**Microbial Contamination of Computer Components in Healthcare Administrative Offices: A Cross-Sectional Study in Benghazi’s Pediatric Hospital**

**Abstract**

**Background:** Microbial contamination of administrative offices in healthcare settings plays an important role in the spread of infection among patients, visitors, and healthcare workers as a result of a deficiency of cleaning and disinfection practices. **Aim:** To evaluate the rate of microbial infection of computer components at Pediatrics Hospital in Benghazi.

**Methods:** A cross-sectional study was conducted in 21 administrative offices at a pediatric hospital in Benghazi from September to November 2021. The data was collected by taking samples (swabs) and using a multiple-choice questionnaire; it included 50 samples, and all the data was analyzed by SPSS software.

**Result:** The highest contamination rate was observed on keyboards (69.2%), followed by the mice (66.7%). Desks showed a lower contamination rate, suggesting that handheld devices may act as primary reservoirs for microbial transmission. The most commonly isolated microorganism was *Staphylococcus albus* (40%), a coagulase-negative *Staphylococcus species* known for its role as an opportunistic pathogen, particularly in immunocompromised individuals. On the other hand, it indicated that 76% of workers said they use alcohol to disinfect their computers, and 52% of them stated they clean their computers in the morning. The high contamination levels suggest that disinfection protocols may be inadequate or inconsistently applied. No significant associations were found between microbial contamination and workers’ age, qualification level, or gender.

**Conclusion:** The findings highlight a concerning level of microbial contamination in the administrative offices of the pediatric hospital, underscoring the urgent need to apply essential precautionary measures to reduce the spread of the infection.

***Keywords:*** *Administrative offices; computers; infection; hospital; keyboard; microbial contamination; mouses.*

**1. Introduction**

Nosocomial infections are infections that occur in a health care facility or are acquired at least after 48 h of admission in the facility. So that it cannot be present at the time of patient admission [1]. These infections cause several illnesses and deaths in the intensive care unit (ICUs) [2]. They also lead to an increase in the hospital costs [3, 4] as well as an increase in the rate of mortality [5]. There are several sources of these infections, one of which is computer equipment, including keyboards and mice, in hospitals and administrative offices. These devices play a crucial role in the indirect transmission of infectious agents [6]. Poor disinfection practices have caused microorganisms to continue surviving on computers, keyboards, and mice. Bacteria can be found on the fingernails, hands, and skin of administrative staff and healthcare workers, which may be easily transferred to keyboards and other frequently touched surfaces [6]. Furthermore, in healthcare settings, pathogens can survive on keyboards and be transmitted through gloves and unwashed hands, resulting in cross-infection [7]. Contaminated hands are a major source of pathogen transmission across multiple hospital surfaces [8]. Pathogens can only be eliminated for a long time from the surfaces when appropriate disinfection and sterilization methods are applied; otherwise, they can survive on the surfaces for extended periods [6]. Therefore, computers act as reservoirs for pathogenic microorganisms and thus significantly contribute to the persistence of the same in healthcare settings [9]. This is partly because computers in healthcare facilities are not considered routine items for disinfection, which predisposes them to microbial contamination and transmission [7]. These bacterial pathogens are commonly encountered in healthcare settings and can be situated on frequently used electronic devices such as computers. Many studies have reported the occurrence of possible pathogens on computers including coagulase-negative staphylococci, diphtheroid, *Micrococcus species*, *Bacillus species*, oxacillin-resistant *Staphylococcus aureus*, oxacillin-sensitive *Staphylococcus aureus*, vancomycin-susceptible *Enterococcus species*, and non-fermentative gram-negative rods, according to Rutala *et al.* (2006). Keyboards have been identified among computer components to be a major reservoir of bacterial contamination in hospital environments [10]. A high percentage of *Staphylococcus aureus*, particularly methicillin-resistant *Staphylococcus aureus* (MRSA), has been detected on keyboards, creating a big risk of hospital infection [11]. Other bacterial species, including *Escherichia coli*, *Salmonella*, and *Shigella*, have been isolated from keyboards, suggesting their potential role in the transmission of these pathogens [7].

