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Review

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

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SUMMARY

Healthcare hygiene plays a crucial role in the prevention of healthcare-associated infections. Patients admitted to a room where the previous occupant had a multi-drug-resistant bacterial infection are at an increased risk of colonization and infection with the same organism. A 2006 systematic review by Kramer *et al.* found that certain pathogens can survive for months on dry surfaces. The aim of this review is to update Kramer *et al.*'s previous review and provide contemporary data on the survival of pathogens relevant to the healthcare environment. We systematically searched Ovid MEDLINE, CINAHL and Scopus databases for studies that described the survival time of common nosocomial pathogens in the environment. Pathogens included in the review were bacterial, viral, and fungal. Studies were independently screened against predetermined inclusion/exclusion criteria by two researchers. Conflicts were resolved by one of two senior researchers. A spreadsheet was developed for the data extraction. The search identified 1736 studies. Following removal of duplicates and application of the search criteria, the synthesis of results from 62 included studies were included. 117 organisms were reported. The longest surviving organism reported was *Klebsiella pneumoniae* which was found to have persisted for 600 days. Common pathogens of concern to infection prevention and control, can survive or persist on inanimate surfaces for months. This data supports the need for a risk-based approach to cleaning and disinfection practices, accompanied by appropriate training, audit and feedback which are proven to be effective when adopted in a 'bundle' approach.

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Introduction

The hospital environment provides a reservoir for pathogens to be transmitted to patients. Patients admitted to a room where the previous occupant had a multi-drug-resistant bacterial infection are at an increased risk of colonization and infection with the same organism [1]. However it has been demonstrated that improvements in routine hospital cleaning result in reduced healthcare-associated infection (HAI) rates [2]. Shared medical equipment also pose additional HAI risks as contaminated equipment may promote the spread of pathogens between patients on the ward [3].

A 2006 systematic review by Kramer *et al.* [4] described the survival times, and factors affecting this survival, for many human pathogens including bacteria, fungi and viruses. Kramer *et al.* found that *Enterococcus* spp. (including vancomycin-resistant enterococcus), *Staphylococcus aureus* (including meticillin-resistant S. *aureus* (MRSA)), *Streptococcus pyogenes*, and many Gram-negative species, such as *Acinetobacter* spp., *Escherichia coli*, *Klebsiella* spp., *Pseudomonas aeruginosa*, *Serratia marcescens*, or *Shigella* spp., can survive for months on dry surfaces. Whereas most respiratory viruses such as corona, coxsackie, influenza, SARS or rhinovirus, can persist on surfaces for a few days. Factors such as humidity, temperature, and material composition of the surface can affect longevity of these pathogens [4].

Understanding the persistence of nosocomial pathogens is important to inform infection prevention guidelines, particularly environmental cleaning. The aim of this review was to use a reproducible approach to update Kramer *et al.*'s review [4] and provide a complete and contemporaneous review of the literature.

Methods

Study design

A scoping review was undertaken in preference to a systematic review, in line with the review's purpose of mapping the available literature, identifying knowledge gaps, and identifying novel infectious diseases publications in light of the COVID-19 pandemic. Moreover, the variability in settings (both clinical and laboratory-based) posed challenges for the conduct of concise, comparable, risk of bias assessments [5]. We followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) [6].

Search strategy

A comprehensive search of the literature was performed using Ovid MEDLINE, CINAHL, and Scopus databases. These databases were searched on 5th March 2023 with no year restrictions but limited to English-language publications. The combination of keywords used were ("cross infection" OR "infection control") AND ("survival" OR "persistence"), OR the organisms listed in Supplementary Table S1.

Study selection

All identified publications were imported from Ovid MEDLINE, CINAHL, and Scopus into Covidence (www.covidence.org), a systematic review software programme, for title, abstract, and full-text screening. Following duplicate removal, titles and abstracts of the remaining citations were screened by two researchers (L.P. and O.S.) against the eligibility criteria (Table I).

Any conflicts were reviewed by one of two senior researchers (P.R. and B.M.), who also checked a 20% sample of the first authors' title/abstract screening results. Relevant articles were then divided equally between two researchers (L.P. and O.S.) for full-text assessment against the inclusion/exclusion criteria. With the support from the same two senior researchers (P.R. and B.M.) approximately 30% of the first authors' full-text assessments were crossed-screened. Any conflicting opinions were resolved through discussions held at regular meetings between four authors (O.S., L.P., B.M., P.R.).

