Published in final edited form as:
J Am Geriatr Soc. 2013 April ; 61(4): 602–614. doi:10.1111/jgs.12175.

Infection Prevention in Long-Term Care: A Systematic Review of Randomized and Non-Randomized Trials

Mayuko Uchida, MSN[1], **Monika Pogorzelska-Maziarz, PhD, MPH**[1], **Philip W. Smith, MD**[2], and **Elaine Larson, PhD, RN**[1]

[1]Columbia University School of Nursing, Center for Health Policy, Center for Interdisciplinary Research to Prevent Infections

[2]College of Medicine, University of Nebraska Medical Center

Abstract

The purpose of this systematic review is to critically review and synthesize current evidence and the methodological quality of non-pharmacologic infection prevention interventions in long-term care (LTC) facilities for older adults. Two reviewers searched 3 electronic databases for studies published over the last decade assessing randomized and non-randomized trials designed to reduce infections in older adults in which primary outcomes were infection rates and/or reductions of risk factors related to infections. To establish clarity and standardized reporting of findings, the PRISMA checklist was used. Data extracted included study design, sample size, type and duration of interventions, outcome measures reported, and findings. Study quality was independently assessed by two reviewers using a validated quality assessment tool. Twenty-four articles met inclusion criteria; the majority was randomized control trials (67%), where the primary purpose was to reduce pneumonia (66%). Thirteen (54%) studies reported statistically significant results in favor of interventions on at least one of their outcome measures. The methodological clarity of available evidence was limited, placing them at potential risk of bias. Gaps and inconsistencies surrounding interventions in LTC are evident. Future interventional studies need to enhance methodological rigor using clearly defined outcome measures and standardized reporting of findings.

Keywords

infections; nursing homes; interventions

INTRODUCTION

Infections in residents of long-term care (LTC) facilities are common, costly, and associated with significant morbidity and mortality [1]. Institutionalized adults over the age of 65 years account for a disproportionate number of infections in LTC settings[2]. An estimated 1.6 to 3.8 million infections occur each year in LTC facilities across the nation and lead to

Corresponding Author: May Uchida, MSN, Columbia University School of Nursing, Center for Health Policy, 617 W. 168th Street Suite 238, New York, NY 10032, Phone (914) 552-9640, mu2188@columbia.edu. Alternate Corresponding Author: Monika Pogorzelska-Maziarz, PhD, MPH, Associate Research Scientist, Columbia University School of Nursing, Center for Health Policy, mp2422@columbia.edu.

Conflict of Interest:
Authors declare no conflicts of interest. See additional COI document.

Author Contributions: Study concept and design: Mayuko Uchida, Monika Pogorzelska-Maziarz, Philip W. Smith, Elaine Larson. Data Analysis, interpretation, preparation of manuscript: Mayuko Uchida, Monika Pogorzelska-Maziarz, Elaine Larson MU, MP, ELL. Final review of paper: Mayuko Uchida, Monika Pogorzelska-Maziarz, Philip W. Smith, Elaine Larson

approximately 388,000 deaths[3]. Additionally, infections in LTC result in frequent hospitalizations, accounting for 27 to 63 percent of all resident transfers[2,3]. Cost estimates for infections in LTC range from $673 million to $2 billion annually[3]. Despite such high mortality and costs associated with infections, a proportion may be preventable[3,4].

Elder LTC residents are especially vulnerable to a variety of infections due to immune dysfunction associated with aging, functional and cognitive limitations and the presence of multiple co-morbidities that affect the integrity of host resistance[5]. Common endemic infections in LTC include urinary tract infections (UTIs) and respiratory tract infections[4]. Outbreaks are also frequently reported and the most common are respiratory and enteric conditions[1,4]. Older adults in these settings also undergo frequent care transitions which have implications for the spread of pathogens[6,7]. Colonization with multiple drug resistant organisms (MDROs) such as methicillin-resistant *Staphylococcus aureus* (MRSA) and vancomycin-resistant enterococci (VRE) in both endemic and epidemic infections is increasingly prevalent[4] which adds to the complexity of prevention and management in this older population.

While there are published guidelines for infection prevention and control in LTC, effective prevention and control measures remain largely inadequate[4]. Most infection prevention interventions in LTC have predominantly been adapted from those designed for acute care—a clinical setting much different from LTC. Compared to hospitals, LTC facilities often provide care for chronic functionally impaired residents for a prolonged period of time with fewer available resources[6,8]. Therefore, directly applying hospital-based interventions to LTC is often unrealistic and may be inefficient given the nature of LTC settings. Identifying evidence-based interventions specific to LTC is needed to tailor care delivery for this growing older population. A previous systematic review examining evidence on infection prevention interventions in LTC have been limited to oral hygiene and have cited a lack of strong evidence[9]. Outbreak reports are frequently used to describe infections in this setting; however, these reports are of limited value for assessing the effectiveness of interventions. We found no systematic reviews which examined the utilization of planned intervention studies on infection prevention and control in LTC. In addition, the quality of currently available evidence is unknown. Such data are important for evaluating and developing future effective infection prevention and control practices. Hence, the purpose of this systematic review was to critically review and synthesize current evidence and the methodological quality of infection prevention interventions in LTC.

METHODS

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement[10] was used as a guide for this systematic review. PRISMA is a 27-item checklist that ensures a standard method for transparent and complete reporting of systematic reviews and meta-analyses; it is increasingly being endorsed by and adhered to for publication[11].

Search Strategy

Two reviewers systematically searched 3 electronic databases: Medline, PubMed, and Cochrane Controlled Trials Register. The search terms, “infections”, “long-term care”, “skilled nursing facilities” and “nursing home” were used in various combinations with “pneumonia”, “sepsis”, “urinary tract infections”, “blood stream infections”, “bacteremia”, “*Clostridium difficile*”, “multiple drug resistant organisms”, and “antibiotic resistant”. In addition to the primary search, reference lists of review articles were also examined for relevant citations. Other relevant studies were identified through expert consultation.

