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Research article

How long do nosocomial pathogens persist on inanimate surfaces? A systematic review

Axel Kramer*[1], Ingeborg Schwebke[2] and Günter Kampf[1,3]

Address: [1]Institut für Hygiene und Umweltmedizin, Ernst-Moritz-Arndt Universität, Greifswald, Germany, [2]Robert-Koch Institut, Berlin, Germany and [3]Bode Chemie GmbH & Co. KG, Scientific Affairs, Hamburg, Germany

Email: Axel Kramer* - kramer@uni-greifswald.de; Ingeborg Schwebke - schwebkei@rki.de; Günter Kampf - guenter.kampf@bode-chemie.de

* Corresponding author

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Abstract

Background: Inanimate surfaces have often been described as the source for outbreaks of nosocomial infections. The aim of this review is to summarize data on the persistence of different nosocomial pathogens on inanimate surfaces.

Methods: The literature was systematically reviewed in MedLine without language restrictions. In addition, cited articles in a report were assessed and standard textbooks on the topic were reviewed. All reports with experimental evidence on the duration of persistence of a nosocomial pathogen on any type of surface were included.

Results: Most gram-positive bacteria, such as Enterococcus spp. (including VRE), *Staphylococcus aureus* (including MRSA), or *Streptococcus pyogenes*, survive for months on dry surfaces. Many gram-negative species, such as Acinetobacter spp., *Escherichia coli*, Klebsiella spp., *Pseudomonas aeruginosa*, *Serratia marcescens*, or Shigella spp., can also survive for months. A few others, such as *Bordetella pertussis*, *Haemophilus influenzae*, *Proteus vulgaris*, or *Vibrio cholerae*, however, persist only for days. Mycobacteria, including *Mycobacterium tuberculosis*, and spore-forming bacteria, including *Clostridium difficile*, can also survive for months on surfaces. *Candida albicans* as the most important nosocomial fungal pathogen can survive up to 4 months on surfaces. Persistence of other yeasts, such as *Torulopsis glabrata*, was described to be similar (5 months) or shorter (*Candida parapsilosis*, 14 days). Most viruses from the respiratory tract, such as *corona*, *coxsackie*, *influenza*, *SARS* or *rhino* virus, can persist on surfaces for a few days. Viruses from the gastrointestinal tract, such as *astro*virus, *HAV*, *polio*- or *rota* virus, persist for approximately 2 months. Blood-borne viruses, such as HBV or HIV, can persist for more than one week. Herpes viruses, such as CMV or HSV type 1 and 2, have been shown to persist from only a few hours up to 7 days.

Conclusion: The most common nosocomial pathogens may well survive or persist on surfaces for months and can thereby be a continuous source of transmission if no regular preventive surface disinfection is performed.

Background

Within the global infection control community, there is an ongoing controversy about the appropriate treatment of inanimate surfaces in hospitals in order to prevent transmission of nosocomial pathogens within an institution. Based on a lack of epidemiological data that would provide evidence of a benefit for the patient from surface disinfection (e.g., from a significant reduction of nosocomial infection rates), some scientists postulate that cleaning of surfaces with non-antimicrobial detergents is generally sufficient [1]. Others prefer cleaning of surfaces with antimicrobial agents, based on data on the risk of infection due to microbial contamination and potential transmission of nosocomial pathogens, at least in the immediate vicinity of patients [2-4].

New guidelines on treatment of surfaces in hospitals take into account more parameters which are considered to be relevant for preventing the transmission of nosocomial pathogens, such as the type of ward or the expected frequency of hand contact with a surface [5,6]. Irrespective of the divergent opinions regarding the appropriate treatment of surfaces, an important parameter for a fair scientific assessment remains, that is, the persistence of nosocomial pathogens on surfaces. The longer a nosocomial pathogen persists on a surface, the longer it may be a source of transmission and thus endanger a susceptible patient or healthcare worker. The aim of this review was therefore to collect and assess the data that have been published in the last decades on persistence of all types of nosocomial pathogens on surfaces, both in the context of surface disinfection and the control of nosocomial outbreaks.

