Article

The comparative efficacy of disinfectant wipes on common-use computer keyboards in a veterinary teaching hospital

Eileen K. Wong, Brandy A. Burgess, Ben M. Brainard, Craig E. Greene, David J. Hurley, Amie Koenig

Abstract — The efficacies of 3 disinfectant wipes at reducing bacterial contamination on keyboards in a veterinary teaching hospital were studied. Thirty common-use keyboards were randomized into "dirty" and "clean" halves. Cultures were obtained from the "dirty" halves. The "clean" halves were disinfected with a randomly assigned wipe [peroxygen (AHP)-, alcohol-, quaternary ammonium (QAC)-based] or untreated (NT) and cultured. Colony-forming units (CFU) were enumerated after 48 hours. Mean reduction in CFU was 91.5%, 65.3%, 94.9%, and 78.8% for the AHP, alcohol, QAC, and NT groups, respectively. There was a significant reduction in CFUs between the dirty and clean keyboard halves within each group but no statistically significant differences were noted between groups. The reduction in CFUs in the NT group was attributed to the mechanical action of wiping the keyboard surface for culture. The use of disinfectant wipes reduced CFUs on keyboards and may be a useful component of veterinary infection control programs.

Résumé — Efficacité comparative de lingettes désinfectantes sur des claviers d'ordinateurs en usage commun dans un hôpital d'enseignement vétérinaire. L'efficacité de trois lingettes désinfectantes à réduire la contamination bactérienne sur des claviers dans un hôpital d'enseignement vétérinaire fut étudiée. Trente claviers en usage commun furent séparés de manière aléatoire en moitié « sale » et « propre ». Des cultures furent obtenues de la moitié « sale ». La moitié « propre » fut désinfectée avec une lingette assignée de manière aléatoire [à base de peroxygène (AHP), alcool, ou ammonium quaternaire (QAC)] ou non traitée (NT) et échantillonnée pour culture. Le nombre d'unités formatrices de colonies (CFU) fut énuméré après 48 heures. La réduction moyenne de CFU était de 91,5 %, 65,3 %, 94,9 %, et 78,8 % pour les groupes AHP, alcool, QAC, et NT, respectivement. Il y avait une réduction significative dans les CFUs entre les claviers des moitiés sale et propre dans chaque groupe mais aucune différence statistiquement significative ne fut notée entre les groupes. La réduction en CFU dans le groupe NT fut attribuée à l'action mécanique de frottage de la surface des claviers. L'utilisation de lingettes désinfectantes a réduit le nombre d'UFC sur les claviers et pourrait être une composante utile des programmes de surveillance des infections vétérinaires.

(Traduit par Dr Serge Messier)

Can Vet J 2020;61:69–74

Introduction

Hospital-associated infections (HAIs) are infections acquired by patients during the course of hospitalization (1). With a prevalence of approximately 4.5 infections per 100 hospital admissions, HAIs in human hospitals throughout the United States result in up to 99 000 deaths and an estimated $28 to 45 billion in direct costs annually (1,2). Hospital-associated infections result in increased duration of hospitalization, cost of care, and morbidity and mortality among human patients (3). While there are limited data available in veterinary medicine, a single study using syndromic surveillance in veterinary teaching hospital ICUs found that HAIs may occur in up to 16% of canine and 12% of feline critical care patients, and that increased duration of hospitalization was a significant risk factor for the development of HAIs (4). Infections acquired during hospitalization are more likely to be caused by organisms that are resistant to many antimicrobial drugs and therefore may be more difficult to treat (5,6).

Environmental surfaces can play an important role in the transmission of infectious agents in the hospital environment

Departments of Small Animal Medicine and Surgery (Wong, Brainard, Greene, Koenig), Population Health (Burgess), and Large Animal Medicine (Hurley), College of Veterinary Medicine, University of Georgia, Athens, Georgia 30602, USA.

Address all correspondence to Dr. Amie Koenig; e-mail: akoenig@uga.edu

This study was funded in part by a grant from the University of Georgia Department of Small Animal Medicine and Surgery Internal Research Program.

