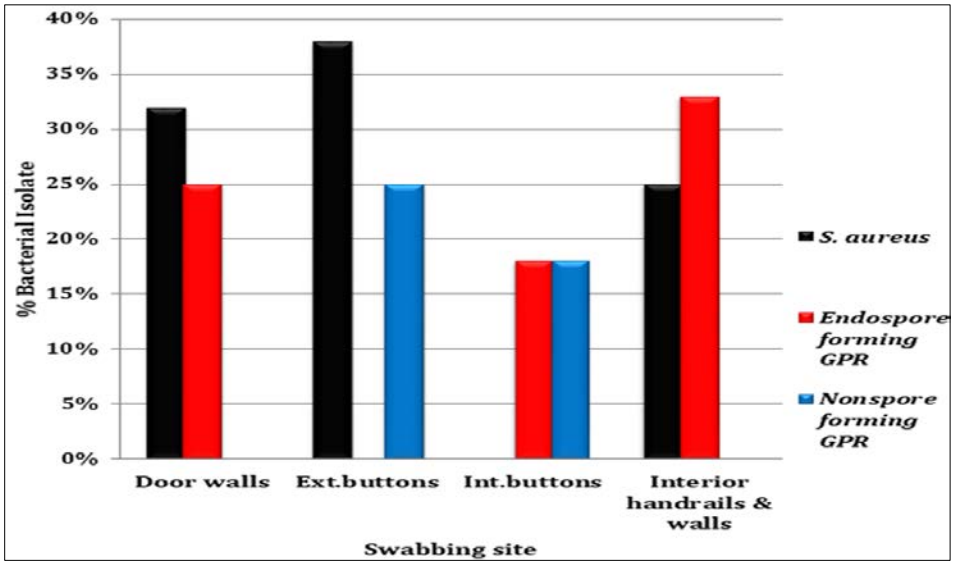


**Fig 2:** The prevalence of most occurring bacteria isolates from both elevators (1 and 2) per swabbing site. GPR: Gram positive rods, Ext. buttons: exterior buttons, and Int.buttons: Interior buttons.

However, NGPR were only isolated from exterior and interior buttons (Fig. 2). Previous studies have revealed insignificant difference on the transfer rates of Gram positive and Gram negative bacteria from inanimate surfaces to fingertips [1]. Our study isolated the highest percentage of Gram positive bacteria (86%) and less of Gram negative bacteria (14%) as shown in fig. 3. We further discovered that the basement, ground floor and sixth floors were the most contaminated sections of the Staircase handrail, and were frequently colonized with *S. aureus* and NGPR with an addition of *Klebsiella* spp (basement), CNS (ground floor) and *Enterobacter* spp (6th floor) (data not shown). Finally, we sought to understand the significant differences in colonization prevalence between E1 and E2, E1 and SHR, and E2 and SHR with a 2-tailed Pearson correlation test. We found that there was a strong correlation between E1 and E2 ($r(25)=0.90$, $p<0.01$), E1 and SHR ($r(17)=0.93$, $p<0.01$), and E2 and SHR ($r(17)=0.74$, $p<0.01$). These suggested that there was a statically strong relationship on the type of bacterial colonizers that were isolated from the elevators and staircase handrail.

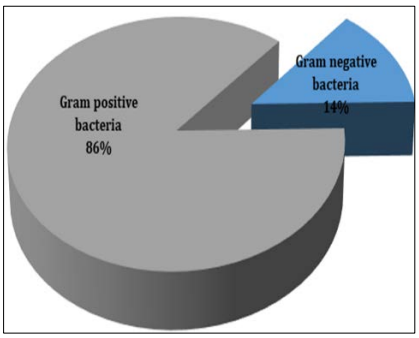


**Fig 3:** The total distribution of Gram positive and Gram negative isolated bacteria from Staircase handrail and Elevators (1 and 2).

## Discussion

Elevators and staircase handrail are very useful in facilitating people's movements and support within a multi storey building. Hospitals are an example of such buildings that utilise elevators for easy and fast movements of doctors, nurses, patients, visitors, foods *etcetera*, from one floor to the other. Due to their usage by multiple people, elevators, especially elevator buttons in the hospital may be an additional or neglected source of microbial contamination [12]. On the other hand, staircase railing provide stability for people especially young children, the elderly, people with disabilities and fatigued patients and others that may graze the railing lightly with their hands in case they need extra support or balance as they ascend or descend the staircases. Due to this purpose, handrails are usually colonized with both viable and nonviable pathogenic microorganisms in hospitals [13]. All these microbial colonizers can be minimized with proper disinfection and cleaning practices. Hospital cleaning and disinfection is also the hallmark of infection control. A plethora of evidence indicate that contamination of hospital surfaces play an important role in the transmission of several key healthcare associated pathogens [14, 15]. Therefore, we thought to understand the effectiveness of cleaning and disinfection practices at Ndola Teaching Hospital (NTH) via assessment of bacterial colonization of elevator buttons, walls and rails, and staircase handrail.

