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Infections and Antibiotic Resistance in Nursing Homes

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INTRODUCTION

The populations of developed countries are becoming increasingly elderly. Aging is associated with an increased frequency of chronic diseases and declining functional status necessitating institutional care for at least some time for a substantial proportion of the elderly (80). Currently, more than 1.5 million individuals reside in nursing homes in the United States (67). While under 10% of the entire population over age 65 years currently reside in nursing homes, it is estimated that 43% of the American population who turned 65 in 1990 will spend some period in a long-term care facility (82). A variety of long-term care facilities provide services for many different elderly populations. These include adult day-care units, residential care facilities, rehabilitation facilities, long-term care facilities, nursing homes, chronic-disease hospitals, and Veteran's Affairs (VA) nursing home care units. However, the largest number of institutionalized individuals reside in nursing homes, and 90% of these are elderly. Nursing homes are residential facilities for persons who require care and related medical or psychosocial services; they may be hospital based or freestanding. This review will be largely restricted to considerations relevant to the nursing home setting as these facilities have the greatest number of residents and also because most information describing infections in long-term care facilities has been reported for the nursing home population.

The patient population and environment of the nursing home provide a milieu that permits the development of infection and promotes transmission of infectious agents (54, 74, 154, 171). The epidemiology, clinical presentation, and natural history of many infections may be unique in this population. More recently, increasing recognition that the environment and patient care practices in the nursing home promote emergence of antimicrobial agent-resistant organisms has heightened awareness of the significance and complexity of infections in this setting (77). This review will describe characteristics of the nursing home population and environment that are relevant to infections, the microbiology and clinical impact of nursing home infections with particular emphasis on antimicrobial resistance, and current approaches to the prevention of infections in these facilities.

THE NURSING HOME POPULATION

The nursing home population presents a wide spectrum of clinical disability. Patients may vary from the ambulatory, physically competent resident with Alzheimer's disease to the comatose, bed-bound patient who is maintained with enteral feeding, an indwelling catheter, and a respirator. Different nursing homes frequently have vastly different populations of patients depending on their mission and patient referral patterns. The clinical impact and significance of infections differ among nursing homes and within the population of an individual nursing home depending on associated comorbidities and functional status of the residents. Reports of infections in nursing homes, however, usually do not stratify observations by functional status or other measures of disability. The heterogeneity of this population must be borne in mind in interpreting the relevance of reports of infection.

The nursing home population is primarily, although not exclusively, elderly. Many aspects relevant to infections in this population reflect a contribution of both physiologic and pathologic aging-associated changes. An appreciation of infections occurring in this setting requires an understanding of these features.

Immunity and Aging

Alterations in the immune system are observed with aging (Table 1) (11, 39, 139, 151). Reports describing specific alterations, however, are often contradictory, and the degree of change and reproducibility of observations vary with the clinical status of the elderly subject and the presence of comorbid illness (151). The greatest variation from the "norm" generally occurs for the most impaired elderly, including those resident in nursing homes.

There is a consistent decline in T-lymphocyte function and cell-mediated immunity with aging, manifested as decreased cutaneous delayed-type hypersensitivity (151). This may be important in permitting the reactivation of latent infections such as varicella-zoster (shingles) or tuberculosis. In addition, elderly subjects demonstrate diminished production of antibody to primary immunization with extrinsic antigens (151). The secondary humoral immune response is relatively well maintained, although it may be quantitatively diminished. This is relevant to immunization in the elderly, in whom decreased responsiveness to both pneumococcal polysaccharide (146) and influenza vaccines (130) has been demonstrated. Serologic diagnostic methods have been assumed to be reliable in the elderly, although this has not been well studied. Variable abnormalities of cytokine response have been reported in the elderly population. A decline of interleukin-2 production with aging has been consistently reported (94). Despite the immunologic changes observed with aging, efforts to correlate immunologic impairment directly with an increased frequency of infection have not been convincing. Increased mortality in

TABLE 1. Physiologic changes of aging that could influence the occurrence and severity of infections in the elderly

System	Aging alterations[a]
Specific immunity	
T lymphocytes	↓ Mature T lymphocytes, ↓ proliferation to mitogen stimulation, ↓ delayed hypersensitivity
B lymphocytes	↓ Antibody production to antigenic challenge, ↑ autoantibodies
Cytokines	↓ Interleukin-2
Skin	Epidermal thinning, ↓ elasticity, ↓ subcutaneous tissue, ↓ vascularity
Respiratory	↓ Cough reflex, ↓ elastic tissue, ↓ IgA[b] secretion, ↓ mucociliary transport
Gastrointestinal	↓ Gastric acidity, ↓ motility
Urinary	↑ Perineal-vaginal colonization (women), ↑ prostate size and ↓ prostatic secretions (men), ↓ urine osmolality

[a] ↓, decrease in; ↑, increase in.
[b] IgA, immunoglobulin A.

nursing home residents with impaired cell-mediated immunity, however, has been reported (39).

Organ Systems and Aging

Alterations in organ systems occur with normal aging, and many of these physiologic alterations contribute to the development of infection (Table 1) (154, 171). For instance, the skin changes associated with aging lead to delayed wound healing; changes in respiratory tract function increase the likelihood of aspiration and pneumonia; alterations in gastrointestinal tract physiology such as decreased gastric acidity increase the likelihood of infection after ingestion of a potential pathogen; and the urinary tract is more vulnerable to infection in both women and men who are elderly, even in the absence of other diseases.

Chronic Disease

The nursing home population has a high frequency of chronic diseases, many of which increase the likelihood of infection (68, 121). A mean number of three chronic, comorbid disease diagnoses is reported in several studies (54, 116). These chronic diseases are often the major factors necessitating institutional care. The most frequently diagnosed underlying chronic diseases include neurologic diseases (especially dementia), peripheral vascular and cerebrovascular diseases, and chronic pulmonary conditions. The prevalence of diabetes is reported to be 10 to 30% in the nursing home population (54, 116). These common chronic illnesses, or comorbidities, contribute to the high frequency of infection in nursing homes. Demented patients frequently have a neurogenic bladder and impaired ability to void that results in an increased frequency of urinary infection (111). Patients with peripheral vascular disease and congestive heart failure are at increased risk for skin and soft tissue infections through impaired vascular supply to extremities and peripheral edema. Patients with chronic obstructive pulmonary disease are likely to have bacterial colonization of the tracheobronchial tree and recurrent bronchopulmonary infections (117). The optimal management of infections in nursing home residents includes ensuring optimal therapy of these associated diseases.

Functional Impairment

The chronic diseases of elderly nursing home patients lead to functional impairment, including immobility, incontinence of bladder and bowel, and limitations in performance of activities for self-care (6, 54, 68, 91, 141, 145). Poorer functional status in the nursing home patient has consistently been reported to be associated with increased occurrence of infection (6, 54, 111, 145). Chair- and bed-bound residents are at risk of pressure ulcers (5, 21). Urinary incontinence is common, affecting as many as 50% of residents in some nursing homes. Approaches to the management of incontinence, including indwelling bladder catheters (177) and external collecting devices for elderly men (78, 123), increase the incidence of urinary infection. Fecal incontinence is also associated with an increased risk of urinary infection (24, 111), but a causative role has not been shown. Both urinary and fecal incontinence may also contribute to extensive environmental contamination with potentially pathogenic or antimicrobial agent-resistant bacteria.

Malnutrition

Biochemical and anthropometric studies repeatedly document that 10 to 50% of nursing home residents are malnourished (66, 95, 100, 168). Over 50% of residents of some nursing homes have been reported to suffer from protein calorie malnutrition (66). Vitamin and zinc deficiencies are also reported (168). The reasons for this high frequency of malnutrition are not understood fully. Comorbid illness, feeding difficulties, and impaired mental awareness contribute to the problem. Bacterial overgrowth of the small bowel by *Escherichia coli* and anaerobic organisms, leading to malabsorption, has been suggested to contribute in some patients (95). Malnutrition is associated with decreased cell-mediated immunity and poorer clinical outcomes, including delayed wound healing and poorer functional status. One comparative study, however, reported that vitamin A supplementation in an elderly nursing home population did not result in a decrease in infections, as measured by courses of antibiotic therapy (106).

Invasive Devices

Invasive devices, including indwelling urinary catheters, percutaneous and nasogastric feeding tubes, tracheostomies, and intravenous catheters, are frequently used to assist in providing care to nursing home residents. These devices uniformly further compromise host defenses by providing an access for bacteria to gain entry to a body site and increase the risk of focal infection. The use of some of these devices, including tracheostomies and intravenous catheters, is increasing in the nursing home population, reflecting the increasing level of impairment among elderly patients currently admitted to these facilities. From 5 to 10% of nursing home residents have long-term indwelling urinary catheters (177) with associated persistent polymicrobial bacteriuria (180) and complications of urinary infection (122, 175, 176). Enteral feeding solutions given to patients with nasogastric and percutaneous feeding tubes may be heavily contaminated with members of the family *Enterobacteriaceae*, including *Serratia* spp. and *Enterobacter* spp. (52, 62). Nasogastric tubes have been reported to be associated with a greater occurrence of aspiration pneumonia in at least one study (48), which is one factor promoting the increased use of percutaneous gastric or jejunal feeding tubes with the subsequent complication of stomal site infections. Tracheostomies with or without chronic respirator therapy lead to bacterial tracheobronchial colonization and increased risk of pneumonia.