Selection Criteria

Type of Studies—All eligible trials had to meet the following inclusion criteria: intervention studies published in English from January 2001 through June 2011, conducted in LTC settings (i.e., nursing homes) with elderly (i.e., population ≥ age 65) in which primary outcomes were infection rates and reductions of risk factors related to infections. This 10 year time frame was chosen because we were interested in relatively recent interventions. Excluded were editorials, commentaries, outbreak studies and interventions in which outcomes focused only on healthcare workers and systemic pharmacological interventions (e.g., antibiotics) other than vaccines. Interventions that only evaluated the efficacy or immunogenicity of vaccines were also excluded. Additionally, we excluded interventions that were conducted solely in LTC hospitals; however we included studies if the sample of residents included both nursing homes and LTC units within hospitals. We considered the intervention to be therapeutic if it provided treatment to reduce the infection being examined. For instance, an intervention evaluating the effectiveness of providing professional oral care for preventing pneumonia was categorized under therapy. On the other hand, an intervention that evaluated the effects of a repeated education program to improve dental hygiene was categorized as educational.

Two reviewers (MU and MP) assessed study eligibility. First, MU independently screened abstract titles for which MP reviewed and confirmed eligibility. Differences in eligibility assessments were resolved by discussion between the entire review team.

Outcome Measures

The primary outcome measures were infection rates and reductions of risk factors related to infections. For instance, studies evaluating pneumonia incidence rates were considered for inclusion. Additionally, evaluation of outcomes such as cough reflex sensitivity, a known risk factor for pneumonia, were included; However, studies that solely evaluated non-specific outcomes of infections such as overall hospitalization rates, mortality and antibiotic prescription usage were excluded since these outcomes may not necessarily be a result of infections. Our primary outcomes were infection rates or risk factors related to infections. Therefore, we also excluded studies even if they reported mortality as a result of an infection if they did not examine infection rates or risk factors for getting that infection.

Data Extraction

Data were extracted based on objectives, study design, sample size, type and duration of interventions, outcome measures reported, and findings. Given the wide range of settings and services provided in LTC, care variations may exist. To further characterize the context under which the interventions were conducted, we also abstracted data by country, the number of interventions employed, the number of facilities included in a given study and whether or not the residents played a direct participatory role during the interventions.

Assessment of Methodological Quality

The same two reviewers independently assessed the quality of studies using a validated tool developed by Downs and Black[12]. This quality assessment tool lists 27 criteria and evaluates both randomized and non-randomized trials. The tool specifically attempts to measure study quality across four domains: study reporting, internal validity-bias, internal validity-confounding and external validity. As done in previously published reviews using the Downs and Black tool, the original version was slightly modified for this review[13]. The modified quality assessment scores were grouped into the following 4 ratings: excellent (26 to 29), good (20 to 25), fair (15 to 19) and poor (less than 15).

Inter-rater reliability was established using a two-step process comparing independently scored ratings. Quality scores within 2 points of each other were considered to be in agreement. First, one study initially assessed to have the greatest score difference was reviewed to make sure the criteria were being interpreted in the same way. Following discussion and resolving differences, the reviewers independently re-assessed those with score differences greater than 3. Upon completion of this process, all studies were rated to be within 2 points from each other.

RESULTS

Study Selection

The electronic database search yielded 1978 articles. After excluding duplicates, 1920 abstract titles were screened for eligibility. Of these, 1889 articles were excluded based on title screening and abstract review (see Figure 1). The main reason for excluding studies was based on the study design: the majority of the studies did not have an interventional component. Upon hand searching reference lists of recent review articles and consulting a LTC expert, 3 additional studies were included. This resulted in retrieval of 34 full text articles as potentially eligible. Upon detailed examination, 8 studies were excluded because their primary outcomes did not include infection rates or reduction of risk factors and 2 studies were excluded because they were feasibility studies leading up to the larger, more recent study conducted by the same investigator.

Characteristics of Studies

Selected characteristics of the reviewed studies are presented in Table 1. The majority of the studies were conducted in the United States (n= 9; 37.5%); the others were conducted in Japan (n=7; 29.1%), Europe (n= 4; 16.7%), and Canada (n= 4; 16.7%). Overall, the majority were randomized control trials (n= 16; 67%)[14–29], where the primary interest was to reduce respiratory infections (n=15; 62.5%) and focused on interventions that provided therapy (n= 17; 70.8%) as opposed to being educational.

Of the 15 studies that examined respiratory conditions, pneumonia was the most commonly reported infection (n=12; 50%), and the most common intervention was oral hygiene. Of the 16 randomized trials, one study [30] was a feasibility study but was included because no subsequent analysis by the same investigator was available. Eight studies[30–37] were quasi-experimental in nature but varied in terms of design complexity. For instance, Kullberg and colleagues[37] examined an oral hygiene education program using a single site pre-posttest design, while Ishikawa and colleagues[35] examined the impact of professional oral cleaning across multiple sites using three interventions.

Across the 24 studies, 12 studies (50%) had more than one component to the intervention, and more than half (n= 15; 62.5%) were conducted at multiple LTC facilities. Approximately three fourths of the studies required direct resident participation during the interventions (n= 18; 75%), whereas, a quarter of the studies tested interventions on healthcare workers, yet still evaluated resident infection outcomes (e.g., hand hygiene studies).

Most studies (n= 21; 87.5%) compared two study groups: an intervention group receiving an infection prevention or risk factor reduction treatment, and a control group receiving usual or no care. Examples of exceptions were those in which 3 dental brand cleansers were compared [17] or two solutions to irrigate urinary drainage bags were compared with water as the control [15].

