# Colonization and Infection with Antibiotic-Resistant Bacteria in a Long-Term Care Facility

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OBJECTIVE: To assess colonization and infection with methicillin-resistant *Staphylococcus aureus* (MRSA), high-level gentamicin-resistant enterococci (R-ENT) and gentamicin and/or ceftriaxone-resistant Gram-negative bacilli (R-GNB) and the factors that are associated with colonization and infection with these organisms.

DESIGN: Monthly surveillance for colonization and infection over a period of 2 years. In the second year, an intervention to decrease MRSA colonization by the use of mupirocin ointment was carried out.

SETTING: Long-term care facility attached to an acute care Veterans Affairs Medical Center.

PATIENTS: A total of 551 patients in the facility were followed for a period of 2 years.

MEASUREMENTS: Colonization and infection rates with MRSA, R-ENT, and R-GNB. Analysis of risk factors associated with colonization and infection with these three groups of organisms.

MAIN RESULTS: In the first year, colonization rates were highest for MRSA (22.7±1% patients colonized each month) and R-ENT (20.2±1%) and lower for R-GNB (12.6±1%). After introduction of decolonization of nares and wounds with mupirocin, the rate of MRSA colonization fell significantly to 11.5 ± 1.8%, but rates remained unchanged for R-ENT and R-GNB. Risk factors for MRSA colonization included the presence of wounds and decubitus ulcers. For R-ENT, the presence of wounds, renal failure, intermittent urethral catheterization, low serum albumin, and poor functional level were significant. For R-GNB, intermittent urethral catheterization, chronic renal disease, inflammatory bowel disease, presence of wounds, and prior pneumonia were significantly associated with colonization. Overall, of infections caused by known organisms, 49.6% were due to MRSA, R-ENT, or R-GNB, and 50.4% were due to susceptible organisms. Infections were more commonly due to R-GNB (21.1% of all infections) than to R-ENT (8.3%) or MRSA (4.6%). The most common infections were urinary tract infections (42.9% of all infections) and skin and soft tissue infections (31.9% of all infections). Risk factors for MRSA infections were diabetes mellitus and peripheral vascular disease, for R-GNB infections were intermittent urethral catheterization and indwelling urethral catheters, and no one factor was associated with R-ENT infection.

CONCLUSIONS: In our long-term care facility, colonization with resistant MRSA and R-ENT was more common than R-GNB, but infections were more often due to R-GNB than R-ENT and MRSA. Several host factors, which potentially could be modified in order to prevent infections, emerged as important in colonization and infection with these antibiotic-resistant organisms. **J Am Geriatr Soc 42:1062–1069, 1994.**

Infections acquired by the elderly in long-term care facilities are a growing problem.[1-3] Many of these infections are caused by antibiotic-resistant bacteria.[4-12] Most studies have focused on infections caused by one particular antibiotic-resistant microorganism and have often been initiated by the occurrence of an outbreak.[12-16] Many have focused on Gram-negative bacilli resistant to aminoglycosides or cephalosporins.[6,15,16] Recently, several reports have emphasized the role of antibiotic-resistant Gram-positive cocci, specifically methicillin-resistant *Staphylococcus aureus* (MRSA)[8-14] and high level aminoglycoside-resistant enterococci (R-ENT).[7] Very few studies have prospectively defined the prevalence and incidence of colonization and infection with several different antibiotic-resistant microorganisms over a prolonged period of time. In this 2-year study, we prospectively determined colonization and infection with MRSA, R-ENT, and ceftriaxone- and/or gentamicin-resistant Gram-negative bacilli (R-GNB) and evaluated the factors associated with patient acquisition of these organisms.

## METHODS

### Facility and Patients

The Ann Arbor Veterans Affairs Nursing Home Care Unit is a 120-bed long-term care facility attached to a 300-bed acute care hospital. There are three services in the

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facility: (1) the geriatric evaluation unit to which all patients are admitted from the acute care hospital for initial evaluation and into which a patient would be transferred, if necessary, for closer medical supervision; (2) the rehabilitation service for patients requiring intensive physical, occupational, or speech therapy, or for patients with stable medical conditions finishing a specified course of therapy for some medical condition; and (3) a long-term care service for patients who have no active medical problem but require a supervised living situation. At any given time, the numbers of patients generally are equally distributed among these three services; however, the mean length of stay among the three services varies: for geriatric evaluation it is 3 months, for rehabilitation 8 months, and for long-term care it is 2 years. The three services are not physically separated. The same nursing staff care for patients on all three services, and patients transfer back and forth between services, depending on their condition. On admission, patients are classified by functional status: Group I are ambulatory and require minimal assistance in activities of daily living; group II require moderate assistance in activities of daily living and have bladder incontinence; and group III require assistance for most activities of daily living and have incontinence of bowel, bladder, or both.[17]

