Bacteriological Monitoring and Evaluation of Cleaning-disinfection of Computer-related Equipment in an Obstetric and Gynecology Hospital

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Abstract

It is already known that computer keyboards and mouses in hospitals are contaminated with different kinds of bacteria. However, the mouse pad has been neglected with regard to both research and regular cleaning and disinfection in hospitals. In our study, we monitored and evaluated the bacteriology degrees of 74 computers’ keyboards, mouses and mouse pads from six departments. The results showed that before cleaning-disinfection, the contamination rate of the mouse pad ranked second following the keyboards. Enterococcus Faecium was cultured from the mouse pads. The computer-related equipment in the wards and outpatient rooms were much more contaminated than that in the operating rooms. Acinetobacter spp. was only isolated from the doctor’s computers. After cleaning-disinfection, 4 strains of MRSA were isolated from the keyboards and the mouses, one and 3 were cultured at day 3 and day 5
after cleaning-disinfection, respectively. One strain of *Pseudomonas Aeruginosa* was isolated from the mouses at day 3 after cleaning-disinfection. These demonstrated that the bacterial contamination of the mouse pads must be as emphasized as that of the keyboards and mouses. Furthermore, It is better to clean and disinfect the computer-related equipment(keyboards, mouses, mouse pads) at least once a day.

**Keywords**: Contamination; Computer-related equipment; Cleaning-disinfection;

**Introduction**

On a global scale, hospital-acquired infections (HAIs) have become one of the most important causes of morbidity and mortality in medical institutions[1-5] and also threaten the safety of health-care providers[6]. According to a survey from the World Health Organization, there are approximately 1.7 million and 4.5 million HAI patients in USA and Europe, respectively, accounting for 37,000 and 100,000 deaths each year. Many pathogens, such as MRSA, VRE, *Acinetobacter, Klebsiella, Listeria, Escherichia coli, Mycobacterium tuberculosis, Pseudomonas aeruginosa* and the Noel virus, can survive on a dry object surface for several months or even a year [7-9]. Therefore, cleaning and disinfecting the high-touch object surfaces is an important measure for controlling HAIs [10].

There have been many studies emphasizing the importance of cleaning and disinfecting the computer keyboard and mouse in healthcare settings, representing an important type of high-touch object surface. One study demonstrated that 95% of keyboards in a teaching hospital had growth of one or more microorganisms, and 5% were positive for pathogens known to be associated with HAI transmission, such as *Staphylococcus aureus* and *Enterococci* [11]. Some studies showed that the keyboard or mouse was one of the most likely bacterial vehicles in the ICU and that the degree of contamination cannot be neglected [12-14]. A survey of two acute district general hospitals indicated that MRSA had been identified on computer terminals (24%), and five of the MRSA-positive terminals were from hospital A, which had a significantly higher rate of MRSA transmission than hospital B [15]. However, the mouse pads have been neglected in both research and the regular cleaning-disinfection in hospitals.

In our research, we aimed to address four issues: 1) The bacteriological characteristics of computer-related equipment, especially the mouse pad; 2) The bacteriological
characteristics of computer-related equipment in different clinical departments; 3) The bacteriological characteristics of doctor’s and nurse’s computer-related equipment in the wards; 4) How often we should clean and disinfect computer-related equipment.

Materials and methods

Study Object Selection

chosen between October 2014 and December 2015 (Supplementary Table 1). In the wards, 1 nurse’s station computer, 1 doctor’s office computer and 1 doctor’s mobile computer from each obstetric and gynecology ward were selected randomly for testing. Five samples were collected from every surface, including before cleaning-disinfection, immediately after cleaning-disinfection and day 1, day 3 and day 5 after cleaning-disinfection.

Sample Method

Samples were collected from the keyboard (including the Number keys, Character keys, Enter key, Shift key, and Space bar), the mouse (except the underside) and the mouse pad (area≥100cm²). Sterile swabs dipped with sterile saline solution or neutralizing agent were smeared and rolled evenly back and forth five times on the surfaces. The hand-contacted part of the swabs was cut off, and the rest was put into a sampling tube containing 10 ml of sterile saline solution or neutralizing agent. All samples (947 samples) were sent to the clinical laboratory immediately.

Bacteriology Identification

In a biological safety cabinet, the sampling tubes were shaken for 30s on an oscillator, 100µl of each sample was transferred to blood-agar culture medium plates, and the plates were cultured for 48 hours at 35°C in an incubator. Colonies were counted and identified by Gram stain, catalase test, oxidase test, plasma coagulase test, biochemical tube test or using a VITEK-2 instrument for bacterial identification. Drug-sensitive testing was only used for detecting MRSA.

