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# Profile of Bacteria Isolated from the Cell Phones of Health Care Providers in a Hospital Setting in Cameroon

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**Abstract:** Health care providers are an integral part of the era of mobile phones. During various activities linked to health care services, they come in contact with their cell phones regularly. These cell phones act as a perfect substrate for nosocomial pathogens, especially in hot–humid conditions, and may serve as a vehicle in transmitting nosocomial infections. This study aimed at determining the profile of bacteria isolated from the cell phones of healthcare providers. A descriptive cross-sectional study was carried out from 1 April to 3 June 2023, where 115 swab samples were collected from the cell phones of health care providers (laboratory personnel, nurses/midwives and doctors) at the Regional Hospital Bamenda. These swabs were inoculated on blood, chocolate and Mac Conkey plates, and the bacteria were identified according to standard microbiological methods and biochemical tests to the genus/specie level. Data were statistically analyzed using the Statistical Package for Social Sciences (SPSS) version 23. The results were presented in frequencies and proportions. The chi square test was used to compare proportions between variables, and the results were considered statistically significant when $p < 0.05$. The bacteria isolated from these cell phones included coagulase-negative *Staphylococci* (CoNS), *Staphylococcus aureus*, *Streptococcus* species, *Pseudomonas aeroginosa*, *Escherichia coli*, *Bacillus* species and *Neisseria* species. All the cell phones of the laboratory personnel were contaminated, followed by those of the nurses/midwives (38; 33.0%) and, lastly, by those of the medical doctors (24; 20.9%). No statistically significant difference was observed between the three categories of health care providers with respect to the presence or absence of bacteria on their cell phones. This study presented that the mobile phones of health care providers are a risk of nosocomial pathogens. The result implies that there is an urgent need to implement and emphasize strategies such as hand washing and decontamination of mobile phones to limit nosocomial infections in the hospital.

**Keywords:** nosocomial pathogens; bacteria; cell phones; health care provider; Regional Hospital Bamenda; Cameroon



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## 1. Introduction

*Background*

Hospital acquired infections (HAI) or nosocomial infections increase day by day, causing significant rates of morbidity and mortality in hospitalized patients. Each year, more than 2 million patients acquire nosocomial infections, resulting in 90,000 deaths [1]. For an infection to be termed nosocomial, it must be up to 48 h after hospitalization, up to 3 days after discharge, up to 30 days after a surgical operation and in a healthcare facility when someone was admitted for reasons other than the infection with whom he or she presented with. The sources of infection can be endogenous or exogenous. Exogenous sources, which can serve as a reservoir of infection, are patients; health care workers; inanimate objects, like cell phones, computer keyboards, faucet handles, stethoscopes,

wrist watches, and other items present in the immediate vicinity of the patient; or the healthcare provider. Possible factors that may lead to the spread of nosocomial infections from cell phones include poor hand hygiene, poor knowledge of decontamination, lack of disinfectants in strategic positions within the health care facility and unavailability of refresher programs or trainings on nosocomial infection control [2].

Mobile phones have become widespread accessories in our world today. In 2013, more than 1.6 billion smart phones were in use worldwide, and it is estimated that this number will approximately triple within the next 8 years [3]. Mobile phones have become part of health professionals' equipment and are used extensively for communication in a clinical setting [4]. However, they are seldom cleaned and are often touched during and after the examination of patients. These cell phones can harbor potential pathogens, become sources of infection for the patients and are also a potential health hazard for self and family members [5,6]. Dhayhi et al. [7], in Saudi Arabia, found notable pathogens, including *Escherichia coli*, *Klebsiella pneumoniae*, *Pseudomonas* species and *Acinetobacter* species, on the cellphones of health staff in a critical care unit.

The widespread use of mobile phones among medical personnel in hospitals is an issue of controversy. The question of concern is how to use the mobile phones safely in the context of medical care [8]. The mobile phones of health professionals can easily be contaminated, as they constantly use their phones as dictionaries and hand references during patient management, follow-up and other work-related issues as they deal with patients having different illnesses [4].

