Role of the Household Environment in Transmission of *Clostridioides difficile* Infection: A Scoping Review

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Abstract **The environment plays a role in healthcare-associated *Clostridioides* (formerly *Clostridium*) *difficile* infection (CDI); however, the role of the environment in community-associated CDI is unknown. The objective of this scoping review was to describe the literature related to the transmission of *C. difficile* in the household environment. We conducted searches of four electronic health and science databases to identify relevant studies. In total, 39 articles published between 1981 and 2020 met the a priori inclusion criteria. Slightly over one half (51.3%, 20 out of 39) of the articles were nonsystematic review articles and thus we excluded them from the synthesis of results. Overall, we included 19 articles in the synthesis of results. None of the studies were experimental studies. Studies assessed or estimated the prevalence of *C. difficile* on household surfaces, colonization of household members (human and animal), or the risk of transmission in the household. This scoping review provides an overview of the global literature related to the role of the household environment in transmission of *C. difficile*. We found a lack of research in this area. Further studies are needed and ideally would be designed to follow household members over time and to test the effectiveness of interventions such as targeted hygiene protocols.**

Introduction

Clostridioides difficile is a pathogen that has been recognized for decades. Historically, *C. difficile* infection (CDI) has been regarded as a healthcare-associated infection (Roth, 2016). Cases of CDI, however, are increasingly being identified in individuals without traditional risk factors for CDI (Delate et al., 2015), suggesting that infections are related to exposure in community settings.

C. difficile spores survive in the environment for several months, and transmission of *C. difficile* has been linked to contaminated surfaces and the hands of healthcare professionals in healthcare settings (Kim et al., 1981). Infection prevention and control practices in healthcare settings include strict environmental cleaning and disinfection protocols. People with CDI can excrete *C. difficile* spores for many weeks posttreatment (Jinno et al., 2012; Riggs et al., 2007; Sethi et al., 2010), which is generally postdischarge from the healthcare setting. Therefore, it is likely that contamination of the household environment occurs, posing a risk to household inhabitants (both human and animal), including a risk of reinfection for the index case.

