ORIGINAL ARTICLE

Outbreak of Healthcare-Associated Infection and Colonization With Multidrug-Resistant *Salmonella enterica* Serovar Senftenberg in Florida

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BACKGROUND. In July 1999, a rare strain of multidrug-resistant *Salmonella enterica* serovar Senftenberg was isolated from the sputum of a trauma patient. Over a 6-year period (1999-2005) in northeast Florida, this *Salmonella* serovar spread to 66 other patients in 16 different healthcare facilities as a result of frequent transfers of patients among institutions. To our knowledge, this is the first outbreak of healthcare-associated infection and colonization with a fluoroquinolone-resistant strain of *S.* Senftenberg in the United States.

OBJECTIVES. To investigate an outbreak of infection and colonization with an unusual strain of *S.* Senftenberg and assist with infection control measures.

DESIGN. A case series, outbreak investigation, and microbiological study of all samples positive for *S.* Senftenberg on culture.

SETTING. Cases of *S.* Senftenberg infection and colonization occurred in hospitals and long-term care facilities in 2 counties in northeast Florida.

RESULTS. The affected patients were mostly elderly persons with multiple medical conditions. They were frequently transferred between healthcare facilities. This *Salmonella* serovar was capable of long-term colonization of chronically ill patients. All *S.* Senftenberg isolates tested shared a similar pulsed-field gel electrophoresis (PFGE) pattern.

CONCLUSION. A prolonged outbreak of infection and colonization with multidrug-resistant *S.* Senftenberg was identified in several healthcare facilities throughout the Jacksonville, Florida, area and became established when infection control measures failed. The bacterial agent was capable of long-term colonization in chronically ill patients. Because the dispersal pattern of this strain suggested a breakdown of infection control practices, a multipronged intervention approach was undertaken that included intense education of personnel in the different institutions, interinstitutional cooperation, and transfer paperwork notification.

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Salmonellosis is a common bacterial infection, with approximately 1.4 million cases occurring annually in the United States; complications result in an estimated 500 deaths a year.[1] In Florida, salmonellosis is a reportable disease, with over 4,600 cases of *Salmonella* infection reported to the Florida Department of Health in 2003. The mainly gastrointestinal illness caused by these organisms is primarily transmitted through contaminated foods, whereas healthcare-associated infections due to *Salmonella* species are rare.[2]

Human infection due to *Salmonella enterica* serovar Senftenberg is infrequent in the United States. This bacterium colonizes the gastrointestinal tract of birds and mammals, and has been isolated from sewage systems, poultry processing plants, and different animal feeds.[3-8] *S.* Senftenberg infections in humans have been documented, mainly in Africa[9,10] and India,[11,12] as well as in 1 US outbreak of gastroenteritis.[13] Nonintestinal infectious syndromes due to *S.* Senftenberg were also reported in the Indian study.[14-18]

Between 1999 and 2005, hospital laboratories in northeast Florida identified more than 150 multidrug-resistant isolates of *S.* Senftenberg from 67 patients in stool, urine, sputum, and wound samples. The cases were investigated by the Florida Department of Health's Bureau of Epidemiology and the Duval County Health Department, and the isolates were forwarded to the Florida Department of Health's Bureau of Laboratories in Jacksonville for comparative genomic analysis by pulsed-field gel electrophoresis (PFGE) and antimicrobial phenotyping and genotyping. This descriptive report seeks to provide an introduction to healthcare-associated *S.* Senftenberg infection.

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METHODS

Study Population

The reported cases were geographically distributed over 2 northeast Florida counties with an estimated population of 1 million. *S.* Senftenberg isolates were reported from July 1999 through October 2005 by 5 of 7 hospitals and by 11 long-term care facilities (LTCFs) among the approximately 50 in the area.