Data extraction

From the included studies, data were extracted into a spreadsheet. Extracted data included: title, author, year of publication, location of study, setting, pathogens assessed, number/type of isolates, organism type, temperature, humidity, wet/dry environment, porous/non-porous surface, types of environments included in sampling, role of biofilm discussed, frequency of environmental sampling, inoculation time (crude, minimum and maximum), sample survivability (viable/non-viable/not discussed). In studies where they reported a range of survival times due to multiple tests, we used the longest reported survival time. Where data was not available or could be clearly interpreted from the study, we did not include those data.

Results

Our search identified 62 papers, in which the survival of 31 pathogens was undertaken in 572 tests. The studies spanned publications from 1963 to 2023 and were conducted in 14 different countries and are summarized in Supplementary Table S2. The selection process and reasons for exclusion are demonstrated in the PRISMA flowchart (Figure 1).

Table I
Eligibility criteria

Inclusion criteria	Exclusion criteria
English language	Non-peer reviewed literature, secondary and review articles, editorials, commentary articles
All methods/designs available	
Primary research	Grey literature
Peer reviewed	Non-English publications
Identifiable 'inoculation' time	Conference proceedings
	Text books
Identifiable environmental contamination of inanimate surfaces	Abstracts not available
Normal ambient conditions — representative of normal healthcare/residential aged care/social care settings	

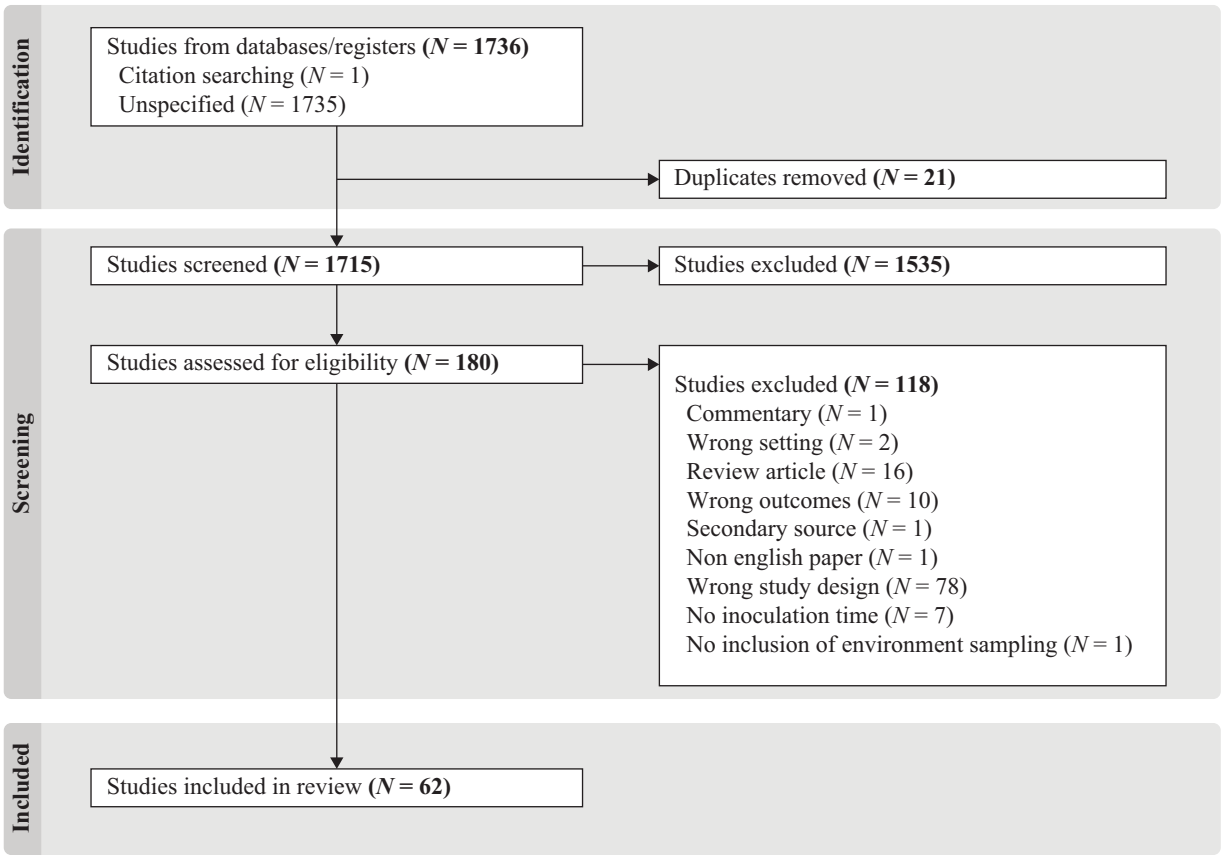


Figure 1. PRISMA flow chart for included papers.