Methods

Search strategy

The literature was systematically reviewed in MedLine on the internet homepage of the National Library of Medicine without language restrictions. The search was done on 29 December 2005 and covered all years available in MedLine. The following search terms were applied: persistence, survival, surface, fomite, bacteria, virus, pathogen, transmission, and nosocomial. In addition, the citations in each study found during the main search were reviewed for potential relevance. Finally, standard textbooks on infection control, bacteriology and virology were examined for information.

Selecting studies

All reports with experimental evidence on the duration of persistence of a nosocomial pathogen on any type of inanimate surface were included. Information from textbooks was also included, even if the chapter itself did not contain experimental evidence. At least two of the investigators decided on the relevance of each report. Reports were not blinded to the investigators so that they knew the names of the authors of all studies.

Interpretation of studies

For a clinically relevant summary, all nosocomial pathogens were grouped according to their importance in causing hospital-acquired hand-transmitted infections [7] and according to their mode of nosocomial transmission [8]. The range of the reported duration of persistence was used as the principle outcome of the search for each nosocomial pathogen. In addition, parameters with potential influence on persistence were evaluated in all experimental studies.

Results

Persistence of bacteria

Most gram-positive bacteria, such as *Enterococcus* spp. (including VRE), *Staphylococcus aureus* (including MRSA), or *Streptococcus pyogenes* survive for months on dry surfaces (Table 1). In general, there was no obvious difference in survival between multiresistant and susceptible strains of *Staphylococcus aureus* and *Enterococcus* spp. [9]. Only in one study was such a difference suggested, but the susceptible strains revealed a very brief survival as such [10]. Many gram-negative species, such as *Acinetobacter* spp., *Escherichia coli*, Klebsiella spp., *Pseudomonas aeruginosa*, *Serratia marcescens*, or *Shigella* spp. can survive on inanimate surfaces even for months. These species are found among the most frequent isolates from patients with nosocomial infections [11]. A few others, such as *Bordetella pertussis*, *Haemophilus influenzae*, *Proteus vulgaris*, or *Vibrio cholerae*, however, persist only for days (Table 1). Mycobacteria – including *Mycobacterium tuberculosis* and spore-forming bacteria, including *Clostridium difficile* – can also survive for many months on surfaces (Table 1).

Overall, gram-negative bacteria have been described to persist longer than gram-positive bacteria [12,13]. Humid conditions improved persistence for most types of bacteria, such as *Chlamydia trachomatis* [14], *Listeria monocytogenes* [15], *Salmonella typhimurium* [15], *Pseudomonas aeruginosa* [16], *Escherichia coli* [17], or other relevant pathogens [18,19]. Only *Staphylococcus aureus* was found to persist longer at low humidity [16].

Low temperatures, e.g., 4°C or 6°C, also improved persistence of most types of bacteria, such *Listeria monocytogenes* [15], *Salmonella typhimurium* [15], MRSA [20], corynebacteria [21], *Escherichia coli* [17,22], *Helicobacter pylori* [23], and *Neisseria gonorrhoeae* [24].

The type of test material does not reveal a consistent result. Although some investigators report that the type of material has no influence on the persistence [25,26], other authors described a longer persistence on plastic

Table 1: Persistence of clinically relevant bacteria on dry inanimate surfaces.

