COMPUTER KEYBOARD AND MOUSE AS A RESERVOIR OF PATHOGENS IN AN INTENSIVE CARE UNIT

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ABSTRACT. Objective. User interfaces of patient data management systems (PDMS) in intensive care units (ICU), like computer keyboard and mouse, may serve as reservoirs for the transmission of microorganisms. Pathogens may be transferred via the hands of personnel to the patient causing nosocomial infections. The purpose of this study was to examine the microbial contamination of computer user interfaces with potentially pathogenic microorganisms, compared with other fomites in a surgical intensive care unit of a tertiary teaching hospital. **Methods.** Sterile swab samples were received from patient's bedside computer keyboard and mouse, and three other sites (infusion pumps, ventilator, ward round trolley) in the patient's room in a 14 bed surgical intensive care unit at a university hospital. At the central ward samples from keyboard and mouse of the physician's workstation, and control buttons of the ward's intercom and telephone receiver were obtained. Quantitative and qualitative bacteriological sampling occurred during two periods of three months each on eight nonconsecutive days. **Results.** In all 14 patients' rooms we collected a total of 1118 samples: 222 samples from keyboards and mice, 214 from infusion pumps and 174 from the ward's trolley. From the central ward 16 samples per fomites were obtained (computer keyboard and mouse at the physician's workstation and the ward's intercom and telephone receiver). Microbacterial analysis from samples in patients' rooms yielded 26 contaminated samples from keyboard and mouse (5.9%) compared with 18 positive results from other fomites within patients' rooms (3.0%; $p < 0.02$). At the physician's computer terminal two samples obtained from the mouse (6.3%) showed positive microbial testing whereas the ward's intercom and telephone receiver were not contaminated ($p = 0.15$). **Conclusions.** The colonization rate for computer keyboard and mouse of a PDMS with potentially pathogenic microorganisms is greater than that of other user interfaces in a surgical ICU. These fomites may be additional reservoirs for the transmision of microorganisms and become vectors for cross-transmission of nosocomial infections in the ICU setting.

KEY WORDS. Computers, hygiene, nosocomial infection, intensive care unit.

INTRODUCTION

Nosocomial infections are an important cause of hospital morbidity and mortality creating increased medical costs [1]. Immunocompromised and immunosuppressed ICU patients are more susceptible to infections and may even die as a consequence of infections acquired in the hospital. The most common mode of transmission of exogen nosocomial pathogens is hand carriage by nursing and medical staff [2].

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Even though the role of the hospital environment as a reservoir of nosocomial pathogens is controversial, the introduction of bedside computers into the patients' rooms in the critical care environment, may play a role in the transmission of nosocomial pathogens [3, 4]. Undisputedly hands are the main source of pathogen transmission. Cross-transmission of microorganisms by the hands of care personnel from computer components at the patients' bedside, might introduce an additional risk for critically ill patients considering the frequent contact of nursing and medical staff during patient care with these fomites.

In this study we examined the contamination rates of computer keyboard and mouse, both used for management of individual patient medical records at the patients' bedside and at the computer user interface of the physician's workstation. Contamination rates of various fomites in and outside patients' rooms were selected for comparative microbiological testing.

MATERIAL AND METHODS

Location

At the surgical ICU of the Department of Anesthesiology, Intensive Care Medicine, and Pain Therapy of the University Hospital Giessen, Germany data have been recorded electronically since 1995. At our institution each of the 14 separate patient rooms is equipped with a computer terminal for bed-sided data-recording. Data are stored in an electronic patient file. Conventional keyboard and mouse hardware without plastic covers are used, grouped with the monitoring device and ventilator in the patients' room. All therapeutic measures are routinely recorded in close proximity to the patient (Figure 1).

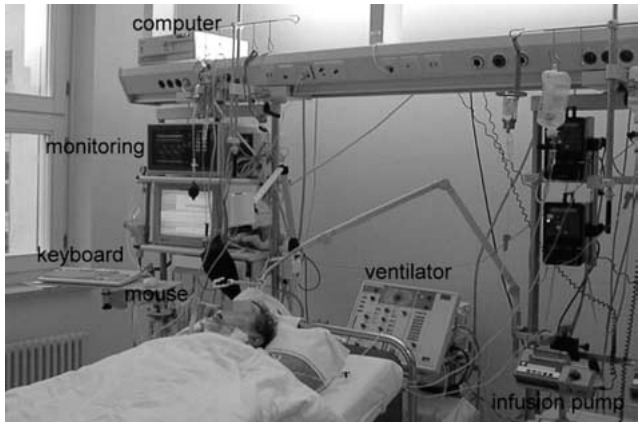

Fig. 1. Arrangement of the monitoring device, ventilator, and computer terminal in a patient room in the ICU.