In this regard, Srikanth et al. (2012) also found that the most common gram-positive bacteria isolated from computers were MRSA, MSSA, and coagulase-negative staphylococci, while *Pseudomonas species*, *Acinetobacter species*, *Escherichia coli*, and *Klebsiella pneumoniae* were the most prevalent gram-negative bacteria isolated [12]. Other bacterial contaminants isolated from computers in the hospital environment include *Klebsiella species*, *Pseudomonas species*, *Enterobacter cloacae*, and *Enterobacter species* [13]. Adequate measures on proper hand hygiene and disinfection principles are very essential for infection prevention. Proper hand-washing before starting and after accessing computers should be ensured in order to prevent microbial transmission, as suggested by Saskatoon Health Region, 2012 and CDC, 2019 [14,15]. A healthcare professional should also avoid gloves while using any electronic equipment, as this acts like a reservoir if not handled correctly for microbial transfer, specified by Saskatoon Health Region, 2012 [14]. Effective cleaning and disinfection practices can help minimize microbial contamination of electronic devices. The Centers for Disease Control and Prevention, 2019, recommends the selection of appropriate cleaning techniques and materials for computer components, including routine cleaning of keyboards, mice, and surrounding surfaces. Protective covers for keyboards and mice can further help reduce contamination and facilitate easier disinfection [16].

For disinfection, it has been shown that: The key disinfectant for keyboards involves the use of 70% isopropyl alcohol or Clorox wipes [16]. (Alberta Health Services, 2020). 0.5% hydrogen peroxide wipes are needed for LCD screens [17]. Hydrogen peroxide and quaternary ammonium compounds have been best described to be the suitable disinfectants for plastic surfaces [17]. Finally, the healthcare facilities should raise awareness among their staff regarding the methods of sterilization for healthcare devices and appropriately decontaminate computer equipment before its movement within the hospital premises [16]. **Aim:** To evaluate the rate of microbial infection of computer components at Pediatrics Hospital in Benghazi.

**2.** **Material and Methods**

A cross-sectional study was carried out in 21 administrative offices at Pediatrics Hospital, Benghazi, Libya. The data were collected from September to November (2021) in two steps:

The first step: 50 samples were taken from computers, keyboards, and mice in the administrative offices; distilled water was placed in the swab tube, and then the swab was taken from the surfaces of the keyboard, mouse, bed, and table; then it was returned to its tubeand transferred directly to the laboratory.

The second step: 21 multiple-choice questionnaires were filled out by users of these computers in the targeted offices. It contains ten questions: four questions about general information of technicians, including gender, age, qualification, and type of employment; two questions regarding whether hands are cleaned before and after using the computer; and four questions about cleaning and disinfecting the keyboard and mouse, type of sanitizer, and time of cleaning and disinfecting the keyboard and mouse.

All data were analyzed by using the statistical software package for the social sciences (SPSS) version 20; the frequency and percentage were calculated, as well as using the Chi-square and the ANOVA tests to study the association between some variables.

**3. Results**

The collected data are summarized in Table 1, depicting an overview of the sample by highlighting key demographic and professional characteristics. It follows from the results that the majority of the sample were females at 67%, while males made up 33% of the sample.

Regarding the age distribution, 48% of the respondents were between 36 and 45 years old, while 28% were between 46 and 55 years old. Other age groups included 25-35 years, 56-65 years, and 66-75 years, each contributing 14%, 5%, and 5%, respectively. The highest number of respondents declared the highest education attainment at the diploma level with a 48% response rate; bachelor's degrees take 38%, while the lower percentages come to 9 and 5 for secondary and preparatory levels, respectively, and none were found at master's or Ph.D. degrees.