Type of bacterium	Duration of persistence (range)	Reference(s)
Acinetobacter spp.	3 days to 5 months	[18, 25, 28, 29, 87, 88]
Bordetella pertussis	3 – 5 days	[89, 90]
Campylobacter jejuni	up to 6 days	[91]
Clostridium difficile (spores)	5 months	[92–94]
Chlamydia pneumoniae, *C. trachomatis*	≤ 30 hours	[14, 95]
Chlamydia psittaci	15 days	[90]
Corynebacterium diphtheriae	7 days – 6 months	[90, 96]
Corynebacterium pseudotuberculosis	1–8 days	[21]
Escherichia coli	1.5 hours – 16 months	[12, 16, 17, 22, 28, 52, 90, 97–99]
Enterococcus spp. including VRE and VSE	5 days – 4 months	[9, 26, 28, 100, 101]
Haemophilus influenzae	12 days	[90]
Helicobacter pylori	≤ 90 minutes	[23]
Klebsiella spp.	2 hours to > 30 months	[12, 16, 28, 52, 90]
Listeria spp.	1 day – months	[15, 90, 102]
Mycobacterium bovis	> 2 months	[13, 90]
Mycobacterium tuberculosis	1 day – 4 months	[30, 90]
Neisseria gonorrhoeae	1 – 3 days	[24, 27, 90]
Proteus vulgaris	1 – 2 days	[90]
Pseudomonas aeruginosa	6 hours – 16 months; on dry floor: 5 weeks	[12, 16, 28, 52, 99, 103, 104]
Salmonella typhi	6 hours – 4 weeks	[90]
Salmonella typhimurium	10 days – 4.2 years	[15, 90, 105]
Salmonella spp.	1 day	[52]
Serratia marcescens	3 days – 2 months; on dry floor: 5 weeks	[12, 90]
Shigella spp.	2 days – 5 months	[90, 106, 107]
Staphylococcus aureus, including MRSA	7 days – 7 months	[9, 10, 16, 52, 99, 108]
Streptococcus pneumoniae	1 – 20 days	[90]
Streptococcus pyogenes	3 days – 6.5 months	[90]
Vibrio cholerae	1 – 7 days	[90, 109]

[27,28], and others yet see a survival advantage on steel [29].

Other factors were rarely investigated and hence provide inconsistent results. Longer persistence has been described with higher inocula [28], in the presence of protein [13], serum [13,24], sputum [30], or without dust [10].

Persistence of fungi

Candida albicans as the most important nosocomial fungal pathogen can survive up to 4 months on surfaces (Table 2). Persistence of other yeasts was described to be similar (*Torulopsis glabrata* 5 months) or shorter (*Candida parapsilosis* 14 days).

The presence of serum or albumin, a low temperature, and high humidity have been described as leading to longer persistence [31].

Persistence of viruses

Most viruses from the respiratory tract such as *corona-*, *coxsackie-*, *influenza*virus, *SARS*, or *rhino*virus can persist on surfaces for a few days. Viruses from the gastrointestinal tract, such as *astro*virus, *HAV*, *polio-* and *rota*virus persist for approximately 2 months. Blood-borne viruses, such as HBV or HIV, can persist for more than one week. Herpes viruses such as CMV or HSV type 1 and 2 have been shown to persist from only a few hours up to 7 days.

The influence of humidity on persistence has been described inconsistently. For entero- [32] and *rhino*virus [33], high humidity was associated with longer persistence. *HSV* [34] and *HAV* [35] can persist longer at low humidity. For *adeno*- [32,34], *rota-* [36,37], and *polio*virus [34,35], conflicting results were reported.

For most viruses, such as *astro-* [38], *adeno-* [34], *polio*virus [34], *HSV* [34], and *HAV* [35], low temperature is associated with a longer persistence.

Inconsistent results are also reported for the influence of type of material. Some authors described that the type of material did not affect the persistence of *echo-* [39], *adeno-* [39-41], *parainfluenza-* [39], *rota*virus [41], RSV [39], *polio-* [41] or *noro*virus [42]. Other investigators found that per-

Table 2: Persistence of clinically relevant fungi on dry inanimate surfaces.

Type of fungus	Duration of persistence (range)	Reference(s)
Candida albicans	1 – 120 days	[31, 53, 99, 110]
Candida parapsilosis	14 days	[110]
Torulopsis glabrata	102 – 150 days	[31]

sistence was favored on non-porous surfaces for *influenza*-virus [43], on formica and gloves for *RSV* [44], and on a telephone receiver for *FCV* [45].

Other parameters for a longer persistence of viruses include the presence of fecal suspension [38] and a higher inoculum [46].

Persistence of other nosocomial pathogens

Cryptosporidium species have been reported to survive on dry surfaces for only 2 hours [47].