Another point of view argues that, if mobile phones are used carelessly in surgical wards or intensive care units (ICU), they may act as a source of infection to patients while handling them, such as during dressing of surgical wounds [9]. In addition, there are no guidelines for disinfection of mobile phones that meet hospital standards. To add, mobile phones are used routinely all day long, and the same phones are used both inside and outside the hospital, playing a possible role in spreading infections to the outside community [10]. There is a scarcity of information about the different bacterial species that are present on the cell phones of health care providers in our setting. Hence, this study was conducted to investigate the profile of bacteria isolated from the cell phones of health care providers at the Regional Hospital Bamenda in order to have baseline data on this subject matter for our setting.

## 2. Materials and Methods

### *2.1. Study Design, Area and Period*

A cross-sectional study was conducted using the cell phones of health professionals (laboratory workers, medical doctors, nurses and midwives) working at The Regional Hospital Bamenda from 1 April to 3 June 2023. This hospitalis located in the Northwest Regional headquarters, Bamenda and situated in the Bamenda II subdivision in Mezam Division. This hospital is bounded to the north by Ntamulung health area, to the south by Atuakom health area, to the west by Alakuma health area and to the east by Ntambang health area. This hospital provides secondary healthcare delivery along with other primary health care facilities to more than 70,000 inhabitants of the Bamenda municipality.

### *2.2. Sample Size and Sampling Technique*

The participants for this study were recruited conveniently based on their availability and willingness to participate in this study. With respect to this, 115 health care providers (25 medical doctors, 49 medical laboratory personnel and 41 nurses/midwives) were recruited for this study.

### *2.3. Selection Criteria*

#### 2.3.1. Inclusion Criteria

Health care providers who were present during the data collection and who voluntarily accepted by signing the consent form were included in this study.

#### 2.3.2. Exclusion Criteria

Those from whom samples were difficult to collect and those who did not completely fill the questionnaire were excluded from this study.

#### 2.3.3. Ethical Considerations

Prior to the data collection, ethical clearance (2023/0542H/UBa/IRB) was obtained from the Faculty of Health Sciences of the University of Bamenda. Administrative authorization to carry out this research was obtained from the Regional Delegation of Public Health, Northwest Region and the Director of the Bamenda Regional Hospital, and informed consent was obtained from each participant. The participants were assured that their data will be used only for recherche purposes and treated with confidentially.

#### 2.3.4. Sample Collection Procedure

Fresh swab samples were collected from the phone of each consenting participant as follows.

A pair of sterile gloves was won for each sample collection procedure. With the help of a marker, the swab tubes were labelled with participant number, sex and department (laboratory, nursing or general consultation for doctors) of the hospital. A sterile cotton-tip swab was moistened with 0.9% normal saline (it is isotonic and has no effect on bacteria). The swab was rolled over the screen or keypad (for non-touchscreen phones) and on the back of the cell phone several times. The sample were then placed in a transportation box and taken to the microbiology laboratory within an hour to prevent them from drying out.

### *2.4. Preparation of Culture Media*

According to the manufacturer's instructions [11], dehydrated blood base agar was placed on a foil paper, measured using a scale balance (42.2 g) and transferred into a clean round-bottom flask containing 1000 mL of distilled water. The solution was mixed well by hand shaking to ensure complete dissolution. The homogenized solution was then put into the autoclave, which was previously plugged into a power source for 15 min to reach the following conditions: 121 °C and a pressure of 15 psi (pounds per square inch); then, the power button was pushed with the aim to sterilize. When the time had elapsed, the pressure in the autoclave was gradually released through the valves by opening them gently. The medium was then removed from the autoclave and allowed to cool to 50 °C, measured with a thermometer. Twenty-five (25) mL of fresh human screened blood obtained from the blood bank was added and mixed carefully to ensure a homogenized mixture.