The distribution concerning the type of job indicates that administrative staff had the highest percentage, 38.2%, followed by physicians, nurses, and physiotherapy specialists, each contributing 14.3% of the sample. Surgical specialists, psychiatric professionals, researchers, and socialists each comprised 4.8%.

**Table 1: Sociodemographic of Computer Users of Administrative Offices at Pediatrics**

|  |  |  |
| --- | --- | --- |
| **Characteristics** | **Options** | **Percentage** |
| **Gender** | Male | 33 |
| Female | 67 |
| **Age** | 25-35 | 14 |
| 36-45 | 48 |
| 46-55 | 28 |
| 56-65 | 5 |
| 66-75 | 5 |
| **Qualification** | Preparatory level | 5 |
| Secondary | 9 |
| Diploma | 48 |
| Bachelors | 38 |
| Master | 0 |
| PhD | 0 |
| **Jobs Type** | Administrative Staff | 38.2 |
| Physician | 14.3 |
| Nurse | 14.3 |
| Physiotherapy Specialist | 14.3 |
| Surgical Specialist | 4.8 |
| Psychiatric | 4.8 |
| Researcher | 4.8 |
| Socialist | 4.8 |

In addition, Table 2 shows hygiene practices about computer usage. The results indicated that 47.6% of the respondents wash their hands before they use the computer, whereas 52.4% of them wash their hands after using them. Only 43% of the workers have been cleaning and disinfecting keyboards in offices regularly, whereas 57% reported cleaning and disinfecting the mouse. About the use of disinfectants, alcohol was the most utilized cleaning agent (76.2%), followed by a combination of alcohol and Clorox (9.5%). A combination of alcohol and soap was the least utilized disinfectant, 4.8%. Surprisingly, only two of the respondents reported not using any disinfectant on their computer components. In all, the findings do give useful information on demographic distribution, educational background, job types, and hygiene practices that need possible improvement in workplace hygiene and sanitation.

**Table 2: Cleaning and disinfecting practice of computer, keyboard, and mouse**

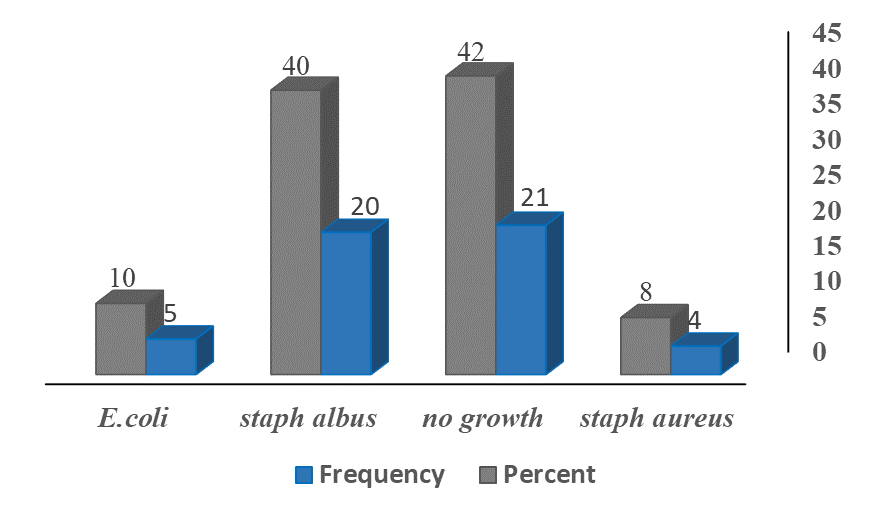
|  |  |  |
| --- | --- | --- |
| **Practice** | **Options** | **Number (%)** |
| Washing workers for their hands before using computer | Yes | 10 (47.6) |
| No | 11 (52.4) |
| Washing workers for their hands after using computer | Yes | 11 (52.4) |
| No | 10 (47.6) |
| Cleaning and disinfected of the Keyboard by workers | Yes | 9 (43) |
| No | 12 (57) |
| Cleaning and disinfecting of the mouse by workers | Yes | 9 (43) |
| No | 12 (57) |
| Type of disinfectant used by workers | Alcohol | 16 (76.2) |
| Alcohol and Chlorine | 2 (9.5) |
| Alcohol and soap | 1 (4.8) |
| Did not use any products | 2 (9.5) |