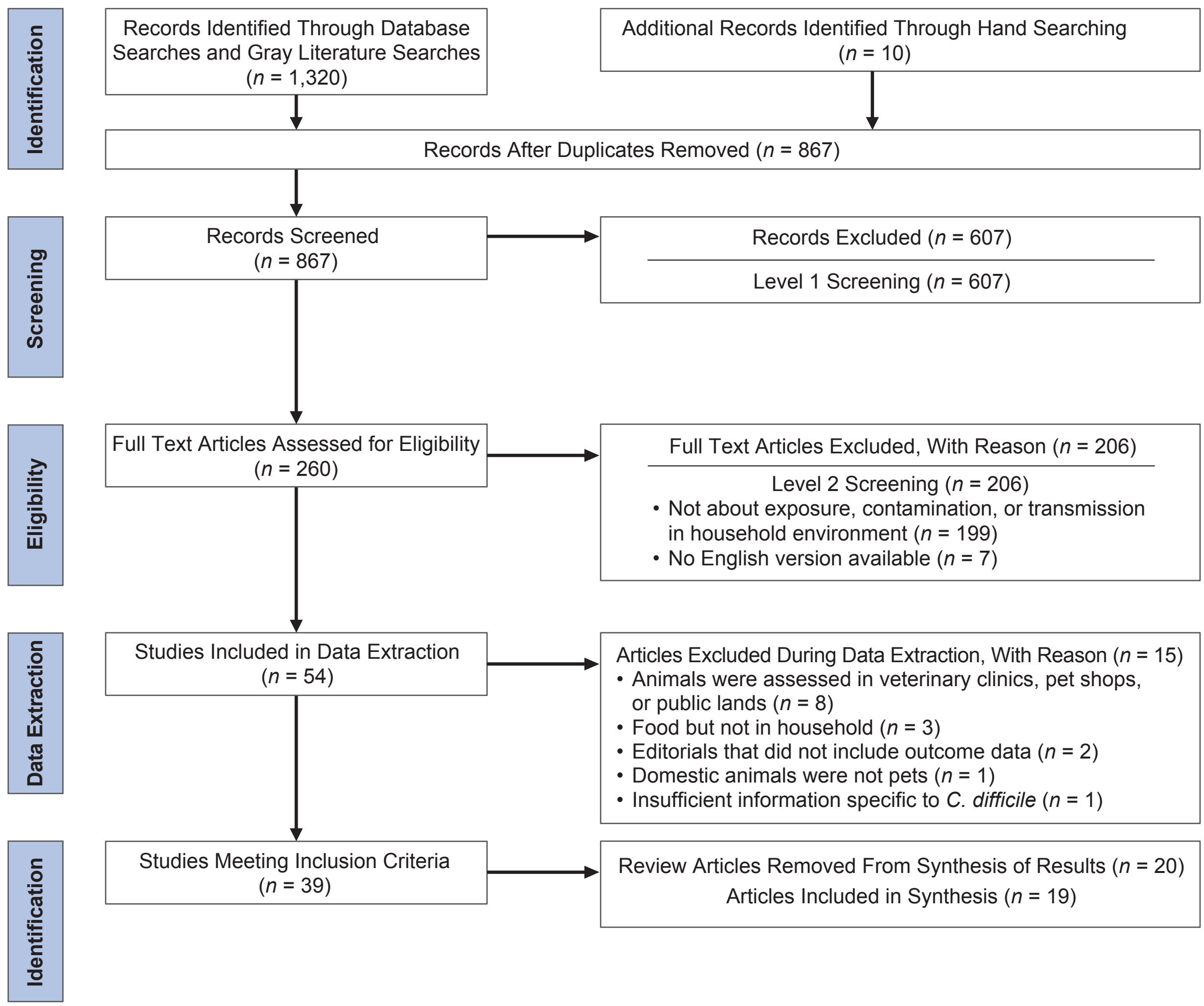
A survey of infection control professionals in hospitals in Ontario, Canada, determined that if household hygiene advice was provided to patients on discharge, it did not contain adequate direction for patients to remove or inactivate *C. difficile* spores from their household environment. Most (66.7%, 30 out of 45) of the infection control professionals who responded, however, thought that the household environment was important in the transmission of *C. difficile* (Egan et al., 2019). Nonetheless, one of the barriers to providing advice for an effective household hygiene protocol was a lack of knowledge about the role of the environment in the transmission of CDI in the household (Egan et al., 2019).

Fecal–oral transmission of enteric pathogens likely occurs in the household environment (Curtis et al., 2003) and routine cleaning could be insufficient to remove pathogens (including *C. difficile*) that can be present when a household member has an infection (Kagan et al., 2002). Researchers have speculated that the same principles of transmission and control of *C. difficile* that apply to healthcare settings should apply also to households (Girotra et al., 2013). Specific studies of *C. difficile* transmission in the household environment, however, seem to be lacking.

The objective of this scoping review was to describe the volume and breadth of scientific literature related to transmission of *C. difficile* in the household environment.

FIGURE 1

Flowchart of Records for Scoping Review for the Role of the Household Environment in the Transmission of *Clostridioides difficile* Infection



Methods

This scoping review followed guidelines by Arksey and O'Malley (2005) and is reported using the Preferred Reporting Items for Systematic Reviews and Meta-Analysis Extension for Scoping Reviews (PRISMA-ScR) guidelines (Tricco et al., 2018). Prior to beginning the literature search, a protocol was registered in the University of Guelph institutional repository called the Atrium (https://hdl.handle.net/10214/21319).

Studies were eligible if they described some aspect of transmission of *C. difficile* in the household environment. Studies of humans and domestic animals within the household along with studies of the household environment itself were eligible.

Keyword searches included variations of the concepts for "household" and "transmission," in addition to terms for *C. difficile*. We conducted searches using the following electronic databases through the McLaughlin Library, University of Guelph: CAB Direct, Web of Science (all database option), and CINAHL. We also searched PubMed via NCBI and conducted a search of the gray literature. Then we searched Google Scholar for dissertation abstracts, government documents, and other reports; only the first 200 citations in Google Scholar were screened for relevance due to the large number of citations identified (Bramer et al., 2017).

Hand searching was conducted of the articles' reference lists where the study population included all three of the populations of interest. Authors were not contacted to identify additional studies.