Petri dishes were removed from their package and placed on a clean, flat surface. Five hundred (500) mL of the 1000 mL of prepared blood agar was poured into a beaker, and subsequently, approximately 15 mL of the media was poured into a single compartment of each petri dish.

To prepare the chocolate agar, the 500 mL that was left was then reheated until the red color changed to a chocolate color, ensuring complete hemolysis of the red blood cells. Approximately 15 mL was again poured on the second compartment of the petri dish. The petri plates were stored in the fridge at 2 to 8 °C until use.

From the lot of petri dishes poured, one was taken at random and incubated at 37 °C (ambient temperature) for 18 to 24 h to check for sterility and to serve as a negative control.

According to the manufacturer's instructions for the preparation of Mac Conkey agar [12], 50.03 g of the dehydrated medium (powder) was suspended in 1 Liter of distilled water. It was mixed thoroughly and placed in the autoclave under the following conditions: 121 °C, 15 psi and for 15 min with the aim to sterilize. The medium was removed from the autoclave and allowed to cool to a temperature of 45 to 50 °C. It was then poured into the third compartment of the petri dishes and allowed to solidify. The plates were stored in a fridge at 2–8 °C until use. One of the plates was incubated for 18 to 24 h at 37 °C to check for sterility and to also to serve as a negative control.

### *2.5. Laboratory Analysis*

In the laboratory, the sampled mobile phone swabs were streaked on the previously prepared blood, chocolate and Mac Conkey agar plates. The inoculated plates were incubated in an incubator aerobically (because the bacteria needed to grow in an oxygenated atmosphere) in an inverted position (so that condensation does not drip onto the plate and interfere with the growing bacteria) at 37 °C for 18 to 24 h.

The plates were then observed for bacterial growth in the form of colonies. Bacterial isolates were characterized macroscopically (color, shape, size and texture) with the naked eye and microscopically after Gram staining and observation under the light microscope.

### *2.6. Identification of Bacteria*

The bacteria isolated in this study were identified by biochemical tests (catalase, coagulase, oxidase and indole tests) and Gram staining. These biochemical tests eased the identification of the isolates on the basis of their biochemical reaction following standard laboratory procedures [12]. The Gram stain procedure enabled the grouping of bacteria into Gram positive and Gram negative.

### *2.7. Data Analysis*

Statistical analysis was performed with the Statistical Package for Social Sciences (SPSS) version 23 (SPSS Inc., Chicago, IL, USA). The data were analyzed using descriptive statistics, such as frequency and proportions. The results were presented using tables. The chi square test was used to compare proportions between variables, and all results were considered statistically significant when $p$-values were less than 0.05.

## 3. Results

### *3.1. Characteristics of Participants*

Out of the 120 health professionals sampled, 115 participated in this study, and the response rate was 95.8%. Five participants were excluded from this study because they did not give their phones for sample collection. The mean age range of this study's participants was 20–30 ($\pm$1) years. The majority of this study's participants belonged to the age group of 20–30 years (46.9%), with a sex ratio of 52 (male):63 (female). The participants reported to have been using their mobile phones for a minimum period of 3 months to a maximum of 48 months, with a mean duration of 25 $\pm$ 2 months. Based on occupation, the laboratory personnel were highly represented (42.6%), followed by the nurses/midwives (35.7%) and, lastly, by the medical doctors (21.7%). According to working experience, health care personnel with up to 5 years of working experience were highly represented in this study. Participants with a bachelor's degree were highly represented (54.8%) (Table 1).