Surveillance and Statistics

Case identification. Florida Statute 381.0031 requires reportable diseases of public health significance, such as salmonellosis, to be reported by clinicians and licensed laboratories to the Florida Department of Health. A case patient was defined as any person with *S.* Senftenberg isolated from a clinical specimen between 1999 and 2005 in northeast Florida. Active case finding was conducted by infection control personnel by culturing urine and stool samples from individuals sharing a room with a confirmed case patient. Stool samples were also tested for the presence of *Salmonella* when diarrhea (ie, 3 or more loose and/or watery stools in 24 hours) developed in any patient in a unit that was housing a confirmed case patient or had housed one in the previous 4 weeks. Stool samples were also collected from healthcare workers who had diarrhea.

Case investigation. Patients' medical records were reviewed and entered into a case report that included the patient's medical history, abnormal physical and laboratory findings, concurrent infections, medical and surgical procedures undergone, and therapy received. The immediate cause of death was determined by a review of death certificates, provided by the Bureau of Vital Statistics, and by discussions with healthcare providers. The information collected was analyzed using Epi Info 2002 (Centers for Disease Control and Prevention).[19]

Laboratory Methods

The initial microbiologic studies for each patient (ie, isolation of the microbe and antibiotic susceptibility testing) were done in the institution of residence. The microbiology department at the Florida Department of Health's Bureau of Laboratories in Jacksonville performed serotyping of the submitted *Salmonella* isolates using the Kaufmann-White scheme.[20,21] Antimicrobial susceptibility phenotypes for the first 29 isolates were determined using a broth microdilution method (Pasco Gram-Negative MIC Panel [6952-30]; Becton Dickinson).

In addition, all isolates were DNA fingerprinted by PFGE using a standardized method developed by the Centers for Disease Control and Prevention program PulseNet.[22,23] Banding pattern differences were assigned as described elsewhere.[24] The DNA fingerprint data were compared using the BioNumerics software package, version 3.5 (Applied Math).

The study was approved by the Florida Department of Health institutional review board (protocol number 1438; claim of exemption 45 CFR 46.101 [4]-Review of existing data).

RESULTS

History and Outbreak Investigation

The index patient. *S.* Senftenberg was first isolated, 1 week after admission, from the sputum of a 47-year-old, severely wounded patient in July 1999. The organism was multidrug resistant and was resistant to ciprofloxacin, an antibiotic that had not been administered to this patient.

Transmission to other patients in the first hospital. In August 1999, a second patient, hospitalized 2 rooms away from the index patient in the same trauma unit, became infected with the *S.* Senftenberg strain, which was isolated from urine and stool samples. Contact isolation procedures were implemented, but 6 more patients became infected in the next 6 months. When surveillance cultures of stool and urine specimens collected from the other patients in the affected unit were performed, 2 more colonized patients were identified as carrying the *S.* Senftenberg strain.

Investigation of the origin of the epidemic bacterium. An attempt to identify a carrier by interviewing healthcare personnel working in the trauma unit and culturing stool specimens for this *Salmonella* strain yielded negative results. Specifically, no one in this large group had handled poultry or was involved in any aspect of animal husbandry, nor was there any exposure to exotic pets. None of these individuals had recently traveled to New Delhi, India, where a nosocomial outbreak of *S.* Senftenberg infection had been reported.[11,12,25-30]

Transmission to other healthcare institutions. In 2000, the *S.* Senftenberg strain spread from hospital 1 to other hospitals and LTCFs (Figure 1). The spread was initiated by the transfer of one of the case patients infected with *S.* Senftenberg in hospital 1 to a nursing home. The 67 cases identified in hospitals and long-term care facilities are represented chronologically in Figure 2. In 6 additional institutions, secondary cases occurred because of transfers between hospitals and LTCFs. There was no seasonal trend in the appearance of the bacterial isolate from each patient.

Infection control. Control, prevention, and surveillance strategies were used to identify potential carriers and to foster constant awareness of the outbreak among hospitals and LTCFs. Any facility involved was urged to initiate active case finding.

Most physicians, when informed of the outbreak, opted not to treat their patients for *Salmonella* infection and/or colonization, but only for the concomitant conditions. *S.* Senftenberg was not believed to have been the immediate cause of death for any infected individual. Its presence merely connoted the patients' debilitating conditions.