Microbiology

Sampling occured during two collection periods of three months on eight nonconsecutive days. Keyboards and mice were sampled for microbial contamination and subsequently tested for quantitative and qualitative analysis of nosocomial pathogens. Selected reference surfaces were three user interfaces (controls of the intravenous infusion pump, ventilator, ward trolley handle bars) inside the patient's room. Fomites outside patients' rooms included surfaces of computer keyboard and mouse at the physician's workstation and the ward's central intercom control panel and telephone receiver. In all sites selected for microbiological testing an area of 20 cm^2 was marked, guaranteeing an identical sampling surface during all 16 collection periods.

A sterile rayon-tipped swab (D2-Tupfer; Heinz Herenz, Hamburg) moistened with sterile saline solution was moved over the surface being tested. After the collection swabs were squeezed in 1 ml sterile saline solution. The suspension was spread to blood agar plates (Columbia Blutagar 109 e; heipha, Heidelberg) and incubated for 48 hours at $36.0 \pm 1.0\,^{\circ}C$ under aerobic conditions. By non-occurrence of growth on the agar plate, a broth medium was inocculated with the remaining swab for possible detection of remaining pathogens. Cultures were inspected daily for visible growth. Positive cultures were gram stained for microscopic inspection, and gram-positive cultures were sub-cultured to selected broth media (Sojapeptone-Caseinpeptone; Sifin, Berlin) for identification using standard microbacteriological testing.

For this study S. aureus, Enterococcus sp., gram-negative rods (Enterobacteriacae, "nonfermenter") and Candida albicans were regarded as potentially pathogenic microoganisms particularly dangerous for immunosuppressed patients in ICU. Growth on the agar plate of two or more colony forming units of the above mentioned organisms indicated a contamination with potentially pathogenic bacteria. Growth in broth medium was not counted as colony forming unit.

Statistics

The Fisher exact test was used to compare the rates of contamination of keyboard and mouse versus fomites in the patient's room, and the contamination rates of keyboard and mouse in the physician's workstation

Table 1. Comparison of all positive cultures (one and more colony forming units) in different settings in the ICU. Distribution of bacterial isolates of potentially pathogenic and non-pathogenic microorganisms

		Potentially pathogenic microorganisms						Potentially non-pathogenic microorganisms									
		Entero-coccus sp.		S. aureus		Gram-negative rods		Micro-coccus sp.		Spore-forming organisms		S. epidermi-dis		Other staphylo-coccus sp.		Mould	
	No. of samples (N)	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%
Patient's rooms																	
Keyboard	222	12	5.4	3	1.4	2	0.9	128	57.7	141	63.5	189	85.1	74	33.3	5	2.3
Mouse	222	2	0.9	13	5.9	0	0	58	26.1	86	38.7	167	75.2	56	25.2	2	0.9
Infusion pump	214	0	0	4	1.9	0	0	28	13.1	41	19.2	71	33.2	14	6.5	4	1.9
Ventilator	222	3	1.4	7	3.2	1	0.5	34	15.3	77	34.7	134	60.4	35	15.8	5	2.3
Ward trolley	174	5	2.9	4	2.3	0	0	19	10.9	47	27.0	83	47.7	11	6.3	2	1.1
Overall	1,054	22	2.1	31	2.9	3	0.3	267	25.3	392	37.2	644	61.1	190	18.0	18	1.7
Central ward																	
Keyboard	16	0	0	0	0	0	0	6	37.5	9	56.3	16	93.8	4	25.0	0	0
Mouse	16	0	0	2	12.5	0	0	7	43.8	5	31.3	15	93.8	4	25.0	0	0
Telephone receiver	16	0	0	0	0	0	0	1	6.3	2	12.5	13	81.3	5	31.3	0	0
Central intercom control panel	16	0	0	0	0	0	0	6	37.5	5	31.3	10	62.5	1	6.3	0	0
Overall	64	0	0	2	3.1	0	0	20	31.3	21	32.8	54	84.4	14	21.9	0	0

No contamination with candida albicans occurred.

versus the ward's intercom control panel and telephone receiver. Additionally we compared results of microbacteriological testing of selected fomites at the central ward versus results obtained in the patients' rooms. The Fisher exact test was also used to compare the rate of contamination of keyboard and mouse of the physician's workstation versus contamination of the terminals in patients' rooms. Bacterial contamination of the sampled mice was compared to results of the tested keyboards. A p value less than 0.05 was considered significant for all statistical comparisons.