**Table 1.** Distribution of participants with regard to socio-demographic data (N = 115).

| Parameters | Categories | Frequency | Percentage |
|---|---|---|---|
| Gender | Male | 53 | 46.1 |
| | Female | 62 | 53.9 |
| Age ranges (years) | 20–30 | 77 | 67.0 |
| | 31–40 | 22 | 19.1 |
| | ≥40 | 16 | 13.9 |
| Occupations | Laboratory personnel | 49 | 42.6 |
| | Nurses/midwives | 41 | 35.5 |
| | Medical doctors | 25 | 21.7 |
| Working experience (years) | ≤1 | 29 | 25.2 |
| | 2–5 | 54 | 47.0 |
| | 6–9 | 27 | 23.5 |
| | ≥10 | 5 | 4.3 |

**Table 1.** *Cont.*

| Parameters | Categories | Frequency | Percentage |
|---|---|---|---|
| Level of education | HND | 26 | 22.0 |
| | Bachelor Degree | 63 | 54.8 |
| | Masters | 13 | 11.6 |
| | Others | 13 | 11.6 |

Others: Assistant nurse, holder of higher professional diploma; HND: higher national diploma.

Out of the 115 cell phones of the health care providers that were swabbed and analyzed, 111 had bacterial contamination, giving a prevalence of 96%.

Socio-Demographic Variables and Bacteria Isolated from Cell Phones of HealthCare Providers

Following a crosstabulation (Table 2), it was realized that female gender and occupation as laboratory personnel, working experience and level of education were significantly associated with the presence of bacteria on the cellphones. The analysis indicated that, based on the presence and absence of bacteria on the cell phones of the participants, gender was found to be statistically associated with having or not having bacteria on the cellphone ($p$ = 0.007). Belonging to the female gender was a predisposing factor to having bacteria on the cellphone. The occupation of the healthcare providers (laboratory personnel, nurses/midwives and medical doctor) was found to be significantly associated ($p$ = 0.033) with bacteria present or absent on their cellphones. Our results show that being laboratory personnel increased the likelihood of having bacteria on the cellphone. The number of years of work experience was found to be statistically associated with the presence or absence of bacteria on the cellphone of the healthcare personnel ($p$ = 0.002). The cellphones of staff with less than 5 years of work experience were more contaminated. Level of education was also found to be statistically associated with the presence or absence of bacteria on the cellphone of the health care personnel ($p < 0.01$). The participants with a master's degree level of education had cellphones with the lowestlevel of bacterial contamination.

**Table 2.** Representation of study participants based on the presence and absence of bacteria on their cell phones (N = 115).

| Parameters | Categories | Presence of Bacteria (N = 111) | | Absence of Bacteria (N = 4) | |
|---|---|---|---|---|---|
| | | n | % | n | % |
| Gender | Male | 47 | 24.9 | 6 | 3.1 |
| | Female | 58 | 35.9 | 4 | 2.4 |
| | $p$-value | / | 0.007 | / | / |
| Age ranges (years) | 20–30 | 72 | 55.4 | 5 | 3.8 |
| | 31–40 | 19 | 4.1 | 3 | 0.6 |
| | ≥40 | 14 | 2.2 | 2 | 0.3 |
| | $p$-value | / | 0.345 | / | / |
| Occupation | Laboratory personnel | 49 | 42.6 | 0 | 0 |
| | Nurses/midwives | 35 | 14.3 | 6 | 2.4 |
| | Medical doctors | 21 | 6.25 | 4 | 1.0 |
| | $p$-value | / | 0.033 | / | / |
| Working experience (years) | ≤1 | 27 | 7.8 | 2 | 0.5 |
| | 2–5 | 49 | 44 | 5 | 2.7 |
| | 6–9 | 25 | 26.4 | 2 | 0.5 |
| | ≥10 | 9 | 0.9 | 1 | 0.1 |
| | $p$-value | / | 0.002 | / | / |

**Table 2.** *Cont.*

| Parameters | Categories | Presence of Bacteria (N = 111) | | Absence of Bacteria (N = 4) | |
|---|---|---|---|---|---|
| | | n | % | n | % |
| Level of education | HND | 24 | 6.2 | 2 | 0.5 |
| | Bachelor Degree | 57 | 35.9 | 6 | 3.7 |
| | Masters | 11 | 1.4 | 2 | 0.5 |
| | Others | 12 | 1.5 | 1 | 0.1 |
| | *p*-value | / | 0.000 | / | / |

N: total number of study participants; n: frequency; %: percentage; others: assistant nurse, higher professional diploma; HND: higher national diploma.