Medication Use

"Polypharmacy" is the norm in the nursing home population. The average nursing home resident receives 5 to 10 different medications at any time (10). Some of these medications may increase the likelihood of infection. For instance, sedatives may impair consciousness and increase the frequency of aspiration; H_2 blockers lead to decreased gastric acidity and may contribute to increased gastrointestinal infections. Other medications such as tricyclic antidepressants and some "antianginal" medications have associated adverse effects such as urinary retention, which increase the likelihood of infection at that site, and drying of mucous membranes, leading to local tissue breakdown in the oropharynx and increased bacterial colonization.

Bacterial Colonization

Patients resident in nursing homes are often extensively colonized with potential pathogens such as *Staphylococcus aureus*, beta-hemolytic streptococci, members of the *Enterobacteriaceae*, or *Pseudomonas aeruginosa*. From 25 to 50% of residents have oropharyngeal colonization with gram-negative or-

TABLE 2. Oropharyngeal colonization with gram-negative organisms in nursing home residents

Determination	Data from given reference		
	Valenti et al. (170)	Irwin et al. (73)	Nicolle et al. (117)
Proportion colonized (%)	23–37	0–29	37–43
Organism (% of total)			
Klebsiella pneumoniae	41	29	42
Escherichia coli	24	10	14
Enterobacter spp.	14	15	19
Proteus mirabilis	4	8	8.8
Pseudomonas aeruginosa	5	15	0
Serratia or *Citrobacter* spp.		11	7.7
Morganella morganii		2	3.8
Acinetobacter spp.		1	5.5

ganisms, most frequently *Klebsiella* spp. (Table 2) (73, 117, 170). Oropharyngeal colonization is associated with an increased incidence of infections and increased mortality; however, it may simply be a marker for greater functional impairment rather than play a causative role in the development of infection (117). Chronic skin lesions, including pressure ulcers, are usually colonized with multiple aerobic and anaerobic organisms (118, 140). The high frequency of asymptomatic bacteriuria (109) may be considered another example of this extensive bacteriologic colonization.

Colonization with these potential pathogens results from the physiologic changes associated with aging, chronic comorbid diseases, and the general debilitation of the nursing home population. It is enhanced by therapeutic interventions and by the increased potential for transmission of organisms among patients in the institutional setting. Intensive antimicrobial use in the nursing home then promotes colonization with organisms of increasing antimicrobial resistance (77, 150). Colonization with these organisms makes it difficult to interpret the significance of microbiological isolates obtained from nursing home patients with clinically diagnosed infections. Sputum cultures frequently grow gram-negative organisms, but these are not necessarily the etiologic cause of pneumonia (116). Similarly, female nursing home residents may have heavy contamination of voided urine specimens by vaginal secretions; isolation of organisms from surface swabs of skin lesions is unhelpful in determining either the presence of infection or the specific etiologic agents when infection occurs.

PROBLEMS IN MANAGEMENT OF INFECTIONS IN NURSING HOMES

Clinical Presentation

Clinical criteria used in the diagnosis of and surveillance for infections in the nursing home have generally been developed from observations in younger populations with limited comorbidities; their validity in the nursing home population is not established (96). Several factors contribute to the difficulty of establishing a clinical diagnosis in these patients. Hearing and cognition are often impaired in nursing home patients; symptoms may not be expressed or correctly interpreted by caregivers. Chronic comorbid clinical conditions obscure the signs and symptoms of infection, leading to misinterpretation or overlooking of symptoms. For instance, chronic incontinence may mask symptoms of urinary infection, or congestive heart failure may mask symptoms of pulmonary infection. In addition, the presentations of infections in nursing home residents are sometimes atypical (96, 119). Illness may present with predominant symptoms of confusion rather than localizing findings (119). The febrile response is impaired relative to younger populations, with both a lower maximal temperature (28, 65, 181) and increased frequency of afebrile infection (58, 97). Alternatively, fever with no localizing clinical findings to identify a source is frequently reported (45, 116). The peripheral leukocyte count in bacterial infection is not as high as that observed for younger populations, frequently remaining within the normal range (181). These limitations in the utility of clinical presentation for diagnosis of infection are problematic not only for patient management but also for programs of infection surveillance in nursing homes.

Diagnostic Testing

Diagnostic specimens have limited utility in the nursing home population, both because they cannot be or are not obtained and because, once obtained, the results may not be interpreted accurately. Many nursing homes do not have on-site diagnostic laboratory or radiologic facilities. In addition, patients may be unable or unwilling to cooperate in the collection of valid specimens. Diagnostic tests, then, are infrequently requested. Even when specimens are obtained, reporting of results back to the ordering physician may be delayed for several days because the specimens are sent to off-site laboratories. In long-term care facilities in Rochester, N.Y., Zimmer et al. (188) reported that a urine culture was obtained for only 57% of episodes that were treated as urinary infection; for lower respiratory infections, chest X rays were obtained for only 24% of episodes and only 3% had sputum cultures. In Manitoba nursing homes, only 10% of episodes treated as lower respiratory infection had sputum specimens sent for culture and 18% had chest X rays (99). Even under optimal conditions, adequate sputum specimens can be obtained from only about 50% of nursing home residents (129). While urine specimens are more frequently obtained, the prevalence of bacteriuria of 30 to 50% in nursing homes means that a positive culture has a low predictive value for the diagnosis of symptomatic infection (109). Similarly, gram-negative organisms are frequently isolated from sputum cultures; however, the significance of these organisms as etiologic agents for pneumonia cannot be determined (116).

Antimicrobial Agent Use

Antimicrobial agents are among the most frequent pharmaceutical agents prescribed in nursing homes. They account for approximately 40% of all systemic drugs used (40, 182). From 50 to 70% of residents receive at least one systemic antimicrobial agent during 1 year (99), and the prevalence of systemic antibiotic use is reported to be 8% (40, 179). In a 9-month surveillance study in a VA nursing home care unit (76), 51% of the 231 study patients received antimicrobial agents at some time during their stay. More than one agent was prescribed for 30% of these patients. In addition, as many as 30% of nursing home patients receive at least one prescription for a topical antimicrobial agent each year (99).

A high proportion of antimicrobial prescriptions given to nursing home patients are considered inappropriate. From 35 to 75% of systemic antimicrobial agents (40, 79, 81, 99, 132, 179, 188) and up to 60% of topical antimicrobial agents (99) are inappropriately used. While inappropriate antimicrobial agent use has been described in virtually all clinical settings where it has been studied, the intensity of antimicrobial agent use, difficulties in clinical diagnosis, and potential for emer-

TABLE 3. Reported point prevalence studies of infections in nursing homes[a]

Reference	Facility (no.)/state[a]	Prevalence (% of patients infected)[b]			
		Total	Respiratory	UTI	SST
Cohen et al. (38)	NH (18)/Connecticut	2.8	0.3	1.2	1.1
	<100 beds	4.8			
	100–150 bed	2.4			
	>150 beds	1.6			
Garibaldi et al. (54)	NH (7)/Utah	16.2	3.7	2.6	6.0
Alvarez et al. (6)	VA/Tennessee	2.4	0.3	1.2	1.0
Scheckler and Peterson (141)	NH (8)/Wisconsin	13.9	3.0	3.5	5.5
Setia et al. (145)	VA/Pennsylvania	12.0	2.3	2.8	5.6
Magaziner et al. (90)	NH (53)/Maryland	5.3	1.2	0.6	2.2
Standfast et al. (155)	VA/New York	32.7	2.0	21.8	8.8

[a] NH, nursing home.
[b] UTI, urinary tract infection; SST, skin and soft tissue infection.

gence of resistant organisms mean that the inappropriate use of antimicrobial agents in the nursing home setting must be of particular concern.

INFECTIONS IN NURSING HOMES

Endemic Infections

Occurrence. Prevalence studies describing infections in nursing homes are summarized in Table 3 (6, 38, 54, 90, 141, 145, 155, 159). The variability in these reports reflects differences in patient populations in different study institutions as well as differing surveillance definitions and methods for case ascertainment. The majority of these studies, however, report a prevalence of infection of greater than 10%. Prevalence surveys would be anticipated to overestimate the occurrence of chronic infections, such as some skin and soft tissue infections, relative to acute infections, such as respiratory infections. The studies summarized, however, are consistent in identifying respiratory tract infections, symptomatic urinary infections, and skin infections as the most common infections.