Statistical analysis

SPSS 17.0 software was used for statistical analysis and used the following parameters: α= 0.05, which may be calibrated according to the specific statistical data:
\[ \alpha' = 2\alpha \div [R \times (R - 1)] \], in which \( R \) was the number of sample rates that had to be compared in pairs. The contamination rate (%) was the proportion of samples with bacterial colonies >10 cfu/cm².

Results

Bacteriological Analysis before Cleaning-disinfection

The bacterial contamination of keyboards, mouses and mouse pads

As shown in Table 1, there were significant differences in the contamination rate between the keyboard group and the mouse group, as well as between the mouse group and mouse pad group, from high to low was keyboards, mouse pads and mice, respectively. The potentially pathogenic bacteria cultured from the computer-related equipment was as shown in Supplementary Table 2, One isolate of Enterococcus Faecium was cultured from the mouse pad. Klebsiella. Pneumoniae, Pseudomonas, and Enterobacter cloacae were isolated from the keyboard. Acinetobacter lwoffii were mainly cultured from the mouse pad and keyboard.

Table 1 The contamination rates of keyboard, mouse and mouse pad.

|        | N  | Contamination Rate (%) | Median | IQR    | P-value¹ |
|--------|----|------------------------|--------|--------|----------|
| Keyboard | 74 | 39.1                   | 9.0    | 1.8-18.3 | 0.000²   |
| Mouse   | 74 | 12.2                   | 2.5    | 1.0-6.0 | 0.004³   |
| Mouse pad | 47 | 34.0                   | 5.0    | 2.0-16.0 | 0.568⁴   |

¹ P-value was calculated for the contamination rate, \( \alpha' = 0.017 \)
² P-value was calculated between the Keyboard group and Mouse group
³ P-value was calculated between the Mouse group and Mouse pad group
⁴ P-value was calculated between the Keyboard group and Mouse pad group

The bacterial contamination of the computer-related equipment in different departments

As shown in Table 2, the computer-related equipment in the wards and outpatient rooms were much more contaminated than that in the other departments. In total, 8 isolates of Staphylococcus aureus were cultured, 5, 1, 1, and 1 from the wards, outpatient rooms, neonatal dept., and delivery room, respectively. Enterobacter cloacae, and Pseudomonas...
were cultured from the wards. *Enterococcus Faecium* was from the neonatal dept. *Klebsiella. Pneumoniae* was isolated from the operating rooms (Supplementary Table 3).

Table 2 The contamination rate of computer-related equipment in different departments before cleaning-disinfection

| Department       | N  | Contamination Rate (%) | Median | IQR       | P-value |
|------------------|----|------------------------|--------|-----------|---------|
| Wards            | 72 | 38.9                   | 8.5    | 3.0-17.5  | 0.000   |
| Outpatient Room  | 42 | 33.3                   | 5.5    | 2.0-14.5  | 0.001   |
| Delivery Room    | 14 | 28.6                   | 4.0    | 1.0-15.3  | 0.036   |
| Medical Dept.    | 10 | 30.0                   | 3.0    | 2.0-15.0  | 0.051   |
| Neonatal Dept.   | 20 | 15.0                   | 0.0    | 0.0-5.8   | 0.325   |
| Operating Room   | 39 | 5.1                    | 1.0    | 0.0-4.0   |         |

1 Contamination rate is the subject of *P*-value calculation, \( \alpha' = 0.005 \)

2 Operating Room as the control group

The bacterial contamination of the doctor’s and nurse’s computer-related equipment in the obstetric and gynecology wards

There was no significant difference in the contamination rate between the doctor’s office/mobile computer-related equipment and the nurse’s computer-related equipment in the obstetric and gynecology wards (Table 3). The species of potentially pathogenic bacteria from the doctor’s computers was more than that from the nurse’s computers, *Acinetobacter lwofii* and *Acinetobacter ursingii* were isolated from the doctor’s computers. One strain of *Enterobacter cloacae* was from the nurse’s computers in the gynecology wards, 2 isolated of *Pseudomonas* were cultured from the obstetric wards (Supplementary Table 4-5).