### Study Design

The study of MRSA, R-ENT, and R-GNB colonization was part of a 2-year project to assess colonization and infection with antibiotic-resistant bacteria and the effect on patient care costs in a long-term care facility.[9] Beginning in June 1989 and continuing through May 1991, all patients in the unit were evaluated with regard to demographics, diagnoses, clinical factors, nutritional parameters, and colonization and infection with MRSA, R-ENT, and R-GNB. Cultures were done at admission for each of the microorganisms studied, monthly thereafter, and at the time of transfer back to long-term care after any hospital admissions. The Human Studies Subcommittee and Research Committee of the Ann Arbor Veterans Affairs Medical Center approved the study protocol and felt that verbal informed consent was adequate.

In the first year of the study, June 1989 to May 1990, colonization was assessed as described. Staff caring for the patients were not made aware of culture results. Standard infection control methods (Universal Precautions combined with category specific precautions, such as contact isolation and respiratory precautions, when required) were used. Patients were treated for infections by their physicians in accordance with cultures obtained for clinical reasons through the clinical microbiology laboratory.

In the second year of the study, June 1990 to May 1991, colonization with MRSA, R-ENT, and R-GNB was assessed in the same manner as the first year. However, an intervention was used in an attempt to decrease MRSA colonization. In all MRSA carriers, mupirocin ointment in a polyethylene glycol base was applied to nares alone from June 1990 to December 1990 and to nares and wounds from January 1991 to June 1991, as described previously.[18] No specific intervention was attempted to decrease colonization with R-ENT or R-GNB. Other than knowledge about MRSA colonization resulting from participation in the mupirocin trial, staff were not made aware of the results of cultures obtained in this study. Again, patients were treated for infections by their physicians based on cultures obtained for clinical reasons through the clinical microbiology laboratory.

### Patient Factors

On admission, data, including age, sex, functional status using an adapted Katz index of activities of daily living (ADL),[17] presence of indwelling tubes or catheters, bladder and bowel function, ability to walk, transfer, and eat unattended, diagnosis prompting admission, underlying illnesses, previous hospitalization, length of stay in both acute and long-term care, and geographic location, movement, and roommates within the long-term care facility, were recorded for all patients.

### Definitions of Colonization and Infection

Colonization was defined by one or more positive cultures for MRSA, R-ENT, or R-GNB from any site. Prospective surveillance for the occurrence of infection was carried out over the 24-month period in all patients in the long-term care facility by a nurse clinician trained in infection control. Each infection was discussed by a panel of three physicians and the nurse clinician to determine whether it met criteria for nosocomial infection as defined by the Centers for Disease Control and Prevention.[19] Data on colonization was not utilized to determine the presence of infection.

### Nutritional Measurements

Serum albumin and blood lymphocyte numbers were measured by standard assays when patients entered the study. Anthropometric measurements were obtained using skin-fold calipers and a plastic tape to measure triceps skin-fold thickness and upper arm circumference. The upper arm muscle area and fat area were calculated as detailed previously.[20] Results were expressed as percent of expected, using Frischano's age-related norms.[21]

### Microbiologic Methods

Anterior nares, oropharynx, perineum, rectum, and wounds were swabbed with sterile rayon-tipped applicator sticks. The swabs used for culturing the perineum were pre-moistened with the transport media contained in the culturette; the swabs used on the other sites were not. The swabs were immediately placed into Stuart transport media, plated within 2 hours, and the plates incubated at 35°C.

Colonization with MRSA was assessed in nares, wounds, rectum, and perineum by streaking the swabs onto colistin-nalidixic acid (CNA) agar containing 5% sheep's blood. Yellow and white colonies that were Gram-positive cocci in clusters on Gram's stain were identified as S. aureus by positive catalase test, positive Accu-Staph latex agglutination test for protein A (Carr-Scarborough Microbiologics, Decatur, GA), and positive tube coagulase test if the Accu-Staph test was equivocal. Methicillin resistance was established if growth occurred after incubation for 24 hours at 35°C on Mueller-Hinton agar containing 4% sodium chloride and 6 μg/mL oxacillin. All isolates were phage-typed by standard methods at the Michigan Department of Public Health Laboratory.