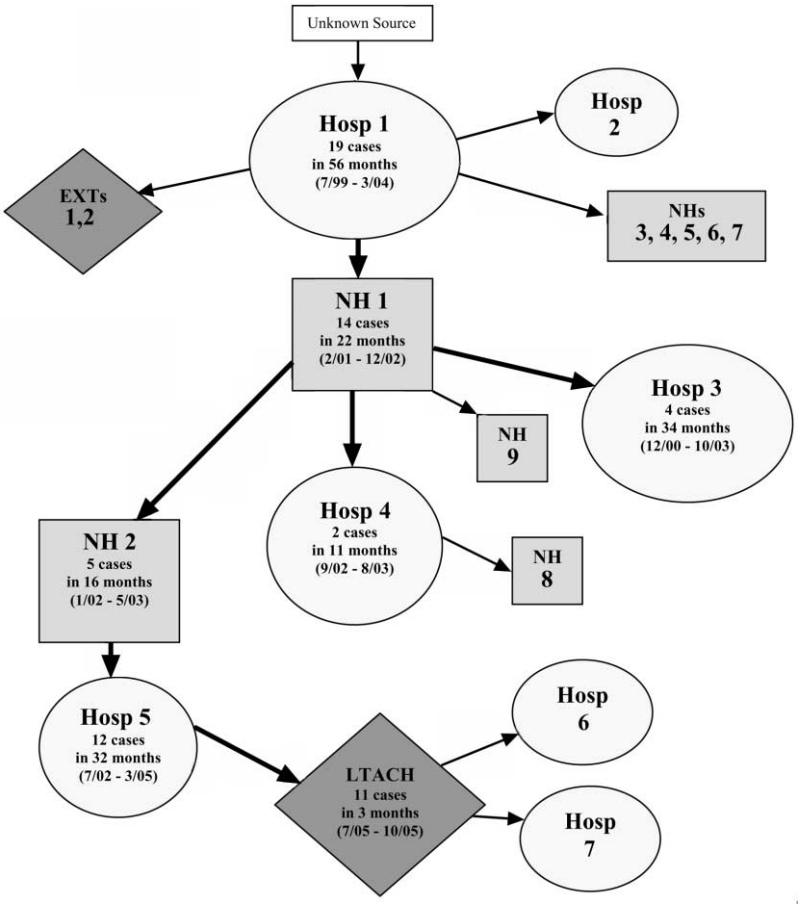

FIGURE 1. The movement of *Salmonella enterica* serovar Senftenberg through northeast Florida. The spread of *S.* Senftenberg started in hospital 1 (Hosp 1). *Thick arrows,* the transfer of patients to institutions where secondary cases occurred (ie, nursing homes [NH 1 and NH 2], hospitals (Hosp 3, Hosp 4, and Hosp 5), and a long-term acute care hospital [LTACH]). *Thin arrows,* transfers of patients to places where no secondary cases erupted (ie, nursing homes [NH 3-9], hospitals [Hosp 2, 6, and 7], and extended care facilities [Ext 1 and Ext 2]). The dates indicate the first and the last month that *S.* Senftenberg was isolated in that institution.

Patient Characteristics

Of the 67 case patients, 52 (78%) were women, and 15 (22%) were men. The median age was 71 years (range, 2-94 years); 55% were white and 45% were African American.

The patients' past and present underlying medical conditions were also investigated (Table 1). Presenting syndromes of *S.* Senftenberg infection were often diarrhea and cystitis followed by variable periods of colonization of the gastrointestinal and urinary tracts. The most common case history included being bedridden (83%) and having diabetes (58%), decubitus ulcers (67%), pneumonia (52%), and/or urinary tract infections (65%). Most (68%) of the patients had undergone surgery in the previous 6 months. The use of indwelling medical devices was frequently part of these patients' medical histories.