Table 3 The contamination rate of computer-related equipment in obstetric and gynecology wards before cleaning-disinfection

| Department           | N  | Contamination Rate (%) | Median | IQR       | P-value |
|----------------------|----|------------------------|--------|-----------|---------|
| Obstetric wards      | 40 | 42.5                   | 9.0    | 5.0-17.5  |         |
| Doctor’s office computers | 14 | 50.0                   | 11.5   | 4.5-19.3  | 0.310   |
| Doctor’s mobile computers | 13 | 46.2                   | 10.0   | 5.5-50.0  | 0.420   |
| Nurse’s station computers | 13 | 30.8                   | 7.0    | 2.0-12.5  |         |
| Gynecology wards     | 27 | 40.7                   | 6.0    | 2.0-22.0  |         |

1 Contamination rate is the subject of *P*-value calculation, \( \alpha' = 0.005 \)
Bacteriological Analysis after Cleaning-disinfection

As shown in Table 4, at day 1 and day 3 after cleaning-disinfection, the contamination rates of the computer-related equipment gradually increased, and the contamination rate of mouse pads ranked the second following the keyboards. 4 strains of MRSA were isolated from the keyboards and the mouses, one and 3 were cultured at day 3 and day 5 after cleaning-disinfection, respectively. Furthermore, the strain of *Staphylococcus aureus* gradually increased (7, 8 and 10 strains). 11, 7, and 7 were isolated from the keyboards, and mouses and mouse pads, respectively. One strain of *Pseudomonas Aeruginosa* was isolated from the mouses at day 3 after cleaning-disinfection (Supplementary Table 6).

Table 4  The contamination rate of computer-related equipment after cleaning-disinfection.

| N       | Cleaning-disinfection Rate (%) | Contamination Rate (%) | Contamination Rate (%) | Contamination Rate (%) | Contamination Rate (%) |
|---------|-------------------------------|------------------------|------------------------|------------------------|------------------------|
|         |                                | BCD 1                  | ACD Day 1              | ACD Day 3              | ACD Day 5              |
| Keyboard| 74                             | 98.5                   | 39.1                   | 46.6                   | 54.8                   | 54.7                   |
| Mouse   | 74                             | 97.9                   | 12.2                   | 17.8                   | 20.6                   | 18.8                   |
| Mouse pad| 47                            | 99.3                   | 34.0                   | 36.2                   | 37.2                   | 27.9                   |

1 BCD: Before Cleaning-disinfection  
2 ACD: After Cleaning-disinfection

Discussion

Cleaning and disinfecting object in the hospital is significantly important for controlling hospital associated infections [16-19]. In this study, we found that the contamination rate of mouse pads ranked second following the keyboards (34.0% vs 39.1%). The mouse pad is one of the high-touch objects so that it can be a “container” for pathogens. In another study was the contamination rate of the mouse pad researched, and
the results were as same as in our study [20]. The mouse pads have been relatively
disregarded in the medical settings. Furthermore, the contamination rates of
computer-related equipment in the wards and outpatient rooms were significantly higher
than that in the operating rooms. In the gynecology wards, the contamination rate of the
doctor’s computer-related equipment was higher than that of nurse’s computer-related
equipment.

The most common bacteria cultured from the computer-related equipment was
*Coagulase-negative staphylococcus*. This finding was similar to the results of William's
study[21]. In total, 60 isolates of *Acinetobacter* were detected including 41 isolates of
*Acinetobacter lwoffii*, 16 isolates of *Acinetobacter ursingii*, and 3 isolates of *Acinetobacter
baumannii*. As an opportunist pathogen, *A.baumannii* is one of the most clinically
significant multidrug-resistant bacteria, which can cause of the nosocomial infections,
especially in intensive care units [22-24]. It can persist and form biofilms on various abiotic
materials in the hospital environment [24]. Contamination of ambient air with
*Acinetobacter baumannii* was also a transmission way in Luis A study [25]. Despite
*Acinetobacter spp.* (*A. lwoffii, A. ursingii*) other than *A. baumannii* were often considered
relatively avirulent bacteria, they were able to be the opportunists in the presence of
indwelling medical devices and caused invasive diseases [26]. A former research found that
indwelling catheter-related with *A. lwoffii* bacteremia in immunocompromised hosts
appeared to be associated with a low risk of mortality [27]. A bacteremia caused by *A.
ursingii* in a patient with a pulmonary adenocarcinoma confirmed that it was an
opportunistic human pathogen for the first time [28]. 33 strains of *Staphylococcus aureus*
were detected, including 4 strains of MRSA. MRSA was previously detected from
healthcare personnel computers [15, 29]. The other importantly isolated bacteria included
*Enterococcus Faecalis, Enterococcus Faecium, Klebsiella. Pneumoniae, Enterobacter
cloacae, and Pseudomonas Aeruginosa*.