Colonization with R-ENT was assessed in wounds, rectum, and perineum by streaking the swabs on CNA plates as noted for MRSA. Colonies producing alpha or no hemolysis were determined to be enterococci by negative catalase

test, positive bile esculin test, and growth in 6.5% sodium chloride. High-level gentamicin-resistance was established if growth occurred on trypticase soy agar containing 500 µg/mL gentamicin.[7]

Colonization with R-GNB was sought in oropharynx, perineum, rectum, and wounds by streaking the swabs on two separate MacConkey agar plates, one containing 40 µg/mL gentamicin and the other 100 µg/mL ceftriaxone. R-GNB were identified to the species level with use of the API-20E system (Analytab Products, Plainview, NY).

### Statistical Methods

Results were expressed as mean ± SE. Data from the first year are reported separate from that of the second year in certain categories because of the intervention to clear MRSA carriage in year two. In the second year, the first 7 months reflects the use of mupirocin in the anterior nares of MRSA carriers, and the second 5 months reflects the use of mupirocin in both anterior nares and wounds of MRSA carriers. The chi-square test or one-way analysis of variance was used to compare colonization rates.

For risk factor analysis, initial univariate analysis was done by using chi-square or Fisher's exact test for ordinal variables with two levels, Mann-Whitney test for ordinal variables with greater than two levels, and Student's $t$ test for continuous variables. In order to evaluate the independent effect of each factor shown to be significant for colonization or infection with each organism by univariate analysis, a stepwise logistic regression model was developed using those variables that were significant at $P < 0.05$ in the univariate analysis.

### RESULTS

A total of 551 patients were entered into the study. There were 542 men and nine women; the mean age was 64.4 ± 0.5 years.

### Rates of Colonization

Colonization at any site was compared for MRSA, R-ENT, and R-GNB in the first year and for the two periods in the second year (Figure 1). While the rate of colonization with R-ENT and R-GNB was relatively constant in all three time periods, MRSA colonization fell significantly after the introduction of mupirocin treatment of both anterior nares and wounds of MRSA carriers from January through June 1991 ($P = 0.0001$). Except in the third period, colonization rates were higher for both MRSA and R-ENT than for R-GNB.

Considering only the first year of the study before mupirocin use and only those three sites in which all three types of resistant organisms were sought (rectum, perineum, and wounds), differences emerged in the pattern of colonization by each type of organism (Figure 2). MRSA was an uncommon colonizer in perineum and rectum and was most often found colonizing wounds, whereas R-ENT colonized all three sites at about the same frequency. R-GNB colonization was the least common in all three sites, and wounds were colonized more often than perineum and rectum.

Not reflected in Figure 2 are other sites of colonization by MRSA and R-GNB. Other than wounds, the highest colonization rates were in anterior nares for MRSA (15.1 ± 1% of patients colonized per month during the first year of the study). Colonization of the oropharynx was determined

Figure 1. Mean (±SE) monthly rate of colonization with antibiotic-resistant microorganisms for the periods listed. MRSA = methicillin-resistant S. aureus; R-ENT = gentamicin-resistant enterococcus; R-GNB = gentamicin and/or ceftriaxone-resistant Gram-negative bacilli. Colonization rates fell significantly for MRSA colonization in the period 1/91–6/91 after mupirocin ointment was used in wounds and anterior nares of carriers, P = 0.0001 by one-way analysis of variance comparing all three time periods.
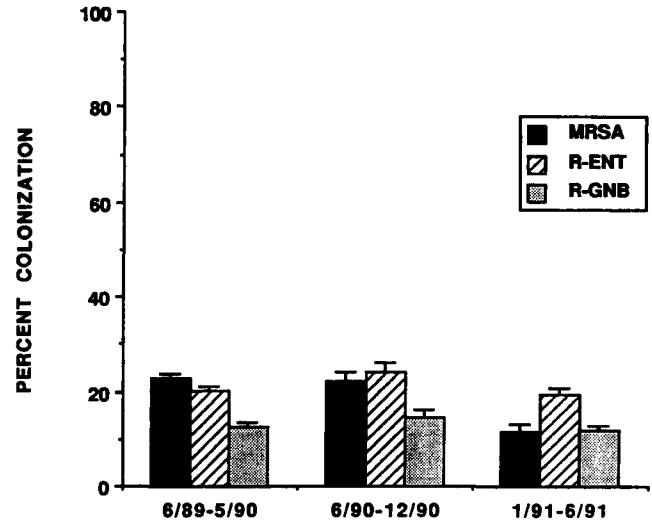


only for R-GNB. Over the 2-year period of the study, 4.3 ± 0.6% of patients each month had R-GNB cultured from the oropharynx.