Multiple specimens were collected from patients. The specimens from which the *S.* Senftenberg strain was isolated, in order of frequency, were stool, urine, sputum, wound, and blood. There were several patients who had multiple specimens from which the strain was isolated. In more than half of the cases in which the *S.* Senftenberg strain was isolated, cultures yielded multiple pathogens, including methicillin-resistant *Staphylococcus aureus* (MRSA) (39% of case patients), vancomycin-resistant *Enterococcus* (VRE) (12%), *Klebsiella pneumoniae* (14%), and/or *Escherichia coli* (18%). In addition, *Clostridium difficile* toxin was identified in culture specimens from 27% of case patients (Table 2).

Carriage of the Epidemic Strain

Of the 23 patients for whom follow-up was possible, the duration of carriage was a median of 7 months (mean, 10.5 months), with a minimum of 1 month and a maximum of 56 months recorded up to the date of this publication. However, 2 patients thought to have been cleared of the bacterium returned to northeast Florida hospitals and were again found to be carriers of *S.* Senftenberg. The other patients could not

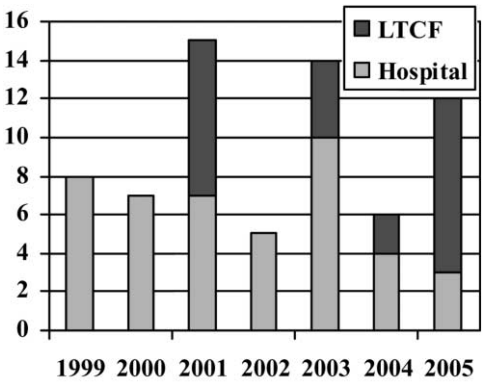

FIGURE 2. Number of first isolates recovered from patients, by year and healthcare facility. LTCF, long-term care facility or nursing home.

be evaluated because they died from their underlying diseases or they were lost to follow-up.

Antibiotic Susceptibility and Molecular Epidemiology

The antibiograms depicted the strains as highly resistant to fluoroquinolones, with varying resistances to the penicillins, the cephalosporins, and other antimicrobials, but uniform susceptibility to cephotetan and meropenem. Early laboratory studies indicated that 15 of the first 28 strains isolated had extended-spectrum β-lactamase (ESBL) genes. Other modalities of resistance were identified, specifically against fluoroquinolones.

One hundred fifty-eight *S.* Senftenberg isolates from the 67 case patients were subtyped by PFGE. Among all the isolates, there were 9 highly related patterns detected (Figure 3). The DNA fingerprints of 7 clones (lanes 2-7 and lane 10 in Figure 3) differed by 3 bands or fewer, compared with the isolate from the index patient. In the 67 primary cultures performed for case patients, 3 clones predominated (lanes 2, 3, and 4 in Figure 3); one clone (lane 2 in Figure 3) accounted for 49% of the primary strains recovered, another (lane 3 in Figure 3) accounted for 21.0%, and a third (lane 4 in Figure 3) accounted for 14.9%. Twenty-six (63.4%) of 41 patients from whom we recovered 2 or more isolates were infected with strains with different DNA fingerprints.

Over the period of this study, 6 epidemiologically unrelated *S.* Senftenberg isolates were submitted to the public health laboratory for serotyping and routine PFGE testing. All of these isolates were obtained from individuals who did not reside in the counties where the outbreak occurred. The 9 *S.* Senftenberg patterns analyzed in this study had 6 or more band differences when compared to the strain recovered from the index patients (data not shown), and the patterns had no matches in the National PulseNet *Salmonella* Database.

DISCUSSION

In 1999, a multidrug-resistant strain of *S.* Senftenberg was isolated from a patient in a Jacksonville, Florida, hospital. During the next 6 years, 66 patients in northeast Florida were infected or colonized with the organism, and this agent spread to 15 other healthcare institutions through many transfers of patients. Fluoroquinolone-resistant *S.* Senftenberg strains have not been reported from other regions of the state.

Neither the source of the bacterium nor the mode of its introduction is known for the first patient, a trauma victim. It appears the transmission was healthcare-associated, resulting from the breakdown of standard infection control measures, and was not associated with contaminated food or contact with animals.