The incidence of infection has also been reported from several nursing homes (Table 4) (6, 43, 47, 51, 69, 75, 76, 91, 116, 141, 142, 173). Many of these reports are from VA facilities, where over 90% of the population is male and, thus, nonrepresentative of the general nursing home population, in which only 20 to 30% are male. Observations reported from the different studies, however, are remarkably consistent. Infection rates vary from 1.8 to 7.1 per 1,000 resident days. The most frequent infections identified are usually respiratory tract infections, varying in rate from 0.46 to 4.4 per 1,000 resident days. In most reports, this includes both upper and lower respiratory infections because of the difficulties in distinguishing the two diagnoses on the basis of clinical criteria alone. The reported incidence of symptomatic urinary infection varies from 0.1 to 2.4 per 1,000 resident days. The influence of different surveillance definitions is notable in reports of incidence of febrile urinary infection. Symptomatic urinary infection may be defined permissively as a positive urine culture in a patient with fever and no other apparent source or restrictively as a positive urine culture in a patient with fever and acute symptoms referable to the urinary tract. Reports using the permissive definition certainly overestimate the occurrence of febrile urinary infection, and those using the restrictive definition certainly underestimate the incidence. The frequency of fever with no apparent source is also highly variable among different studies, again reflecting differences in surveillance definitions.

The clinical and economic impact of endemic infections in the nursing home population has not been carefully measured. These patients are chronically impaired, and additional morbidity from intercurrent infection is difficult to measure. In addition, in some cases, such as the fully dependent, noncommunicative, demented patient, mortality may not be considered an undesirable outcome. Prolongation of institutionalization may also not be meaningful as a measure of morbidity or cost in these permanently institutionalized residents.

Indices that may be used as measures of the impact of endemic infections include the volume of antimicrobial agent use, frequency of transfer to acute-care facilities for management of infection, and infection-related mortality. The intensity of antimicrobial agent use in nursing homes has been discussed earlier. Reports summarizing antimicrobial agent use consistently identify urinary infection as the most frequent diagnosis for which treatment is prescribed, with respiratory infections second in frequency (40, 99, 179, 182, 188). The frequency of adverse effects and costs of antibiotics have not been reported. From 7 to 30% of patients transferred from nursing homes to acute-care institutions are transferred for management of infections (60, 72, 76, 83). Respiratory and urinary infections are the infection diagnoses that most commonly require transfer (60, 72). The frequency with which patient transfer occurs will vary with the ability of the home institution to manage acutely ill patients, including the provision of parenteral therapy.

One prospective study reported that 6.3% of all infectious episodes in nursing homes were associated with death, or 10.3 deaths per 100 residents per year (116). However, overall mortality is reported to be similar in residents with and without infection (76). The only common infection with a high case/fatality ratio is pneumonia. Autopsy series of elderly nursing home residents consistently fail to identify an infection other than pneumonia as an immediate cause of death (63, 111). Further evaluation of the clinical impact of endemic infections in nursing home patients and the most appropriate means to measure this impact are needed to fully understand the significance of the high frequency of infection that is observed.

Respiratory tract infection. (i) Upper respiratory tract infection. Upper respiratory tract infection in nursing home patients includes sinusitis, otitis media, otitis externa, and pharyngitis. Generally, the incidence of upper respiratory tract infection is reported to be less than that of lower respiratory tract infection. For instance, Scheckler and Peterson (141) reported 1.1 upper respiratory tract infections per 100 resident months compared with 1.9 episodes of pneumonia and bronchitis. The different clinical syndromes included as upper respiratory tract infections are usually reported as a single group, and the incidence of infection at each site is not known for this population. In addition, reports describing the microbiology of these infections are not available. Group A streptococcus may cause pharyngitis, but most reports of streptococcal pharyngitis in the nursing home describe relatively uncommon episodes of epidemic infection (143); rates of endemic streptococcal pharyngitis have not been reported. Thus, the relative contributions of group A streptococci, viruses, or other etiologic agents to endemic pharyngitis are unknown. Overall, these infections seem to have limited impact in the nursing home population.

TABLE 4. Reports of the incidence of infection in nursing homes

Reference	Study duration	Facility/state or province[a]	Incidence per 1,000 resident days[b]				
			All infections	Respiratory	UTI	SSI	GI
Magnusson and Robb (91)	2 mo	VA, ICW, & NH/Pennsylvania	3.4	0.46	2.4	0.3	0
Alvarez et al. (6)	4 yr	VA/Tennessee	2.7	0.7	1.2	0.5	NS
Nicolle et al. (116)	1 yr	Veterans/Manitoba (Canada)	4.1	1.8	0.1	1.0	0.9
Farber et al. (47)	1 yr	VA/Pennsylvania	6.7	3.2	1.8	0.1	0
Vlahov et al. (173)	1 yr	NH/Maryland	3.6 3.8	1.1 1.2	1.2 1.3	0.2 0.5	0.7 0.2
Franson et al. (51)	28 days	VA/Wisconsin	4.6	1.0	2.3	1.0	NS
Scheckler and Peterson (141)	6 mo	Rural NH (n = 8)/Wisconsin	3.6	1.3	1.6	0.5	0.04
Jackson et al. (75)	3 yr	Proprietary NH/California	7.1	3.3	1.3	1.8	0.09
Schicker et al. (142)	1 yr	VA/Wisconsin	5.4	2.0	1.9	0.7	0.24
Jacobson and Strausbaugh (76)	9 mo	VA/Washington	2.6	0.9	1.0	0.45	0.15
Hoffman et al. (69)	1 yr	VA/Florida	4.6	1.0	1.9	0.09	0
Darnowski et al. (43)	2 yr	NH/Ontario	9.5	4.4	1.5	2.1	NS

[a] ICW, intermediate-care ward; NH, nursing home.
[b] UTI, urinary tract infection; SSI skin and soft tissue infection; GI, gastrointestinal tract infection; NS, not stated.

(ii) Lower respiratory tract infection. Lower respiratory tract infections, including both pneumonia and bronchitis, are the most important infections occurring in nursing homes in both frequency and clinical consequences. Increased aspiration of oropharyngeal contents and impaired pulmonary clearance mechanisms resulting from physiologic aging changes, as well as chronic pulmonary, cardiovascular, and neurologic disease, contribute to the high incidence of pneumonia. Pneumonia is the only infection that is an important contributor to mortality in this population, with a reported case/fatality rate of 6 to 23% (75, 76, 116, 141). In many cases, however, a decision for nonaggressive therapy may have been made, and the contribution of pneumonia to unanticipated mortality is not clearly known.

Studies of the etiologies of nursing home-acquired pneumonia are generally flawed because they rely on expectorated sputum specimens to define bacteriology. Sputum specimens cannot differentiate oropharyngeal colonization from pulmonary infection. Invasive methods to establish an etiologic cause such as transtracheal or transthoracic aspiration or bronchoscopy are infrequently performed in the nursing home population. Bacteremia, which would permit identification of the causative agent through blood cultures, occurs in less than 25% of cases. With these limitations in mind, the reported bacteriology of endemic pneumonia in nursing home patients is summarized in Table 5 (14, 47, 93, 129, 130). *Streptococcus pneumoniae* remains the most important pathogen. Patients with chronic obstructive pulmonary disease have an increased frequency of bronchopneumonia associated with *Haemophilus influenzae* and *Moraxella catarrhalis*. There is an increased occurrence of gram-negative organisms such as *Klebsiella pneumoniae* in the nursing home relative to other populations. In at least one study in which specimens for culture were obtained through transtracheal aspiration, 37% of episodes were reported to have mixed respiratory flora (14).

Viral infections, particularly influenza A, are important contributors to lower respiratory tract infection in long-term care facilities. However, reports of influenza A infections are limited to descriptions of epidemic infection. Atypical pathogens such as *Chlamydia pneumoniae*, *Mycoplasma pneumoniae*, and *Legionella pneumophila* may cause pneumonia in nursing home residents but appear to be relatively infrequent.

(iii) Tuberculosis. The occurrence of *Mycobacterium tuberculosis* is variable among different institutions, although it is an important cause of infection in some nursing homes (12, 23, 157, 158). The prevalence of positive tuberculin skin tests in nursing home residents has been reported to vary from 21 to 35% (128, 158, 183). While active tuberculosis in nursing home residents is usually due to reactivation of latent infection, primary infection or reinfection may occur following exposure to an infectious case (12). An Arkansas study reported that residents with negative skin tests on admission to nursing homes had a 5%/year conversion rate in a home with a known infectious case; the rate was 3.5%/year in a home without a known case (158). Approximately 10% of skin test convertors who did not receive prophylactic isoniazid therapy developed active infection. When an infectious case occurs, delay in diagnosis due to preexisting chronic pulmonary symptoms or delay in obtaining a chest radiograph may lead to prolonged, extensive exposure of other residents and staff.