The frequency of interventions varied across all and within similar intervention studies ranging from weekly to as long as 1 year. Additionally, the duration of the follow-up measurements varied from 4 days to longer than a year. Furthermore, differences were found in the content level of similar interventions. For instance, two quasi-experimental studies[31,32] evaluating the impact of alcohol based hand sanitizers on nosocomial infection rates provided hand sanitizers to healthcare workers in one facility. While Mody and colleagues[32] conducted a multimodal intervention (i.e., baseline questionnaires, 3 week basic hand hygiene education for both groups, and 12 week education period for intervention group), Fendler and colleagues[31] provided hand sanitizers and instructed staff on usage at the time of distribution.

Participants

Sample sizes varied and ranged from 20 to 1,006 residents; four studies had sample sizes less than 50. For those studies that did not require direct resident participation during the interventions, sample size was often not reported; instead, for example, investigators reported 16 nursing home units as their sample population.

Outcomes

Thirteen (54%) of 24 studies reported statistically significant results in favor of interventions on at least one of their outcome measures. Of the 9 studies reporting infection rates, respiratory infection rates were explicitly mentioned in 5 studies[18,20,21,28,31]. All other studies measured one or more infection risk-related outcomes: 8 studies measured oral bacteria (e.g., number of colony forming units, plaque scores, presence of *Candida albicans*); one study measured bacteriuria; one study measured vaccination rates; 4 studies evaluated acquisition and or eradication of multiple drug resistant organisms; 5 remaining studies measured outcomes such as cough reflex sensitivity and nosocomial infection rates without further specification.

In general, there was no standardized definition used to examine infection rates. While many studies defined an outcome measure, they varied in terms of how infections were confirmed —using clinical judgment, radiographs, other laboratory tests or all three. Three studies explicitly[31,32] or indirectly[24] mentioned using nosocomial infection definitions derived from the McGeer criteria[38], a guideline used for defining infections in LTC. One study [19] reported to monitor *S. aureus* infections based on the Centers for Disease Control and Prevention definitions, whereas another study reported to have developed their own clinical definitions of pneumonia and incorporated some of the McGeer criteria[21].

Methodological Quality of Studies

The methodological quality of the available evidence varied, and none of the included studies fulfilled all Downs and Black criteria, with quality scores ranging from 11 to 27 out of 29 possible points (mean: 18.8). The largest proportion of studies (n= 9; 37.5%) were rated as ‘fair’ quality. Alternatively, 7 studies were rated good and only 3 studies had excellent quality. Five studies received a score of 15 or less indicating poor quality. A frequently observed weakness was a lack of power analysis. In 10 of the 16 randomized studies, the randomization method and allocation concealment measures were not adequately described.

DISCUSSION

The interventions audited for this review varied considerably in terms of their content, intensity, and duration. Definitions used for infections had substantial variability, making between-study comparisons difficult. Particularly problematic was the lack of clarity in

definitions of outcome measures; some studies used clinical assessments alone whereas others included laboratory indicators. Despite the wide gaps, some critical insights and meaningful patterns have emerged from among these recent interventions.

First, the majority of interventions were randomized control trials. This was surprising given the nature of LTC settings. Since the residents live within the same facility, it is often not feasible to blind the residents or healthcare workers caring for the residents. In many of the studies reviewed, proper allocation concealment was absent, leading to lower overall quality ratings and potential risks of bias. If future interventions are to be implemented under current LTC structures (i.e., residential setting, socializing between residents) adequate study methods to blind the researchers, data analysts and statisticians should still be done; additionally, studies could utilize cluster randomized trial designs which can reduce some of the risks of bias within studies.

Second, despite the high prevalence reported in LTC, few interventions specifically targeted UTIs. Of the reviewed studies, only one study [15] carried out an intervention to reduce bacterial counts in urinary drainage bags and two studies [24,31] reported UTI rates in aggregate as part of the larger evaluation of nosocomial infection rates. The frequency of therapeutic interventions focusing on oral hygiene is not surprising given the known prevalence of pneumonia in LTC. However, more studies need to evaluate interventions aimed at other types of infections on the rise such as multi-drug resistant organisms.

Finally, only one study [22] explicitly addressed the costs of conducting the intervention. With the increasing cost of healthcare being a focal policy issue, there is serious need to pair current effectiveness data with economic evaluations. Cost-effectiveness analysis complements clinical evidence evaluation and is increasingly used to guide institutional and public policy decisions [39]. Few economic analyses of infection prevention strategies have been conducted in LTC[22]. More economic evidence is needed to guide future decisions in LTC that are tailored for this population.

Limitations

This review has several limitations. Only English-language articles published in peer-reviewed journals after 2001 were included. Limiting our search to publications after 2001, however, is justified given the dramatic changes in infection prevention and control over the past decade[7]. By including only published papers, we realize that publication bias may exist. However, given that many of the studies reported non-significant findings, we do not think this is likely. Attempts were made to be comprehensive in the search strategy; however, because our selection criteria had a narrow focus, this may have resulted in exclusion of some effective interventions. For instance, we realize that many intervention studies in LTC have focused on healthcare workers and their rates of vaccinations and hand-hygiene compliance. Additionally, it is important to note that older adults can reside in LTC settings other than nursing homes. For instance, we excluded other extended care settings such as psychiatric institutions where the residents are typically much younger than nursing home residents[4]. Furthermore, the exclusion of outbreak reports may have led to missing interventions developed during these types of events.

Implications for Practice and Future Research

Gaps and inconsistencies surrounding infection prevention interventions in LTC are evident. In general, the quality of evidence surrounding these interventions is weak. Valid data regarding infection rates and risk reduction strategies are essential for guiding surveillance and practice decisions. Perhaps most relevant, such data are vital to inform nursing home administrators and policymakers that infection prevention strategies are as important in LTC

as in hospitals for improving patient safety and quality of care. Infections in LTC, particularly those associated with multi-drug resistant organisms, are of major importance to the entire healthcare system because of the frequent transition of patients between the LTC and acute care settings.