The most common species of R-GNB colonizing patients were Acinetobacter species (16.5% of colonized patients), Pseudomonas species (14.5%), Pseudomonas aeruginosa (11.9%), Klebsiella pneumoniae (10%), Escherichia coli (8.7%), and Enterobacter cloacae (8.7%).

Figure 2. Mean (±SE) monthly rate of colonization by antibiotic-resistant bacteria at various sites during the first year of the study (6/89–5/90). MRSA = methicillin-resistant S. aureus; R-ENT = gentamicin-resistant enterococcus; R-GNB = gentamicin and/or ceftriaxone-resistant Gram-negative bacilli. Wound data are expressed as the percent of patients who had wounds that could be cultured.
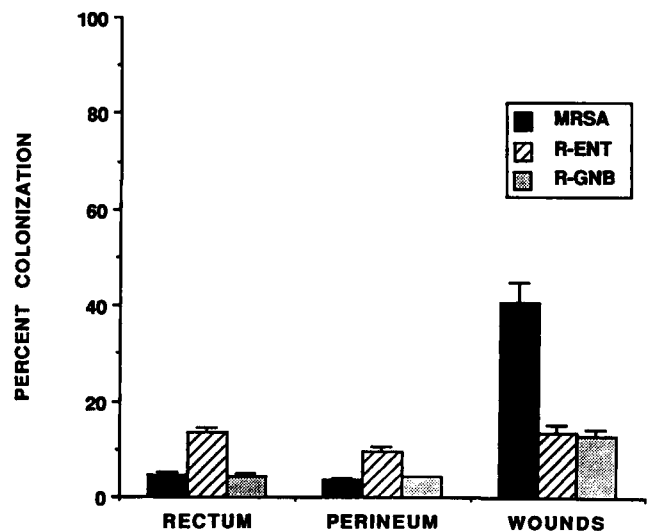
## Risk Factors for Colonization with Antibiotic-Resistant Bacteria

Evaluation of risk factors for MRSA colonization was carried out for year 1 when no measures had been taken to change colonization patterns. Twelve variables were found to be associated with MRSA colonization at any site (Table 1); however, only two of these variables - presence of wounds and decubitus ulcers - were independently associated with MRSA colonization by logistic regression analysis (Table 2).

Since there were no changes noted with colonization with R-ENT as a result of the intervention to decrease MRSA carriage, data from both years of the study were combined in the analysis of risk factors associated with colonization. Univariate analysis showed 12 factors associated with colonization at any site with R-ENT; many of these were markers for poor functional status (Table 3). Logistic regression revealed five independent variables associated with R-ENT colonization (Table 2). Colonization at any site with R-GNB was associated with 10 different factors (Table 4), but stepwise logistic regression analysis revealed only five independent variables associated with colonization (Table 2).

### Rates of Infection

Because of the intervention to decrease MRSA colonization and, presumably, infections, data are divided into infections in the first year (6/89–5/90) and in the two periods in the second year. Overall, there were 326 infections caused by antibiotic-resistant and antibiotic-susceptible bacteria acquired in the long-term care facility - 181 in year one, 64 in the period June through December 1990, and 81 in the period January through June 1991 (a total of 145 in year 2).

Table 2. *Factors shown by stepwise logistic regression to be independently associated with colonization by antibiotic-resistant bacteria*

| Factor | Odds Ratio | 95% Confidence Interval | P Value |
|---|---|---|---|
| **MRSA** | | | |
| Presence of wounds | 3.1 | 1.8–5.4 | 0.0001 |
| Decubitus ulcer | 2.7 | 1.1–6.5 | 0.027 |
| **R-ENT** | | | |
| Presence of wounds | 2.6 | 1.7–3.9 | 0.0001 |
| Renal failure | 2.4 | 1.4–4.3 | 0.002 |
| Intermittent cath. | 2.4 | 1.3–4.3 | 0.004 |
| Katz functional scale | 1.8 | 1.3–2.5 | 0.0001 |
| Serum albumin | 1.6 | 1.1–2.2 | 0.015 |
| **R-GNB** | | | |
| Intermittent cath. | 3.9 | 2.2–6.9 | 0.0001 |
| Inflammatory bowel D. | 3.4 | 1.2–9.9 | 0.022 |
| Chronic renal D. | 2.7 | 1.1–6.8 | 0.035 |
| Presence of wounds | 1.9 | 1.2–3.0 | 0.008 |
| Prior pneumonia | 1.9 | 1.0–3.6 | 0.038 |

MRSA = methicillin-resistant *S. aureus;* R-ENT = gentamicin-resistant enterococcus; R-GNB = gentamicin- and/or ceftriaxone-resistant Gram negative bacilli; cath. = urethral catheterization.