Urinary tract infection. Urinary tract infection is the most common bacterial infection in nursing homes (109). In prevalence studies performed in Europe, Canada, and the United States, 17 to 55% of women and 15 to 31% of men without indwelling catheters in nursing homes were bacteriuric (109). The incidence of bacteriuria is also high. In a male population from whom monthly urine cultures were obtained, the incidence of new episodes of bacteriuria was 45 per 100 patient years (110). In a female population, 1.2 infections per resident year were identified (113). Early recurrence of bacteriuria fol-

TABLE 5. Bacteria reported as etiologic agents in subjects with nursing home-acquired pneumonia

Bacteria	No. (%) of isolates reported by:				
	Garb et al. (53) (n = 47)	Marrie et al. (93)[a] (n = 12)	Peterson et al. (129) (n = 40)	Bentley (14) (n = 115)	Phillips and Branaman-Phillips (131) (n = 92)
Streptococcus pneumoniae	9 (19)	2 (17)	12 (30)	37 (32)	31 (34)
Klebsiella pneumoniae	14 (30)	3 (25)	3 (7.5)		2 (2.2)
Hemophilus influenzae	2 (4.3)		9 (23)	6 (5.2)	21 (23)
Enterobacter spp.	5 (11)	1 (8.3)			1 (1.1)
Escherichia coli	3 (6.4)	2 (17)	5 (13)		6 (6.5)
Serratia marcescens	2 (4.3)				
Pseudomonas aeruginosa	2 (4.3)		1 (2.5)		6 (6.5)
Citrobacter spp.	1 (2.1)		1 (2.5)		2 (2.2)
Proteus spp.			1 (2.5)		2 (2.2)
Branhamella catarrhalis			5 (13)		4 (4.3)
Other gram-negative bacteria				20 (17)	6 (6.5)
Staphylococcus aureus	9 (19)	1 (8.3)	3 (7.5)	2 (1.7)	11 (12)
Mixed		3 (25)		50 (43)	NS[b]

[a] No isolate for 58% of patients.
[b] NS, not stated.

lowing treatment is the norm, with as many as 50% of men or women experiencing recurrence within 6 weeks of therapy (110, 114). The 5 to 10% of patients in nursing homes managed with long-term indwelling catheters have a 100% prevalence of bacteriuria, usually with three to five organisms isolated at any time (180).

Despite this extraordinary prevalence and incidence, urinary infection is usually asymptomatic. Clinical and microbiologic limitations in the diagnosis of symptomatic infection, however, limit efforts to accurately measure the morbidity from urinary infection. When an expected prevalence of bacteriuria is 20 to 50%, any patient with fever has a high likelihood of a positive urine culture, and bacteriuria has a low predictive value for symptomatic urinary infection. Thus, while a negative urine culture may be useful in excluding a urinary source for an episode of fever, a positive urine culture is not helpful in defining a urinary source for symptoms.

Given these provisos, rates of symptomatic urinary infection of 0.11 to 0.15 per bacteriuric year have been reported in studies with restrictive clinical definitions that require the presence of localizing genitourinary symptoms or signs (110, 113). Symptomatic urinary infection is reported as the diagnosis necessitating transfer from a nursing home to an acute-care facility in 1 to 8% of such transfers (60, 72). The urinary tract is the most common source of bacteremia in the institutionalized elderly, contributing to over 50% of episodes (102, 115, 137, 144), with a case/fatality ratio of 16 to 23% (102, 115, 145). Bacteremia occurs significantly more frequently in subjects with indwelling urinary catheters (102, 137). The reported microbiology of urinary infection in nursing homes is summarized in Table 6 (6, 110, 113, 148). The predominant bacterial species may vary substantially among institutions, reflecting local endemic flora. The reports summarized are from asymptomatic populations. The bacteriology of symptomatic urinary infection is not well described but is assumed to be similar. For women, *E. coli* remains the most common infecting organism, isolated from 50 to 60% of bacteriuric subjects (113). *Proteus mirabilis* is isolated more frequently than *E. coli* in men. Gram-negative organisms of increased antimicrobial resistance, including *K. pneumoniae*, *Providencia* spp., *Morganella morganii*, *Enterobacter* spp., *Citrobacter* spp., and *P. aeruginosa*, are frequently isolated. Gram-positive organisms, including *Enterococcus* spp., coagulase-negative staphylococci, and, less frequently, *S. aureus*, are also identified.

Providencia stuartii is an organism with a unique proclivity for causing infections in nursing homes (49, 102). The major site of isolation of the organism is the urinary tract of patients with long-term indwelling catheters or external urine-collecting devices (49, 180). The occurrence of *Providencia stuartii* infection is highly variable among different facilities. When present, it is often identified in urine cultures from virtually all patients with long-term catheters. In one facility, one ward was observed to have a very high prevalence of *Providencia stuartii* urinary isolates, whereas a second ward with a similar patient population had virtually no isolates of this organism from urine culture (110) (Table 6). These observations suggest that cross-infection either through the environment or on the hands of staff members is the major determinant of *Providencia stuartii* urinary infection in the nursing home.

Skin and soft tissue infection. (i) Pressure ulcers. The frequency of pressure ulcers in nursing home patients reflects the quality of nursing care (5, 147); decubiti are usually preventable. The reported prevalence of pressure ulcers has varied from 1.6 to 24% (21, 98, 118) in different institutions, with incidences as high as 10 to 30% of patients per year (15, 21) and as low as 3.4 to 4.8 episodes per 100,000 resident days (118). Patients with immobility, sensory impairment, and incontinence are at increased risk for development of pressure ulcers (15). Infected ulcers are reported to occur from 0.1 to 0.3 episodes per 1,000 resident days (47, 141), or 1.4 per 1,000 ulcer days (118). Complications of infected pressure ulcers include cellulitis, osteomyelitis, and bacteremia. Muder et al. (102) reported that 36% of bacteremic skin and soft tissue infections was due to infected decubiti, with a case/fatality ratio of 14% for all skin infections.

Pressure ulcers are frequently colonized with several different organisms. Surface cultures yield a polymicrobial flora of gram-positive and gram-negative aerobic and anaerobic species (5, 118). Thus, surface cultures are not considered reliable to identify infection or, when infection is clinically present, to

TABLE 6. Microbiology of bacteriuria in nursing home populations

Bacteria	No. (%) of isolates by gender				
	Male (110)[a]		Mixed (148)[a] (n = 45)	Women (113)[a] (n = 56)	Male (6)[a,b] (n = 290)
	Ward 1 (n = 78)	Ward 2 (n = 40)			
Escherichia coli	4 (5.1)	9 (23)	11 (24)	30 (54)	38 (13)
Proteus mirabilis	26 (33)	10 (25)	17 (38)	14 (25)	57 (20)
Klebsiella pneumoniae	4 (5.1)	3 (7.5)	6 (13)	6 (11)	26 (9.0)
Providencia spp.	19 (24)				60 (21)
Pseudomonas aeruginosa	16 (21)	7 (18)	9 (20)	2 (3.6)	34 (12)
Morganella morganii	3 (3.8)				
Enterobacter spp.		2 (5.0)		1 (1.8)	3 (1.0)
Citrobacter spp.	1 (1.3)	2 (5.0)		2 (3.6)	12 (4.1)
Serratia spp.					20 (6.9)
Enterococcus spp.	2 (2.6)	4 (10)	2 (4.4)	1 (1.8)	34 (12)
Group B streptococcus	2 (2.6)				2 (0.7)
Streptococcus aureus	1 (1.3)	1 (2.5)			2 (0.7)
Coagulase-negative staphylococcus		2 (5.0)			2 (0.7)

[a] Reference.
[b] Includes patients with indwelling catheters.

identify infecting organisms. Aspirates from the ulcer margin have been suggested to be more reliable to identify infecting organisms, but this technique has a low yield in general and has not been validated for this population. Aspirates from the ulcer margin may occasionally yield growth of potential pathogens even from clinically uninfected ulcers (118). The organisms most frequently isolated include *S. aureus*, beta-hemolytic streptococci, gram-negative organisms including members of the *Enterobacteriaceae* and *Pseudomonas* spp., and other gram-positive organisms such as *Enterococcus* spp. (118, 140). Anaerobic organisms also contribute to infection. Colonization with methicillin-resistant *S. aureus* (MRSA) occurs frequently in institutions with endemic MRSA (20, 162).

(ii) Cellulitis. Acute cellulitis occurring in the nursing home population is usually due to beta-hemolytic streptococci (usually group A or group B) or *S. aureus*. However, in cases in which cellulitis is a complication of pressure ulcers or chronic foot ulcers in patients with diabetes or peripheral vascular impairment, infections with other agents, including members of the *Enterobacteriaceae*, anaerobes, or a polymicrobial flora, are common.