Table 3 shows infection rates in various components of computers and surroundings in the administrative office, Pediatric Hospital, Benghazi. It can be seen from the results that the highest infection rates were recorded in the peripherals of computers: keyboard and mouse, with values of 69.2% and 66.7%, respectively. Thus, both devices showed high contamination and, consequently, poor hygiene due to their frequent use and poor disinfection. Among others, tables had the highest infection rate of 53.3%, followed by doors, which were equally distributed between infected and non-infected samples, having a percentage rate of 50%: 50%. The main computer unit had an infection rate of 33.3% while 66.7% were not infected. Notably, the bed and window surfaces all had a 100% infection rate, which is high in these areas. In sum, this may require an improved hygiene approach and the implementation of more stringent cleaning procedures within the hospital environment to reduce the potential transmission of infection.These findings pinpoint the urgent need for stringently disinfecting; especially the highly common facilities of keyboards and mice, extending to frequently used furniture, which would make for a safer, more hygienic workplace.

**Table 3: Infection rate of computer components and surrounding area in the administrative office in the Pediatric Hospital in Benghazi**

|  |  |  |  |
| --- | --- | --- | --- |
| **Area** | **Infection** | **Frequency** | **Percent** |
| **Computer** | Infected | 1 | 33.3 |
| Non-infected | 2 | 66.7 |
| **Mouse** | Infected | 8 | 66.7 |
| Non-infected | 4 | 33.3 |
| **Keyboard** | Infected | 9 | 69.2 |
| Non-infected | 4 | 30.8 |
| **Table** | Infected | 8 | 53.3 |
| Non-infected | 4 | 30.8 |
| **Door** | Infected | 2 | 50.0 |
| Non-infected | 2 | 50.0 |
| **Bed** | Infected | 2 | 100.0 |
| Non-infected | 0 | 0 |
| **Windows** | Infected | 1 | 100.0 |
| Non-infected | 0 | 0 |

Figure 1 shows that the highest percentage of 42% of no microbial growth in the samples reflects that some parts were properly disinfected. But out of all contaminated samples, the most frequent microorganism was *Staphylococcus albus*, which was found in 40% of the samples and proved to be highly predominant in the environment where the samples were tested. It further denotes 10% contamination of the samples on account of *Escherichia coli* *(E. coli),* which denotes fecal contamination and poor hygiene practices. *Staphylococcus aureus*, a pathogenic bacterium, was identified in 8% of the samples, which may lead to nosocomial infections in case of not proper management being conducted. These findings indicate that continuous enforcement of strict infection control practices, such as routine disinfection, proper hand hygiene practices, and cleaning of high-touch surfaces, is essential to reduce microbial contamination in health care.



**Figure 1: Microbial growth present in collected swab samples**

This is supported by the data in Table 4, where *Staphylococcus albus* was the most prevalent bacterial species isolated from keyboards and mice with prevalence rates of 53.8% and 58.3%, respectively. These surfaces could be a common reservoir for *S. albus* since they are frequently contacted by humans. Also, *Staphylococcus aureus* was mostly isolated from window and bed surfaces, with a 100% isolation rate from these surfaces, hence posing a potential risk for contamination at these places. These findings emphasize the importance of regular disinfection practices regarding commonly touched surfaces to reduce the transmission of bacteria.