The epidemiology of this outbreak was complex. With the exception of the first patient, who recovered from the trauma, and transient urinary tract colonization in a young child, the remaining 65 patients were elderly and debilitated, or ill with chronic end-of-life conditions. Almost half of the patients from whom *S.* Senftenberg was recovered were colonized. The patients who were infected also became carriers after their infection was cleared. Such colonization was prolonged and characterized by unpredictable, intermittent shedding, with the result that a patient carrying the organism provided an opportunity for the agent to spread farther. Although 2 patients were determined to be free of the epidemic agent, they later became carriers again.

Infection and colonization with multidrug-resistant *S.*

TABLE 1. Clinical Characteristics of 66 Patients Infected or Colonized With *Salmonella enterica* Serovar Senftenberg

Clinical condition or syndrome	No. (%) of patients
Pneumonia	34 (52)
Dementia	29 (44)
Lack of mobility (bedridden)	55 (83)
Decubitus ulcers	44 (67)
Urinary tract infection	43 (65)
Surgical condition	
Surgery in past 6 mos	45 (68)
Open surgical wound	31 (47)
Diabetes	38 (58)
Fecal incontinence	41 (62)
Urinary incontinence	39 (59)
Indwelling device	
Central IV access	41 (62)
Peripheral IV access	57 (86)
Feeding tube	43 (65)
Gastrostomy tube	38 (58)
Foley catheter	53 (80)

NOTE. There was a total of 67 infected and/or colonized patients; 1 medical record was unavailable for review. IV, intravenous.

TABLE 2. Frequency of Concurrent Infecting Pathogens Isolated From 66 Patients Infected or Colonized with *Salmonella enterica* Serovar Senftenberg

Pathogen(s) isolated	No. (%) of patients
MRSA	26 (39)
VRE	8 (12)
Klebsiella pneumoniae	9 (14)
Escherichia coli	12 (18)
Clostridium difficile	18 (27)
Any 1 of the above	46 (70)
Any 2 of the above	17 (26)
Any 3 of the above	7 (11)
Any 4 of the above	2 (3)

NOTE. There was a total of 67 infected and/or colonized patients; 1 medical record was unavailable for review. MRSA, methicillin-resistant *Staphylococcus aureus;* VRE, vancomycin-resistant enterococci.

Senftenberg, although rare, demands public health awareness. In the asymptomatic patients identified early on, before surveillance cultures were done, the organism was not thought to be highly communicable. The perception of salmonellosis as a foodborne disease hindered attempts at controlling its spread in and among healthcare facilities. However, when an outbreak of *S.* Senftenberg infection and colonization occurred in a second institution, it became clear that communication between referring and receiving facilities was inadequate, as were the infection control measures. Local health departments in northeast Florida responded by providing information to affected facilities, promoting *S.* Senftenberg awareness among infection control practitioners in the area, and increasing communication between healthcare institutions about the transfer of patients.

Proper infection control practices are important in the reduction of the transmission of *S.* Senftenberg within healthcare facilities. Use of contact precautions for an extended period is difficult to maintain in a healthcare facility, although it has shown that spread of the bacterium can be prevented. Modern isolation precautions were updated to include standard and contact precautions for people infected and/or colonized with multidrug-resistant organisms.[31] Compliance with hand hygiene guidelines and appropriate barrier precautions is the core of these prevention strategies.[32] Multiple studies have shown that the rate of hand hygiene compliance is less than 50%.[32,33] Contact precautions are now being observed in all institutions for management of a patient known to have harbored *S.* Senftenberg. Outbreaks of infection and/or colonizations may only be controlled if infection control guidelines are persistently followed by all healthcare personnel.