Discussion

The most relevant nosocomial pathogens can persist on dry inanimate surfaces for months. In addition to the duration of persistence, some studies have also identified factors influencing persistence. A low temperature, such as 4°C or 6°C, was associated with longer persistence for most bacteria, fungi and viruses. High humidity (e.g., > 70%) was also associated with longer persistence for most bacteria, fungi, and viruses, although for some viruses conflicting results were reported. A few studies also suggest that a higher inoculum is associated with longer persistence. The type of surface material and the type of suspension medium, however, reveal inconsistent data. Overall, a high inoculum of the nosocomial pathogen in a cold room with high relative humidity will have the best chance for long persistence.

In most reports with experimental evidence, persistence was studied on dry surfaces using artificial contamination of a standardized type of surface in a laboratory. In most studies, bacteria were prepared in broth, water or saline. Viruses were usually prepared in a cell culture medium [48]. The main advantage is that the environmental conditions are consistent regarding temperature and air humidity. In addition, the effect of temperature or relative humidity can only be determined under controlled conditions, which are much easier to ensure in the laboratory. However, this may not always reflect the clinical situation, in which surfaces can be simultaneously contaminated with various nosocomial pathogens and different types of body fluids, secretions etc. Yet the question remains: what is the clinical evidence for the role of surfaces in nosocomial infections?

In hospitals, surfaces with hand contact are often contaminated with nosocomial pathogens [49-51], and may serve as vectors for cross transmission. A single hand contact with a contaminated surface results in a variable degree of pathogen transfer. Transmission to hands was most successful with *Escherichia coli*, *Salmonella* spp., *Staphylococcus aureus* (all 100%) [52], *Candida albicans* (90%) [53], *rhino* virus (61%) [54], *HAV* (22% – 33%) [55], and *rota* virus (16%) [56,57]. Contaminated hands can transfer viruses

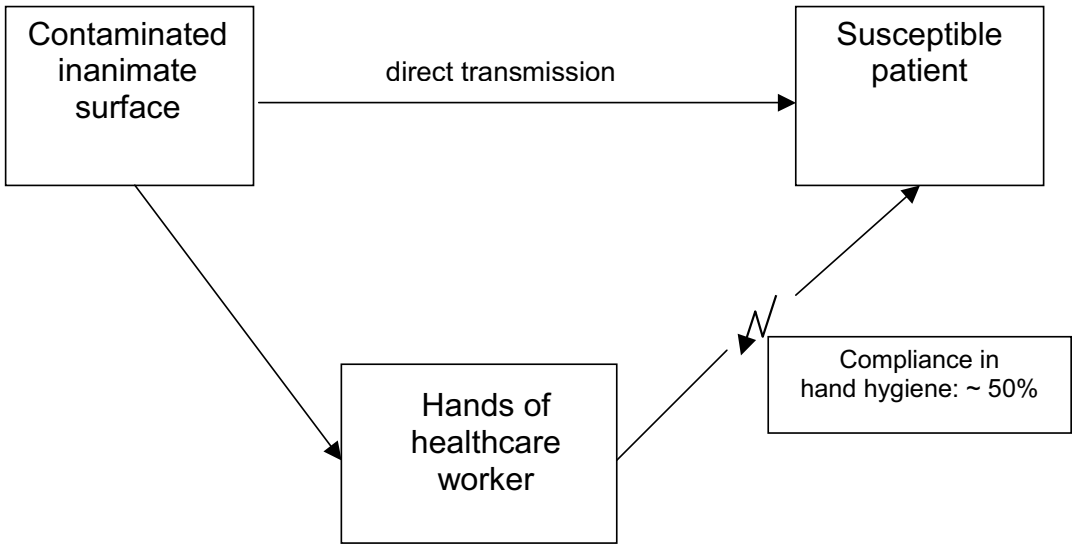

Figure 1
Common modes of transmission from inanimate surfaces to susceptible patients.

Table 3: Persistence of clinically relevant viruses on dry inanimate surfaces.

