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CRITICAL REVIEW

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Disinfection with sodium hypochlorite in hospital environmental surfaces in the reduction of contamination and infection prevention: a systematic review*

Desinfecção com hipoclorito de sódio em superfícies ambientais hospitalares na redução de contaminação e prevenção de infecção: revisão sistemática

Desinfección con hipoclorito de sodio en superficies ambientales hospitalarias en la reducción de contaminación y prevención de infección: revisión sistemática

Samantha Storer Pesani Pereira[1], Hadelândia Milon de Oliveira[2], Ruth Natalia Teresa Turrini[1], Rúbia Aparecida Lacerda[1]

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[1] Universidade de São Paulo, Escola de Enfermagem, Departamento de Enfermagem Médico-Cirúrgica, São Paulo, SP, Brazil.

[2] Universidade de São Paulo, Escola de Enfermagem, Programa de Pós-Graduação em Enfermagem na Saúde do Adulto, São Paulo, SP, Brazil.

ABSTRACT

Objective: To search for evidence of the efficiency of sodium hypochlorite on environmental surfaces in reducing contamination and prevention of healthcare-associated infection HAIs. **Method**: Systematic review in accordance with the Cochrane Collaboration. **Results**: We analyzed 14 studies, all controlled trials, published between 1989-2013. Most studies resulted in inhibition of microorganism growth. Some decreased infection, microorganism resistance and colonization, loss of efficiency in the presence of dirty and surface-dried viruses. **Conclusion:** The hypochlorite is an effective disinfectant, however, the issue of the direct relation with the reduction of HAIs remains. The absence of control for confounding variables in the analyzed studies made the meta-analysis performance inadequate. The evaluation of internal validity using CONSORT and TREND was not possible because its contents were not appropriate to laboratory and microbiological studies. As a result, there is an urgent need for developing specific protocol for evaluating such studies.

DESCRIPTORS

Disinfection; Sodium Hypochlorite; Health Facilities; Cross Infection; Review.

Correspondence Addressed to:
Hadelândia Milon de Oliveira
Rua Terezina, 495, Adrianópolis
CEP 69057-070 – Manaus, AM, Brazil
hmilon@usp.br

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INTRODUCTION

Over 30 years ago, Spaulding established an approach to the treatment of hospital equipment, classifying them according to their potential risk of contamination and transmission of infection in: critical, semi-critical and non-critical items[1]. This classification also founded several guidelines recommendations for aseptic procedures[2-5].

According to this classification, the critical items are those which come into direct contact with sterile tissues or vascular system as well as other items that are connected to them. They, therefore, need sterilization. The semi-critical items come into contact with mucous membranes or non-intact skin. In these cases, high-level disinfection is recommended. And non-critical items come in contact with intact skin, but not mucous membranes, so the only recommendation is cleaning[1].

In 1991, the Centers for Disease Control and Prevention (CDC) proposed an additional category to the original Spaulding classification for non-critical items called environmental surfaces which, in turn, can be divided into equipment surfaces (X-ray apparatus, hemodialysis machine etc.) and housekeeping surfaces (furniture, floor, wall, table top etc.)[6].

There are still doubts about the treatment to be given to environmental surfaces. Theoretically, if included as non-critical items in the original Spaulding classification, they only need cleaning[1]. But the Disinfection and Sterilization in Healthcare Facilities guidelines proposed by CDC considers that environmental surfaces are frequently touched by hands and may potentially contribute to secondary transmission by contaminated hands of health professionals or by contact of medical equipment, which are subsequently used in patients[4]. It is also known that certain microorganisms that cause healthcare-associated infections (HAIs) are resistant to common cleaning processes, survive for long periods on surfaces under dry conditions and can be transferred not only through hands, but also by air movement in the environment[7]. Such considerations have been referred to defend the disinfection and not just cleaning environmental surfaces.

Virtually, the risk of transmission of infection by non-critical items has not been documented[7]. However, a systematic review has shown that available studies do not yet allow a conclusion and, given the complex and multifactorial nature of HAIs, well-designed studies that systematically investigate the role of disinfecting surfaces in the transmission of infection are still needed[8]. In turn, the National Evidence-Based Guide Related to Infection Prevention in Health Care (epic3), instead of generalizing the treatment of any item recommend levels of cleaning or disinfection procedures, according to circumstances of use, contamination and occurrences of cases of colonization or infection[9].