The environmental survival time for different pathogens from the included papers are presented in Table II. We included all data reported from the included papers in this table. The longest survival time identified for a Gram-negative bacterium was 600 days (*Klebsiella pneumoniae*) and for a Gram-positive bacterium was 300 days (*S. aureus*) respectively. The survival time for *Candida* spp. was 28 days.

In studies where the type of surface a pathogen was tested on could be easily identified and classified into a porous or non-porous surface, we identified the reported range of survival times for various pathogens (Table III). There are instances where surfaces could not be classified into porous or non-porous and therefore, the data in Tables II and III at the pathogen level may appear inconsistent. From the available data, the maximum survival time on porous surfaces was higher for *Acinetobacter* sp., *E. coli*, *K. pneumoniae* and *S. aureus*.

Discussion

This scoping review has provided updated data on the reported persistence of pathogens in the healthcare environment, and adds to the growing evidence of the importance of healthcare hygiene [1,4,68]. Assadian and colleagues describe a risk-based approach to healthcare hygiene based on three inter-related risk profiles, that of the patient, the surface and the pathogen. Understanding the relationship between these is crucial to informing cleaning and disinfection practices in the different environments in healthcare [68].

This review identified that clinically important pathogens have been found to persist for long periods of time; *S. aureus* 318 days, *C. difficile* 140 days, *Acinetobacter* spp. 90 days, *E. coli* 56 days, *K. pneumoniae* 600 days, and *C. auris* 14 days. New for this review is the finding that SARS-CoV2 had a reported maximum survival of two days. This however was limited to one study. Differences in survival times in our review, compared with other evidence synthesis or evidence summaries, may be explained by different search methods and different inclusion criteria, in particular conditions we were interested in papers representative of normal healthcare, residential aged care or social care settings.

Pathogens surviving in the environment for varying points of time, potentially for long periods of time, emphasizes the importance of routine and terminal room cleaning, in addition to the cleaning of equipment between patients. The critical importance of cleaning is further supported by evidence of an increased risk of pathogen acquisition from prior room occupants of *S. aureus*, *C. difficile*, *Acinetobacter* spp. and *Klebsiella* spp. [1] which we have found to survive between 90 and 600 days. A multi-modal approach to environmental cleaning has been suggested as being the most beneficial approach, inclusive of cleaning and care staff [69,70].

This review identified some differences in survival times for several pathogens when compared with Kramer *et al.*'s review [4], e.g, *E. coli*, *Serratia* spp., *Salmonella* spp. It is uncertain why these differences were identified, but one explanation may be differences in the search method and inclusion/exclusion criteria.

Table II
Range of survival by pathogen

	Pathogen	Range of survival in days (unless otherwise indicated)	Studies (references)
Gram positive	*Staphylococcus aureus*	<1 min to 318	[7–32]
	Clostridioides difficile	0.13–140	[33–36]
	Coagulase-negative *Staphylococcus*	<1 min to 28	[12,23,24,37]
	Micrococcus spp.	10–10	[12]
	Streptococcus mutans	0.13–0.2	[21]
	Bacillus spp.	1–28	[22,24]
	Enterococcus spp.	0.02–287	[10,12,14,15,19,22,24,39,43,45,47–49]
Gram negative	*Acinetobacter* spp.	0.04–90	[12,14,15,22,24,29,38–43]
	Burkholderia cepacia	0.13–8	[12,44]
	Citrobacter freundii	0.06–0.11	[45]
	Escherichia coli	<1 min to 56	[8,10,12–15,20–24,43,45,46]
	Klebsiella pneumoniae	0.57–600	[15,43,45,50,51]
	Proteus mirabilis	0.16–0.16	[43]
	Pseudomonas spp.	0.08–7	[8,10,12,15,18,19,22,24,29,43,44,47,52,53]
	Salmonella spp.	0.29–5	[12]
	Serratia spp.	0.29–20	[12,14,15,22,43]
	Stenotrophomonas maltophilia	0.29–1	[12]
	Haemophilus influenzae	1–1	[19]
Fungi	*Candida auris*	14–14	[54]
	Candida spp.	0.13–28	[20–22,36,54,55]
Virus	Animal virus	0.5–7	[56,57]
	Coronavirus	0.04–20	[58–60]
	Cytomegalovirus	<1 min to 0.01	[61]
	Human virus	<1 min to 12	[57,62–66]
	SARS-CoV	1–2	[67]

Human virus – hepatitis A virus, herpes simplex, human immunodeficiency virus, influenza, parainfluenza, respiratory syncytial virus. Animal virus – pseudorabies, bovine viral diarrhoea virus, feline calicivirus, canine parvovirus.