All searches were conducted by the first author on September 27, October 15, and

December 21, 2020. Search strategies were adjusted for each platform to account for variations in syntax. No date restrictions were applied, and the language was restricted to English.

Search results were uploaded into EndNoteX8 Desktop reference management software. Duplicate references were removed using its de-duplication functionality. The EndNote library was uploaded into DistillerSR systematic review software.

Screening for eligibility of both title and abstract (level 1 screening) and full text (level 2 screening) was conducted by two of the authors, working independently. Training was provided and interrater reliability scoring was used to ensure consistency.

Level 1 screening was conducted using the following questions:

- Does the article discuss *C. difficile*?
- Is the article about contamination, exposure, or transmission in the household environment?

If the reviewers agreed that the answer to either question was "no," the article was excluded. Discrepancies between the reviewers were resolved by consensus. If reviewers agreed that the answer to both questions was "yes" or "unclear," the article was moved into level 2 screening. Full text articles were acquired through University of Guelph library resources and uploaded into DistillerSR to complete level 2 screening.

Level 2 screening questions were evaluated independently by two reviewers using the following questions:

- Is the full text available in English?
- Does the article describe contamination, transmission, or exposure of *C. difficile* in the household environment?

If both reviewers answered "no" for either question, the article was excluded. Discrepancies between the reviewers were resolved by consensus. Figure 1 contains a decision flowchart outlining the inclusion and exclusion process.

A data extraction form was created in DistillerSR. Changes from the protocol were made to the data extraction form to provide additional options to characterize studies. Any conflicts were resolved through consensus. Data items extracted from the studies included characteristics, publication type, population studied, study design, study purpose, and study outcome. A short summary of each study was also extracted by one author, which was not described in the protocol. Study design was determined based on the description of how the study was conducted (i.e., methodology, purpose of study, enrollment of subjects) rather than the declaration of study authors if there was inconsistency in declaration and methodology. Table 1 contains a description of the characteristics of the studies identified and included in this scoping review. Notably, there were no experimental studies identified.

The data extracted from each study were exported from DistillerSR into an Excel 2011 spreadsheet. Descriptive statistics and graphs were then generated.

TABLE **1**

Characteristics of Studies Identified in Scoping Review Process

Study Characteristic	# (%)
Source (*N* = 39)	
Journal	34 (87.2)
Editorial	2 (5.1)
Fact sheet	1 (2.6)
Government report	1 (2.6)
Textbook excerpt	1 (2.6)
Year published (*n* = 19)	
1981	1 (5.3)
1983	1 (5.3)
2001	1 (5.3)
2010	1 (5.3)
2012	1 (5.3)
2013	2 (10.5)
2014	1 (5.3)
2016	2 (10.5)
2017	3 (15.7)
2018	2 (10.5)
2019	1 (5.3)
2020	3 (15.7)
Location (*n* = 19)	
U.S.	10 (52.6)
Canada	3 (15.8)
UK	2 (10.5)
Slovenia	2 (10.5)
Germany	1 (5.3)
Japan	1 (5.3)

Study Characteristic	# (%)
Population (*n* = 19) *	
Environment	6 (31.6)
Humans	5 (26.3)
Environment, humans, and animals	3 (15.7)
Humans and animals	2 (10.5)
Animals and environment	1 (5.3)
Humans and environment	1 (5.3)
Animals	1 (5.3)
Design (*n* = 19)	
Prevalence	9 (47.4)
Case-control	3 (15.7)
Case series	2 (10.5)
Cross-sectional	2 (10.5)
Incidence	1 (5.3)
Case-control and quasi-experimental	1 (5.3)
Other (simulation)	1 (5.3)
Randomized controlled	0 (0)
Cohort	0 (0)

Note. At the time of the literature review, the Berinstein et al. (2021) reference was prepublished online in 2020 prior to formal publication in 2021. As such, that reference is listed in this table as being published in 2020.

* Cases or household contacts of a confirmed case were the specific subject of the studies with human populations. Studies of animals assessed domestic pets. Studies of the environment included surfaces as well as food in the household.

Results

Short summaries of the included studies are provided, organized by study design (in order of frequency) and presented in the order of the population studied (humans, animals, environment, or combinations of these populations).