(iii) Conjunctivitis. Conjunctivitis has been reported frequently as a common infection in nursing homes, but the frequency is variable in different institutions. A prevalence of 0.3 to 3.4% has been reported in different surveys (54, 90, 141). Conjunctivitis occurs more frequently in elderly residents with greater functional impairment (18, 54). It is likely that a high proportion of conjunctivitis cases are noninfectious but are due to irritative or other factors (18). The bacteriology of endemic conjunctivitis is not well studied. *S. aureus* is the organism most frequently isolated; infections with upper respiratory flora such as *Moraxella catarrhalis* and *Haemophilus* spp. are also reported (18). These organisms may be isolated, however, from the conjunctivae of patients without clinical conjunctivitis in the nursing home (18). Conjunctivitis has been reported as a clinical presentation for some patients in outbreaks caused by group A beta-hemolytic streptococcus and MRSA (22, 31).

(iv) Other skin infections. Reactivation of latent herpesvirus infections manifested as orofacial herpes simplex (cold sores) and dermatomal varicella-zoster (shingles) occurs in the nursing home population, but the frequency in these populations is not well described. Jackson et al. (75) reported that shingles and herpes simplex infections each accounted for 0.5% (0.9 episodes per 10,000 patient days) of all skin or mucous membrane infections observed over 3 years in one nursing home.

Mucocutaneous candidal infections occur frequently (172, 185). These may manifest as thrush, angular cheilosis, intertriginous infections, and vulvovaginal candidiasis. Jackson et al. (75) reported that 4% of all infections in a 3-year period were candidal, with an incidence of 0.28 per 1,000 resident days. Other studies have reported a prevalence of oral candidiasis as high as 47% (185).

Gastrointestinal infections. Gastrointestinal infections in the nursing home are usually identified and reported as outbreaks (88, 116). The spectrum of agents responsible for epidemic infections ranges from enterotoxins such as those associated with *S. aureus*, *Clostridium perfringens*, and *Bacillus cereus* to invasive pathogens, including *Salmonella* spp. and *Shigella* spp. (88). Occasional outbreaks have been attributed to viral agents such as rotaviruses or Norwalk-like agents. No surveys have identified either the incidence or the prevalence of infectious diarrhea in the nonepidemic setting. Most episodes of diarrhea in the nursing home patient are probably noninfectious in origin and are related to the patient's underlying disease, medications (including antibiotics), or diet, especially high-protein nutritional supplements.

TABLE 7. Organisms isolated from bacteremic nursing home patients

Bacteria	No. (%) of isolates reported in reference:			
	Muder et al. (102)[a] (n = 203)	Nicolle et al. (115) (n = 30)	Setia et al. (144) (n = 108)	Rudman et al. (137) (n = 33)
Staphylococcus aureus	30 (15)	3 (10)	14 (13)	3 (9.1)
Enterococcus spp.	16 (7.9)	1 (3.3)	4 (3.7)	3 (9.1)
Coagulase-negative staphylococci	8 (3.9)		1 (0.9)	
Beta-hemolytic streptococcus	9 (4.4)	2 (6.7)	4 (3.7)	
Streptococcus pneumoniae	8 (3.9)	4 (13)	1 (0.9)	3 (9.1)
Other gram-positive bacteria	1 (0.5)		3 (2.8)	
Escherichia coli	26 (13)	11 (37)	35 (32)	5 (15)
Providencia stuartii	27 (13)		6 (5.6)	8 (24)
Proteus spp.	26 (13)	3 (10)	15 (14)	6 (18)
Klebsiella pneumoniae	18 (8.9)	2 (6.7)	11[b] (10)	
Pseudomonas aeruginosa	11 (5.4)		8[c] (7.4)	2 (6.1)
Morganella morganii	6 (3.0)			
Other gram-negative bacteria	8 (3.9)	1 (3.3)	2 (1.9)	3 (9.1)
Anaerobes	9 (4.4)	3 (10)	4 (3.7)	
Case/fatality ratio (%)	21	24	35	21

[a] Includes data from both intermediate-care and nursing homes.
[b] Includes *Enterobacter* spp.
[c] Includes *Serratia* spp.

Toxigenic *Clostridium difficile* has been reported to be endemic in some nursing homes (13, 166). The prevalence of *C. difficile* stool carriage has been reported to be 9 to 26%, with higher rates identified after antibiotic therapy. It is uncertain at this time whether this phenomenon is limited to selected nursing homes or is generalizable. In those nursing homes with high rates of colonization with endemic *C. difficile*, most patients are asymptomatic, but carriage may persist for an extended time (13).

Bacteremia. Bacteremia in nursing homes is usually secondary to a focal site of infection, reflecting the relatively infrequent use of central vascular lines in these facilities to date. The most common source, as previously noted, is the urinary tract. The majority of nonurinary cases are secondary to skin and soft tissue infection or pneumonia. The incidence of bacteremia is reported to vary widely, from 4 to 39 episodes per 100,000 resident days. The reported variation likely reflects differences in patient populations and interventions in different institutions. The case/fatality ratio for bacteremic patients is 21 to 35% (102, 115, 137, 144) and is consistent with reports of mortality rates in other populations in which similar organisms have been isolated. Table 7 summarizes the microbiology of bacteremia in nursing homes (102, 115, 137, 144). From 9 to 22% of episodes are polymicrobial, with a soft tissue source most frequently associated with polymicrobial bacteremia.

Outbreaks of Infection

The nursing home provides a milieu that is conducive to outbreaks of infectious diseases due to the close proximity of susceptible patients in the institutional setting and subsequent cross-transmission of organisms among patients through contacts with staff members or environmental contamination. Many different microorganisms with different modes of transmission have been reported to cause outbreaks in the nursing home setting. These include outbreaks of upper and lower respiratory tract infection, urinary tract infection, gastrointestinal tract infection, conjunctivitis, and some skin infections. Certain microorganisms, including group A streptococci,

TABLE 8. Organisms reported to have caused outbreaks in nursing homes

Organism	Reference(s)
Bacteria	
Staphylococcus aureus	20, 71, 88, 103, 160, 162, 167
Group A streptococcus	8, 31, 64, 134, 136, 143
Escherichia coli O157:H7	27, 138
Salmonella spp.	9, 75, 88
Shigella spp.	88
Bordetella pertussis	1
Haemophilus influenza	152
Campylobacter jejuni	88
Aeromonas hydrophila	17
Antimicrobial agent-resistant gram-negative bacilli	77, 135, 150, 186
Clostridum perfringens	88
Clostrium difficile	14
Bacillus cereus	88
Mycobacterium tuberculosis	12, 108, 157, 158
Viruses	
Influenza A and B	7, 34, 37, 59, 70, 75, 124, 125, 156
Parainfluenza	46, 75
Respiratory syncytical virus	3, 46
Adenovirus	46
Rhinovirus	46
Coronavirus	46
Rotavirus	75, 92
Calicivirus	75
Norwalk agent	56, 75, 127
Parasites	
Giardia lamblia	184
Entamoeba histolytica	88
Sarcoptes scabie var. *hominis*	44

MRSA, *Salmonella* spp., and resistant gram-negative organisms, produce outbreaks in which patients present with a variety of different clinical syndromes. Organisms reported as causes of nursing home outbreaks are listed in Table 8.

Influenza. The single most important etiologic agent in outbreaks of infection in nursing homes is influenza. Outbreaks are usually due to influenza A, although outbreaks caused by influenza B may also occur (36, 61, 124). Influenza outbreaks frequently affect a high proportion of nursing home residents, as many as 50 to 100%; many staff members may also be ill (7, 59, 70, 156). The case/fatality ratios are also high: 10 to 35% of ill residents (124). Lack of influenza immunization, presence in larger institutions (125), and comorbidities such as congestive heart failure and chronic obstructive pulmonary disease increase the risk for both infection and mortality.

Gastrointestinal infections. Outbreaks of gastrointestinal infection are common in long-term care facilities. Food-borne outbreaks are most frequently caused by *Salmonella* spp., although many other organisms have been implicated (88). While food products are usually the vehicle for introduction of the organism, subsequent person-to-person spread often occurs, prolonging the duration of the outbreak. Fecal incontinence in patients may facilitate patient-to-patient transmission. Case/fatality ratios of up to 12% have been reported for some outbreaks due to *Salmonella* spp. and enterohemorrhagic *E. coli* (88). By contrast, the case/fatality ratio for most other pathogens is low.

Scabies. Scabies outbreaks have been repeatedly reported in nursing homes (44). Transmission from patient to patient, patient to staff, and staff to patient and via environmental fomites all contribute to outbreaks.

Group A streptococcus. Outbreaks of group A streptococcal (*Streptococcus pyogenes*) infection have been frequently reported in nursing homes (8, 31, 134, 136, 143). Infected patients may present with bacteremia, pneumonia, cellulitis, wound infection, pharyngitis, or conjunctivitis (143). Rarely, a toxic shock-like syndrome occurs. Residents with skin ulcers and wounds are at greater risk of invasive infection. In most outbreaks, geographic localization to a floor or wing of the facility occurs (143).

