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State of the Science Review

The survival and inactivation of enteric viruses on soft surfaces: A systematic review of the literature

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Background: Worldwide, enteric viruses are the main cause of acute gastroenteritis. In humans, these viruses spread via person-to-person contact, food, water, and/or the environment. Their survival and inactivation on hard surfaces have been extensively studied; however, nonlaunderable soft surfaces, such as upholstery and carpet, have received little attention. The aim of this systematic review was to determine factors that influence the survival and inactivation of enteric viruses on nonlaunderable soft surfaces.
Methods: EBSCO and Web of Science were searched for experimental studies published between 1965 and 2015 using Preferred Reporting Items for Systematic Reviews and Meta-Analyses methods. Titles and abstracts were screened using 3 eligibility criteria. The quality of all study methods was also assessed.
Results: Our search yielded 12 articles. Viruses survived between 0 hours and 140 days depending on surface and environment conditions. Virus survival was influenced by temperature, relative humidity, organic content, and deposition method. A variety of chemistries were tested across studies and were shown to have a varied effect on enteric viruses. Chlorine, glutaraldehyde, vaporous ozone, and hydrogen peroxide were the most efficacious against enteric viruses (> 3-log reduction).
Conclusions: Environmental factors, such as temperature and relative humidity, can influence survival of enteric viruses on nonlaunderable soft surfaces. The efficacy of liquid and vaporous chemistries are associated with surface and virus type.
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Acute gastroenteritis (AGE) is among the top-5 causes of death worldwide.[1] Most cases occur in young children in resource-poor countries, whereas in industrialized countries, such as the United States and in Europe, AGE sickens individuals across all age groups with the most common symptoms being vomiting and diarrhea. AGE etiologies include both microorganisms (bacteria, viruses, and parasites) and chemical compounds (toxins and pharmaceutical drugs). Enteric viruses are the most common etiology with caliciviruses, such as human noroviruses and rotaviruses, causing most cases of illness.[2-4]

The primary mode of transmission (direct or indirect) of all enterics, including viruses, is the fecal-oral or vomitus-oral route, which occurs via person-to-person contact, food, water, and/or environmental surfaces.[5] Although most cases of illness are due to person-to-person transmission, a growing body of evidence suggests contaminated environmental surfaces play an important role in spreading viruses.[6-8] Surfaces in the environment can become contaminated by direct contact with vomit or feces, soiled hands, aerosolized virus generated by vomiting, or airborne virus that settles after disturbance of a contaminated surface (eg, walking on contaminated carpeting). However, just because a surface becomes contaminated with an enteric pathogen does not mean the pathogen survives, illustrating the importance of examining their survival and persistence on surfaces. Survival of enteric bacteria and viruses has been studied on hard surfaces but little attention has been given to studying enterics, particularly viruses, on soft surfaces. It is presumed that intrinsic factors, such as surface properties or virus characteristics, and extrinsic factors, including temperature and

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relative humidity of the environment, influence survival just as they do with enterics on hard surfaces.

Studying survival of enteric viruses on soft surfaces, particularly nonlaunderable soft surfaces, is essential for 2 reasons. First, semienclosed environments, such as long-term-care facilities, restaurants, and schools are common settings for AGE outbreaks, particularly norovirus outbreaks. These settings often include many soft surfaces (eg, carpeted floors, upholstered furniture, and draperies), which epidemiologic evidence suggests the surfaces may play a role in transmission of enteric viruses.[9-13] Secondly, laboratory studies investigating transfer efficiency have demonstrated the transfer of infectious viral surrogates from soft surfaces to hands and inanimate objects.[14,15] These studies conclude that virus-surface interactions influencing survival and transmission may be much more complex on soft surfaces than hard surfaces, presumably because of the porous and 3-dimensional nature of soft surfaces, so knowledge regarding influencing factors on hard surfaces cannot necessarily be used in relation to soft surfaces.[16,17]

Identifying factors associated with survival on soft surfaces is the underpinning of the design of inactivation treatments, which are essential to prevent as well as control the spread of enteric viruses. Published literature reviews have focused primarily on the environmental contamination of hard surfaces by enteric viruses with limited attention given to soft surfaces.[18-20]

Although validated procedures have been developed to inactivate enteric viruses, such as human noroviruses (HuNoV), on hard surfaces, such procedures are not available for nonlaunderable soft surfaces. Understanding which inactivation chemistries are efficacious (> 3-log reduction) against enteric viruses is also critical to understanding survival and persistence. To our knowledge, this has not been reviewed in detail.