Prevalence Studies

A Japanese prevalence study published in 2001 involved the enrollment of 1,234 individuals from seven groups: three classes of university students (n = 234), workers at two hospitals (n = 284), employees of a company (n = 89), and self-defense force personnel (n = 627) (Kato et al., 2001). Stool samples were collected from subjects and follow-up stool cultures were requested 5–7 months later from individuals who were culture positive. Family members of culture-positive individuals also provided stool samples to be examined for colonization.

A study conducted in the UK looked at the potential of pets as a reservoir of *C. difficile* (Borriello et al., 1983). Fecal samples from dogs (*n* = 52) and cats (*n* = 20) were forwarded to researchers from veterinary hospitals and from colleagues to determine the prevalence of colonization with *C. difficile*.

The earliest reported study that estimated the prevalence of *C. difficile* in the household environment was published in 1981 in the U.S. (Kim et al., 1981). This study was conducted after the index case in an outbreak of *C. difficile* in a newborn intensive care unit experienced a recurrence of CDI after discharge home. The investigators collected samples from the bathroom (floor [*n* = 15], sink cabinets [*n* = 15], and inside toilet seat cover [*n* = 10]); bedrooms (floor [*n* = 15], bookcase [*n* = 4], linens [*n* = 10], and toys [*n* = 15]); living room (crib [*n* = 10]); utility room (floor [*n* = 10], freezer door [*n* = 5], and soiled clothing [*n* = 10]); soil in yard (*n* = 2); and tap water (*n* = 2). Samples were also collected from a control home.

A study conducted in Houston, Texas, examined 30 single family dwellings (Alam et al., 2014). Researchers collected 3–5 samples from each household. A total of 127 environmental samples from shoes (*n* = 63), bathrooms (*n* = 15), other household surfaces (*n* = 37), and dust (*n* = 12) were analyzed to determine prevalence of *C. difficile* in the household environment.

Another study also conducted in Houston, Texas, involved examining the soles of shoes (*n* = 280), doorsteps (*n* = 186), cleaning supplies (*n* = 189), kitchens (*n* = 191), and restrooms (*n* = 189) in a convenience sample of 1,079 households over a 2-year period (2013–2015) to estimate prevalence of *C. difficile* in the household environment (Alam et al., 2017).

A study conducted in the U.S. reported the examination of 35 rural and urban households to estimate the prevalence of *C. difficile* in the environment (Rodriguez-Palacios et al., 2017). A total of 467 samples of food (collected from 188 kitchen pots or refrigerators [no other detail provided]) and 278 samples of environmental surfaces (kitchen countertops [*n* = 32], sinks [*n* = 56], refrigerator shelves [*n* = 59], gloves [*n* = 23], shoes [*n* = 56], and washing machines [*n* = 52]) were collected.

One study in Slovenia of urban and rural households that had a dog involved sampling shoes, slippers, and dog paws to estimate the prevalence of *C. difficile* in the household environment (Janezic et al., 2018). In total, 20 households provided a total of 90 samples collected from dog paws (*n* = 25), shoes (*n* = 44), and slippers (*n* = 21).

Another study estimated prevalence of *C. difficile* in the outdoor household environment (Janezic et al., 2020). Researchers examined outdoor sites in the gardens of five households in Slovenia: four were rural households and one was from a suburban area. A total of five samples were taken at each house: three from the compost pile, one from the flower garden, and one from the vegetable garden.

A study conducted in Southwestern Ontario, Canada, to estimate the prevalence of *C. difficile* involved collection of environmental samples from 9 locations in each of 84 households in a convenience sample of households that had a dog (Weese et al., 2010). The sample locations were the kitchen sink and tap (*n* = 84), refrigerator shelf (*n* = 84), toilet (*n* = 83), kitchen counter (*n* = 84), vacuum cleaner contents (*n* = 81), and any pet food bowls (*n* = 84). The study also assessed colonization of dogs (*n* = 139) and cats (*n* = 14) from these households.

Case-Control Studies

A study published in the U.S. used records of military dependents receiving healthcare to evaluate risk factors related to community-associated CDI, including exposure to a family member with CDI (Adams et al., 2017). Cases were identified as those with diagnostic codes for CDI and were matched on age and sex with three controls (i.e., individuals without diagnosis codes for CDI).