RESULTS

A total of 1118 samples of user interfaces in 14 patient rooms and the central physician's and nurse's station were obtained, collected over two periods of three months on a total of eight nonconsecutive days. From the patients' rooms we collected 222 samples each of keyboards, mice and ventilators, 214 samples of automatic infusion pumps, and 174 samples of the ward trolley handle bars (of eleven trolleys available three are routinely used in double bedrooms). From the physician's and nurse's workstation we obtained 16 samples each of keyboard and mouse, intercom control panel and telephone receiver.

Contamination rates of the sampled fomites are shown in table 1 classified into potentially pathogenic and non-pathogenic microorganisms. The highest rate of contamination in patients' rooms was found on keyboards with 5.4% Enterococcus sp. and mice with a contamination with S. aureus of 5.9%. S. aureus was isolated from two of 16 samples (12.5%) obtained from the mouse of central physician's computer. Gram-negative rods were isolated in only two samples taken from keyboard and one from ventilator in a patient room. No contamination with Candida albicans occurred.

Among non-pathogenic miroorganisms analysis showed a contamination with S. epidermidis, being part of the normal skin flora. Table 2 shows the contamination rates of potentially pathogenic bacteria in different settings (two and more colony forming units). Fomites in patient rooms were contaminated as follows: keyboards (6.8%), mice (5.0%), trolley (4.6%). In the central workstation the highest contamination rate was found for the mouse (12.5%). In patients' rooms automatic infusion pumps showed the lowest contamination rate with 0.9%. All other fomites in the central workstation were not contaminated. Samples of computer user interfaces in patients' rooms ($p < 0.42$) and at the physician's station ($p < 0.14$) showed no significant differences. Likewise analysis of keyboards in the patients' rooms versus central workstation ($p < 0.28$) and contamination of mice in patients' rooms and the central workstation ($p < 0.20$) yielded no significant difference.

Table 2. Comparison of contamination rates with potentially pathogenic microorganisms (two and more colony forming units) of fomites in patients' rooms and in the central ward

	No. of samples (N)	Potentially pathogenic microorganisms	
		n	%
Patients' rooms			
Keyboard	222	15	6.8
Mouse	222	11	5.0
Infusion pump	214	2	0.9
Ventilator	222	8	3.6
Ward trolley	174	8	4.6
Overall	1,054	44	4.2
Central ward			
Keyboard	16	0	0
Mouse	16	2	12.5
Telephone receiver	16	0	0
Central intercom control panel	16	0	0
Overall	64	2	3.1

Contamination rates of user interfaces in patients' rooms were generally higher (4.2%) than those of the computer at the physician's station (3.1%; $p < 0.68$).

Table 3 shows the contamination with potentially pathogenic bacteria of keyboard and mouse in the patients' rooms compared with reference fomites in patients' rooms and the central workstation. The overall result ($p < 0.01$) and the results obtained from the patients' rooms ($p < 0.02$) were significantly different, whereas no significant difference ($p < 0.15$) was found for samples from the central workstation.

DISCUSSION

Computer technology for the management of individual patient medical records has become an essential part in all aspects of modern medicine. Consequently the computer keyboard and mouse in an ICU setting may act as a reservoir for microorganisms and contribute to the transfer of pathogens to patients as recent studies and reviews have indicated [3, 4].

The study of Bures et al. [5] revealed a twofold increased contamination rate (multiresistant S. aureus,

Table 3. Comparison of contamination rates of computer user interfaces (keyboard and mouse) versus other interfaces in patients' rooms (infusion pump, ventilator, ward trolley) and central ward (central intercom control panel and telephone receiver)

	No. of samples (N)	Potentially pathogenic microorganisms		
		n	%	*p*-value
Patient's rooms				
Computer user interfaces	444	26	5.9	
Other interfaces[a]	610	18	3.0	< 0.02
Central ward				
Computer user interfaces	32	2	6.3	
Other interfaces[b]	32	0	0	< 0.15
Overall				
Computer user interfaces	476	28	5.9	
Other interfaces together	642	18	2.8	< 0.01

Computer user interfaces: keyboard and mouse.
Other interfaces:
[a] Infusion pump, ventilator, ward trolley;
[b] Central intercom control panel and telephone receiver.

gram-negative rods, Enterobacter sp., Entercoccus sp.) for computer keyboards (24%) when compared with faucet handles (11%) in an ICU. However, this difference was not statistically significant.