The predominant infections were urinary tract infections (42.9% of all infections over 2 years) and skin and soft tissue infections (31.9% of all infections over 2 years) (Table 5).

In 102 (31.3%) of the 326 infections, most of which were lower respiratory tract infections and skin and soft tissue infections, specifically cellulitis, the organism causing infection was not known. Of 224 infections in which the

Table 1. *Univariate analysis of risk factors associated with colonization by methicillin-resistant Staphylococcus aureus prior to the use of mupirocin ointment*

| | Percent of Patients | | |
|---|---|---|---|
| Factor | Colonized | Not Colonized | P Value |
| Underlying conditions | | | |
| Presence of wounds | 40.3 | 19.0 | 0.0001 |
| Decubitus ulcers | 18.0 | 7.6 | 0.005 |
| Prior pneumonia | 20.1 | 9.9 | 0.009 |
| Anemia | 37.0 | 23.2 | 0.009 |
| Chronic renal failure | 19.4 | 9.8 | 0.01 |
| Peptic ulcer D. | 24.8 | 14.3 | 0.01 |
| Chronic arthritis | 48.4 | 35.3 | 0.02 |
| Coronary artery D. | 39.5 | 28.4 | 0.04 |
| Katz Functional Scale | | | |
| I | 17.8 | 31.4 | 0.0003 |
| II | 48.1 | 48.8 | |
| III | 34.1 | 19.8 | |
| Nutritional parameters ($\bar{x} \pm$ SD) | | | |
| Serum albumin | 3.7 ± 0.6 | 4.0 ± 0.6 | 0.004 |
| Lymphocyte number | 1689 ± 736 | 1914 ± 711 | 0.005 |
| Lymphocyte percent | 22.2 ± 8.6 | 24.2 ± 8.9 | 0.04 |

Table 3. *Univariate analysis of factors associated with colonization by gentamicin-resistant enterococci*

| | Percent of Patients | | |
|---|---|---|---|
| Factor | Colonized | Not Colonized | P Value |
| Underlying conditions | | | |
| Presence of wounds | 46.0 | 25.4 | 0.0001 |
| Chronic renal failure | 20.3 | 8.7 | 0.0004 |
| Recurrent UTIs | 19.9 | 9.5 | 0.0009 |
| Neurogenic bladder | 38.5 | 9.5 | 0.003 |
| Prior pneumonia | 17.2 | 9.8 | 0.008 |
| Decubitus ulcers | 21.7 | 14.5 | 0.02 |
| Diabetes mellitus | 36.6 | 26.6 | 0.02 |
| Peripheral vascular D. | 36.5 | 27.3 | 0.02 |
| Devices, Procedures | | | |
| Intermittent cath. | 23.5 | 10.1 | 0.0001 |
| Gastrostomy tube | 5.0 | 1.4 | 0.02 |
| Katz Functional Scale | | | |
| I | 14.6 | 38.3 | 0.0001 |
| II | 51.5 | 44.5 | |
| III | 33.8 | 17.1 | |
| Nutritional parameters | | | |
| Serum albumin ($\bar{x} \pm$ S.D.) | 3.6 ± 0.6 | 3.8 ± 0.6 | 0.0001 |

cath. = urethral catheterization.

Table 4. *Univariate analysis of factors associated with colonization with gentamicin- and/or ceftriaxone-resistant Gram-negative bacilli*

| | Percent of Patients | | |
| Factor | Colonized | Not Colonized | *P* Value |
| --- | --- | --- | --- |
| Underlying conditions | | | |
| Recurrent UTIs | 20.5 | 10.8 | 0.007 |
| Presence of wounds | 44.2 | 31.6 | 0.01 |
| Inflammatory bowel D. | 7.0 | 2.3 | 0.02 |
| Prior pneumonia | 17.8 | 10.7 | 0.03 |
| Chronic renal D. | 7.8 | 3.2 | 0.03 |
| Osteoarthritis | 19.4 | 12.6 | 0.04 |
| Devices, Procedures | | | |
| Intermittent cath. | 27.9 | 11.0 | 0.0001 |
| Gastrostomy tube | 6.2 | 1.7 | 0.01 |
| Katz Functional Scale | | | |
| I | 23.6 | 30.5 | 0.04 |
| II | 47.2 | 47.9 | |
| III | 29.1 | 21.7 | |
| Nutritional parameters | | | |
| Serum albumin ($\bar{x} \pm$ S.D.) | 3.7 ± 0.6 | 3.8 ± 0.6 | 0.04 |

cath. = urethral catheterization.

organism was documented, 111 (49.6%) were due to the antibiotic-resistant bacteria, MRSA, R-ENT, or R-GNB, and 113 (50.4%) were due to susceptible staphylococci, streptococci, Gram-negative bacilli, and other organisms.