Figure 1. The keyboards were divided into halves delineated by the middle of the numeral 7. Each half was randomly assigned to be "dirty" or "clean."

(7). Of particular concern are user interfaces such as common-use computer keyboards in patient care areas. Studies performed in human intensive care and burn units have shown that computer keyboards are commonly contaminated with potential pathogens and may serve as a fomite for pathogens that may cause HAIs (8–11). More recently, researchers in Scotland found similar results in veterinary practices (12).

Computer keyboards present a cleaning and disinfection challenge as they are commonly used in patient care areas, have many cracks and crevices, and are not amenable to the use of standard disinfection procedures (e.g., spraying with a liquid chemical disinfectant). Disinfectant wipes have been shown to have varying efficacy for reducing bacterial contamination of keyboards in the human healthcare setting, and several studies report sustained reduction of keyboard contamination when using various disinfectants (11,13,14). Disinfectant wipes may thus be a viable option for reducing bacterial contamination on keyboards located in patient care areas of a veterinary teaching hospital, but only a few studies have been performed in the veterinary environment in which patient populations and their microbiota differ from those in human hospitals. Bender et al (15) demonstrated that routine cleaning of computer keyboards in a veterinary environment decreased recovery of *Staphylococcus* spp. from their surfaces, but they did not compare the efficacy of different disinfectant products (15).

The primary objective of this study was to determine the efficacy of 3 commonly used disinfectant wipes (peroxygen-based, 70% isopropyl alcohol-based, and quaternary ammonium-based) for reducing bacterial contamination of keyboards. It was hypothesized that the 3 different disinfectant wipes would be equally effective in significantly reducing the bacterial load found on common-use keyboards in patient care areas of a veterinary teaching hospital.

Materials and methods

Common-use keyboards located in specialty service patient care areas throughout the University of Georgia Veterinary Teaching Hospital were used to assess the efficacy of 3 disinfecting agents in reducing the number of colony-forming units (CFUs) of bacteria cultured from the keyboard surfaces. The time it took for each of the disinfectants to dry following cleansing was also quantified. The teaching hospital has an electronic medical record system, and computers are used by faculty, house officers, students, and technicians for reviewing patient files, submitting requests for diagnostic imaging, viewing the results of laboratory testing, ordering medications from the pharmacy, submitting requests for advanced procedures (e.g., surgery, endoscopy, anesthesia, diagnostic imaging), and typing discharge notes.

Part 1: Efficacy of keyboard cleaning agents

A total of 30 common-use QWERTY keyboards (Dell Keyboard KB212-B; Dell, Round Rock, Texas, USA) from 14 different patient care areas throughout the University of Georgia Veterinary Teaching Hospital were tested. Each keyboard was studied in a randomized crossover design of peroxygen-based (AHP) (Preempt Wipes; Virox Technologies, Oakville, Ontario), 70% isopropyl alcohol-based (Premoistened Clean-Wipes; VWR International, Radnor, Pennsylvania, USA), and quaternary ammonium-based compound (QAC) (Lysol Disinfecting Wipes; Reckitt Benckiser, Parsippany, New Jersey, USA) disinfectant wipes with a minimum 2-week washout period between treatments. Treatment order was randomized using a random number generator (Microsoft Excel for Mac 2011 Version 14.5.2; Microsoft Corporation, Redmond, Washington, USA). Five additional keyboards were used as a no treatment (NT) group. Keyboards were sampled on a day of the week that the service area had scheduled patient appointments.

The keyboards were divided into right and left halves (the left half delineated by all keys located to the left of middle of the numeral 7 key and the right half delineated by all keys located to the right of the middle of the numeral 7 key) (Figure 1), with the surface area of each half measuring 126 cm^2. Each half was randomly designated as the untreated "dirty" side or the disinfected "clean" side with a coin toss performed at each sampling time. The surface of the "clean" half of the keyboard was wiped with its assigned disinfectant for 5 s in an S-shaped pattern to cover that half of the keyboard. Following disinfection, the keyboard was allowed to dry before sample collection (below).