In our study the contamination rate of keyboard and mouse was 6% when compared with reference fomites showing a rate of only 3%. The reduced colonization rate compared to the findings of Bures et al. [5] may be due to better compliance with the institution's hand washing policy.

The sampled potentially pathogenic microorganisms contained a small quantity of Entercoccus sp. and S. aureus located mostly in the rooms of patients, thus being a potential source of infection. Results of gram-negative rods were of minor importance only. The contamination rate of fomites outside patients' rooms with S. epidermidis, a microbe of the resident skin flora with low virulence, was comparatively high. The reduced colonization with epidermal bacteria in patients' rooms may be explained by the compliance with the hospitals' hand disinfection policy during direct patient care activities. However, S. epidermidis was also sampled in patients' rooms especially on computer user interfaces. It may be presumed that computer keyboards come into contact with providers' hands more frequently than do perfusors and ventilators.

This increased contact may explain the higher contamination rate of terminal keyboard and mouse, a possible source of cross-transmission of potentially pathogenic organisms and pathogens. Direct contact of nurses and physicians with both the patient and the computer terminal at the bedside, where electronic data entry and patient care activities often alternate, put the patient at a higher risk. Requests for reinforced computer hardware infection control procedures for bedside computers seem to be justified. Plastic keyboard and mouse covers with regular cleaning policies lead to a reduction of contamination [3]. However, the benefit of routine surface disinfection measures to reduce nosocomial infections has not been clearly demonstrated [6]. Hence, the additional costs incurred by these measures, do not seem to be justified.

Also plastic keyboard covers do not provide secure protection against bacterial transmission, considering that the frequent use by providers leads to a quick recontamintion of these surfaces. Without hand washing or gloving, staff contact with keyboard or mouse, even without direct patient contact, may lead to a transmission of pathogens [7]. Hence, it is recommended that dealing with computer hardware the same infection prevention measures should be enforced than those for direct patient contact.

Comparing the contamination between user interfaces in patients' rooms and computer hardware at the ward, results show a uniform colonization of keyboard and mouse regardless of their proximity to the patient. This confirms the findings of Bures et al. [5] who detected similar rates of contamination of computer hardware regardless of their geographic location within the ward. In their investigation of computer terminals in two different hospitals Devine et al. [8] found contamination rates with MRSA of 24%. This shows that infection prevention measures like hand disinfection have to be enforced in all areas of the intensive care environment and should not be restricted to medical and care activities and the use of computers in the patients' rooms. In this context the comparably high contamination rate of the wards' telephone receiver similar to the colonization of the computer hardware should be mentioned as a possible indication of its frequent use.

The potential effects of these contaminations for the patients were not subject of this study. However, keeping in mind the long survival time of potentially pathogenic microorganisms, particularly on plastics, this contributes to the hypothesis of computers acting as reservoirs of nosocomial infections. Even though Dharan et al. [6] report a reduction of the colonization rate of microorganisms through enforcement of a surface disinfection policy, this did not reduce the rate of nosocomial infections. Hence the process of correct hand disinfection is still the mainstay of any prevention measure for the reduction of hospital acquired infections [9–11].

However, hand disinfection policies should not be reserved to direct patient care activities but should be extended to fomites within the patient's proximity and other locations in the ward including computer keyboards and mice in the ICU setting. It should be mentioned that the contamination rates observed in the sampled ICU remained well below that of other studies [5] indicating a high compliance with the institution's infection control policy.

However, in our study we found a higher contamination rate of computer user interfaces, like keyboard and mouse, compared to other fomites in the ICU setting regardless of their proximity to the patient. A relation of contamination rates of the sampled fomites and the rate of nosocomial infections remains to be investigated in a future study. Handling of computer keyboard and mouse asks for a strict compliance with hand disinfection policies. The potential effect of these measures on the rate of nosocomial infections remains to be studied.

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