ANTIMICROBIAL RESISTANCE

Sources

Antimicrobial agent-resistant bacteria may be introduced into nursing homes by two different routes. They may emerge endogenously in patient flora during courses of antimicrobial therapy, or they may enter with new residents who are already colonized or infected. Emergence may reflect selection of resistant strains or acquisition of genetic determinants that confer resistance by either spontaneous mutation or gene transfer.

Spontaneous mutations that confer resistance are thought to be rare, but two studies have suggested that gene transfer plays an important role in long-term care facilities. In an outbreak caused by ceftazidime-resistant bacteria in a chronic-care facility in Massachusetts, Rice et al. reported that the outbreak arose from plasmid transmission among different species and genera of *Enterobacteriaceae* and not from dissemination of a single resistant isolate (135). The outbreak, which involved 29 patients, was caused by strains of *K. pneumoniae*, *Enterobacter cloacae*, *E. coli*, *Serratia* spp., *Enterobacter agglomerans*, and *Citrobacter diversus* that produced similar extended-spectrum beta-lactamases whose genes were located on closely related plasmids. The outbreak had followed the introduction of ceftazidime into the facility and its widespread empiric use. Shlaes and colleagues reported similar observations in their study of gentamicin-resistant gram-negative bacilli in a VA nursing home care unit (150). One *E. coli* plasmid, which conferred resistance to ampicillin, carbenicillin, tetracycline, and sulfonamides, proved identical to plasmids from two *Citrobacter freundii* strains and a *Providencia stuartii* strain isolated from three different patients.

The introduction of resistant strains by colonized or infected patients who are admitted from other facilities has also been documented. One VA study reported the entry of an MRSA strain into the nursing home by a patient who was colonized at the referring hospital (162). Another VA study revealed that 8 of 10 patients admitted to an intermediate-care ward were already colonized with strains of members of the *Enterobacteriaceae* carrying a plasmid encoding a novel beta-lactamase (149).

Regardless of the route of entry for resistant pathogens into the nursing home, antimicrobial usage drives selection pressure for new acquisitions. Bjork and colleagues (16) reported that, in 10 patients with chronic indwelling urinary catheters residing in a VA nursing home care unit in North Dakota over 30 months, 70% of 63 antibiotic courses resulted in bacteriuria with organisms resistant to the antibiotic that had been administered. As 40% of the positive urine cultures were polymicrobial, it is likely that antimicrobial therapy merely selected out the more resistant strains. The authors identified cross-infection in only one case. Of note, in this study, a significantly

greater percentage of *E. coli* strains isolated from nursing home residents were resistant to ampicillin, tetracycline, and trimethoprim-sulfamethoxazole than *E. coli* strains isolated from patients in the adjoining hospital.

Occurrence

The appearance of antimicrobial agent-resistant bacteria in nursing homes and other long-term care facilities has been repeatedly documented since the early 1970s. Most information is derived from surveillance studies of infections in nursing home residents or outbreak investigations. No studies have defined the overall magnitude of this problem in a systematic manner, but available data suggest that antimicrobial agent-resistant pathogens are frequently encountered in this setting. Certain types of antimicrobial agent-resistant pathogens, e.g., penicillin-resistant pneumococci and erythromycin-resistant streptococci, have not yet been reported in nursing home populations, but their increasing prevalence in other settings means they should be anticipated.

Terpenning and colleagues at the Ann Arbor VA nursing home care unit screened all residents during a 2-year period for colonization or infection with MRSA, enterococci with high-level gentamicin resistance, and gram-negative bacilli resistant to either gentamicin or ceftriaxone (165). During the first year, before a mupirocin decolonization protocol was initiated, the percentage of residents colonized with MRSA averaged 22.7% ± 1%. In the same year, 20.2% ± 1% of patients were colonized with resistant enterococci and 12.6% ± 1% were colonized with resistant gram-negative bacilli. The last two rates were unchanged during the second year of the study. During the study, 50% of the infections with an identified etiology were caused by one of the antibiotic-resistant pathogens. This study offers the most comprehensive picture of the role that antimicrobial agent-resistant pathogens can play in the ecology of nursing home care units. Piecemeal observations from surveillance studies and outbreak investigations suggest that the experience at the Ann Arbor VA facility is not atypical. Moreover, the composite published experience likely represents only the tip of the iceberg.

MRSA. The presence of MRSA in nursing homes was first reported in 1970 by O'Toole et al., whose hospital outbreak was initiated by a patient referred from a local nursing home (120). Reports of MRSA cases in U.S. nursing homes and other long-term care facilities increased dramatically in the late 1980s. Outbreaks or high rates of endemic MRSA colonization and infection were reported from facilities in California, New York, Illinois, Michigan, Minnesota, Missouri, Pennsylvania, Washington, Oregon, Maryland, and Kentucky (2, 20, 25, 71, 103, 105, 107, 160–162, 165, 167, 169, 174). These reports emanated from both community and VA nursing homes, from large and small facilities, from urban and nonurban settings, and from adult and pediatric units. The sheer volume of these reports suggested that MRSA became entrenched in nursing homes throughout the country in the late 1980s.

Thurn et al. (169) surveyed all of 445 long-term care facilities in Minnesota by questionnaire in 1980; 395 (88%) facilities responded, and 12% of these reported MRSA cases. MRSA was acknowledged as a problem for 80% of these facilities, and 69% of facilities with MRSA cases had sought outside help or consultation for its control. In 1991, Mylotte and colleagues surveyed 81 long-term care facilities located in eight western counties in New York (107). Of the 75 responding facilities, 81% indicated that they had identified one or more MRSA cases in the preceding year and 21% indicated that they had an infection control problem with MRSA. Larger bed size of the facility was statistically associated with MRSA prevalence. In Oregon, Ward and Strausbaugh sent questionnaires to 192 nursing homes in 1990 (174). Of the 109 facilities that responded, only 1 indicated that it had MRSA cases in 1985 and 1986, whereas 34 (31%) reported MRSA cases in 1989. Twelve of the 26 counties with facilities responding had one or more facilities reporting MRSA cases. Both large (>59 beds) and small (20 to 39 beds) facilities reported MRSA cases in 1989. The number of MRSA cases in the involved facilities also increased substantially during the period 1985 to 1989. Thus, these three surveys, performed at different times in different parts of the country, depict widespread involvement of nursing homes and other long-term care facilities in the national MRSA problem.

MRSA strains in nursing homes have also acquired fluoroquinolone resistance. Ciprofloxacin resistance was noted in MRSA strains isolated in 1988 from 12 residents of eight nursing homes in metropolitan New York within 3 months after the drug had become commercially available (25). During an MRSA outbreak at a VA nursing home care unit in Washington, ciprofloxacin-resistant strains of MRSA appeared in the second quarter of 1988; within a year, all strains isolated from residents in the facility were resistant to this drug (162).

Gram-negative uropathogens. Urine cultures from nursing home patients often yield antimicrobial agent-resistant gram-negative bacilli. These include highly resistant strains of bacteria belonging to genera that are usually susceptible to most antimicrobial agents when isolated from other populations. For instance, ampicillin-resistant isolates of *E. coli* and cephalothin-resistant isolates of *Klebsiella* spp. are common in nursing homes (47, 54, 102, 148). Other resistant urinary pathogens belong to genera that are noted for resistance to multiple agents. For example, *Providencia* spp., which are often resistant to beta-lactam and aminoglycoside antibiotics, are frequently isolated in nursing homes from the urine of catheterized residents but are rarely recovered in other settings (4, 87, 102, 155, 178, 180).

Aminoglycoside resistance in gram-negative uropathogens has been repeatedly observed (4, 57, 89, 102, 148, 165). In a 1-day prevalence study conducted in seven nursing homes in Salt Lake City, Utah, Garibaldi and colleagues found that 33% of the gram-negative uropathogens were gentamicin resistant (54). Similarly, in a prevalence study conducted in a VA nursing home care unit in suburban Cleveland, Ohio, Shlaes and colleagues isolated gentamicin-resistant gram-negative bacilli from the urine of 16% of the patients (150). Resistance to trimethoprim and the combination of trimethoprim-sulfamethoxazole has been frequently documented in nursing homes (16, 102, 148, 186). Wingard et al. detected colonization of urine or perineum with trimethoprim-resistant gram-negative bacilli in 52% of patients at a VA nursing home care unit surveyed at quarterly intervals over a 2-year period (186). Resistance to fluoroquinolones has also been described (87, 101). Prospective surveillance in seven skilled nursing facilities in southern California found that approximately one-third of urinary *Pseudomonas* isolates and 12% of isolates of the family *Enterobacteriaceae* were norfloxacin resistant (87). Lastly, resistance to beta-lactam antibiotics (e.g., penicillin and cephalosporin) has commonly been noted in uropathogens from long-term care facilities (16, 47, 54, 102, 135, 148). Thus, gram-negative bacilli isolated from the urine of nursing home patients demonstrate resistance to many antimicrobial agents and, in fact, number among the most resistant microbes known.