A second study published in the U.S. evaluated risk factors for young children acquiring CDI (Weng et al., 2019). *C. difficile* cases were identified via the Emerging Infections Program of the Centers for Disease Control and Prevention. Controls were randomly chosen from a commercial database of telephone numbers or from birth registries; controls resided in the same surveillance catchment area. Exposure to household members who had CDI, diarrhea, or wore diapers was evaluated, as were various foods (including eggs, dairy, raw vegetables, plant-based protein, red meat, poultry, seafood, and well or spring water) as potential risk factors for CDI.

A third study in the U.S. was conducted with patients who were CDI positive (*n* = 435) and CDI negative (*n* = 461) (Berinstein et al., 2021). Cases and controls were identified using electronic medical records and then verified by manual chart review. An electronic survey was administered to assess household exposures to pets as well as intake of meat, dairy, and salad as potential risk factors.

Case Series Studies

A case series report published as an editorial in the UK reported results of a study conducted to determine the presence of CDI. The researchers searched a database of microbiological reports to identify cases of CDI with the same address or surname as a case (Baishnab et al., 2013). Individuals who appeared to live in the same household as a case were contacted for further investigation into their experiences related to CDI.

A case series study conducted in the U.S. involved telephone interviews with community-associated CDI cases (*n* = 984) to ask about frequency of exposure to household members with CDI, exposure to household pets, and consumption of food (i.e., chicken, beef, pork, lamb) during a typical week (Chitnis et al., 2013). Cases were classified into one of three levels of exposure based on the information provided in the interview. Stool samples were also collected from a convenience sample (40%) of the interviewed patients. The samples were cultured for *C. difficile*.

Cross-Sectional Studies

A study published in the U.S. to assess risk of transmission within family contacts included individuals from households with two or more members enrolled in the same health insurance plan (Miller et al., 2020). Cases of CDI were identified using diagnostic codes. Individuals were assigned to one of four groups based on their exposure to a family member (i.e., family member with CDI diagnosis in the prior 60 days or not) and their CDI status (i.e., positive or negative).

A German cross-sectional study involved enrollment of a convenience sample of geographically diverse households (n = 415) that had a dog and/or a cat. The study aim was to estimate frequency of possible exposures to pets as a source of *C. difficile* (Rabold et al., 2018). Fecal samples were collected from companion animal owners (n = 578) and animals (n = 1,447) to determine CDI status (i.e., positive or negative) as well as gather information on intensity of contact between owners and pets (e.g., sleeping in same bed, washed in tub or shower, licking face of owner) and health status of the humans (e.g., diarrhea, chronic disease).

Incidence Study

A Canadian study was conducted with patients who had been diagnosed with CDI in tertiary care centers to measure incidence in household contacts (Loo et al., 2016). Case participants (n = 51) and household contacts (n = 67) provided stool or rectal swabs and responded to a survey on risk factors on enrollment. The swabs and survey were repeated during home visits that were conducted monthly for 4 months. The study defined probable transmission in household contacts (i.e., humans or animals) as conversion of a negative to positive *C. difficile* result on one of the monthly fecal samples with an identical or closely related pulsed-field gel electrophoresis (PFGE) pattern as the index case.

Case-Control and Quasi-Experimental Study

A U.S. study involved adults experiencing recurrent CDI who were scheduled for fecal microbiota transplantation (FMT) as treatment (Shaughnessy et al., 2016). Cases were identified from patients at a University of Minnesota gastroenterology clinic. Controls were matched on age and geographic location and were recruited from outside the healthcare setting. The investigators visited each of the 16 participating households (8 of the individuals undergoing FMT and 8 controls). The households of those undergoing FMT were visited twice (7 days prior and 10 days post-FMT). Environmental samples were collected from vacuum cleaners (n = 27), toilets (n = 30), bathrooms (n = 29), computers (n = 24), bathroom doors and light switches (n = 27), microwaves (n = 24), refrigerators (n = 24), remote controls (n = 24), and telephones (n = 24) during all household visits.