**Table 4: Types of bacteria present in keyboards, mice, tables, doors, beds, and windows**

|  |  |  |  |
| --- | --- | --- | --- |
| **Area** | **Infection** | **Frequency** | **Percent** |
| Computer | No growth | 2 | 66.7 |
| *Staph. albus* | 1 | 33.3 |
| Total | 3 | 100.0 |
| Mouse | No growth | 4 | 33.3 |
| *Staph. albus* | 7 | 58.3 |
| *E.coli* | 1 | 8.3 |
| Total | 12 | 100.0 |
| Keyboard | No growth | 4 | 30.8 |
| *Staph. albus* | 7 | 53.8 |
| *E.coli* | 2 | 15.4 |
| Total | 13 | 100.0 |
| Table | No growth | 8 | 53.3 |
| *Staph. albus* | 4 | 26.7 |
| *E. coli* | 2 | 13.3 |
| Total | 14 | 93.3 |
| Door | *Staph. aureus* | 1 | 25.0 |
| No growth | 2 | 50.0 |
| *Staph. albus* | 1 | 25.0 |
| Total | 4 | 100.0 |
| Bed | *Staph. aureus* | 2 | 100.0 |
| Windows | *Staph. aureus* | 1 | 100.0 |

Furthermore, table 5 represents ANOVA and Chi-Square tests analysis for testing the relationship between different demographics and behavioral attributes with infection on keyboards, mice, and tables. The findings of the ANOVA test reveal that bacterial infection on a keyboard, mouse, or table is not statistically related to either the age or qualifications of the workers because of the fact that all p-values are above 0.05 significance levels. Also, the results of this Chi-Square test show that there is no significant association in workers' gender or in their handwashing practices with bacterial contamination on these surfaces, since all the reported p-values are above 0.05. Therefore, based on these findings, it is possible to conclude that age, qualifications, gender, and handwashing behavior do not influence contamination levels on computer-related surfaces in this study. This revision improves clarity, strengthens the scientific tone, and ensures precision in reporting statistical results. Please let me know if you need further refinements.

**Table 5: relationships between workers age and mice, keyboards, and table infection by using ANOVA test**

|  |  |  |  |
| --- | --- | --- | --- |
| **`** | **Computer infection** | **Mean Square** | **P value** |
| Age | Keyboards Infection | 0.009 | 0.934 (ANOVA Test) |
| Mouse Infection | 0.167 | 0.699 (ANOVA Test) |
| Table Infection | 0.377 | 0.606 (ANOVA Test) |
| Gender | Keyboards Infection | 1.040 | 0.308 ( Chi Square Test) |
| Mouse Infection | 0.686 | 0.408 ( Chi Square Test) |
| table Infection | 1.659 | 0.198 ( Chi Square Test) |
| Qualifications | Keyboards Infection | 3.085 | 0.53 (ANOVA Test) |
| Mouse Infection | 2.667 | 0.08 (ANOVA Test) |
| Table Infection | 2.492 | 0.077 (ANOVA Test) |
| Hand Washing | Keyboards | .325 | 0.569 ( Chi Square Test) |
|  | Mouse | .171 | 0.679 ( Chi Square Test) |
|  | Table | .026 | 0.872 ( Chi Square Test) |

**4. Discussion**

This study indicated that computer keyboards were the most contaminated with bacteria, at 96.2%, followed by mouse contamination at 66.7%, while tables had the lowest contamination rate at 53.3%. This agrees with a study conducted in northwestern Ethiopia where Alemu et al. (2015) stated that bacteria grew on both keyboards and mice at a rate of 100% [18]. In addition, there is the evidence by Koscova *et al. (2018),* which found that in the University of Veterinary Medicine and Pharmacy, the keyboard surfaces contamination rate was an alarming 96%. On the same note [6], a study conducted in Korea by Hong *et al.* (2013) reported that keyboards and mice in the emergency departments of three teaching hospitals had an 80% microbial contamination rate [19]. In addition, the study conducted by Nazeri *et al.* (2019) at Kashan University of Medical Sciences indicated that 76% of computer components and electronic devices were contaminated in ICU and health service hospitals [20]. Similarly, Olu-Taiwo *et al.* (2021) reported that 63.3% of keyboards in healthcare universities in Ghana were contaminated [13]. Amer (2017) also reported that the contamination rate of computers and mice in the Abu Salim Higher Institute of Medical Sciences in Tripoli, Libya, was 100%, higher than that of keyboards [21].