Despite the new products and new technologies for disinfection procedures, sodium hypochlorite is still one of the most widely used and accessible products in terms of cost and benefit. This study intends to seek evidence on their efficiency on environmental surfaces in reducing contamination and prevention of healthcare-associated infections - HAIs.

METHOD

A systematic review in accordance with the recommendations of the Cochrane Collaboration was conducted. The searches were performed from December 2013 to February 2014 in the databases COCHRANE, LILACS, PubMed/MEDLINE, SciELO, CINAHL, in addition to references cited in the studies found. We used the PICO strategy: Participants = tests in situ or in vitro with microorganisms commonly isolates from environmental surfaces and medical equipment; Intervention = sodium hypochlorite application; Comparison = other products or different concentrations of hypochlorite; Outcome = degree of colonization reduction, contamination or microorganism resistance, or prevention of HAIs.

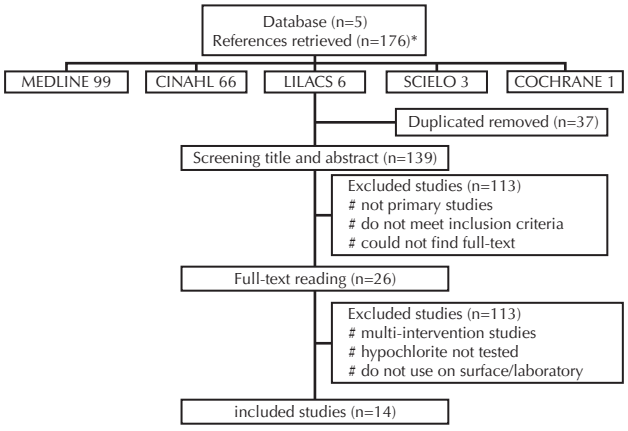
The inclusion criteria were: primary studies without language restriction and publication period, obtained in full. Exclusion criteria were: multimodal interventions, the lack of use of sodium hypochlorite and the non-use of the product on laboratory surfaces.

For the selection of the descriptors, we used the tools provided by CINAHL (Cumulative Index to Nursing and Allied Health Literature), MeSH (Medical Subject Headings Section) of the PubMed/MEDLINE and DeCS (Health Sciences Descriptors) and Synonyms combinations of terms obtained by means of prior readings, resulting in combinations: "sodium hypochlorite/pharmacology" AND "disinfection/methods" AND hospitals AND surfac* / "infections control/methods" AND "environmental microbiology" AND hospitals AND surfac* /"cross infection" AND "sodium hypochlorite" / "sodium hypochlorite/pharmacology" AND hospitals. The search strategy used was the same for each database, the screening was performed for more than two reviewers.

The data analysis criteria followed the steps: 1) screening of studies; 2) study characteristics (methodological design, scope, setting, tested microorganism, sodium hypochlorite concentration, outcome, conclusion); 3) analysis of evidence provided by TREND protocol version 1.0 (designed for non-randomized studies)[10] and CONSORT (designed for randomized trials)[11], if their applications were possible.

RESULTS

Figure 1 shows the result of the flow chart diagram. There was a predominance of studies from PubMed/Medline (99), followed by CINAHL (66), LILACS (7), SciELO (3) and COCHRANE (1). Most studies were excluded because they were duplicates, not primary study, did not meet the question asked, or was not possible to obtain the full-text to apply the inclusion or exclusion criteria. Of the 26 remaining studies after reading in full, the other 12 studies were excluded since they are simultaneous multi-interventions, they did not test the sodium hypochlorite or have it tested in non-environmental surface or tested along with other products, preventing recognition of their isolates effect. Thus, 14 studies were included.



*No study was found by reading references of studies obtained from the databases.

Figure 1 – Selection process of studies in the databases - Sao Paulo, SP, Brazil, 2014

A total of five full-text studies not found were excluded: 1) Hoefel HHK, Porto BS, Petrillo VF. Soluções germicidas e detergentes para uso no Hospital de Clinicas de Porto Alegre/Desinfetantes e sabonetes. Rev. HCPA Fac. Med. Univ. Fed. Rio Gd. Sul 1988;8(3):208-11; 2) Coates D. Disinfectants and spills of body fluids. Nurs RSA. 1992 Jun;7(6):25-7; 3) Kaboth U, Junge U. Prophylaxis of viral hepatitis. Clin Gastroenterol. 1974 May;3(2):453-70; 4) Carswell JW. Precautions against HIV transmission in hospitals.Trop Doct. 1989 Jul;19(3):131-2; 5) Lehman HH. Flame-resistant fabrics. Hospitals. 1973 Oct 16;47(20):98-106.