To promote clarity in reporting of infection prevention interventions, future researchers and clinicians conducting such interventions should follow standardized protocols. One way of ensuring adequate reporting is to use existing publication guidelines endorsed by major biomedical journals such as the consolidated standards of reporting trials (CONSORT http://www.consort-statement.org/) for randomized control trials and the transparent reporting of evaluations with nonrandomized designs (TREND http://www.cdc.gov/trendstatement). Both guidelines, CONSORT, originally published in 2001 and most recently updated in 2010 and TREND, published in 2004 were developed to improve clarity and consistency of reporting research. In a review by Larson and Cortazal[11] the extent to which these guidelines have been adopted for use in peer-reviewed publications varied. In their analysis, they found 565 PubMed citations using CONSORT, while only 5 studies were retrieved using TREND. Considering the frequency in which non-randomized studies are used in infection prevention and control studies, the relatively low uptake of TREND for reporting non-randomized interventions is concerning. Additionally, other researchers have cited the need to use a more standard nomenclature to describe non-randomized interventions by uniformly referring to pre-post intervention studies as quasi-experimental to avoid confusion[40]. In our analysis, of the 24 studies published after 2001, only one randomized trial[27] reported using the CONSORT statement or other similar publication guidelines.

On the basis of our review, we recommend the adoption of existing publication guidelines to assist in establishing clarity and consistency across future interventional studies. Adoption of these guidelines should be embraced by journal authors and editors as a part of standard practice for reporting research. We refer readers to the Resource Center on Enhancing the QUAlity and Transparency Of health Research (EQUATOR http://www.equator-network.org/resource-centre/library-of-health-research-reporting/) Network for a complete list of currently available reporting guidelines as it expands on CONSORT, TREND, PRISMA and other reporting guidelines for various types of research designs.

CONCLUSION

Infection prevention in LTC facilities is an increasingly important area of research and yet significant gaps exist in the quality of interventions currently reported. Future researchers and practitioners in LTC need to establish a comprehensive understanding of accurate and consistent measures for enhancing methodological clarity using clearly defined outcome measures and standardized reporting of findings. With increased attention surrounding potentially avoidable infections, more high quality interventions will need to be tested to solve the complicated problems of infection prevention and control in LTC.

Acknowledgments

Authors would like to thank Dr. Patricia Stone, Dr. Elizabeth Cohn and Kenrick Cato (doctoral student) for their assistance with review of the manuscript.

Funding Sources: This paper was generously supported by the National Institutes of Health, National Institute of Nursing Research [T90 NR010824], [R01NR010107], [F31NR013810-01] and the Jonas Center for Nursing Excellence.

Sponsor's Role: The sponsor had no role in the design, methods, data collection, analysis and writing of this manuscript.

References

1. Jones, A.; Dwyer, L.; Bercovitz, A., et al. The National Nursing Home Survey: 2004 overview. Vol. 132009. National Center for Health Statistics; http://www.cdc.gov/nchs/data/series/sr_13/sr13_167.pdf
2. Richards C. Infections in residents of long-term care facilities: An agenda for research. Report of an expert panel. J Am Geriatr Soc. 2002; 50:570–576. [PubMed: 11943058]
3. Strausbaugh LJ, Joseph CL. The burden of infection in long-term care. ICHE. 2000; 21:674–679.
4. Smith PW, Bennett G, Bradley S, et al. SHEA/APIC guideline: Infection prevention and control in the long-term care facility, July 2008. ICHE. 2008; 29:785–814.
5. [Accessed October 1st, 2011] Older Americans 2010 Key Indicators of Well-Being. Federal Interagency Forum on Aging-Related Statistics. 2010. http://www.agingstats.gov/agingstatsdotnet/Main_Site/Data/2010_Documents/Docs/OA_2010.pdf
6. Mody L, Bradley SF, Galecki A, et al. Conceptual model for reducing infections and antimicrobial resistance in skilled nursing facilities: Focusing on residents with indwelling devices. Clin Infect Dis. 2011; 52:654–661. [PubMed: 21292670]
7. Rogers MAM. Incidence of antibiotic-resistant infection in long-term residents of skilled nursing facilities. AJIC. 2008; 36:472–475.
8. Castle NG, Engberg J. The influence of staffing characteristics on quality of care in nursing homes. Health Serv Res. 2007; 42:1822–1847. [PubMed: 17850522]
9. Sjogren P, Nilsson E, Forsell M, et al. A systematic review of the preventive effect of oral hygiene on pneumonia and respiratory tract infection in elderly people in hospitals and nursing homes: Effect estimates and methodological quality of randomized controlled trials. J Am Geriatr Soc. 2008; 56:2124–2130. [PubMed: 18795989]
10. Liberati A, Altman DG, Tetzlaff J, et al. The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate healthcare interventions: Explanation and elaboration. BMJ. 2009; 339:b2700. [PubMed: 19622552]
11. Larson EL, Cortazal M. Publication guidelines need widespread adoption. J Clin Epidemiol. 2012; 65:239–246. [PubMed: 22000815]
12. Downs SH, Black N. The feasibility of creating a checklist for the assessment of the methodological quality both of randomised and non-randomised studies of health care interventions. J Epidemiol Community Health. 1998; 52:377–384. [PubMed: 9764259]
13. Samoocha D, Bruinvels DJ, Elbers NA, et al. Effectiveness of web-based interventions on patient empowerment: A systematic review and meta-analysis. J Med Internet Res. 2010; 12:e23. [PubMed: 20581001]
14. Banting DW, Hill SA. Microwave disinfection of dentures for the treatment of oral candidiasis. Spec Care Dentist. 2001; 21:4–8. [PubMed: 11795452]
15. Washington EA. Instillation of 3% hydrogen peroxide or distilled vinegar in urethral catheter drainage bag to decrease catheter-associated bacteriuria. Biol Res Nurs. 2001; 3:78–87. [PubMed: 11931525]
16. Adachi M, Ishihara K, Abe S, et al. Effect of professional oral health care on the elderly living in nursing homes. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2002; 94:191–195. [PubMed: 12221387]
17. Gornitsky M, Paradis II, Landaverde G, et al. A clinical and microbiological evaluation of denture cleansers for geriatric patients in long-term care institutions. J Can Dent Assoc. 2002; 68:39–45. [PubMed: 11844417]
18. Yoneyama T, Yoshida M, Ohrui T, et al. Oral care reduces pneumonia in older patients in nursing homes. J Am Geriatr Soc. 2002; 50:430–433. [PubMed: 11943036]
19. Mody L, Kauffman CA, McNeil SA, et al. Mupirocin-based decolonization of Staphylococcus aureus carriers in residents of 2 long-term care facilities: A randomized, double-blind, placebo-controlled trial. Clin Infect Dis. 2003; 37:1467–1474. [PubMed: 14614669]
20. McElhaney JE, Gravenstein S, Cole SK, et al. A placebo-controlled trial of a proprietary extract of North American ginseng (CVT-E002) to prevent acute respiratory illness in institutionalized older adults. J Am Geriatr Soc. 2004; 52:13–19. [PubMed: 14687309]