### Infections Caused by Gram-Negative Bacilli

The most common infecting organisms were Gram-negative bacilli, but the majority were not antibiotic-resistant (Table 6). Of a total of 153 infections caused by Gram-negative bacilli, 69 (45.1%) were gentamicin and/or ceftriaxone resistant. The Gram-negative bacilli causing most infections were *P. aeruginosa* (20.9% of GNB infections), *P. mirabilis* (18.9%), *K. pneumoniae* (17%), and *E. coli* (15.7%). Acinetobacter species and non-aeruginosa Pseudomonas species, although the most common coloniz-

Table 5. *Site of infections caused by both antibiotic-susceptible and antibiotic-resistant bacteria acquired in a long-term care facility over a period of 2 years*

| | Number (%) of Infections in Each Period* | | |
| Types of Infections | 6/89–5/90 | 6/90–12/90 | 1/91–6/91 |
| --- | --- | --- | --- |
| Urinary tract | 78 (43.1) | 25 (39.9) | 37 (45.7) |
| Skin/soft tissue | 59 (32.6) | 17 (27.0) | 28 (34.5) |
| Lower respiratory | 29 (16.0) | 14 (22.2) | 8 (9.9) |
| Bone/joint | 8 (4.4) | 1 (1.5) | 3 (3.7) |
| Bacteremia | 4 (2.2) | 5 (7.9) | 2 (2.5) |
| Other | 3 (1.7) | 1 (1.5) | 3 (3.7) |
| Total | 181 | 64 | 81 |

* In periods 6/90–12/90 and 1/91–6/91, attempts were made to eradicate MRSA colonization in all patients in the facility.

Table 6. *Bacterial infections acquired in a long-term care facility*

| | Number (%) of Infections in Each Period | | |
| Organism | 6/89–5/90 | 6/90–12/90 | 1/91–6/91 |
| --- | --- | --- | --- |
| Gram-positive cocci | 37 (20.5) | 12 (18.8) | 22 (27.1) |
| MRSA | 9 (5.0) | 3 (4.7) | 3 (3.7) |
| MSSA | 5 (2.8) | 0 | 4 (4.9) |
| R-ENT | 15 (8.3) | 7 (10.9) | 5 (6.2) |
| S-ENT | 5 (2.8) | 1 (1.6) | 7 (8.6) |
| Other (*S. epidermidis, S. pneumoniae*) | 3 (1.6) | 1 (1.6) | 3 (3.7) |
| Gram-negative bacilli | 90 (49.7) | 29 (45.3) | 34 (42.0) |
| R-GNB | 41 (22.6) | 15 (23.4) | 13 (16.0) |
| S-GNB | 45 (24.9) | 14 (21.9) | 19 (23.5) |
| Other (*Haemophilus*) | 4 (2.2) | 0 | 2 (2.5) |
| Unknown organism | 54 (29.8) | 23 (35.9) | 25 (30.9) |
| Total | 181 | 64 | 81 |

MRSA = methicillin-resistant *S. aureus;* MSSA = methicillin-susceptible *S. aureus;* R-ENT = gentamicin-resistant enterococcus; S-ENT = enterococcus lacking high-level gentamicin resistance; R-GNB = gentamicin- and/or ceftriaxone-resistant Gram bacilli; S-GNB = gentamicin and ceftriaxone susceptible gram negative bacilli.

ers, rarely caused infection. As expected, susceptibility to gentamicin and ceftriaxone varied among species of Gram-negative bacilli. Of 32 *P. aeruginosa* infections, 27 (84.4%) were caused by resistant strains. *P. mirabilis*, the second most common infecting organism, was resistant in 58.6% of the episodes of infections. In contrast, most *E. coli* and *K. pneumoniae* infections were due to susceptible strains (83.3% and 88.5%, respectively). Most often Gram-negative bacilli caused urinary tract infections; much less commonly they caused skin and soft tissue infections and lower respiratory tract infections. *P. aeruginosa* was the most common Gram-negative bacillus causing skin and soft tissue infections, as well as pneumonia.