Of the included studies, 12 were published in the twenty-first century, four studies in the last decade (2010-2013). Only two were published in the previous century (1989-1999). The publications were mainly on internationally recognized and specialized journals on the topic of HAIs: Infection Control and Hospital Epidemiology (5); Journal of Hospital Infection (5); American Journal of Infection Control (2). Two were published in Brazil, one of them also in a specialized journal on the topic of HAIs (Brazilian Journal of Microbiology) and another in a general nursing journal (*Ciência, Cuidado e Saúde*).

Table 1 presents a summary of the included studies, containing scope, types of study, testing and outcome, investigated microorganisms, hypochlorite concentrations applied and conclusion.

Table 1 – Synthesis and evaluation of the studies included in the systematic review - Sao Paulo, SP, Brazil, 2014.

Ref.	Type of study	Scope	Setting	Microorganism	Outcome	Concentration of Sodium hypochlorite	Conclusion on hypochlorite efficiency
12	Controlled trial*	Bacterial resistance to antiseptics and disinfectants in two hospitals.	In vitro	MRSA (isolates from surface. environmental and ICU equipment)	Microbial resistance	0.05% 0.1% 0.2%	Effectiveness similar to 1% and 2% hypochlorite, 2% chlorhexidine, 2% quaternary ammonium , 2% peracetic acid and 10% formaldehyde. Less effective for 4% acetic acid, 70% ethanol and 2% glutaraldehyde.
13	Controlled trial*	Effects of hospital cleaning and disinfectant agents and survival of the epidemic resistant bacteria.	In vitro	*C. difficile* spore and vegetative (isolates from human faecal emulsion)	Microbial inactivation	0.5% detergent	All products and concentrations (3-Chloro-based formulations, 1 detergent and 1 hydrogen peroxide) inhibited growth in culture, however, in traditional hypochlorite concentrations were only able to inactivate spores.
14	Controlled trial*	Phenolic X Sodium hypochlorite, cleaned, dirty conditioned and contaminated with blood and bodily fluids.	In vitro	S. *aureus (NCTC4163)*, E. coli (NCTC 8196), P aeru. Ginosa (NCTC 6570)	Microbial inactivation	0.25%	Phenolics and hypochlorites are substantially inactivated in the presence of organic matter. Sodium hypochlorite, even at high concentration (10000ppm) and phenol may be ineffective for treating blood splash applied to 9 parts of disinfectant to 1 part of blood.
15	Controlled trial*	Sodium hypochlorite Action X peracetic acid.	In vitro	MRSA (isolates case of hospital infection)	Microbial inactivation	0.1%	Both disinfectants were equivalent after 5 minutes of contact with MRSA suspension. The increased time for 10 min intensified action, allowing the death of the bacteria at concentrations of each of the two disinfectants 10 times lower
16	Controlled trial*	Action of oxidizing microbicides in soiled surfaces in relatively short contact times at room temperature.	In vitro	*C. difficile* (clinical isolate spores)	Microbial inactivation	0.1%, 3% 0.5% and 0.5% acidified	All inactivate spores in times depending on the concentration. Hypochlorite and hypochlorite acidified regular 5000mg/L 10 minutes; regular hypochlorite 3000mg/L: 20 minutes; Hydrogen peroxide: 13 minutes; chlorine dioxide and hypochlorite regular 1000mg/L: 30 minutes.