Other organisms. At least three other kinds of antimicrobial agent-resistant pathogens have been identified in nursing homes. Zervos et al. reported the prevalence of high-level aminoglycoside-resistant enterococci in a VA nursing home care unit and community nursing home in Ann Arbor, Mich., in 1986 (187). Cultures of urine specimens and rectal swabs indicated that 4.3% of the residents in the community nursing home and 47% in the VA facility were colonized with aminoglycoside-resistant enterococci. The higher rate of colonization in the VA nursing home care unit patients was thought to reflect the high rate of colonization (36%) in the acute-care division of the Ann Arbor VA Medical Center. Vancomycin-resistant strains of *Enterococcus faecalis* and *Enterococcus faecium* have recently been reported from nursing homes in Oklahoma (50).

Smith and colleagues described an outbreak caused by an ampicillin-resistant strain of *H. influenzae* involving six patients in a nursing home and adjoining hospital during a 1-month period (152). Two patients were bacteremic and one died. All patients had personal contact with at least one other case patient, suggesting person-to-person spread. Sturm et al. reported a similar outbreak involving 15 patients in a pulmonary rehabilitation center in The Netherlands (164). The outbreak strain of *H. influenzae* was resistant to amoxicillin, trimethoprim-sulfamethoxazole, chloramphenicol, and tetracycline. Lastly, Choi et al. described a 1988 nursing home outbreak caused by a *Salmonella heidelberg* serotype frequently expressing multiple resistance (35). Forty-four (22%) of the 199 residents were affected. Patients treated with antibiotics excreted the outbreak strain for a median duration of 14 weeks, prolonging the presence of a potential source for additional cases.

Risk Factors for Acquisition

For infection. Only two studies have examined risk factors for infection with antimicrobial pathogens in nursing home patients. Muder and colleagues reported risk factors for MRSA infection in residents of their VA intermediate-care ward and nursing home care unit (103). In a stepwise logistic regression analysis, both persistent MRSA colonization and dialysis were independent risk factors for MRSA infection. Terpenning et al., in Ann Arbor, Mich., identified risk factors for infection caused by both MRSA and resistant gram-negative bacilli (165). By stepwise logistic regression analysis, diabetes mellitus and peripheral vascular disease were significant independent risk factors for MRSA infection. Intermittent urinary catheterization and presence of an indwelling urinary catheter were significant independent risk factors for infection caused by resistant gram-negative bacilli.

For colonization. A number of studies have reported risk factors for colonization with antimicrobial agent-resistant pathogens in nursing homes (2, 20, 71, 77, 101, 150, 165, 167, 186). Taken as a whole, they indicate that poor functional status, prior antibiotic use, presence of wounds (such as pressure sores), and presence of foreign bodies (such as urinary catheters) predispose nursing home residents to colonization with resistant microbes. Long-term care facilities often house large numbers of patients with these risk factors. Thus, spread and persistence of resistant strains in this environment are anticipated.

(i) MRSA. In a case control study conducted in a community nursing home, Thomas et al. reported that nasogastric intubation and antibiotic therapy in the previous 6 months were the most important factors associated with MRSA colonization (167). Hsu, reporting the results of eight prevalence surveys in one community nursing home over a 15-month period, associated MRSA carriage with several measures of patient debility including bedridden or chair- or bed-confined status and presence of pressure ulcers, feeding tubes, or urinary catheters (71). Murphy et al. examined preadmission risk factors for MRSA colonization in patients of a large university-affiliated long-term care facility (105). By stepwise logistic regression analysis, they found that prior positive MRSA culture, male sex, urinary incontinence, and presence of a pressure sore were independent risk factors for MRSA colonization at admission. Lastly, Terpenning et al., using stepwise logistic regression, found both presence of wounds and presence of pressure ulcers to be independent risk factors for MRSA colonization (165).

(ii) Gram-negative uropathogens. Shlaes and colleagues identified risk factors for urinary colonization with gentamicin-resistant gram-negative bacilli in patients of a VA nursing home care unit near Cleveland, Ohio, using stepwise logistic regression (150). Perineal or rectal colonization with gentamicin-resistant strains and presence of a urinary catheter were significant independent risk factors. Another study at the same institution by Wingard et al. examined carriage of trimethoprim-resistant gram-negative bacilli (186). Functional status and length of stay were significant independent risk factors for colonization; functional status was the most important risk factor for acquiring trimethoprim-resistant strains by cross-colonization. Gaynes et al., studying colonization with multiply resistant gram-negative bacilli in patients admitted to the hospital from community nursing homes, reported, by discriminant analysis, that bladder dysfunction, residence in large nursing homes, age, and prior antibiotic use were independent risk factors (55). Muder et al. (101) reported that decubiti, clinical infection, and prior quinolone use were independent risk factors for acquisition of fluoroquinolone-resistant organisms. Lastly, Terpenning et al. identified intermittent catheterization, inflammatory bowel disease, chronic renal disease, presence of wounds, and prior pneumonia to be independent risk factors for colonization with gentamicin- and/or ceftriaxone-resistant gram-negative bacilli in a stepwise logistic regression analysis (165).

(iii) Enterococci with high-level gentamicin resistance. Two studies, both from the Ann Arbor VA nursing home care unit, have identified risk factors for colonization with gentamicin-resistant strains of enterococci (165, 187). In the first study, a one-day prevalence survey reported by Zervos et al. in 1987, the need for advanced nursing care and antibiotic therapy in the preceding 3 months were independent risk factors for colonization (187). In the second study, a 2-year surveillance study reported by Terpenning et al. in 1994, presence of wounds, renal failure, intermittent catheterization, low Katz functional status, and low serum albumin were independent risk factors for colonization with strains possessing high-level resistance to gentamicin (165).

Natural History

The literature on MRSA confirms that antimicrobial agent-resistant pathogens persist once introduced into long-term care facilities. They spread to other residents and become endemic. Widespread dissemination throughout some facilities has been documented. For example, 15 months after the introduction of MRSA into a VA nursing home care unit in Washington, a prevalence study identified 34% of the patients and 7% of the staff to be colonized with MRSA (162). Several studies have documented large proportions of residents colonized with MRSA over extended periods of observation. Bradley and colleagues performed monthly surveillance cultures on

residents of the VA nursing home care unit in Ann Arbor, Mich., over a 2-year period (20). The mean monthly colonization rate for MRSA at any site was 23% ± 1%. Individual patients remained colonized for months at a time; in fact, 65% of the 60 patients who were evaluated for at least 3 months after MRSA colonization was documented exhibited persistent or probable persistent colonization. Muder et al. noted similar persistence in MRSA carriers at another VA facility in Pennsylvania and documented an increased infection rate in MRSA carriers (103). Similar findings of MRSA persistence have been reported from studies in community nursing homes. For example, Thomas et al. performed surveillance cultures on residents of a skilled nursing facility in California on two occasions and found 9.1% of residents to be colonized or infected with MRSA at the time of the first survey and 6.6% to be colonized or infected at the time of the second survey, 3 months later (167). Likewise, in a 15-month surveillance study of an Illinois nursing home, Hsu found that 5 to 16% of the residents were colonized with MRSA on each of the eight sampling dates (71).

The persistence of antimicrobial agent-resistant bacteria in nursing homes has been attributed to a number of factors, but the presence of large numbers of patients with acknowledged risk factors appears most important (29, 77). These patients have significant underlying diseases and indwelling foreign bodies (urinary catheters, feeding tubes, tracheostomies, etc.); they frequently receive antimicrobial therapy; and they generally stay for months to years. A number of institutional factors may also contribute. Unlike hospitals, nursing homes house a majority of their patients in two- or four-bed rooms, and patients are frequently brought together for meals and various types of therapy. These interactions may increase the likelihood of person-to-person transmission. High patient-to-staff ratios, staffing by nonprofessional personnel, frequent turnover of health care workers, meager emphasis on infection control, and limited facilities for handwashing may also facilitate cross-infection (54, 55, 77). In large facilities with greater numbers of skilled-care beds, increased prevalence of patients colonized with resistant pathogens has been observed (55). Several survey studies have documented deficiencies in the infection control programs of U.S. and Canadian long-term care facilities (26, 41, 84, 133). Lastly, antibiotic usage seems to play a role in the persistence of resistant strains in long-term care facilities. Rice and coworkers, for example, noted that restrictions on the empiric use of ceftazidime in their chronic-care facility led to a transient reduction in the number of ceftazidime-resistant cases in the subsequent 6-month period (135).

Transmission

Few nursing home studies have focused specifically on the sources, reservoirs, and means of transmission of resistant organisms. It seems likely that the same factors responsible for the spread and maintenance of MRSA and other resistant pathogens in hospitals are operative (19, 104). For MRSA, infected and colonized residents are thought to constitute the major reservoir and source of resistant strains. Of note, however, in the 1-year study reported by Bradley et al. at the Ann Arbor VA center, only 3% of the 258 patients at risk appeared to acquire their MRSA strain from a roommate (20). These findings suggest that other sources may be present. Although several studies have documented MRSA carriage in health care workers in nursing homes, none have directly implicated staff in strain transmission (160, 162, 167). Several studies from nursing homes have also reported the recovery of MRSA and enterococci with high-level aminoglycoside resistance from environmental surfaces (20, 85, 163, 187), but the potential role of the inanimate environment as a reservoir or source is otherwise unexplored.