Regarding the bacterial species isolated from the computer components, Staphylococcus albus was the most frequent bacterium isolated in this study, with a prevalence of 58.3% on mice and 53.8% on keyboards. Relatively low levels of contamination with *Escherichia coli* were present on mice, keyboards, and tables. Interestingly, *Staphylococcus aureus* was more abundant on beds and windows than on computer components. In contrast, the results of Koscova *et al.* (2018) showed that among isolated bacteria from computer keyboards, the most common were *Staphylococci* and *Bacillus spp*. in 96%, *E. coli* in 50%, *Enterobacter cloacae* in 37.5%, and *Citrobacter freundii* in 25%, but also fungi and yeast [6]. Similarly, Olu-Taiwo *et al.* (2021) identified *Staphylococcus epidermidis* as the most frequent bacterium on keyboards, with a prevalence of 40.1%, followed by *Klebsiella spp.* at 20.4%, while *Enterococcus cloacae* had the lowest prevalence, at 3.3% [13]. In the ICU of Kashan University, the most important bacteria were coagulase-negative Staphylococci (72%), followed by *Micrococcus spp*. (48%), *Bacillus spp*. (18.6%), *Enterobacteriaceae* (12%), and *Staphylococcus aureus* (6.6%), with yeast contamination reaching 38.6%, according to Nazeri *et al.* (2019) [20]. Moreover, one study done by Alemu *et al.* (2015) in northwestern Ethiopia reported that Gram-negative bacteria isolations were more predominant than Gram-positive bacteria isolations from keyboards and mice. The most frequent was coagulase-negative Staphylococcus with an isolation rate of 35.2% in keyboards and 48% in mice, which was followed by *Bacillus spp.* 25% and 24% respectively, then *S. aureus* 24.1% in keyboards and 23% in mice [18]. Hong *et al.* (2013) presented that the contamination rate of CONS was 100% on keyboards (51%) and 45% on mice while S. aureus contamination presented a minimum rate of 2% and only on keyboards [19]. These differences in isolation rates of bacteria may be related to protocols for disinfection and infection control applied in various healthcare settings. The present study also did not find any statistically significant relationship between the contamination rate of computer components and age of hospital workers using these computers. This disagrees with a study by Ubani *et al.,* 2012, which indicated that there is a positive relationship between age and contamination of computers, with computers used by workers below 39 years having a higher rate of infection, likely due to poor hygiene habits within this age bracket [22]. In addition, in this study, there was no significant relationship between the gender of workers and the contamination of keyboards, mice, and tables [22]. However, the findings from Kuwait have disagreed with this, as contamination rates were reported to be significantly higher on computers used by females as compared to those used by males (82% vs. 55%) according to Ali (2017) [23]. The researchers attributed this to the larger number of female respondents and that males used personal computers more than shared laboratory computers. This agrees with the results by Al-Doub *et al.* (2008) in Kuwait, who found that 64% of females preferred the use of a computer at work while only 27% of males did [24]. On the other hand, Ubani *et al.* (2012) found higher rates of contamination on computers used by males, attributing the trend to unsanitary practices such as nose-picking, which was significantly more prevalent among males 80%, compared to females 20.7%. This study did not establish any relationship between the qualifications of workers and the infection rate of computer components [22]. However, the study noted that computers used by workers with graduate-level qualifications had higher rates of contamination. Such were also the findings of Hong *et al.* (2012) in Korea, Amer *et al.* (2017) at Abuslim Higher Institute and Trauma Hospital, and Nazeri *et al.* (2019) in ICU, Kashan University, as they all indicated that there existed no significant association between the worker's qualification and computer contamination. This finding is supported by Nazeri *et al.* (2019), who reported that computers utilized by nursing personnel carried a higher risk of contamination than those used by other health professionals. These findings bring into sharp relief the dire need for better hygiene practices and routine disinfection in order to minimize microbial contamination of computer components within healthcare settings. Regular hand hygiene, proper disinfection of computer equipment, and adherence to strict infection control can go a long way in minimizing the risk of pathogen transmission and enhancing patient safety [19-21].