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Ref.	Type of study	Scope	Setting	Microorganism	Outcome	Concentration of Sodium hypochlorite	Conclusion on hypochlorite efficiency
17	Controlled trial*	Antiseptics and detergents action against *Candidas*.	In vitro	*albicans, tropicalis, lusitaniae, parapsilosis, kefyr, labrata* (clinical isolates)	Growth inactivation	5.25%	Varying degrees of growth inhibition as applied product (4% chlorhexidine alcohol, 10% povidone, 3% chloroxylenol; 5.25% sodium hypochlorite) hypochlorite showed growth inhibition after 30 seconds of contact.
18	Controlled trial*	Germicidal activity of two antiseptic and one hospital disinfectant after 5 minutes of contact.	In vitro	Gram-susceptible and resistant (isolates from University and hospital)	Microbial reduction	0.01% 0.1%	Although with significant variations depending on the concentration. A 0.1% was effective against 92.2% of all strains after 5 minutes. Similar effect for antiseptic (4% chlorhexidine chlorhexidine with cetrimide). 0.01% Hypochlorite decreased significantly the effect.
19	Controlled trial*	Bactericidal activity against five disinfectants isolates from various environmental surfaces and microorganisms susceptible and resistant equipment to antibiotics.	In vitro	*MRSA, E. spp, P. aeruginosa, K. Methicillin-resistant pneumoniae, S. aureus, S. epidermidis, S. haemolyticus, S. marces* cens, E. cloa cae, E. coli, P. mirabilis	Microbial inactivation	0.5; 1%; 2%	The most effective disinfectants were hypochlorite and aldehydes. Phenolic and quaternary ammonium need to be used at higher concentrations than suggested in the literature. Out of 21 strains resistant to antibiotics, 11 (52%) and 8 (38%) were resistant to quaternary ammonia and phenolic compounds, respectively. Among the six isolates susceptible to the antibiotic, two (33%) showed the same resistance to disinfectants. Wide diversity and lack of correlation between susceptibility to antibiotics and susceptibility to disinfectants in the hospital strains. No statistically significant difference of action for resistant and susceptible strains.
20	Controlled before and after , Randomized for surface.	Surfaces daily cleaning with quaternary ammonium (before) and sodium hypochlorite (after) in high incidence areas of infection	In situ (rooms and surface of frequent touch)	C. difficile	Infection	0.55%	Reduction of incidence of C. *difficile* infection in 85% of 24.2 to 3.6 cases per 10,000 patient-days and prolongation of the mean time between the cases of 8 to 80 days. However, there is recognition of the limitations to control all confounders.
21	Controlled before and after , Randomized for surface	dry steam hydrogen peroxide X hypochlorite in the disinfection of surfaces .	In situ	C. difficile (isolates floors and furniture of patient rooms)	Contamination reduction	0.5%	But significantly lower reduction to the dry steam of hydrogen peroxide - System of dry steam hydrogen peroxide: 91% - Sodium hypochlorite: 50%
22	Controlled trial*	Infection before and after exchange of disinfectant for final cleaning in 3 hospitals.	*In situ* (room and equipment surfaces	C. difficile (isolates from infected patients)	Infection	0.5%	Reduced incidence of infection of 0.85 to 0.45 and reduction of the prevalence in 48% for the two intervention years, compared to the quaternary ammonium.
23	Controlled trial*	Infection during outbreak and after intervention with disinfection in a medical ICU and other surgical ICU in two phases: 2012 and 2013.	In situ (surface and equipment)	C. difficile	Infection	0.5%	Significant reduction of *C. difficile* infection Medical ICU: 16.6 to 3.7 cases/1000 patient-days in the first stage and 2.8 in the second stage; Surgical ICU: 10.4 to 3.9 cases/1000 patient-days in the first stage and 2.2 in the second stage.

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Ref.	Type of study	Scope	Setting	Microorganism	Outcome	Concentration of Sodium hypochlorite	Conclusion on hypochlorite efficiency
24	Controlled trial, cross-over	Sodium hypochlorite X neutral detergent in reducing infection .	In situ (two hospital areas)	C. difficile	Infection	1000ppm 0.1%	Area cleaned with hypochlorite: significant reduction of infection: 8.9 to 5.3 cases /100 admissions. Clean area with detergent: no significant effect. There is some evidence that hypochlorite for cleaning environmental surfaces significantly reduces the incidence of *C. difficile* infection, but emphasizes the potential for confounding factors.
25	Controlled trial*	Various virus persistence in dry surfaces and disinfecting effect on the infectivity of viruses with and without rehydration before disinfection.	In vitro (isolate in plasma and culture)	lipid and non-lipid virus enveloped transmitted by the human and nonhuman blood	Virus inactivation	0.1%	Infectious virus remained for long periods on surfaces when dry. All disinfectants tested (9.1% sodium hypochlorite, 80% ethanol, 0.1 NaOH) significantly reduced the survival of the dry virus, but rehydration in plasma offered protective effect, reducing their actions. Hypochlorite resulted in a reduction of >4 log for all viruses under dry conditions, but limited when rehydrated in plasma, except for HIV and PRV that had complete inactivation.