However, age ranges were not found to be significantly associated.

### *3.2. Class andSpecies of Bacteria Isolated from the Cell Phones of HealthCare Providers*

Seven species of bacteria were isolated from the cell phones of the health care providers. The Gram-positive bacteria (80.6%) isolated in this study were coagulase-negative *Staphylococci* (CoNS), *Staphylococcus aureus*, *Bacillus* species and *Streptococcus* species. The following were the CoNS identified in our study: *Staphylococcus epidermidis* (19.0%), *Staphylococcus saprophyticus* (13.5%) and *Staphylococcus hominis* (5.3%).

The Gram-negative bacteria (19.4%) included *Pseudomonas aeruginosa*, *Escherichia coli* and *Neisseria* species (Table 3).

**Table 3.** Representation of study participants based on the class and species of bacteria isolated from cell phones.

| Bacterial Class | Bacterial Species | CoNS Identified | N° of Cell Phones | Percentage |
|---|---|---|---|---|
| Gram positive | Coagulase-Negative *Staphylococci* | / | 37 | 37.8 |
| | | *Staphylococcus epidermidis* | 19 | 19.0 |
| | | *Staphylococcus saprophyticus* | 13 | 13.5 |
| | | *Staphylococcus hominis* | 5 | 5.3 |
| | *Staphylococcus aureus* | / | 22 | 22.7 |
| | *Bacillus* species | / | 17 | 16.3 |
| | *Streptococcus* species | / | 8 | 3.8 |
| Gram negative | *Pseudomonas aeroginosa* | / | 10 | 5.4 |
| | *Escherichia coli* | / | 19 | 13.5 |
| | *Neisseria* species | / | 1 | 0.5 |
| Total | / | / | 115 | 100 |

CoNS: coagulase-negative *Staphylococci*.

### *3.3. Bacterial Contamination Rate of Cell Phones of Different Health Care Personnel*

The mobile phones of the laboratory workers were found to be significantly contaminated with bacteria compared to those of the nurses/midwives and medical doctors ($p = 0.003$) (Table 4).

**Table 4.** Rate of bacterial contamination of cell phone per type of health care personnel.

| Health Care Workers | Presence of Bacteria | | Absence of Bacteria | | Total | |
|---|---|---|---|---|---|---|
| | n | % | n | % | n | % |
| Total | 111 | 96.5 | 4 | 3.5 | 115 | 100 |
| Laboratory personnel | 49 | 42.6 | 0 | 0 | 49 | 42.6 |
| Nurses/midwives | 38 | 33 | 3 | 2.6 | 41 | 35.7 |
| Medical doctors | 24 | 20.9 | 1 | 0.9 | 25 | 21.7 |
| *p*-value | / | 0.003 | / | 0.058 | / | 0.052 |

n: frequency; %: percentage.

### *3.4. Predisposing Factors That Lead to Bacterial Contamination of Cell Phones of Health Care Personnel*

Four main predisposing factors that lead to bacterial contamination on the cell phones of health care personnel were identified in this study: the type of cell phone used by the health care worker, manipulating the cell phone while attending to patients, the use of soap and water for hand hygiene before and after attending to patients and the frequency of cell phone decontamination.

This study found that 81 health care personnel indicated that they manipulated their cell phones while attending to their patients, giving a percentage of 70.0. All of them had mobile phones contaminated with bacteria. The difference in the proportion of health care personnel (who practiced the habit) with the presence of bacteria on their cell phones compare to those who did not was statistically significant ($p < 0.001$).