**5. Conclusion**

Bacterial infection in pediatric administrative offices is a major concern and can facilitate the easy spread among patients and health professionals. Contamination rates in one study were high on keyboards, mice, windows, and tables; *Staphylococcus albus*, *Escherichia coli*, and *Staphylococcus aureus* were the three most common bacteria. Most of the workers used disinfectants for cleaning, among which alcohol and chlorine-based disinfectants were commonly used, though a small percent did not employ any disinfection methods. There was no significant correlation between the infection rate with and gender, age, qualification level, type of disinfectant used, and handwashing practice. No significant association was also found between qualification level and infection rate. The findings point out proper disinfection practices and hygiene of hands to minimize the contamination caused by bacteria for a safer workplace.

**Limitation**

The limitation of this study was the difficulty of administrative procedures in this hospital, which took a long time to get a response from the head of the hospital.

**Ethical Approval:**

As per international standards or university standards written ethical approval has been collected and preserved by the author(s).

Disclaimer (Artificial intelligence)

Option 1:

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

Option 2:

Author(s) hereby declare that generative AI technologies such as Large Language Models, etc. have been used during the writing or editing of manuscripts. This explanation will include the name, version, model, and source of the generative AI technology and as well as all input prompts provided to the generative AI technology

Details of the AI usage are given below:

1.

2.

3.

**References**

[1]. Neely AN, Sittig DF. Basic microbiologic and infection control information to reduce the potential transmission of pathogens to patients via computer hardware. *Journal of the American Medical Informatics Association*. 2002 Sep 1;9(5):500-8.

[2]. Ribeiro LF, Lopes EM, Kishi LT, Ribeiro LF, Menegueti MG, Gaspar GG, Silva-Rocha R, Guazzaroni ME. Microbial community profiling in intensive care units expose limitations in current sanitary standards. *Frontiers in Public Health*. 2019 Aug 28;7:240.

[3]. Ghosh P, Valia R. Economic burden of hospital acquired infections in India: a systematic review of published evidence. *Value in Health*. 2018 Sep 1;21:S88.

[4]. CDC, Health Topics – Healthcare-associated Infections (HAI). [Internet]. U.S Centers Disease Control Prevention; 2021 [cited 2025 Feb 17]. Available online at <https://www.cdc.gov/policy/polaris/healthtopics/hai/index.html>

[5]. World Health Organization. Report on the burden of endemic health care-associated infection worldwide. 2011.

[6]. Koscova J, Hurnikova Z, Pistl J. Degree of bacterial contamination of mobile phone and computer keyboard surfaces and efficacy of disinfection with chlorhexidine digluconate and triclosan to its reduction. *International journal of environmental research and public health*. 2018 Oct;15(10):2238.

[7]. Malik K, Naeem N. Study of bacteria on computer s mice and keyboards. *Int J Curr Microbiol App Sci*. 2014;3(4):813-23.

[8]. Vermeil T, Peters A, Kilpatrick C, Pires D, Allegranzi B, Pittet D. Hand hygiene in hospitals: anatomy of a revolution. *Journal of Hospital Infection*. 2019 Apr 1;101(4):383-92.

[9]. Hartmann B, Benson M, Junger A, Quinzio L, Röhrig R, Fengler B, Färber UW, Wille B, Hempelmann G. Computer keyboard and mouse as a reservoir of pathogens in an intensive care unit. *Journal of clinical monitoring and computing*. 2004 Feb;18:7-12.