The study also involved collection of stool samples from household contacts (n = 12) of index cases of patients with recurrent CDI who were undergoing FMT and were analyzed for *C. difficile* colonization. Information on household cleaning practices (e.g., frequency and use of bleach), hand hygiene, and CDI knowledge was also collected. Fecal samples were also collected from pets (n = 8) in households of individuals about to undergo or who had recently undergone FMT and compared with pets in households of those controls without CDI. Comparisons were made between cases and controls (case-control) and before and after FMT (quasi-experimental).

Simulation Study

A simulation study conducted in Canada involved the review of CDI cases in the database of a Quebec hospital (Pépin et al., 2012). Cases in the same household were identified by searching the hospital database to find individuals with the same phone number at the time of diagnosis. Census data were used to estimate the number of spouses, parents, and children of the cases and to estimate the expected number of cases in household members to calculate an estimated risk of transmission to household contacts living with a case of CDI.

Discussion

Summary of Evidence

This scoping review describes the literature examining household transmission of *C. difficile*. The results highlight several gaps in knowledge about the role of the household environment in transmission of *C. difficile*.

There were no experimental studies among the literature identified in this review, which is significant, as experimental studies provide an opportunity to minimize confounding factors and provide greater evidence to infer causality than observational studies (Dohoo et al., 2012). The studies that were most common in the current body of literature were prevalence studies of *C. difficile* in humans, animals, or the environment, the results of which cannot be used to infer causality related to the cause of infection. Prevalence studies can be informative in identifying the environmental reservoirs of *C. difficile*—but by nature of their design, they lack control groups and are therefore not appropriate to evaluate risk factors associated with CDI infection.

Most of the outcomes of the studies could be considered process or proxy outcomes in the sense that they are not measuring the most desirable outcome of incidence of CDI in response to transmission of *C. difficile*. The complexity of the transmission of *C. difficile* makes it a difficult disease to study with respect to definitively identifying when transmission of an infection has occurred. A sufficient (and currently undefined) number of *C. difficile* spores must be ingested and subsequent disruption of the intestinal microbiome must also happen for an infection to occur, but there can be significant time in between these two occurrences. This review identified only one study that defined and measured probable transmission within household members and that study followed subjects only for a 4-month period (Loo et al., 2016). This lack of longitudinal studies designed to estimate transmission risk is a significant gap in knowledge.

C. difficile is known to colonize in humans and animals and to survive in the environment, including in food and water (Warriner et al., 2017). While the specific transmission dynamics in the household are unknown, there is likely to be interaction among these three reservoirs. Only three studies identified by this review used a holistic or One Health approach to examine all potential *C. difficile* reservoirs in the household (i.e., humans, animals, and the environment). Future studies should be designed to consider all risks in household transmission.

Limitations

While the goal of this review was to identify all research related to *C. difficile* transmission in the household environment, it is possible that some relevant research was not identified in our search. One limitation of this study is that it did not intentionally search for studies related to *C. difficile* using "domestic pets" or "food" in the search terms because these studies might not be limited to the household environment. Thus, studies related to these two elements could have been missed. There was also a potential for language bias, because we excluded seven articles because they were in a language other than English.

Conclusion

The findings of this scoping review indicate a lack of research on the risk of transmission of *C. difficile* in the household environment. This lack of research is a barrier to understanding the risks posed to others in the household by a household member (human or animal) who is positive for *C. difficile*, and of the risk the environment poses to a person with nonhealthcare-associated risk factors for developing *C. difficile*.

Further studies designed to follow CDI patients over time and to measure outcomes—such as development of CDI in household contacts, studies designed to test the effectiveness of interventions such as targeted hygiene for household contacts, or environmental decontamination to prevent the development of CDI—would be helpful to better understand how the household environment might contribute to this infection. This knowledge would enable the creation of consistent household decontamination advice for CDI patients and those at risk of acquiring an infection of *C. difficile*.

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Did You Know?

The U.S. Environmental Protection Agency has designated January as National Radon Action Month. Radon is the leading cause of lung cancer deaths among nonsmokers in the U.S., claiming the lives of approximately 21,000 people each year. Learn more about the national effort to take action against radon and how to plan your outreach events at www.epa.gov/radon/national-radon-action-month-information.