Amongst the 115 health care workers sampled, 93.9% said they used soap and water for hand hygiene. Out of this number, 90.4% had bacterial contamination on their mobile phones, and only 3.5% did not have any bacteria isolated from their cell phones. Only seven personnel said they never used soap and water for hand hygiene, giving a prevalence of 6.1, and so, all their cell phones had bacteria. The difference between those who use soap and water for hand hygiene and for whom bacteria were present on their cell phones was not statistically significant ($p = 0.948$). Similarly, the difference between those who use soap and water and who did not have bacteria present on their cell phones was not statistically significant ($p = 0.465$).

In this study, all participants (23.5%) who indicated that they always decontaminated their mobile phones had bacteria isolated from their mobile phones as against (1.7%) whose cell phones were free of bacteria. This difference was statistically significant ($p < 0.001$). These staff used 70% alcohol to clean their cellphones after each day's work in their different departments of work in the health facility. Comparisons could not be made with other methods of decontamination, as that was the only method common to them.

All 27 health care personnel who indicated that they never decontaminated their mobile phones had bacteria isolated from their cell phones. This difference was not statistically significant ($p = 0.058$). Thirty-six (31.3%) of them said they decontaminated their phones occasionally. Out of this number, one had no bacteria isolated from their phone. The difference between the presence and absence of bacteria on cell phones was statistically significant ($p < 0.001$).

Among the 115 cell phones of the health care workers analyzed, 98 were touch-screen phones, representing 85.2%, while 17 were phones with keypads, representing 14.8%. Ninety-five (82.6%) of the phones with touch screens had bacterial contaminants, and only three did not have any bacterial contamination, with the difference being statistically significant ($p < 0.001$). Touch-screen cell phones were significantly more contaminated than keypad cell phones ($p = 0.037$) (Table 5).

**Table 5.** Distribution of study participants based on predisposing factors that lead their cell phones to bacterial contamination (N = 115).

| Predisposing Factor | Categories | Presence of Bacteria (N = 111) | | Absence of Bacteria (N = 4) | | Total | |
|---|---|---|---|---|---|---|---|
| | | n | % | n | % | n | % |
| Manipulating cell phone while attending to patients | Yes | 81 | 70.4 | 0 | 0 | 81 | 70.0 |
| | No | 30 | 26.1 | 4 | 3.5 | 34 | 29.6 |
| | *p*-value | / | <0.001 | / | 0.182 | / | |
| Use of soap and water for hand hygiene | Yes | 100 | 90.4 | 4 | 3.5 | 108 | 93.9 |
| | No | 7 | 6.1 | 0 | 0.0 | 7 | 6.1 |
| | *p*-value | | 0.948 | | 0.465 | | |
| Frequency of cell phone decontamination | Always | 27 | 23.5 | 0 | 0.0 | 27 | 23.5 |
| | Never | 49 | 42.6 | 3 | 2.6 | 52 | 45.2 |
| | Occasionally | 35 | 30.4 | 1 | 0.9 | 36 | 31.3 |
| | *p*-value | / | 0.054 | / | 0.391 | / | / |

**Table 5.** *Cont.*

| Predisposing Factor | Categories | Presence of Bacteria (N = 111) | | Absence of Bacteria (N = 4) | | Total | |
|---|---|---|---|---|---|---|---|
| | | n | % | n | % | n | % |
| Cell phone type | Touch screen | 95 | 82.6 | 3 | 2.6 | 98 | 85.2 |
| | Keypad | 16 | 13.9 | 1 | 0.9 | 17 | 14.8 |
| | *p*-value | / | 0.037 | / | 0.391 | / | / |

N: total number of study participants; n: frequency; %: percentage.