The above isolated potentially pathogenic bacteria were also cultured from the samples
of the HAI patients in our hospital, their detection rates were as shown in Table 5. the most
common pathogens from HAI patients were *Enterococcus Faecalis*. this may be associated
with the characteristic of maternity hospitals,with the large number of samples taken from
the genital tract. *Staphylococcus aureus* and *Coagulase-negative staphylococcus* were also
the main pathogens from HAI patients. The majority of *Staphylococcus aureus* were cultured from surgical incisions, and 12 cases were MRSA positive. In the process of “patient-object-patient” pathogens transmission, hand carriage plays an important role.

| Strain                                      | Strain (%) |
|---------------------------------------------|------------|
| Enterococcus Faecalis                       | 113 (14.9) |
| Staphylococcus aureus                       | 38 (5.0)   |
| MRSA                                        | 12 (1.6)   |
| Coagulase-negative staphylococcus           | 31 (4.1)   |
| Klebsiella, pneumoniae                      | 26 (3.4)   |
| Enterococcus Faecium                        | 25 (3.3)   |
| Enterobacter cloacae                        | 9 (1.2)    |
| Pseudomonas Aeruginosa                      | 9 (1.2)    |
| Acinetobacter baumannii                     | 3 (0.4)    |
| Acinetobacter Iwoffii                       | 1 (0.1)    |
| Micrococcus                                 | 1 (0.1)    |

A limitation of the study was the absence of bacteria homology detection among different computer equipment or between the computer equipment and HAI patients who were infected with the same bacteria. It will be further explored in the future study.

**Conclusions**

In summary, we found that the cleaning and disinfection of mouse pads must be brought to attention in the hospitals. Furthermore, it was better to clean and disinfect the computer-related equipment at least 1 time/day. At the same time, health-care workers should stick to good hand hygiene.

**Acknowledgements**

Not applicable

**References**

1. Schumacher M, Allignol A, Beyersmann J, Binder N, Wolkewitz M. 2013. Hospital-acquired infections appropriate statistical treatment is urgently needed! *Int J Epidemiol* **42**:1502-1508.
2. Allegranzi B, Bagheri Nejad S, Combescure C, et al. 2011, Burden of endemic health-care-associated infection in developing countries: systematic review and meta-analysis. *Lancet* 377:228–241.

3. Klevens RM, Edwards JR, Richards CL, et al. 2007. Estimating health care-associated infections and deaths in U.S. hospitals, 2002. *Public Health Rep* 122:160–166.

4. ECDC. Annual epidemiological report on communicable diseases in Europe, 2008: Report on the State of Communicable Diseases in the EU and EEA/EFTA Countries. 2008.

5. Yatin Mehta, Abhinav Gupta, Subhash Todi, et al. 2014. Guidelines for prevention of hospital acquired Infections. *Indian J Crit Care Med* 18: 149-163.

6. Flanagan ME, Welsh CA, Kiess C, et al. 2011. A national collaborative for reducing health care associated infections: current initiatives, challenges, and opportunities. *Am J Infect Control* 39:685-689.

7. Dancer SJ. 2009. Mopping up hospital infection. *J Hosp Infect* 43: 85-100.

8. Dancer SJ. 2008. Importance of the environment in meticillin resistant *Staphylococcus aureus* acquisition: the case for hospital cleaning. *Lancet Infect Dis* 8:101-113.

9. Kramer A, Schwebke I, Kampf G. 2006. How long do nosocomial pathogens persist on inanimate surfaces? *BMC Infect Dis* 16:130.

10. Murni IK, Duke T, Kinney S, et al. 2015. Reducing hospital-acquired infections and improving the rational use of antibiotics in a developing country: an effectiveness study. *Arch Dis Child* 100: 454-459.

11. Schultz M, Gill J, Zubairi S, Huber R, Gordin F. 2003. Bacterial Contamination of Computer Keyboards in a Teaching Hospital. *Infect Control Hosp Epidemiol* 24:302-303.

12. Ghamdi AA, Shukri H, Yamani A, Hawsawi H, Bagatadah K, Gharawi L, Shukri N, AlEnazi W. 2011. Computer keyboards and mice contamination at intensive care unit in Western Region in Kingdom of Saudi Arabia. *J Crit Care* 26:38–39.

13. Hartmann B, Benson M, Junger A, Quinizio L, Röhrig R, Fengler B, Färber UW, Wille B, Hempelmann G. 2004. Computer Keyboard and Mouse as a Reservoir of Pathogens in an Intensive Care Unit. *J Clin Monit Comput* 18:7-12.