21. Meydani SN, Leka LS, Fine BC, et al. Vitamin E and respiratory tract infections in elderly nursing home residents: A randomized controlled trial. JAMA. 2004; 292:828–836. [PubMed: 15315997]
22. Trick WE, Weinstein RA, DeMarais PL, et al. Comparison of routine glove use and contact-isolation precautions to prevent transmission of multidrug-resistant bacteria in a long-term care facility. J Am Geriatr Soc. 2004; 52:2003–2009. [PubMed: 15571534]
23. Watando A, Ebihara S, Ebihara T, et al. Daily oral care and cough reflex sensitivity in elderly nursing home patients. Chest. 2004; 126:1066–1070. [PubMed: 15486365]
24. Liu BA, McGeer A, McArthur MA, et al. Effect of multivitamin and mineral supplementation on episodes of infection in nursing home residents: A randomized, placebo-controlled study. J Ameri Geriatr Soc. 2007; 55:35–42.
25. Wendt C, Schinke S, Württemberger M, et al. Value of whole-body washing with chlorhexidine for the eradication of methicillin-resistant Staphylococcus aureus: A randomized, placebo-controlled, double-blind clinical trial. Infect Control Hosp Epidemiol. 2007; 28:1036–1043. [PubMed: 17932823]
26. Meurman JH, Parnanen P, Kari K, et al. Effect of amine fluoride-stannous fluoride preparations on oral yeasts in the elderly: A randomised placebo-controlled trial. Gerodontology. 2009; 26:202–209. [PubMed: 19702819]
27. Baldwin NS, Gilpin DF, Tunney MM, et al. Cluster randomised controlled trial of an infection control education and training intervention programme focusing on meticillin-resistant Staphylococcus aureus in nursing homes for older people. J Hosp Infection. 2010; 76:36–41.
28. Maruyama T, Taguchi O, Niederman MS, et al. Efficacy of 23-valent pneumococcal vaccine in preventing pneumonia and improving survival in nursing home residents: double blind, randomised and placebo controlled trial. BMJ. 2010; 340:c1004. [PubMed: 20211953]
29. Nishiyama Y, Inaba E, Uematsu H, et al. Effects of mucosal care on oral pathogens in professional oral hygiene to the elderly. Arch Gerontol Geriatr. 2010; 51:e139–143. [PubMed: 20494464]
30. Quagliarello V, Juthani-Mehta M, Ginter S, et al. Pilot testing of intervention protocols to prevent pneumonia in nursing home residents. J Am Geriatr Soc. 2009; 57:1226–1231. [PubMed: 19558483]
31. Fendler EJ, Ali Y, Hammond BS, et al. The impact of alcohol hand sanitizer use on infection rates in an extended care facility. Am J Infect Control. 2002; 30:226–233. [PubMed: 12032498]
32. Mody L, McNeil SA, Sun R, et al. Introduction of a waterless alcohol-based hand rub in a long-term-care facility. Infect Contorl Hosp Epidemiol. 2003; 24:165–171.
33. Thai TP, Keast DH, Campbell KE, et al. Effect of ultraviolet light C on bacterial colonization in chronic wounds. Ostomy Wound Manage. 2005; 51:32–45. [PubMed: 16230765]
34. Yamada H, Takuma N, Daimon T, et al. Gargling with tea catechin extracts for the prevention of influenza infection in elderly nursing home residents: A prospective clinical study. J Altern Complement Med. 2006; 12:669–672. [PubMed: 16970537]
35. Ishikawa A, Yoneyama T, Hirota K, et al. Professional oral health care reduces the number of oropharyngeal bacteria. J Dent Res. 2008; 87:594–598. [PubMed: 18502972]
36. Hutt E, Radcliff TA, Oman KS, et al. Impact of NHAP guideline implementation intervention on staff and resident vaccination rates. J Am Med Dir Assoc. 2010; 11:365–370. [PubMed: 20511104]
37. Kullberg E, Sjogren P, Forsell M, et al. Dental hygiene education for nursing staff in a nursing home for older people. J Adv Nurs. 2010; 66:1273–1279. [PubMed: 20546361]
38. McGeer A, Campbell B, Emori TG, et al. Definitions of infection for surveillance in long-term care facilities. Am J Infect Control. 1991; 19:1–7. [PubMed: 1902352]
39. Weinstein M, Skinner J. Comparative effectiveness and health care spending implications for reform. N Engl J Med. 2010; 362:460–465. [PubMed: 20054039]
40. Harris AD, Lautenbach E, Perencevich E. A systematic review of quasi-experimental study designs in the fields of infection control and antibiotic resistance. Clin Infect Dis. 2005; 41:77–82. [PubMed: 15937766]