## 4. Discussion

### *4.1. Cell Phone Contamination and Socio-Demographic Characteristics of Participants*

The cell phones of female staff were found to be more contaminated than those of male staff. This result is contrary to the one obtained by Amala et al. [13] in Nigeria and similar to the one obtained by Yao et al. [14] in China. More studies support the fact that cell phones of females are more contaminated than those of males, such as the study in Nigeria by Ya'aba et al. [15] who found that the mobile phones of female students exhibited a higher contamination rate (75.0%) compared to those of male students (72.2%). Though this was not in a health setting, these results were similar to those obtained in our study. The bacterial load was also significantly higher in females ($41.9 \times 10^3$ CFU/mL) than in males ($28.8 \times 10^3$ CFU/mL). Additionally, a greater proportion of the cell phones belonging to females were contaminated with various bacteria, including *Staphylococcus* spp. Another study by Mushabati et al. [16] in Zambia found an overall prevalence of mobile phone contamination among healthcare workers of 79%. Although it did not specifically segregate the data by gender, it highlighted that coagulase-negative *Staphylococci* (CoNS) were the predominant isolates, suggesting a high risk of contamination in this population, including females. Conversely, in a study by Bissong and Moukou [17] in the West Region of Cameroon, they found no significant difference in mobile phone contamination rates based on gender, with a *p*-value of 0.617, indicating that phones from both males and females had similar levels of bacterial contamination. The study emphasized that factors like hand hygiene practices and phone usage frequency were more critical than gender in determining contamination levels. Also, in the study by Nader et al. [7] in Saudi Arabia, they indicated that the overall bacterial contamination rates did not show a significant difference between male and female healthcare workers' phones ($p = 0.156$). This suggests that both genders are similarly at risk for mobile phone contamination, regardless of the specific bacteria isolated. A separate study that focused on fungal contamination found that male students had significantly more contaminated phones than females ($p = 0.005$), indicating that, in some contexts, males may have higher contamination levels overall.

The fact that the cell phones of female staff are more infected than those for male staff can be explained by the fact that female staff are more attached to their cell phones than their male counterparts [18]. The healthcare providers in our study within the age range of 20–30 years had the highest rate of bacterial contamination on their cell phones. This is in line with a study carried out by Auhim et al. [19] in Iraq, which was aimed at investigating the bacteria on cell phones of adults in urban healthcare facilities.

### *4.2. Overall Prevalence of Cell Phones Contaminated, Bacteria Species and Class Isolated from the Cell Phones of HealthCare Providers*

This study reveals that there is a high prevalence (96.0%) of bacteria on the cell phones of health care providers at the Regional Hospital Bamenda. This is in accordance with the study by Elkholy et al. [20] in Cairo, Egypt that reported mobile phone contamination of 96.5% and also the one by Ustun et al. [21] in Turkey that reported a prevalence that was approximately the same. Our result was far from the one obtained by Alighardashi et al. [22] in Hamedan, Iran, where they found a lower prevalence of 56.25% with a sample size of 48. The difference between the results can be linked to factors such as the environment under study, sampling method and various laboratory processes.

CoNS and *Staph. aureus* were the most common Gram-positive bacteria isolated from the cell phones of the health care providers. The predominance of CoNS reflects the fact that the normal commensal of the skin can easily be transferred to any object that comes in contact with the body surface, as suggested by Leroy et al. [23]. Also, the combination of constant handling and the heat generated during phone calls will facilitate the survival and growth of the microorganisms on the cell phone surface [24]. Even though CoNS is a component of normal skin flora, in a hospital setup, it could emerge as a pathogenic microorganism causing nosocomial infections.

The high prevalence of *Bacillus* species isolated in more than one-third of the cell phones confirms that they are omnipresent in nature and able to colonize anything they come across, with the cell phones of health care providers being no exception [25].