Samples were collected separately from each side using sterile, pre-moistened sponges (Solar Biologicals Sterile Sponge with Neutralizing Buffer; Weber Scientific, Hamilton, New Jersey, USA) that were wrung out to remove excess buffer. The sponges were wiped across half of the keyboard in an "S"-shaped pattern with a gloved hand and new gloves were donned before each culture. The sponges were then placed in individual sterile bags (Nasco Whirl-Pak Write-On Bags — 24 oz.; Nasco, Fort Atkinson, Wisconsin, USA) with 25 mL of Dey-Engley disinfectant-neutralizing broth (Difco D/E Neutralizing Broth; Becton, Dickinson and Company, Sparks, Maryland, USA), agitated, and allowed to sit at room temperature for 10 min. After

Table 1. Numbers of CFU after 48 hours of incubation, before and after cleaning with a disinfectant wipe.

	N	Least squares means	95% CI	Median	IQR	Mean CFU/cm^2
AHP						
Dirty	30	14.40	6.67, 22.19	12.00	9, 21	28.57
Clean	30	1.31	−5.72, 8.35	0.50	0, 2	2.60
Alcohol						
Dirty	30	23.90	16.20, 31.72	14.50	8, 26	47.42
Clean	30	8.58	1.54, 15.62	1.00	0, 3	17.02
QAC						
Dirty	30	19.99	12.24, 27.75	10.00	7, 26	39.66
Clean	30	3.18	−3.86, 10.22	1.00	0, 4	6.31
NT						
Pre	10	20.39	4.85, 35.93	15.5	10, 23	40.46
Post	10	6.51	−7.58, 20.60	2.5	1, 9	12.92

AHP — accelerated hydrogen peroxygen; CFU — colony-forming unit; CI — confidence interval; IQR — interquartile range; NT — no treatment; QAC — quaternary ammonium compound.

10 min, the sponge and solution were kneaded, and 100 μL aliquots of this solution were plated onto tryptic soy blood agar plates (TSBA) (BBL TSA II 5% SB Agar Plates; Becton, Dickinson and Company) using a sterile 30-mm bacterial spreader (Bio Plas 30 mm Bacti Cell Spreader; Blue, Bio Plas, San Rafael, California, USA). All plates were incubated for 48 h at 35°C and CFUs on each plate were enumerated by hand after 24 and 48 h of incubation.

Dirty (pre) culture samples from 5 NT keyboards were obtained as described. After each half keyboard had dried from the initial sampling, a second pre-moistened sterile sponge was wrung out and used to collect a post-culture sample from the same half of the keyboard in the same manner. Following incubation for 24 and 48 h at 35°C, CFUs on each plate were enumerated as described.

The average number of CFUs/cm^2 on each keyboard half was calculated using the following method. The number of CFUs counted on each plate represented the number of CFUs per 100 μL aliquot of broth solution that was cultured. This was used to estimate the number of CFUs within the entire 25 mL (25 000 μL) of broth, which represented the total number of CFUs obtained from the keyboard half. An estimated CFU/cm^2 was calculated for each keyboard half using a measured surface area of 126 cm^2. The percent reduction in CFU between cultures obtained from the dirty half of the keyboard and the clean half of the keyboard was calculated using the following equation:

$$\% \text{ reduction} = [(\text{dirty CFU/cm}^2 - \text{clean CFU/cm}^2)/\text{dirty CFU/cm}^2] \times 100.$$

The percent reductions were then averaged for each treatment group.

Cultures and CFU enumeration were performed for the 5 NT keyboards and all disinfectant wipes on all keyboards with a minimum 2-week washout between sampling periods.

Part 2: Drying time

The time it took for the keyboards to dry after cleaning with each disinfectant wipe was also quantified. A total of 6 keyboards were studied in a randomized crossover design of the 3 disinfectant wipes: AHP-, alcohol-, and QAC-based wipes. The keyboards were randomized using a random number generator to order the disinfectants used and were wiped with their respective disinfectant agent for approximately 5 s until the entire surface of the keyboard was wet. All drying time studies were performed in a small draft-free room at room temperature (21°C to 23°C). The time it took to completely visibly dry after cleaning was measured to the nearest second using a stopwatch. Subjective characteristics, including formation of suds and residue, were also noted for each disinfectant wipe.