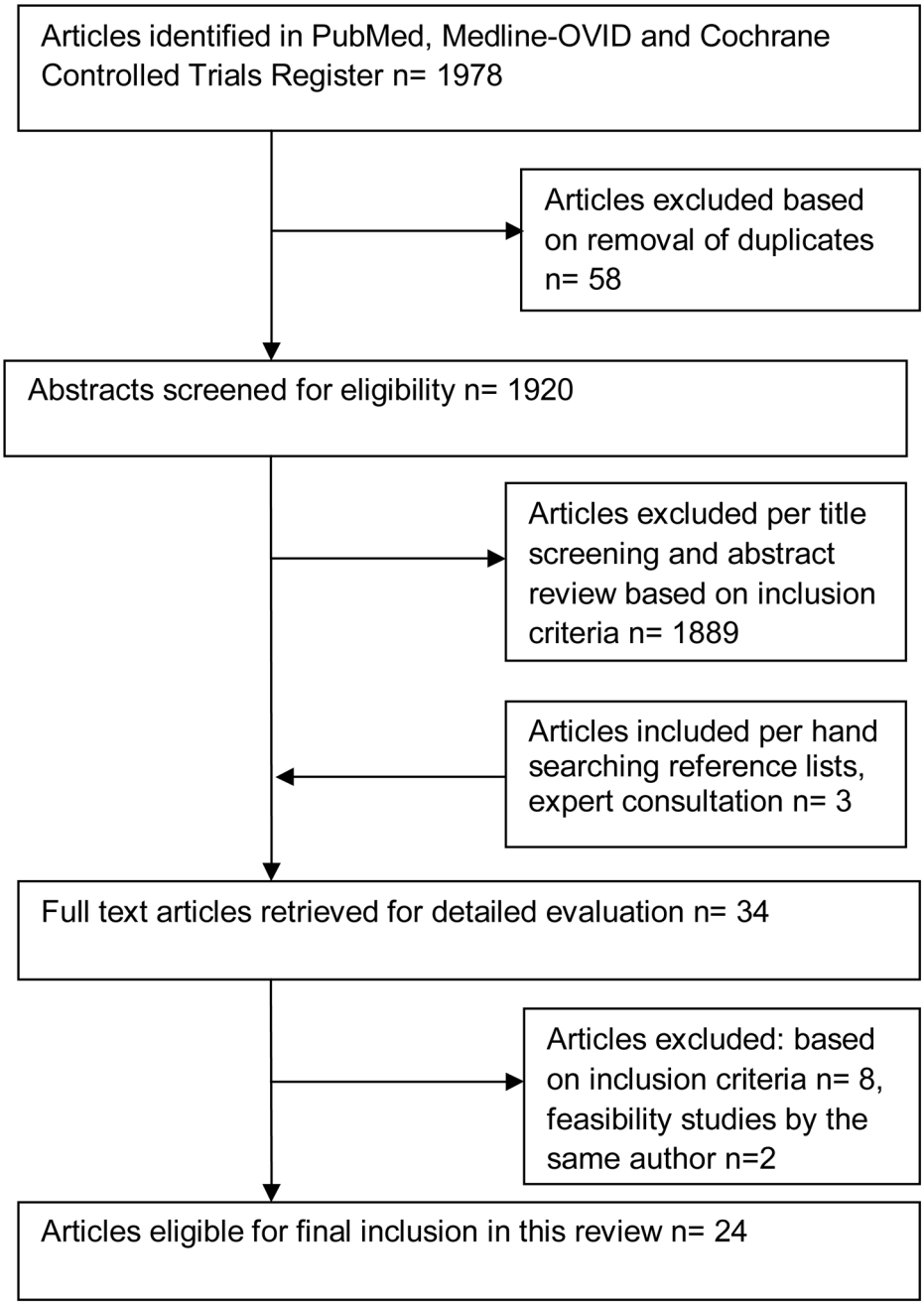

Figure 1.
Flow Diagram

Table 1

Select Study Characteristics and Quality of Included Studies

Source	Infection Type	Objective	Study Design	Sample[a]	Type of Intervention	Intervention	Outcome Measures[b]	Results	Statistically Significant[c]	Mean Quality Score[d]
Banting et al.[14] **2001**	Respiratory	To determine effectiveness of microwave energy to disinfect dentures compared with conventional soaking	RCT, intervention duration 14 days, 3 months follow up	34 residents, mean age 81 with upper dentures from 3 institutions	Therapy	Both groups received topical antifungal for 14 days, all dentures scrubbed with antimicrobial soap on days 1, 5, and 10; Intervention group dentures microwaved; control dentures soaked in conventional solution	C. *albicans*, staphylococcus species	Microwave treatment is more effective than conventional soak treatment for eradicating C. *albicans* on dentures	(+)	16
Washington[15] **2001**	Urinary	To determine effects of 1 time instillation of 3% hydrogen peroxide versus distilled vinegar in drainage bags to reduce bacteriuria	RCT, one time instillation, bags sampled at 24-hour intervals over 4 days	20 residents, mean age 69.9 from 5 skilled care facilities	Therapy	Instillation of urinary drainage bags with 50ml of hydrogen peroxide or 50 ml of distilled vinegar; control group bags instilled with water	Bacteriuria	Urine cultures obtained at only the 48-hour interval showed reduction in bacteriuria for bags irrigated with vinegar	(+/−)	14.5
Adachi et al.[16] **2002**	Respiratory	To evaluate effectiveness of professional oral care on oral microorganisms related to pneumonia	RCT, 24 months	141 residents, mean age 84 from 2 NHs	Therapy	Professional oral care weekly by dental hygienists; control received usual care	C. *albicans*, staphylococcus species	Professional oral care by dental hygienists reduced microorganisms related to pneumonia	(+/−)	13
Fendler et al.[31] **2002**	Nosocomial Infections	To assess impact of alcohol hand sanitizer use on nosocomial infection rates	Quasi-experimental 34 month study period	A 3-story NH	Educational, Hand hygiene	Hand sanitizer provided to 2nd and 3rd floors of facility; remainder of facility served as control and received no hand sanitizer	Nosocomial infection rates: respiratory/urinary	Reduction in nosocomial infection rates seen in hand sanitizer group	(+)	12.5
Gornitsky et al.[17] **2002**	Respiratory	To assess effectiveness of 3 denture cleaners in reducing	RCT, total study period 35 days	37 residents, mean age 84 with complete upper	Therapy	3 commercial dental cleansers used according to manufacturer's instructions;	Count of colony-forming units (CFU) of oral *Candida* and *Streptococcus* mutans, plaque scores	Reduction in CFU of *Candida* and *Streptococcus* mutans, reduction in level of plaque scores in	(+)	23