Gram-negative bacteria were isolated from only 19.4% of the mobile phones. Our finding reflects the feature of the studies by Datta et al. [26] and Amira et al. [27] in the same field. Important Gram-negative nosocomial pathogens, such as *P. aeroginosa* and *E. coli*, were isolated in this study. According to a report by Marc et al. [28] in Saudi Arabia, *Pseudomonas* is metabolically versatile, ubiquitous in both terrestrial and aquatic environs and very difficult to manage in infections. The presence of this bacterium on the cell phones of medical personnel should be a call for concern. *E. coli* is the most prevalent aerobic bacteria in human/animal feces, as noted by Karabay et al. [29] in Nigeria. Its presence suggests fecal contamination. Also, poor personal hygiene or contamination from already contaminated sites may account for the presence of this organism. Infections by *E. coli* range from gastroenteritis, urinary tract infections to wound infections. According to Tambekar et al. [30] in Nigeria, the presence of *E. coli* is a direct indicator that other enterobacteriaceae are carried on mobile phones. The presence of *Neisseria* species, isolated in this study, can be the result of contaminated surfaces or inappropriate handling of contaminated samples and subsequent contact with the cell phone. The high rate of bacterial contamination on the cell phones of medical personnel suggests their regular exposure to the bacteria in the hospital environment, possibly transmitted in the course of carrying out their professional duties. Contact with surfaces, patients and infected materials and the individual's level of personal hygiene may influence the rate of bacterial colonization.

### *4.3. Rate of Bacterial Contamination with Regard to the Category of HealthCare Provider*

Among the different professions, the medical laboratory personnel had a high prevalence rate. Our result is similar to the study by Kuhu et al. [24] in Afghanistan that reported high levels of bacterial contamination on cell phones. Infact, the high prevalence found in our study could be explained by the fact that medical laboratory personnel deal more directly with infected specimens; the aerosols created in laboratories and the contact of their mobile phones with the laboratory benches could account for the high prevalence rate. Nurses/midwives had the second highest prevalence, followed by medical doctors. The medical doctors consulting rooms and their tables are generally occupied by those on shift for each day. Many persons making use of a particular table means that several indigenous bacteria will be deposited on it for possible transmission. The patient folders are read through by doctors and nurses to know a patient's history, the previous prescription forms and laboratory results. This may aid in the adherence of microbes to the palms for onward transmission to mobile phones. The stethoscopes and sphygmomanometers used by doctors and nurses could mediate the transfer of bacteria, as stipulated by Amira et al. [27].

### Predisposing Factors That Lead to Bacterial Contamination of Cell Phones of Health Care Providers

Predisposing factors to bacterial contamination of the cellphones of healthcare workers are a crucial public health issue, as manipulating cellphones while attending to patients and poor device disinfection habits and handwashing increase the chances of bacterial contamination. The factors influencing bacterial contamination identified in this study are similar to those in the studies in the West Region of Cameroon by Bissong and Moukou [17]

and in Zambia by Mushabati et al. [16]. Additionally, this study identified phone design and material as two of the factors. The design and materials used in mobile phones can influence bacterial retention. Touch screens tend to trap moisture and dirt more than traditional keypads, making them more susceptible to contamination.

## 5. Conclusions

From this study, it can be concluded that more than three-fourths of the cell phones belonging to healthcare personnel harbored pathogens, including nosocomial pathogens, of which the health care providers were unaware. As there are no guidelines for care, cleaning and restriction of mobile phones in health care settings, their use can play an important role in the transmission of infections to patients and probably could also be a vehicle for the transmission of biological weapons. There is a great need for health care providers to be aware of the risk of using cell phones without any guidelines in the hospital environment.

## 6. Recommendations

The following recommendations can be addressed:

1. Since a restriction on the use of mobile phones by healthcare providers in hospitals is not a practical solution, we suggest that healthcare providers should practice increased adherence to infection control precautions, such as hand washing with soap and water before each use of the cellphone.
2. Sensitization to enlighten health care personnel to address the role of cell phones acting as fomites for infection transmission should be a priority.
3. Ultrasonic cleaning by an ultrasonic cleaner can clean the cell phones thoroughly and safely.
4. Sterilizing cell phone chargers are now being marketed, which can charge and sterilize at the same time.

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**Informed Consent Statement:** Informed consent was obtained from all participants. Participation in the study was totally free and voluntary. Participants had the liberty to quit the study at any point in time.

**Data Availability Statement:** The data that support the findings of this study are available from the corresponding author upon reasonable request.

**Conflicts of Interest:** The authors declare no conflicts of interest.

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