14. Moore G, Muzslay M, Wilson AP. 2013. The Type, Level, and Distribution of Microorganisms within the Ward Environment: A Zonal Analysis of an Intensive Care Unit and a Gastrointestinal Surgical Ward. *Infect Control Hosp Epidemiol* 34:500-506.
15. Cooke RP, Wright EP. 2001. Is methicillin-resistant Staphylococcus aureus (MRSA) contamination of ward-based computer terminals a surrogate marker for nosocomial MRSA transmission and handwashing compliance? *J Hosp Infect* **48**:72-75.

16. Dancer SJ. 2009. The role of environmental cleaning in the control of hospital-acquired infection. *J Hosp Infect* **73**:378-385.

17. Pereira da Fonseca TA, Pessôa R, Felix AC, Sanabani SS. 2016. Diversity of Bacterial Communities on Four Frequently Used Surfaces in a Large Brazilian Teaching Hospital. *Int J Environ Res Public Health* **13**:152.

18. Donskey CJ. 2013. Does improving surface cleaning and sterilization reduce health care-associated infections? *Am J Infect Control* **41**:12-19.

19. Otter JA, Yezli S, Salkeld JA, French GL. 2013. Evidence that contaminated surfaces contribute to the transmission of hospital pathogens and an overview of strategies to address contaminated surfaces in hospital settings. *Am J Infect Control* **41**:6-11.

20. Man GS, Olapoju M, Chadwick MV, Vuddamalay P, Hall AV, Edwards A, Kerr JR. 2002. Bacterial contamination of ward-based computer terminals. *J Hosp Infect* **52**:314-315.

21. Rutala WA, White MS, Gergen MF, Weber DJ. 2006. Bacterial Contamination of Keyboards: Efficacy and Functional Impact of Disinfectants. *Infect Control Hosp Epidemiol* **27**:372-377.

22. Munoz-Price LS, Weinstein RA. 2008. Acinetobacter infection. *N Engl J Med* **358**:1271-1281.

23. Atlanta, GA. 2013. Antibiotic resistance threats in the United States. Centers for Disease Control and Prevention 2013.

24. Pawelek K, Agnieszka C, Monika P, Dorota R, Jadwiga WM. 2017. Acinetobacter baumannii isolated from hospital-acquired infection: biofilm production and drug susceptibility. *APMIS* **125**:1017 – 1026.

25. Luis A. Shimose, Yohei Doi, Robert A. Bonomo, Dennise De Pascale, Roberto A. Viau, Timothy Cleary, Nicholas Namias, Daniel H. Kett, L. Silvia Munoz-Price. 2015. Contamination of Ambient Air with Acinetobacter baumannii on Consecutive Inpatient Days. *J Clin Microbiol* **53**:2346-2348.

26. H. Seifert, A. Strate, A. Schulze, G. Pulverer. 1994. Bacteremia due to Acinetobacter Species Other than Acinetobacter baumannii. *Infection* **22**:379-385.

27. Ku SC, Hsueh PR., Yang PC, Luh KT. 2000. Clinical and Microbiological Characteristics of Bacteremia Caused by Acinetobacter Iwoffii. *Eur J Clin Microbiol Infect Dis* **19**:501–505.
28. Julien L, Liliana MA, Anne F, Etienne P, Gerard H, Patrick AD, Grimont AB. 2003. Bacteremia Caused by Acinetobacter ursingii. *J Clin Microbiol* 41: 1337–1338.

29. Oguzkaya-Artan M, Baykan Z, Artan C, Avsarogullari L. 2015. Prevalence and risk factors for methicillin resistant Staphylococcus aureus carriage among emergency department workers and bacterial contamination on touch surfaces in Erciyes University Hospital, Kayseri, Turkey. *Afr Health Sci* 15: 1289-1294.

Authors' contributions

Meiling Li designed the study, finished all experimental tests, collected and analyzed the data and wrote the manuscript. Shufang Chen made a contribution to design the study, analyze data and wrote the manuscript. Tingyan Lu guided the bacteria test and data analysis. Hongwei Zhang contributed to guide the data analysis and modify the manuscript. Xueying Mao done a great job to revise and polish the manuscript in English. Li Shen took part in doing the experimental test. Yan Lu took part in the design of this study. Shufang Leng took part in collect the data. All authors read and approved the final manuscript.

Additional information

Competing interests: The authors declared no conflict of interest in the manuscript.

Funding: This research was funded by the hospital funding (GFY5508)