Data analysis

Data were entered into a spreadsheet, validated, and descriptive statistics were calculated using commercially available statistics software (PROC GEN MOD, SAS 9.4; SAS, Cary, North Carolina, USA). Bacterial counts (CFUs) were log-transformed to facilitate parametric analyses. A paired *t*-test was used to compare log-transformed CFUs on dirty *versus* clean halves within each group. Multivariable linear regression was used to assess the dependent variable of bacterial reduction following 48 h of incubation. Variables included in the model were determined *a priori* as factors of interest or potential confounding variables and were therefore included in the model regardless of *P*-value. The independent variables evaluated included the keyboard location [categorized as emergency room, medicine, surgery, or other (cardiology, dermatology, oncology, ophthalmology, and radiology)], sample period (1, 2, or 3), and disinfectant type (AHP, Alcohol, QAC, or NT). Least squares means bacterial reduction and 95% confidence intervals (CI) were derived from linear regression models. Disinfectant wipe drying times were evaluated for normality and paired *t*-tests were used to make comparisons. A critical α of 0.05 was used for all statistical comparisons.

Results

Part 1: Efficacy of keyboard cleaning agents

In this study, the dirty keyboards averaged 28.57 to 47.42 CFU/cm^2 for each of the disinfectant wipe study groups

Table 2. Multivariable model Least Squares Means reduction in log10 CFUs at 48 hours of incubation (controlling for keyboard location).

Disinfectant	Least squares means baseline count in $\log_{10}$ CFUs	95% CI	Least squares means reduction in $\log_{10}$ CFUs	95% CI	Percent reduction*
AHP	1.09	0.95, 1.23	0.97	0.73, 1.20	91.5%
Alcohol	1.18	1.04, 1.32	0.99	0.76, 1.20	65.3%
QAC	1.10	0.96, 1.24	0.86	0.63, 1.10	94.9%
NT	1.06	0.78, 1.34	0.75	0.28, 1.23	78.8%

AHP — accelerated hydrogen peroxygen; CFU — colony-forming unit; CI — confidence interval; NT — no treatment; QAC — quaternary ammonium compound; *percent difference between least squares means for "dirty" and "clean" samples where positive values represent reduced growth.

Table 3. Drying times for disinfectant wipes in seconds.

Disinfectant	N	Mean	SD	Minimum	Maximum	95% LCL	95% UCL
AHP	6	483.17	275.36	147.00	905.00	194.19	772.14
Alcohol	6	96.83	16.17	68.00	108.00	79.87	113.8
QAC	6	422.17	157.87	273.00	613.00	256.50	587.84

AHP — accelerated hydrogen peroxygen; QAC — quaternary ammonium compound; SD — standard deviation; LCL — lower confidence limit; UCL — upper confidence limit.

(Table 1). While controlling for keyboard location, reductions in average CFUs were detected in each of the 3 treatment groups; use of the AHP product resulted in a 91.5% reduction in CFUs, use of the alcohol product resulted in a 65.3% reduction, and use of the QAC product resulted in a 94.9% reduction. The NT group also demonstrated a reduction in average CFUs, with a 78.8% reduction (Table 2). There was a statistically significant difference between CFUs enumerated on dirty and clean halves within each treatment group ($P < 0.001$ for each disinfectant wipe and $P = 0.006$ for the NT group). No statistically significant differences in percent reduction were noted between any of the 3 treatment groups or the NT group (P-values ranged from 0.36 to 0.84). Residual contamination of the keyboards following disinfection was 2.60 CFU/cm^2, 17.02 CFU/cm^2, 6.31 CFU/cm^2, and 12.92 CFU/cm^2 for the AHP, alcohol, QAC, and NT groups, respectively (Table 1). Neither location of the keyboard nor sample period was associated with percent reduction ($P = 0.15$).