The results of the current study reveals that solid surfaces are colonized by viable organisms and people using them can act as carriers. These findings are in agreement with the results obtained in previous studies [16, 17] where they isolated pathogenic bacteria from elevator buttons and concluded that elevators are actually contaminated with potential pathogens. Al-Ghamdi *et al* 2011 [16] reported the highest contamination rate of elevator buttons (97%) and our study confirms that elevator buttons are heavily contaminated with rate of less than 40% (fig. 1). The difference could be attributed to the less number of elevators that were included in our study while Al-Ghamdi *et al*. included residential and shopping mall elevators. Furthermore, our study showed that besides elevator buttons, interior walls and handrails were contaminated mostly by *S. aureus* and endospore forming Gram positive bacilli (fig. 2). These findings could be as a result of touching or leaning on the elevator walls and holding the interior handrail for support. According to previous studies, there is no significant difference on the rate of spreading Gram positive and

Gram negative bacteria between inanimate surfaces and animate ones [11, 18], but our study found the highest percentage of Gram positive bacteria (86%) and less of Gram negative bacteria (14%) as shown in figure 3. Survival of bacteria on inanimate objects is large enhance by the relative humidity [18]. A study by Tang (2009) found the high prevalence of Gram positive cocci followed by Gram positive rods, Gram negative rods and Gram-negative cocci in indoor air [19] and *S. aureus* can persist longer at low humidity [20] which could explain the highest prevalence of *S. aureus* in our study (fig 1B). Thus, Gram-positive organisms tend to tolerate dry conditions better than Gram-negative organisms due to variations in the bacterial cell wall structure, because the lipid double-layer structure with a thin peptidoglycan layer of Gram negative bacteria does not adequately confer protection against physical stress, hence humidity is required to enhance their survival on inanimate surfaces [18].

The Gram positive bacteria such as *S. aureus*, EGPR, CNS, *S. saprophyticus*, NGPR and *Streptococcus* spp were the most isolated microorganisms from both elevators while Gram negative ones included *Escherichia coli*, *Klebsiella* spp, *Enterobacter* spp, and *Providencia rettgei*. Despite *S. aureus* being part of the normal human microbiota, it may cause a wide range of infections such as bacteremia, sepsis, pneumonia, endocarditis and osteomyelitis, and can cause hard to treat nosocomial infection due to multidrug resistance acquisition [21, 22]. The second most prevalent bacteria in our study was the endospore forming Gram positive rods (EGPR, fig 1B). These organisms are widely distributed in the environment and can also be found in dust and maybe medically insignificant but may cause self-limiting infections. The other type of isolates were the non-endospore forming Gram positive rods (NGPR) and CNS that are human commensals and may also be present in the inanimate hospital environment, and can cause nosocomial infection [23, 24]. Further Gram positive bacteria isolated with less frequency but may cause nosocomial infection such as sinusitis, otitis media, pneumonia, bacterial meningitis, bacteraemia and acute exacerbations of chronic bronchitis, were *Streptococcus* spp and *S. saprophyticus* (fig. 1B). Among the Gram negative bacteria isolated in this study, *Klebsiella* spp were the most prevalent, and this finding agreed with Nawas *et al* 2018 [25] who isolated the same bacteria from 17% of the sampled elevators [25]. Within the *Klebsiella* spp there is *K. pneumoniae*, one of the common cause of hospital acquired pneumona, urinary tract infections and intraabdominal infections [26], but our study did not determine whether *K. pneumoniae* was amidst the isolated *Klebsiella* spp.

On the other hand, staircase handrail (SHR) was also assessed for bacterial colonization due to the fact that it provides stability for people as they ascend or descend the staircases. As expected, SHR was also contaminated but few isolates in comparison with those from elevators were noted. Amongst these isolates, *S. aureus* (47%) topped the list followed by NGPR (21%), CNS (15%) and <1% apiece of *Klebsiella* spp, *Streptococcus* spp and *Enterobacter* spp, and our findings were in agreement studies conducted elsewhere [2, 18, 27, 28]. We further discovered that the basement, ground and sixth floors were the most contaminated sections of the SHR, and were frequently colonized with *S. aureus* and NGPR with an addition of *Klebsiella* spp (basement), CNS (ground floor) and *Enterobacter* spp (6th floor). This maybe because these areas are frequently populated by people awaiting to use the elevators as they receive people from outside the hospital (i.e. basement and ground floors) while the sixth floor could be due to the presence of a fee paying clinic, restaurant and is also hosting a research centre – so maybe frequently visited thereby contaminating the SHR. The study further found a strong correlation on the prevalence of bacteria colonizers of elevators and staircase handrail ($p<0.01$).

In conclusion, our study has revealed that elevators and staircase handrail are contaminated with both Gram positive and negative bacteria and are equally important areas that require keen interest in infection prevention and control, as they may be a conduit for hospital acquired nosocomial infections. Thus, when hospital wards, beds, sinks etc are being swabbed periodically to assess the contamination levels during infection control programs, elevators and staircase handrail should not be overlooked or neglected. The study further revealed that some isolates such as *S. aureus*, *Escherichia coli* and *Klebsiella* species are common carriers of antibiotic resistant genes, and it would have been more informative if the susceptibility pattern was assessed or resistant markers were identified, however our study could not, hence additional studies are warranted. Further limitations of this study included lack of speciating most of the isolated organisms, and determining the effectiveness of the cleaning solution or disinfectant being used on these inanimate objects for infection control. Thus, all these warrant in-depth assessments.

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**Declaration of interest statement**

Authors declare no conflict of interest

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