All studies used interventions and tested the action of sodium hypochlorite. Regarding the type of intervention, they are divided between those which conducted tests only in laboratory (*in vitro*)[12-19] and those which tested samples directly (*in situ*) in various environmental surfaces: floors, walls, equipment etc.[20-24]. Thus, all induced microbiological tests. Among the tested microorganisms, most strains represented clinical isolates from patients or surfaces and equipment, being resistant to several antibiotics. The most tested microorganism was C. *difficile*[13,16,20-24], followed by S. aureus, MRSA or not[12,14-15,19], various species of *Candida*[17] and lipophilic viruses[25], various Gram[18], *E. coli*[14] and others[19].

Only four studies sought, as an outcome, a direct correlation between microbicidal action of disinfectant and infection rates[20,22-24]. Most of them were correlated to inactivation rates, reduction or inhibition of microbial growth[13,15-19,21,25]. Furthermore, a study tested the outcome microbial resistance[12]. With two exceptions[14,25], the other studies presented results favorable to the action of sodium hypochlorite to the proposed outcomes, either for inactivation or inhibition of microbial growth[13,15-19,21], reduction of infection[20,22-24], microbial resistance[12]. Among the exceptions, one of them showed loss of efficiency in a situation of heavy dirtying with organic matter[14]. The other was effective for dry viruses, but not in the presence of rehydrated virus[25].

Although in most studies the results have been favorable to the action of hypochlorite, efficiency varied according to time of exposure and concentration. The concentrations ranged from 0.01% to 5.25%. Similarly, the concentrations of the products used for comparison.

The hypochlorite was superior to quaternary ammonium[13,19,22,25], composed by quaternary ammonium[17], detergent[13,24], hydrogen peroxide[13], povidone iodine[17], 4% chlorhexidine[17], phenolic[19]. It was equivalent to 2% quaternary ammonium[12] chlorhexidine[12], formaldehyde[12], ethanol[25], NaOH[25], peracetic acid[15], hydrogen peroxide[16], aldehydes[19], and phenol in the presence of large amounts of organic matter[14]. And it was less than the hydrogen peroxide under dry steam[21] hydrogen peroxide[16], chlorhexidine[18], and chlorhexidine with cetrimide[18].

All studies are controlled trials, thus, all of them performed interventions that included product testing and established comparisons. Only three assessed their interventions, two considering before and after with randomization[20-21], and a cross-over without mentioning randomization[24]. The randomization has been done to the surfaces for comparison of applying different products. However, authors who reported randomization in the methodology, recognized in the conclusion that this was not a randomized controlled trial, but only before-and-after randomization[20].

While all studies have used a single type of investigation (controlled trial), meta-analysis was not adequate due to the variety of resources used in conducting the interventions, regarding the source, types of microorganisms, collecting materials, means of microbial culture, surfaces, products, concentrations and outcomes. It can be considered that each study used a singular intervention strategy. None of them were similar to each other. Similarly, in the internal validity analysis, the protocols available - CONSORT and TREND were not possible to apply. The content of the checklists were not adequate to the nature of the studies whose subjects were surfaces and microorganisms.

DISCUSSION

It is known that healthcare-associated infections (HAIs) represent a substantial risk to patient safety and several transmitter pathogens of these infections are on surfaces and equipment more often handled by professionals and patients. Although the direct relationship of the presence of

pathogens in these surfaces with the transmission of HAIs is not yet sufficiently clarified, at least in specific locations and situations disinfection actions are recommended, not just cleaning[9].

It is observed that despite being one of the most traditional disinfectants, hypochlorite remains studied and compared with other technologies and products.

It was presented that hypochlorite showed superior action or equivalence to most other products with broad microbicidal action, including spores, and progressive action as longer exposure time and concentration, especially those related to HAIs transmission.

When compared to other products, hypochlorite was equal or more effective in the majority of studies, however, it was inferior in concentration of 0.5% to the dry steam system of hydrogen peroxide[21].

There were also contradictory results compared to chlorhexidine[17-18] and hydrogen peroxide[16]. The breadth and efficiency of their action were directly related to the concentration and the time employed, with variation between studies, as well as the types of microorganisms. Such situations led to varying degrees of inactivation or inhibition of microorganism growth.

Nearly all microorganisms tested corresponded to those most often responsible for occurrences of HAIs. C. *difficile* is the most tested[13,16,20-24], probably for its great ability to survive in the environment. This result favors the recognition of hypochlorite action on hospital microorganisms.