Part 2: Drying time

Alcohol-based wipes had a faster drying time than QAC- or AHP-based wipes ($P = 0.005$ and 0.016, respectively) (Table 3). No significant difference in drying time was noted between QAC- and AHP-based wipes ($P = 0.66$). While the alcohol and AHP products did not create foam or leave behind any visible or tactile residue, cleaning with the QAC product produced a moderate amount of foam and left a visible thin white film.

Discussion

This study documents substantial bacterial contamination of common-use keyboards throughout the University of Georgia Veterinary Teaching Hospital and demonstrates reductions in average CFUs following cleaning with AHP-, alcohol-, and QAC-based wipes. Interestingly, similar reductions in average CFUs were noted when the keyboards were simply wiped with sponges moistened with a neutralizing buffer, suggesting that bacterial contamination can be reduced by the mechanical action of wiping. Ultimately, this study did not find statistically significant differences in CFU reductions between any of the 3 treatment groups or the NT group.

In human hospitals, the assessment of surface hygiene relies on either the identification of an indicator organism of potential high-risk to patients in any amount (including methicillin-resistant *Staphylococcus aureus, Clostridium difficile,* or multi-drug resistant Gram-negative bacilli) or the quantitative assessment of the total number of aerobic colonies found within a specified area (16). An appropriately cleaned and disinfected surface in a clinical environment should have < 1 CFU/cm^2 of an indicator organism or < 2.5 CFU/cm^2 total aerobic colony count (16). We chose to use the aerobic colony count pre- and post-disinfection as an indicator of efficacy of the disinfectant wipe. In this study, dirty keyboard contamination ranged from 28.57 to 47.42 CFU/cm^2 for each test group, indicating considerable contamination; this is not surprising given the proximity of these keyboards to areas of routine patient care and frequency of use. Interestingly, however, all treatments, including no treatment, resulted in reductions in the average number of CFUs. Because disinfectants are expected to eliminate most types of pathogenic bacteria (except bacterial spores) on inanimate objects, one would anticipate that any of the 3 disinfectant wipes would better help to reduce keyboard contamination than simply wiping them down with a moistened sponge. Furthermore, both AHP and QAC contain detergents, which can greatly reduce bacterial counts on surfaces (17). Nevertheless, mechanical action is known to reduce bacterial contamination and biofilms, even without the use of soaps and detergents (18). It is possible that wiping with the sponge provided more mechanical cleaning than the smooth-surfaced wipes and that this contributed to the comparable CFU reduction in the NT group. Additional studies using wipes moistened with

saline or water as a control group, instead of a no treatment group, would better delineate the difference in CFU reduction between disinfection and cleaning with wipes.

While percent reductions in CFUs were documented for all disinfectant wipes evaluated, none of the treatments successfully decreased the mean total aerobic colony count to less than 2.5 CFU/cm^2. This is an unanticipated finding, as Rutala et al (11) found that several disinfectant wipes (including those containing QAC and 70% isopropyl alcohol) were effective at decreasing CFU growth on keyboards by 95% to 100%. However, this group did not evaluate the final CFU/cm^2, so making direct comparisons is difficult. This group also only tested the efficacy of disinfectants on 5 individual test keys and not on a complete keyboard. It is possible that the entire keyboard poses a greater cleaning challenge, as the crevices between the keys may be harder to reach with the wipes. The configuration of the keyboard itself may also significantly affect the ability to adequately disinfect it, as keyboards with higher profile keys, like the ones used in this study, may be more difficult to clean by physical wiping than those with lower profile keys or touch screen keys. If a single wipe, as applied to the keyboards in this study, is insufficient to attain the desired level of keyboard disinfection, additional protocols (e.g., using multiple wiping cycles, longer wiping duration, or more detailed wiping) or use of keyboard covers should be tested to see if they can achieve superior disinfection. Keyboards may accumulate visible biofilms from skin oils that may be difficult to remove with a single wipe, and multiple wiping cycles or a regular wiping regimen may be more effective than the protocol tested here. This study did not address the level of visible contamination of these keyboards, and additional studies to investigate if gross contamination is a confounding factor in the ability of a single wipe to achieve appropriate CFU reduction are warranted. The 3 disinfectant wipes used in this study were chosen based on products currently in use in this hospital, and a different product not tested here may be more efficacious. For example, Jones et al (13) noted sustained and significant reduction in CFUs of bacteria cultured from common-use hospital keyboards with use of a 2% chlorhexidine in 70% isopropyl alcohol spray.