In alignment with Assadian's emphasis on understanding the surface profile risk, this review found that generally pathogens are reported to survive longer on porous surfaces. Whilst much of the healthcare environment is comprised of non-porous surfaces, the opportunity for harbouring persistent pathogens is facilitated through porous surfaces found with gowns, paper records, bedding and clothing, all common features in a hospital environment.

There are limitations in this review. We were unable to replicate Kramer's search methods from the published review,

Table III
Range of survival time by pathogen and surface

Surface	Pathogens of interest [c]	Range of survival in days (across studies)	Studies (references)
Non-porous[a]	*Acinetobacter* spp.	0.29–60	[12,14,15,22,24,29,41]
	Clostridioides difficile	0.13–140	[33,35,36]
	Escherichia coli	0.25–11	[8,12,14,15,20,22,24]
	Klebsiella pneumoniae	2–2	[15]
	Pseudomonas spp.	0.21–7	[8,12,15,22,24,29,47,52]
	Staphylococcus aureus	0.04–60	[8,14,17,20,22,24,26,27,29,31,32]
Porous[b]	*Acinetobacter* spp.	1.5–90	[12,40,42,43]
	C. difficile	0.25–3	[35]
	E. coli	0.29–25	[12,13,22,43]
	K. pneumoniae	4–600	[43,50]
	Pseudomonas spp.	0.08–7	[12,18,43,47]
	S. aureus	1–168	[7,12,13,16–18,22,30–32]

[a] Examples of non-porous samples identified included: glass, vinyl, stainless steel, plastic, metal, ceramic, copper, Formica, enamel.
[b] Examples of porous surfaces included: paper, linen, wood, sponge, cotton, polyester, wool, fabric.
[c] Selected pathogens chosen, of important relevance to infection prevention. Full details of all papers and results are provided in Supplementary data.

this may explain a difference in the studies identified and reported survival times. The decision to perform a scoping review was made once it became clear a systematic review was not feasible given the broad range of heterogenous studies identified, therefore we are unable to report on the strength or quality of the studies. Importantly differences in sampling, laboratory techniques and the number of different experiments per organism in each study may also have influencde the data. Many of the studies were poorly described, revealed little data and there was inconsistent reporting of organism nomenclature. Another limitation is that the effect of survival micro-organisms in spore form or as a dry surface biofilm has not been reported in this review. Some studies have demonstrated survival times of greater than a year for MRSA [71], however initial conventional sampling methods showed no growth. The inability of conventional laboratory methods in the detection of viable but non-culturable environmental organisms has been demonstrated in other studies [72—74]. This means that our findings could be considered as a minimum potential survival time for biofilm-forming organisms such as *Candida auris* [75].

The importance of healthcare hygiene in the prevention of HAIs in undeniable. Inoculated, high-touch surfaces represent an important reservoir in facilitating infection perpetuation within healthcare facilities. Contamination of hands is a common method of transmission for nosocomial pathogens [76—78]. Contaminated surfaces can facilitate transmission of pathogens to hands and hands similarly may transfer pathogens to surfaces [79—82]. Cleaning and disinfection practices need to be informed by a risk-based approach, and also need to include appropriate training, audit and feedback, proven to be effective when adopted in a 'bundle' approach [2]. Further research is required to identify more effective methods of detecting environmental contamination including biofilms, efficient cleaning regimes and the efficacy of enhanced chemistries and 'no-touch' technologies to eliminate persistent pathogens.

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Author contributions

L.P.: methodology, data collection, data analysis, writing — original draft, review and editing. O.S.: methodology, data collection, data analysis, writing — original draft, review and editing. B.G.M.: conceptualization, methodology, formal analysis, data curation, writing — review and editing, supervision. A.J.: methodology, data curation, writing — review and editing. M.K.: conceptualization, methodology, data curation, writing — review and editing. D.J.B.: conceptualization, methodology, writing — review and editing. P.L.R.: conceptualization, methodology, formal analysis, data curation, writing — original draft, review and editing, supervision.

Conflict of interest statement

The authors report no conflicts of interest.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jhin.2024.01.023.

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