The results of the direct relationship of hypochlorite action with the transmission of HAIs are questionable, because, although four studies have sought this relationship with an outcome that showed favorable results, these studies have problematic aspects in their research designs[20,22-24]. For example, all compared the infection rates before and after the intervention, they did not control for confounding variables, mainly related to intrinsic and extrinsic risk factors. Two of them recognize this limitation[20,23].

Even so, despite obtaining significant reductions of environmental contamination (66.5%) and new colonization (24.8%). The others did not help determine if intervention occurred only with the use of hypochlorite or if there were also changes in techniques and cleaning frequency[13,22].

Thus, the 14 included studies responded favorably to the question of this systematic review, in relation to the antimicrobial action of hypochlorite, but not in reducing the occurrence of HAIs, so there is no way to conclude by evidence, either through meta-analysis, or by internal validity analysis.

Most studies of this review sought to detail the stages of the investigation; however, none of them presented references or standards for previously validated experimental procedures, determining extremely variable strategies. Moreover, although they constitute comparative studies, none of them had strict care control for confounding variables[26].

Even if the use of sodium hypochlorite present efficiency in its action against microorganisms associated with HAIs transmission, several issues still hinder the development of a protocol for safe use, including, especially, a relationship between concentration, action time, type and resistance of the microorganism, type and concentration of dirty.

CONCLUSION

Sodium hypochlorite presents undeniable microbicidal action on causative agents of HAIs. It was not possible to complete their direct participation in reducing colonization and/or transmission of HAIs, due to methodological problems of the analyzed studies, mainly related to the control of confounding variables. Overall, the studies in this review have extreme methodological variations, which was not sufficient to conclude that evidence to be prepared a hypochlorite application protocol that includes specific conditions of time of action, concentration and type of microorganism. At the same time, it urges the development of protocols to analyze the internal validity of microbiological experimental studies that precisely allow the evidence sought in this review.

RESUMO

Objetivo: Buscar evidências sobre a eficiência do hipoclorito de sódio em superfícies ambientais na redução de contaminação e prevenção de infecção associada à assistência à saúde-IRAS. **Método**: Revisão sistemática em conformidade com a Colaboração Cochrane. **Resultados**: Foram analisados 14 estudos, todos experimentais controlados, publicados entre 1989-2013. A maioria resultou em inibição de crescimento microbiano. Alguns apresentaram redução de infecção, da resistência microbiana e da colonização, perda de eficiência na presença de sujidade e vírus secos reidratados. **Conclusão:** O hipoclorito constitui desinfetante efetivo, todavia persiste a questão da relação direta com a redução de IRAS. A ausência de controle de variáveis de confusão nos estudos analisados impossibilitou a metanálise. Não foi possível avaliação de validade interna pelos CONSORT e TREND, pois seus conteúdos não se mostraram apropriados às investigações realizadas, laboratorial e microbiológica. Em razão disso, urge a necessidade de desenvolvimento de protocolo específico para avaliação de estudos dessa natureza.

DESCRITORES

Desinfecção; Hipoclorito de Sódio; Instituições de Saúde; Infecção Hospitalar; Revisão.

RESUMEN

Objetivo: Buscar evidencias acerca de la eficiencia del hipoclorito de sodio en superficies ambientales en la reducción de contaminación y prevención de infección asociada con la asistencia a la salud-IRAS. **Método:** Revisión sistemática en conformidad con la Colaboración Cochrane. **Resultados:** Se analizaron 14 estudios, todos experimentales controlados, publicados entre 1989-2013. La mayoría resultó en inhibición de crecimiento microbiano. Algunos presentaron reducción de infección, de la resistencia microbiana y la colonización, pérdida de eficiencia en la presencia de suciedad y virus secos rehidratados. **Conclusión:** El hipoclorito constituye desinfectante efectivo. Sin embargo, persiste el tema de la relación directa con la reducción de IRAS. La ausencia de control de variables de confusión en los estudios analizados imposibilitó el metanálisis. No fue posible la evaluación de validez interna por los CONSORT y TREND, pues sus

contenidos no se mostraron apropiados para las investigaciones llevadas a cabo, tanto de laboratorio como microbiológicas. En virtud de eso, urge la necesidad de desarrollo de protocolo específico a fin de evaluar los estudios de esa naturaleza.

DESCRIPTORES
Desinfección; Hipoclorito de Sodio; Instituciones de Salud; Infección Hospitalaria; Revisión.

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