### Infections Caused by Gram-Positive Cocci

Infections caused by Gram-positive cocci were less common than those caused by Gram-negative bacilli, but were more likely to be antibiotic-resistant (Table 6). Among 24 culture-proved staphylococcal infections, MRSA were more common than MSSA (62.5% vs 37.5%). However, this is undoubtedly an under-representation of the number of MSSA infections. Many infections for which no pathogen was isolated were skin and soft tissue infections, usually cellulitis. Most were treated with antibiotics, which would not be effective for MRSA, improved on therapy, and were likely the result of MSSA or streptococci. Of the culture-documented staphylococcal infections, all of the nine MSSA infections were skin and soft tissue infections or osteomyelitis, and 13 of 15 MRSA infections were skin and soft tissue infections or osteomyelitis, including two patients with bacteremia.

Enterococcal infections were more often caused by gentamicin-resistant strains than susceptible strains (67.5% vs 32.5%). Most enterococcal infections (75%) were urinary tract infections, and 73.3% of the urinary tract infections were caused by gentamicin-resistant strains. The remainder of the enterococcal infections were skin and soft tissue

infections, usually wounds, and equal numbers were due to resistant and susceptible strains of enterococci.

### Risk Factors for Infection with Antibiotic-Resistant Bacteria

Stepwise logistic regression showed several factors to be significant for predicting infection with MRSA and R-GNB (Table 7). MRSA infection was associated with the presence of diabetes mellitus and peripheral vascular disease, and R-GNB infection was associated with the use of either indwelling Foley catheters or intermittent urethral catheterization. R-ENT infection was not associated with any one specific risk factor.

### DISCUSSION

This study provides insight into the role antibiotic-resistant organisms play in colonization and infection in the long-term care setting. Having not been prompted by an outbreak, it differs from other studies, which have focused on the spread of one antibiotic-resistant organism within a facility.[12, 13, 16] Although similar to other prevalence surveys of infections in long-term care,[1–3, 22–26] it differs in that it specifically assesses the contribution of antibiotic-resistant organisms to the overall problem of infections in long-term care.

Colonization with antibiotic-resistant organisms, especially Gram-positive cocci, was common. The rate of colonization with MRSA was similar to that noted by others studying similar facilities,[10, 11] but clearly much higher than that noted in other non-veterans facilities.[22] Although we previously noticed an association of MRSA colonization with poor functional status,[9] further analysis using stepwise logistic regression methods showed the only independent risk factors to be the presence of wounds and decubitus ulcers. However, in the case of infections with MRSA, wounds and decubitus ulcers were not significant risk factors; rather, the presence of diabetes mellitus and peripheral vascular disease showed strong associations with MRSA infection. Thus, colonization of wounds with MRSA was common, but most patients did not develop infection unless other factors associated with poor vascular supply were present as well.

Although there were only nine MRSA infections before the eradication efforts with mupirocin and six during the eradication phase, these infections often were severe. For example, two patients had bacteremia, five had osteomyeli-

tis, and 10 of 15 episodes required hospitalization for therapy with intravenous vancomycin.[9, 18]

Our efforts to eradicate MRSA with mupirocin did not decrease the number of infections significantly,[18] probably because we had a low rate of infection to begin with, but did lead to the selection of MRSA strains carrying a plasmid for mupirocin resistance.[27] Perhaps decolonization should be specifically aimed at those at highest risk of developing infection, ie, those patients with diabetes mellitus and peripheral vascular disease. If targeted decolonization were to be performed, as is done in hemodialysis patients, who are at increased risk of S. aureus infections,[28, 29] then perhaps the development of mupirocin resistance would be less likely than that seen when mupirocin is used chronically and in a widespread fashion.[18, 27, 30]

Increasing antibiotic resistance has become a major problem among enterococci. High-level resistance to gentamicin as a marker for resistance to all aminoglycosides first emerged as a major problem in the 1980s and has since spread widely.[7, 31, 32] Even more worrisome is the recent spread of resistance to penicillins and to vancomycin.[33, 34] Neither of these resistance pattterns were sought in our study since they had not yet appeared in our medical center at the time the study was begun in June 1989.

Colonization with R-ENT was associated with many underlying risk factors, many of which were found with MRSA also. Colonization patterns with R-ENT were similar to those for MRSA in regard to acquisition in the facility.[9] However, persistence of colonization was very different from that noted with MRSA; patients were more likely to have only transient or intermittent R-ENT colonization and frequently had new strains appear over time.[35] Only five factors were independently associated with R-ENT colonization, and no one factor emerged as independently associated with R-ENT infection.

R-ENT strains were more than twice as likely as those strains lacking high-level gentamicin resistance to cause infection; most infections with R-ENT were urinary tract infections. These infections responded well to therapy with amoxicillin and did not require aminoglycosides for synergistic killing.[32, 36] Thus, in comparison with MRSA, R-ENT infections were more common, but were not as severe, did not require hospitalization, and were easily treated with oral therapy.

