HEALTH CARE REFORM

Multistate Outbreak of *Serratia marcescens* Bloodstream Infections Caused by Contamination of Prefilled Heparin and Isotonic Sodium Chloride Solution Syringes

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Background: To investigate clusters of *Serratia marcescens* (SM) bloodstream infections (BSIs) at health care facilities in several states and determine whether contaminated prefilled heparin and isotonic sodium chloride solution (hereinafter, saline) syringes from a single manufacturer (company X) were the likely cause, we performed an outbreak investigation of inpatient and outpatient health care facilities from October 2007 through February 2008.

Methods: Active case finding for clusters of SM BSIs. Information on SM BSIs was obtained, and SM blood isolates were sent to the Centers for Disease Control and Prevention (CDC). Culture specimens were taken from various lots of prefilled heparin and saline syringes by health care facilities and the CDC to test for the presence of SM. The SM isolates from syringes and blood were compared by pulsed-field gel electrophoresis.

Results: A total of 162 SM BSIs in 9 states were reported among patients at facilities using prefilled heparin and/or saline syringes made by company X. Cultures of unopened prefilled heparin and saline syringes manufactured by company X grew SM. Of 83 SM blood isolates submitted to the CDC from 7 states, 70 (84%) were genetically related to the SM strain isolated from prefilled syringes. A US Food and Drug Administration inspection revealed that company X was not in compliance with quality system regulations.

Conclusions: A multistate outbreak of SM BSIs was associated with intrinsic contamination of prefilled syringes. Our investigation highlights important issues in medication safety, including (1) the importance of pursuing possible product-associated outbreaks suggested by strong epidemiologic data even when initial cultures of the suspected product show no contamination and (2) the challenges of medical product recalls when production has been outsourced from one company to another.

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SERRATIA MARCESCENS (SM) IS AN aerobic gram-negative bacterium that is ubiquitous in the environment. It is a well-known cause of health care–associated infections, especially urinary tract infections, wound infections, and bloodstream infections (BSIs). *Serratia marcescens* has also been the source of many health care–associated outbreaks, often the result of contamination of products such as medication vials,[1,2] disinfectants,[3,4] hand soaps,[5,6] medical devices,[7,8] and medications prepared by compounding pharmacies.[9,10]

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On November 14, 2007, a nurse working at an outpatient infusion center in Texas contacted the Centers for Disease Control and Prevention (CDC) because 5 patients with cancer had been hospitalized with SM BSIs over a 1-week period. On December 6, 2007, clinicians in Chicago, Illinois, notified the CDC of an outbreak of SM BSIs among patients receiving supplies from a local home care company. Furthermore, on January 14, 2008, clinicians at a referral cancer center in Texas, in a different city from the infusion center, reported an outbreak of SM BSIs.

Herein, we describe our investigation of these outbreaks, which led to the identification of a multistate outbreak of SM BSIs associated with the use of contami-

nated prefilled heparin and isotonic sodium chloride solution (hereinafter, saline) syringes manufactured by a single company (hereinafter, company X).

METHODS

EPIDEMIOLOGIC INVESTIGATIONS

In November of 2007, the CDC and the Texas Department of State Health Services (TDSHS) conducted an on-site investigation at the chemotherapy infusion center that reported the initial outbreak. This investigation included a review of medication preparation and infection control practices, as well as a cohort study, based on retrospective medical record review, of all patients treated at the clinic during the outbreak period to identify risk factors for SM BSIs. Investigators in Chicago and at the referral cancer center in Texas also conducted detailed reviews of common exposures among patients with SM BSIs in December of 2007 and January of 2008, respectively. Because data on product lot numbers were available in Chicago, the investigators there were able to link specific lot numbers of medications with the patients who received them. Specific information on lot numbers used for patients in other facilities was not available.