[10]. Rutala WA, White MS, Gergen MF, Weber DJ. Bacterial contamination of keyboards: efficacy and functional impact of disinfectants. *Infection Control & Hospital Epidemiology*. 2006 Apr;27(4):372-7.

[11]. Fukada T, Iwakiri H, Ozaki M. Anaesthetists' role in computer keyboard contamination in an operating room. *Journal of Hospital Infection*. 2008 Oct 1;70(2):148-53.

[12]. Srikanth P, Sivasubramanian S, Sudharsanam S, Thangavel G, Jagannathan K. Assessment of aerobic bacterial contamination of computer keyboards in a tropical setting. *J Assoc Physicians India*. 2012 Aug 1;60(8):18-20.

[13]. Olu-Taiwo M, Laryea CA, Kweku Mykels D, Forson AO. Multidrug-Resistant Bacteria on the Mobile Phones and Computer Keyboards of Healthcare University Students in Ghana. *Canadian Journal of Infectious Diseases and Medical Microbiology*. 2021;2021(1):6647959.

[14]. Saskatoon Health Region, Computer Equipment – Cleaning and Disinfection. [Internet]. Saskatoon Health Region; 2012 [cited 2025 Feb 17]. Available from: <https://www.saskhealthauthority.ca>.

[15]. CDC, Recommendations of CDC and the Healthcare Infection Control Practices Advisory Committee (HICPAC). [Internet]. U.S Centers Disease Control Prevention; 2019 [cited 2025 Feb 17]. Available from: <https://www.cdc.gov/infectioncontrol/guidelines/environmental/index.html>

[16]. Alberta Health Services, Bedside Computers and Electronic Devices. [Internet]. Alberta Health Services; 2020 [cited 2025 Feb 17]. Available from: <https://www.albertahealthservices.ca/assets/healthinfo/ipc/if-hp-ipc-cleaning-disinfection-info.pdf>

[17]. Ide N, Frogner BK, LeRouge CM, Vigil P, Thompson M. What’s on your keyboard? A systematic review of the contamination of peripheral computer devices in healthcare settings. *BMJ open*. 2019 Mar 1;9(3):e026437.

[18]. Alemu A, Misganaw D, Wondimeneh Y. Bacterial profile and their antimicrobial susceptibility patterns of computer keyboards and mice at Gondar University Hospital, Northwest Ethiopia. *Biomed Biotechnol*. 2015;3(1):1-7.

[19]. Hong DY, Park SO, Lee KR, Baek KJ, Moon HW, Han SB, Shin DH. Bacterial contamination of computer and hand hygiene compliance in the emergency department. *Hong Kong Journal of Emergency Medicine*. 2013 Nov;20(6):387-93.

[20]. Nazeri M, Arani JS, Ziloochi N, Delkhah H, Arani MH, Asgari E, Hosseini M. Microbial contamination of keyboards and electronic equipment of ICU (Intensive Care Units) in Kashan University of medical sciences and health service hospitals. *MethodsX*. 2019 Jan 1;6:666-71.

[21]. Hamida Amer A. Bacterial contamination of computer keyboards and mice in university and hospital settings. *DJ International Journal of Medical Research*. 2017;2(1).

[22]. Ubani EK, Oluduro AO, Ofoezie IE. A survey of common habits of computer users as indicators of possible environmental contamination and cross infection source. *African Journal of Biotechnology*. 2012;11(9):2241-7.

[23]. Ali K. Bacterial contamination of frequently touched surfaces in computers in health care settings: a comparative study. *International Journal of Infection Control*. 2017 Dec 11;13(2).

[24]. Al-Doub E, Goodwin R, Al-Hunaiyyan A. Students' Attitudes Toward E-learning in Kuwait's Higher Education Institutions. 2008. Paper presented at Asia-Pacific Society for Computers in Education 16th Conference on Computer's in Education.