As in the hospital, patient-to-patient spread primarily between patients and the transiently colonized hands of a health care worker is thought to be the principal mode of transmission. Isolation of resistant pathogens from the hands of health care workers and observations on the timing of new cases support this theory for MRSA (85, 86), resistant gram-negative uropathogens (150, 186), and *H. influenzae* (152, 164). Although not well studied, no evidence published to date has strongly implicated indirect contact via environmental sources, droplet or airborne generation by colonized patients with tracheostomies, or contaminated common vehicles as important means of spread of antimicrobial agent-resistant pathogens in nursing homes.

TABLE 9. Recommended approaches to the prevention and minimization of infections in nursing homes

Management strategies
Infection control program
Surveillance
Outbreak investigation
Policies, isolates, environment, staff
Education
Antimicrobial utilization program
Employee health program
Patient care strategies
Optimal management of associated diseases
Optimal nutrition
Avoidance of invasive devices
Vaccination
Influenza
Pneumococcus
Tetanus
Screening
Tuberculosis
Outbreak management
Mechanism for early identification
Policies for laboratory utilization
Case finding and analysis
Isolation and cohorting
Specific therapy

PREVENTION AND CONTROL OF INFECTIONS IN NURSING HOMES

Despite the high prevalence and incidence of infections in nursing homes, there has been little evaluation of methods to limit infection. A number of approaches have been proposed (Table 9). These recommendations are, in most cases, based on extrapolations of programs that are considered to be effective in acute-care facilities or based on clinical observations in the nursing home population; they are not based on evidence of efficacy from studies performed in the nursing home setting. There is a need for critical evaluation of strategies that may be effective in decreasing the occurrence or impact of infections and antimicrobial resistance in the nursing home population.

Administrative Programs

Most nursing homes have infection control programs, although the components of these programs vary among different institutions and reports repeatedly document widespread deficiencies in such programs (26, 41, 54, 84). The overall goal of the infection control program is to prevent infections and,

when that is not possible, to limit interpatient transmission of potential pathogens (112). An infection control program in the nursing home must have an effective administrative structure that promotes the efficient operation of the program as well as adequately trained personnel to carry out the work of the program. Access to trained professionals in microbiology, infectious diseases, or other medical disciplines may not be as readily available as in acute-care institutions. Ensuring access to expert consultants, when necessary, should be a component of the program.

Surveillance for infections in the nursing home is integral to the program (153). Valid infection surveillance requires the use of standard definitions appropriate for the nursing home (96), effective case finding measures, systematic analysis and reporting of data, and an awareness to identify potential outbreaks as early as possible. The optimal method for surveillance in nursing homes is not defined. It likely differs depending on the unique characteristics, staffing, and patient populations of different institutions. Approaches to infection surveillance in nursing homes have included prevalence surveys, incidence surveys, active and passive case identification, and focused surveillance.

Institutional policies must be developed for practices relevant to infection control. These include handwashing, isolation practices, environmental issues, food preparation, employee health, preadmission screening, and vaccination policies for staff and patients. Several national documents or guidelines which will assist in developing policies for selected important infectious diseases in nursing homes have been published. Topics addressed include influenza (32, 33), tuberculosis (12), group A streptococcus (143), and scabies (44).

An antimicrobial review program should also be developed. This may be a component of the infection control program. If the program is not developed administratively within the infection control program, close interaction and cooperation between the two programs must be assured. Several approaches to promoting optimal antimicrobial agent use, such as a restricted formulary, clinical guidelines for empiric antimicrobial use, and antimicrobial usage review, may be incorporated into such a program. Physician participation is essential. Issues related to antimicrobial use will receive greater priority with increasing recognition of the role of the nursing home in the clinical and societal problems of antimicrobial resistance.

The nursing home setting presents unique challenges that may impair optimal function of the infection control program. First, individuals who manage and perform the work of the program frequently have other institutional duties that limit the time available to the infection control program and that frequently take priority. In Canada, 93% of individuals responsible for infection control in nursing homes have additional job duties unrelated to infection control (26), and in Maryland 60 to 97% of infection control practitioners in nursing homes have other duties (84). Personnel who work in infection control in long-term care facilities may have limited training and limited access to training programs (41, 84). This problem has been addressed by the development of regional training programs in some areas. These have been shown to lead to improvements in the knowledge of practitioners and the effectiveness of programs (42). Additional problems in developing and maintaining an effective infection control program include a high turnover of patient care staff, many of whom have a lower level of training that those in acute-care institutions, and the virtual absence of evaluation supporting cost-effectiveness of proposed interventions in the current climate of resource limitation.

Patient Care Practices

Patient-specific strategies to prevent infection are targeted to increase general and specific immunity and, hence, limit susceptibility to infection. These include maintenance of adequate nutrition and optimal management of associated chronic diseases. For example, nursing care practices should attempt to minimize or prevent the occurrence of aspiration in patients with neurologic impairment, avoid trauma to neuropathic feet, and prevent development of pressure ulcers in patients with limited mobility. Ensuring optimal use of immunizing agents is important, including pneumococcal vaccination (30) and yearly influenza vaccination (32).

Use of invasive devices should be limited to those situations in which they are essential for patient care. When tube feeding is necessary to maintain nutritional status, percutaneous gastrostomy or jejunostomy feeding tubes may be preferred over nasogastric tubes because of a reported decreased occurrence of aspiration pneumonia (48); however other studies have not supported this observation (37, 126). It has been suggested that use of external condom catheters for incontinence in men may be associated with a lower incidence of invasive urinary infection compared with long-term indwelling catheters, but this, too, is controversial because of a reported increased incidence of phimosis and skin irritation that predisposes to urinary infection in patients with these types of external collection devices (49). Further evaluation of the relative benefits and risks of different supportive care approaches and their influence on infections should be a priority in this population.

Outbreak Management

Outbreaks of infection should be anticipated in the nursing home, and policies to respond to a suspected or proven outbreak must be developed prior to occurrence. Such policies should include general aspects of outbreak management, including identification, communication, and authority, as well as specific issues related to the most frequent organisms likely to occur (e.g., influenza or salmonellosis). Adequate management requires ongoing surveillance for infection to ensure early identification, specific criteria to identify a potential outbreak, case finding strategies, and laboratory backup to identify the etiologic agent and plan appropriate interventions. For instance, specific plans to direct the collection and processing of specimens for stool cultures or respiratory viral studies in an outbreak situation should be drawn up. Authority within the institution to initiate appropriate measures to control an outbreak should be clearly defined. Early notification and ongoing communication within the institution and with appropriate public health authorities must be outlined clearly prior to the crisis of an epidemic.

The response to the outbreak must include immediate control measures to identify and isolate cases, as appropriate, and limit patient and staff exposure. Control measures will include use of patient isolation or cohorting, limitations in patient movement and interaction within the facility, and, frequently, specific therapy. Examples of the latter include administration of amantidine in influenza outbreaks (33), penicillin in group A streptococcal outbreaks (143), prophylactic isoniazid for tuberculosis skin convertors (12), and treatment for scabies (44). Compliance with isolation practices leads to special problems in nursing homes. As patients' rooms are, in fact, their permanent residence, transfer within the institution for isolation purposes is disruptive for patients and family. Cognitively impaired residents will not be able to understand the reasons for and practices of isolation, and it may be difficult to restrict movement for some of these patients. Policies developed

should acknowledge these potential problems and identify the methods by which they will be addressed.

An integral part of outbreak management is a review and analysis of the course of the outbreak, impact, and potential problem areas that may be changed to improve management in the future. This is optimally achieved through development of a written descriptive and summary report that should be submitted to appropriate committees and administrative personnel in the institution and public health personnel, when appropriate.

CONCLUSIONS

Infections are common in nursing homes and present many unique challenges. The interaction of chronic diseases and physiologic changes associated with aging along with the facilitation of transmission in the institutional environment lead to a high rate of endemic infections and continual risk for outbreaks of infection. The high frequency of infection results in intense antimicrobial use within the nursing home. The inherent clinical and laboratory diagnostic uncertainty leads to an overuse of empiric antibiotics. All of these factors contribute to the present crisis of increasing antimicrobial resistance among nursing home patients. Current trends suggest that nursing home populations will be even more impaired in the future, while resources available to support their care, including infection control programs, may be further restricted. The challenges for the future are to minimize infection in the nursing home while limiting the emergence of antimicrobial resistance with optimal, cost-efficient care. There is an urgent need for clinical studies to evaluate strategies for the prevention and management of infections in the nursing home patient.

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