Source	Infection Type	Objective	Study Design	Sample[a]	Type of Intervention	Intervention	Outcome Measures[b]	Results	Statistically Significant[c]	Mean Quality Score[d]
		microorganisms on dentures		dentures from 2 institutions		water served as control		intervention group compared to control		
Yoneyama et al.[18] **2002**	Respiratory	To assess whether oral care reduces pneumonia	RCT, follow up 2 years	417 residents, mean age 82 years from 11 NHs	Therapy	Enforced oral hygiene measures and oral cleaning by dental hygienists once a week; control group received usual care	Pneumonia rates	Incidence of pneumonia was lower in intervention group	(+)	20.5
Mody et al.[32] **2003**	Nosocomial Infections	To examine impact of alcohol based hand rub on infection rates	Quasi-experimental 11 month observation period following introduction of hand rub	2 NH units	Educational, Hand hygiene	Educational campaign to introduce alcohol based hand rubs	Nosocomial infection rates	No difference in nosocomial infection rates after introduction of alcohol based hand rubs	(−)	15
Mody et al.[19] **2003**	Multiple Drug Resistant Organisms	To determine efficacy of intranasal ointment vs. placebo in reducing S. *aureus* colonization	RCT, 6 months follow up	127 persistent carriers of S. *aureus*, mean age 76.2, from 2 long-term care facilities	Therapy	Mupirocin therapy or placebo administered twice daily for 14 days to nares and/or wound surfaces	S. *aureus* colonization, reduction in S. *aureus* infections in residents treated with Mupirocin	Mupirocin significantly eradicated colonization in 93% of intervention group while 85% of placebo group remained colonized	(+)	22.5
McElhaney et al.[20] **2004**	Respiratory	To compare ginseng with placebo in reducing acute respiratory illness (ARI)	RCT, 2 influenza seasons, 12 weeks of supplement	198 residents, mean age 83 from NHs, assisted living	Therapy	Oral, twice daily ginseng CVT-E002 200 mg for 12 weeks or placebo	Acute respiratory illness rates	Incidence of lab-confirmed influenza and lab-confirmed ARI due to influenza and RSV higher in placebo; 89% lower relative risk of ARI in the intervention group compared to placebo	(+)	23
Meydani et al.[21] **2004**	Respiratory	To determine the effect of Vitamin E supplements on respiratory infections	RCT, 1 year intervention period	617 residents, mean age 84, from 33 long-term care facilities	Therapy	Daily administration of Vitamin E(200 IU) or placebo (containing only 4 IU of Vitamin E) for one year	Incidence of respiratory infections	Supplementation with Vitamin E resulted in lower respiratory infection rates, but did not differ significantly	(−)	26
Trick et al.[22] **2004**	Multiple Drug Resistant Organisms	To compare acquisition of antimicrobial resistant organisms on units with different contact isolation precaution measures	RCT, 6 month study period	283 skilled unit residents, median age range 55–59 at a single facility	Resource Comparison	Healthcare workers assigned to either the contact isolation group or routine glove use group without contact isolation	Acquisition rate of multiple drug resistant organisms	No difference in acquisition of VRE/MRSA with glove use without contact isolation compared to contact isolation group	(−)	16

Source	Infection Type	Objective	Study Design	Sample[a]	Type of Intervention	Intervention	Outcome Measures[b]	Results	Statistically Significant[c]	Mean Quality Score[d]
Watando et al.[23] 2004	Respiratory	To explore effects of intensive oral care on impaired cough reflex sensitivity	RCT, intervention duration 30 days	60 residents, mean age range 85 to 87.2 from a single NH	Therapy	Intensive oral care group received cleaning by caregivers daily for 5 minutes after every meal for 1 month; care augmented by dental hygienists once a week; control group received usual care	Cough reflex sensitivity	Cough reflex sensitivity at 30 days improved in intervention group; cough reflex sensitivities higher in the intervention group compared to control group	(+)	20
Thai et al.[33] 2005	Multiple Drug Resistant Organisms	To evaluate ability of Ultraviolet light C (UVC) to reduce amount of bacteria in chronically infected ulcers	Quasi-experimental pre-post, no follow up	22 residents, mean age 71.8, recruited from wound clinics, residential and inpatient care floors and area NHs	Therapy	Single 180 second treatment using UVC lamp placed 1 inch from wound bed, no comparison group	Bacteria count in wound (MRSA, S. *aureus*, and combinations of other types of bacteria)	Reduction in amount of bacteria seen in residents after single UVC treatment	(+)	15.5
Yamada et al.[34] 2006	Respiratory	To evaluate effects of gargling tea catechin on prevention of influenza infection	Quasi-experimental; study duration 3 months	124 residents, mean age 83 from a single NH	Therapy	Gargled with tea catechin extract 3 times daily for 3 months; control group gargled without tea catechin	Influenza infection rates	Incidence of influenza was lower in group that gargled with catechin compared to control group	(+)	17
Liu et al.[24] 2007	Nosocomial Infections	To evaluate effect of vitamin and mineral supplementation on episodes of infection	RCT, received study medication for 19 months, 18 month surveillance period	763 residents, mean age 85 from 21 long-term care facilities	Therapy	Multivitamin and mineral supplementation versus placebo administered daily for 19 months	Nosocomial infection rates	No difference in infection rates between the multivitamin and mineral supplementation group versus placebo group	(−)	27
Wendt et al.[25] 2007	Multiple Drug Resistant Organisms	To assess whole body washing with chlorhexidine for eradicating MRSA	RCT, intervention duration 5 days, 30 day follow up	114 MRSA positive residents, mean age 71.4 in intervention group, from hospital and area NHs	Therapy	Whole body washing using chlorhexidine solution or placebo for 5 days; both groups received mupirocin nasal ointment 3 times a day for 5 days and used chlorhexidine mouth rinse twice daily	MRSA Eradication	No difference in overall MRSA eradication rate after 30 days between intervention group and placebo	(−)	25