The choice of disinfectant to be used may also depend on other factors including drying time, formation of suds, product scent, residue left on the keyboards, preservation of keyboard function, and cost. We thus evaluated drying time with each of the disinfectant wipes and found that the keyboards dried significantly faster when alcohol wipes were used to disinfect them and that no visible residue was left behind. While the faster drying time and lack of residue may increase user compliance, it is also important to consider the fact that its rapid evaporation may limit contact time of the alcohol with any pathogens. A contaminated surface may not be adequately disinfected if the alcohol evaporates before an appropriate contact time is reached, and general recommendations for alcohol-based disinfectants is a contact time greater than 1 min (19). In this study, the visible drying time for the entire surface of each alcohol-disinfected keyboard was longer than 1 min.

Although alcohol wipes had a faster drying time and did not statistically differ from the other treatment groups with regard to reduction in keyboard bacterial load, we cannot definitively recommend that this product be used for routine keyboard disinfection without considering the possibility that the other disinfectants may have residual antimicrobial effects that alcohol does not. Due to its rapid drying time, alcohol is not considered to have any residual effects; however, quaternary ammonium products have residual antimicrobial activity even after drying (13). Although there was no statistically significant difference between the treatments, the difference between a 94.9% and a 65.3% reduction in CFUs may still be biologically relevant and of clinical importance. It is also known that some of the disinfectants (QAC) have residual effects following application that may extend their effects. Additional studies are warranted to investigate whether these residual effects would result in clinically relevant differences in duration of disinfectant efficacy.

There are several limitations to this study. Because only decreases in standard aerobic colony counts were quantified after disinfection with each respective wipe, it is unknown whether the wipes equally reduced numbers of pathogenic bacteria, non-pathogenic bacteria, or both. The AHP-, alcohol-, and QAC-based disinfectants are labeled as being efficacious for a wide range of pathogens and should be effective against these organisms (20); however, further studies identifying specific organisms cultured before and after cleaning would help determine if some wipes are superior for specific bacterial or viral reduction. Furthermore, each disinfectant agent has a different antimicrobial spectrum, and choice of product may also depend on the types of organisms anticipated to be present in the keyboard environment. Although we demonstrated a decrease in bacterial load for all tested protocols, re-colonization dynamics were not assessed. Thus, the optimal frequency of disinfection (daily, twice daily, etc.) was not determined, and we were unable to verify residual antimicrobial activity for any disinfectant wipes. Additional studies investigating the time to re-colonization are indicated in order to determine what cleaning protocol would best minimize keyboard contamination. Lastly, while it was not the goal of this paper, characterization of the bacterial population of these keyboards would be valuable in determining if there are significant numbers of pathogenic or multi-drug resistant organisms that may pose greater risk for patients and staff. These organisms can then be compared to the organisms cultured from HAIs occurring around the same time to see if keyboard contamination has any correlation to the development of HAIs.

This study demonstrates that common use keyboards in animal care areas of a veterinary teaching hospital are likely to be highly contaminated and suggests that they should be routinely cleaned and disinfected. Although the optimal disinfection protocol is yet to be determined, this study demonstrates that use of any of 3 commercially available wipes reduced overall aerobic counts on keyboards and may be a useful component of an infection control program.

Acknowledgments

This study was funded in part by a grant from the University of Georgia Department of Small Animal Medicine and Surgery Internal Research Program. Preliminary results were presented

as an oral abstract at IVECCS 2018, New Orleans, Louisiana, USA.

The authors declare that there were no conflicts of interest.

The authors thank Barbara Artelt, Department of Small Animal Medicine and Surgery at the University of Georgia College of Veterinary Medicine, for her assistance with laboratory work. CVJ

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