Type of virus	Duration of persistence (range)	Source
Adenovirus	7 days – 3 months	[32, 34, 38–41, 111]
Astrovirus	7 – 90 days	[38]
Coronavirus	3 hours	[112, 113]
SARS associated virus	72 – 96 hours	[114]
Coxsackie virus	> 2 weeks	[34, 111]
Cytomegalovirus	8 hours	[115]
Echovirus	7 days	[39]
HAV	2 hours – 60 days	[35, 38, 41]
HBV	> 1 week	[116]
HIV	> 7 days	[117–119]
Herpes simplex virus, type 1 and 2	4.5 hours – 8 weeks	[34, 111, 118, 120]
Influenza virus	1 – 2 days	[39, 43, 121, 122]
Norovirus and feline calici virus (FCV)	8 hours – 7 days	[42, 45]
Papillomavirus 16	> 7 days	[123]
Papovavirus	8 days	[118]
Parvovirus	> 1 year	[118]
Poliovirus type 1	4 hours – < 8 days	[35, 118]
Poliovirus type 2	1 day – 8 weeks	[34, 38, 111]
Pseudorabies virus	≥ 7 days	[124]
Respiratory syncytial virus	up to 6 hours	[44]
Rhinovirus	2 hours – 7 days	[33, 125]
Rotavirus	6 – 60 days	[36 – 38, 41]
Vacciniavirus	3 weeks – > 20 weeks	[34, 126]

to 5 more surfaces [58] or 14 other subjects [59]. Contaminated hands can also be the source of re-contaminating the surface, as shown with *HAV* [55,58]. Compliance rates of healthcare workers in hand hygiene are known to be around 50% [7]. Due to the overwhelming evidence of low compliance with hand hygiene, the risk from contaminated surfaces cannot be overlooked (Figure 1).

The main route of transmission is via the transiently contaminated hands of the healthcare worker [60-62]. An outbreak of nosocomial infections due to *Acinetobacter baumannii* in a neurosurgical intensive care unit may serve as an example. A direct correlation was found between the number of environmental isolates obtained during screening and the number of patients who were colonized or infected with the same strain during the same calender month [63].

During outbreaks, the environment may play a significant role for transmission of nosocomial pathogens, as suggested by observational evidence. This has been described for various types of microorganisms, such as *Acinetobacter baumannii* [64-66], *Clostridium difficile* [67-69], MRSA [65,70], *Pseudomonas aeruginosa* [4,65], VRE [65,71-77], *SARS* [78,79], *rota-* [80,81], and *noro*virus [82]. However, the evidence to support a role of environmental contamination is not equally strong for all types of nosocomial pathogens. For *Clostridium difficile*, MRSA, and VRE, data are stronger than for other pathogens, such as *Pseudomonas aeruginosa* or *Acinetobacter baumannii*, of which multiple types were detected in the environment, and which did not always correlate with the acquired strain [83].

The role of surface disinfection for the control of nosocomial pathogens has been a contentious issue for some time [3]. Routine treatment of clean floors with various types of surface disinfectants (some of them had rather poor bactericidal activity) has been described to have no significant impact on the incidence of nosocomial infections [84]. Disinfection of surfaces in the immediate environment of patients, however, has been described to reduce acquisition of nosocomial pathogens such as VRE [85] or *Acinetobacter baumannii* [86]. It is therefore advisable to control the spread of nosocomial pathogens at least in the direct inanimate environment of the patient by routine surface disinfection.

Conclusion

Most nosocomial pathogens can persist on inanimate surfaces for weeks or even months. Our review supports current guidelines which recommend a disinfection of surfaces in specific patient-care areas in order to reduce the risk of transmission of nosocomial pathogens from inanimate surfaces to susceptible patients.

Competing interests

GK is a paid employee of Bode Chemie GmbH & Co. KG, Hamburg, Germany.

Authors' contributions

All authors contributed to the conception, review of studies, and analysis of data. All authors were involved in drafting and revising the manuscript. All authors approved the final version of the manuscript.

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