Our aim was to review published studies to answer the following 2 research questions: What factors influence the survival of enteric viruses on nonlaunderable soft surfaces? and, What chemistries are associated with the inactivation of enteric viruses on nonlaunderable soft surfaces?

METHODS

We used the Preferred Reporting Items for Systematic Reviews and Meta-Analyses principles to create a transparent (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) PRISMA, valid review (Fig 1). The PRISMA statement, an evidence-based set of 27 items used to conduct systematic reviews and meta-analyses, is an international standard. To be included in our analysis, each article had to meet 3 eligibility criteria: peer-reviewed in a scientific journal, published in English, and used an experimental study design that examined survival and/or inactivation of AGE-associated enteric viruses on nonlaunderable soft surfaces. A nonlaunderable soft surface material was defined as a porous material that could absorb and wick liquid. Hereafter these surfaces are referred to as soft surfaces. Please note that raw soft surface materials, in general, can be used to create both launderable and nonlaunderable surfaces. Studies in which filters, membranes, and laundry practices

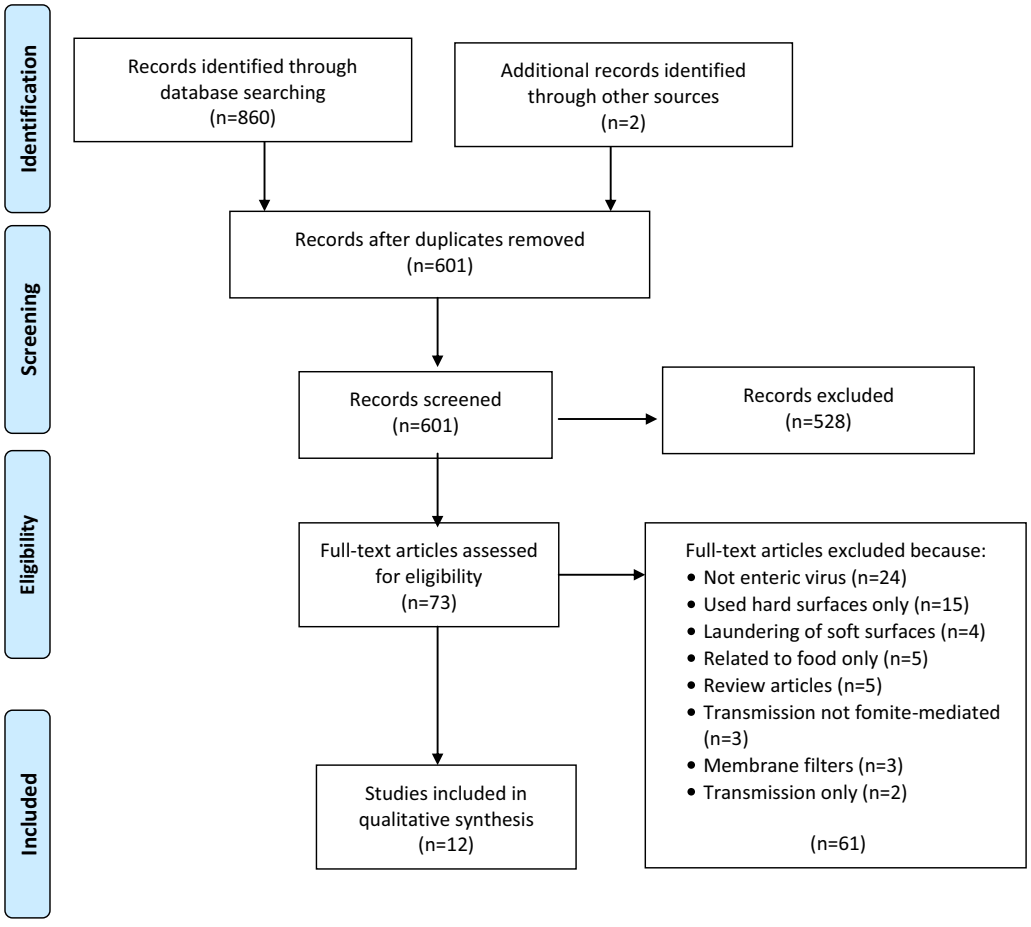

Fig 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses flow chart describing the literature search procedure.

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