Source	Infection Type	Objective	Study Design	Sample[a]	Type of Intervention	Intervention	Outcome Measures[b]	Results	Statistically Significant[c]	Mean Quality Score[d]
Ishikawa et al.[35] 2008	Respiratory	To evaluate longitudinal prevalence of oropharangeal bacteria	Quasi-experimental 5 months study duration	202 residents, mean age range 79.9–82.5, from 3 NHs	Therapy	Provided professional oral care by a dental hygienist once a week with varying modality, intensity and frequency	Colony forming units (CFU) for total bacteria, streptococci, staphylococci, *Candida*, Pseudomonas	Levels of oropharangeal bacteria decreased across all 3 facilities when weekly professional care was instituted	(+)	13.5
Meurman et al.[26] 2009	Respiratory	To examine the use of a topical amine fluoride-stannous fluoride combination (AmF-SnF2) on oral *Candida*	RCT, study duration 8 months	194 NH residents, mean age 82 in intervention group, 83 in placebo	Therapy	AmF-SnF2 mouth rinse and toothpaste preparations used twice daily as part of routine daily oral hygiene regimen; comparison group received placebo	Oral *Candida* counts	AmF-SnF2 did not affect mean oral *Candida* counts but median *Candida* counts decreased in intervention group while an increase was seen in placebo paste group	(−)	17
Quagliarello et al.[30] 2009	Respiratory	To test intervention protocols for feasibility, staff adherence and effectiveness in reducing pneumonia risk factors	Quasi-experimental 3 months study duration	52 NH residents(30 in oral hygiene intervention group, 20 in swallowing intervention group), mean age 86	Therapy	Oral hygiene group assigned to manual oral brushing plus chlorhexidine mouth rinse at different frequencies daily; no control; Swallowing group assigned to 90 degree feeding posture, swallowing techniques or manual brushing daily	Oral plaque scores, frequency of cough during swallowing	90% of residents in oral hygiene group had significant reduction in plaque scores at end of 3 months oral care intervention; Frequency of cough during swallowing reduced in all 3 groups but manual brushing was not significantly more effective than 90 degree feeding posture or instruction in swallowing techniques with each meal	(+/−)	18
Baldwin et al.[27] 2010	Multiple Drug Resistant Organisms	To test impact of an infection control education and training program on MRSA prevalence	RCT, 12 months	793 residents, from 32 NHs, mean age 84	Educational	In-depth infection control education and training program to 16 nursing homes, control group received usual care	MRSA prevalence	No effect on MRSA prevalence over 12 month study period between intervention group and control	(−)	24.5
Hutt et al.[36] 2010	Respiratory	To test effects of multi-disciplinary intervention implementing national evidence based guidelines	Quasi-experimental conducted during 3 influenza seasons	16 NHs	Educational	Institutional changes and educational sessions of NHAP guidelines, control group	Vaccination rates	No improvement of resident vaccination rates seen in intervention group versus control	(−)	11

Source	Infection Type	Objective	Study Design	Sample[a]	Type of Intervention	Intervention	Outcome Measures[b]	Results	Statistically Significant[c]	Mean Quality Score[d]
						received usual care				
Kullberg et al.[37] 2010	Respiratory	To evaluate effect of repeated education program for nursing staff to improve dental hygiene	Quasi-experimental pre-post design, 3 weeks follow up	43 residents from single NH included in evaluation, age range 66–69	Educational	Dental hygiene education led by dental hygienist for nursing staff; residents were given electronic toothbrushes; recommended to use chlorhexidine gel twice daily	Oral plaque scores	At 3 weeks post education and training, residents showed reduction in plaque scores	(+)	15.5
Maruyama et al.[28] 2010	Respiratory	To determine effectiveness of 23-valent pneumococcal vaccine on pneumonia incidence	RCT, follow up 26 months	1006 residents from 9 hospitals, 23 NHs, mean age 84.7	Vaccine	Residents received pneumococcal vaccine, control group received placebo	Pneumonia incidence	Pneumonia/ Pneumococcal pneumonia incidence reduction seen in intervention group	(+)	26.5
Nishiyama et al.[29] 2010	Respiratory	To assess effects of mucosal care on colonization of oral pathogens	RCT, 12 month study duration	50 NH residents, mean age 76.1	Therapy	Professional oral care with mucosal care (mucosal cleaning); control: professional oral care with no mucosal care	Number of *Streptococcus* mutans, number of residents with *Candida* species	*Streptococcus* counts decreased significantly throughout 12 months for residents with mucosal care; Residents with *Candida* significantly higher in no mucosal group	(+)	19

[a] Sample size displayed is the number enrolled, not necessarily the number of subjects who participated in the study.

[b] Select outcome measures displayed reporting infection rates or risk factors related to infections.

[c] Statistical significance reported (+) if study found results ($p<0.05$) on outcome measures, (−) if study found no significance on outcome measures, (+/−) if study found both significant and non-significant results;

[d] Mean Quality Score was the average quality score between the two reviewers using the adapted Downs and Black tool.