The DNA fingerprint data from this study demonstrate how PFGE can be used to track a bacterial strain over extended periods. Guidelines by Tenover et al.[24] were used to interpret the banding patterns and revealed that the strains recovered from our epidemiologically clustered patients were closely related or possibly related (ie, having 1 or 2 genetic differences, manifest as 2-3 or 4-6 band differences, respectively). In addition, epidemiological data and antimicrobial susceptibility data (mainly regarding fluoroquinolone resistance) was used to assign patients to the cluster. Unclustered strains (ie, those that were deemed epidemiologically unrelated) had more than 3 genetic differences (more than 6 band differences), a result consistent with the published guidelines.[24] These findings correlated with *gyr*A and *par*C gene mutations, and the presence of plasmids with integrons and extended-spectrum β-lactamase genes (data not shown).[34] When the initial isolates appeared 7 years ago, there was little quinolone resistance being reported in *Salmonella* species, but that is not the case anymore.[2,35-38]

The northeast Florida experience with *S.* Senftenberg is most comparable with the Indian exposures in the New Delhi area involving the same species and serotype, but the spectrum of infection and colonization reported here was not as diverse, compared with that outbreak. The outbreaks in India demonstrated the potential of this organism for nosocomial transmission, the prolonged resilience of this organism in the environment, and the multidrug-resistant nature of the strain.[25-30] The nosocomial spread of *S. enterica* serovar Schwarzengrund, although involving a different serotype, was also comparable with the present outbreak.[2]

The outbreak of infection and colonization with *S.* Senf-

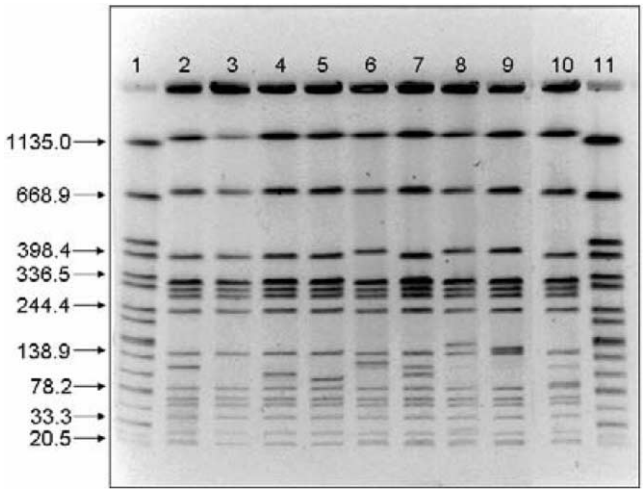

FIGURE 3. Pulsed-field gel electrophoresis (PFGE) patterns of representative epidemiologically-related *Salmonella enterica* serovar Senftenberg isolates. *Lanes 1* and *11,* PulseNet molecular weight standard H9812 (an *S. enterica* serovar Braenderup strain); *lane 2,* isolate from the index patient; *lanes 3-10,* selected *S.* Senftenberg isolates associated with the study. The molecular weights are given in kilobase-pairs.

tenberg described here has commonalities with the spread of MRSA, VRE, and certain multidrug-resistant, gram-negative bacteria among chronically ill institutionalized patients. They all cause a prolonged carrier state after first isolation, colonizing chronically ill patients who have drainage from mucosae, wounds, or tubes and thriving in an environment where there is extensive use of antimicrobials.

Seven years ago, in northeast Florida, an outbreak of infection and colonization with *S.* Senftenberg began, involving mainly chronically ill and debilitated patients. The bacterium was resistant to many antimicrobials, and was able to colonize mucosal membranes and drainage sites for extended periods of time. The outbreak is still considered ongoing because some infected or colonized patients are still living in healthcare facilities and residing in the community, which may lead to additional spread of the organism. The chronicity of the *S.* Senftenberg carrier state is similar to that seen in patients colonized with VRE, MRSA, and multidrug-resistant nosocomial gram-negative bacteria. The exchange of patients infected or colonized with *S.* Senftenberg among institutions needs to be done with care and with due forewarning. The outbreak described here illustrates the challenges involved in controlling outbreaks of multidrug-resistant organisms in healthcare settings.

ADDENDUM

After the analysis was completed for this study, an additional case was detected. A 68th patient became colonized with the epidemic strain of *S.* Senftenberg. The scenario of transmission, as well as the clinical and microbiological data, are the same as those for the rest of the series.

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Potential conflicts of interest. All authors report no conflicts of interest relevant to this article.

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