Although colonization with R-GNB was lower in all sites than R-ENT or MRSA, those organisms were more likely to cause infection. Other studies of infections in long-term care facilities have noted Gram-negative bacillary infections as a major problem.[22, 24, 25] Those studies that also assessed antibiotic resistance found that resistance is common in Gram-negative bacilli causing infections in long-term care facilities,[4, 16, 24, 37, 38] and also have noted that transmission can occur from patient-to-patient, probably via hands of health care workers in this setting.[6, 15]

Although several underlying risk factors were associated with R-GNB colonization, infection was associated only with intermittent urethral catheterization or chronic indwelling Foley catheters. In many studies, indwelling catheters have been associated with a markedly increased risk of colonization, infection, and selection of antibiotic-resistant Gram-negative bacilli.[1, 2, 25, 37] In our facility, we have few patients with indwelling urinary catheters and many more in whom intermittent catheterization is per-

Table 7. *Factors shown by stepwise logistic regression to be associated with infections caused by antibiotic-resistant bacteria*

| Factor | Odds Ratio | 95% Confidence Interval | P Value |
|---|---|---|---|
| **MRSA** | | | |
| Diabetes mellitus | 5.1 | 2.1–18.6 | 0.001 |
| Peripheral vascular D. | 4.3 | 1.3–14.3 | 0.019 |
| **R-GNB** | | | |
| Intermittent cath. | 5.0 | 2.2–11.3 | 0.0001 |
| Foley catheter | 11.9 | 1.2–119 | 0.03 |

MRSA = methicillin-resistant *S. aureus*; R-GNB = gentamicin and/or ceftriaxone resistant Gram negative bacilli; cath. = urethral catheterization.

formed. Although infection rates tend to be lower with intermittent catheterization than with indwelling catheters,[39] this practice was significantly associated with infection with R-GNB.

Overall, urinary tract infections were the most common infections, as noted by other studies in long-term care.[1, 22–25] Skin and soft tissue infections were also commonly seen. However, respiratory infections accounted for only 16% of the infections acquired in the facility, a figure lower than that noted by others.[24, 26] Bacteremias were uncommon, occurring in only 11 patients over the course of 2 years, and were mostly related to urinary tract infections.

We do not know whether these data are broadly applicable to other long-term care facilities. Except for the work of Scheckler,[22] most studies on the role of antibiotic-resistant organisms in the long-term care setting have been carried out in Veterans Affairs facilities[6, 7, 9–11, 15, 18] or have been done only in patients from long-term care facilities transferred to an acute care hospital for an acute illness.[4, 8] A decade ago, in eight rural Wisconsin nursing homes in which 75% of the residents were women, Scheckler found no MRSA and only three gentamicin-resistant Gram-negative bacilli.[22] Whether the rate of antibiotic resistance in such rural areas has remained this low in the last decade is not known.

Veterans Affairs long-term care facilities tend to report higher rates of colonization with antibiotic-resistant organisms. Perhaps this is related to the frequent movement of patients to the acute care facility, which is often attached to the nursing home care unit. For example, we noted that 20% of patients with MRSA colonization brought the organism in from the acute care hospital and only 10% acquired MRSA in the long-term care facility.[9] Movement between hospitals and long-term care units by physicians, especially house staff, who care for patients in many Veterans Affairs long-term care facilities, may contribute to the spread of some resistant organisms.[40, 41]

Perhaps more important than the above points are patient factors. Even within different Veterans Affairs facilities, there are differences in the types of patients cared for; underlying diseases, acuity of illness, and functioning of the unit as an intermediate care unit, a rehabilitation unit, or a long-term care unit may explain differences noted in rates of infection with antibiotic-resistant organisms in different veterans facilities.[9–11] In general, it appears that the more ill the patients served and the more skilled care required, the greater the infection rates with antibiotic-resistant organisms.[9, 10]

Similar studies should be repeated in other types of long-term care facilities, such as community-based and private facilities, and in different geographic areas of the country to assess the importance of infection with antibiotic-resistant organisms. Only then can effective approaches be formulated to deal with the problem. For now, one approach might be to modify, when feasible, those factors that appear to be associated with the highest risk of infection. For example, decreasing the use of indwelling urethral catheters and using careful techniques for intermittent catheterization are measures that could be undertaken. Preventing skin breakdown with subsequent development of decubitus ulcers should be a priority. Perhaps specific decolonization efforts for certain organisms, such as MRSA, might be undertaken, but only in high-risk patients.

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