IDENTIFICATION OF ADDITIONAL CASES

Based on initial information from Texas and Illinois, the investigation quickly focused on heparin syringes from company X. Because the distribution network for the heparin syringes was relatively small, company X and the single distributor were able to provide the CDC with contact information for facilities or companies (N = 16 in 4 states) that had received prefilled heparin syringes. In early December 2007, the CDC contacted those recipients to inquire about cases of SM BSI. In most instances, the recipient was a distributing pharmacy that had sent the products to other facilities, which were, in turn, contacted. The saline syringes were produced in much larger quantities, the distribution network was more complicated, and direct contact with each recipient was not possible. To enhance case finding efforts, in mid-December, the CDC also requested reports of other SM BSI outbreaks by circulating inquiries on the CDC's Epidemic Information Exchange and the Emerging Infections Network electronic mail distribution list. State health departments also distributed these requests to clinicians. Clinicians reporting SM BSIs were asked to complete a standard case report form on which they were asked to provide demographic and clinical characteristics of affected patients as well as details regarding the timing and dosing of intravenous medications those patients had received. We defined a definite case as an SM BSI at a facility using prefilled syringes made by company X that was related to the outbreak strain by pulsed-field gel electrophoresis (PFGE) and a probable case as an SM BSI at a facility that used the syringes but for which isolates were not available.

LABORATORY METHODS

Health care facilities took culture samples from unopened prefilled heparin and saline syringes either by using membrane filtration or by injecting the contents of the syringes into blood culture bottles. In addition, unopened syringes from 4 lots of heparin and 4 lots of saline were sent to the CDC's Division of Healthcare Quality Promotion for testing. Company X also took culture samples from heparin syringes and sent opened heparin syringes filled with nutrient broth for culture.

At the CDC laboratory, syringes were opened under sterile conditions, the outer surfaces were wiped with alcohol, 70%, and the contents were tested for sterility by membrane filtration with a modified US Pharmacopeia standard sterility test method.[11] The contents of each syringe were aseptically expelled into membrane filter funnels or into separate pooling vessels prior to transfer into the funnels. The contents were filtered through gridded 47-mm, 0.45-μm membrane filters by vacuum in a laminar flow clean bench. The filters were then rinsed with 100 mL of sterile phosphate-buffered saline or Butterfield phosphate buffer by vacuum. The filters were then transferred with sterile forceps to nonselective Tryptic soy agar with sheep blood, 5% (BAP; Becton Dickinson, Sparks, Maryland), and gram-negative selective MacConkey II agar (MAC agar; Becton Dickinson), incubated at 35°C for a maximum of 3 days, and then incubated at ambient room temperature (25°C) for 11 days (total incubation time, 14 days). In addition, samples of unopened prefilled heparin and saline syringes were analyzed with the Bacterial Surveillance Assay (T5000 Biosensor System; Ibis Biosciences, Carlsbad, California) for the detection of bacterial DNA.[12]

Molecular typing of SM isolates was performed by PFGE with a modified Pulsenet standard (free) protocol (http://www.cdc.gov/PULSNET/protocols.htm). *Serratia marcescens* and Universal Standard *Salmonella* serotype Braenderup H9812 chromosomal DNA were digested with the restriction endonucleases *Spe*I and *Xba*I, respectively. Restriction fragments were separated with the CHEF Mapper XA Pulsed Field Electrophoresis System (Bio-Rad Laboratories, Hercules, California). The PFGE conditions were a gradient of 6.0 V/cm, an angle of 120°, a temperature of 14°C, switch times of 2 to 40 seconds, and a total run time of 22 hours. The PFGE gel images were scanned and saved as TIFF files, and we used BioNumerics software (Applied Maths, Austin, Texas) to analyze the genetic relatedness of the clinical and syringe isolates. The similarity of patterns was based on Dice coefficients, and a dendrogram was built by using the unweighted-paring group method. Isolates were considered genetically related (ie, potentially from a common source) if their patterns were more than 80% similar.

RESULTS

EPIDEMIOLOGIC INVESTIGATIONS

From November 5 to December 5, 2007, 21 of the 101 patients treated at the chemotherapy infusion center in Texas developed symptomatic BSIs and had blood and/or catheter tip cultures that grew SM, yielding an attack rate of 20.8%. Observations of medication preparation and infection control practices did not reveal substantial changes or lapses in technique. Review of administered intravenous medications showed that the only exposure common to all case patients was heparin flush syringes from company X. In multivariate analysis, exposure to a heparin flush was independently associated with SM BSI (odds ratio, undefined; $P = .007$).[13] Although the specific heparin flush lot numbers received by each patient were not documented, we determined, on the basis of the facility's medication inventory records, that 1 particular lot of this product was in predominant use when SM BSIs occurred. Investigators in Chicago also found that all patients with SM BSIs had been exposed to this same lot of heparin flush from company X.

At the referral cancer center in Texas, 5 cases of SM BSI were identified among patients who also had exposures to heparin flushes. However, 18 additional cases

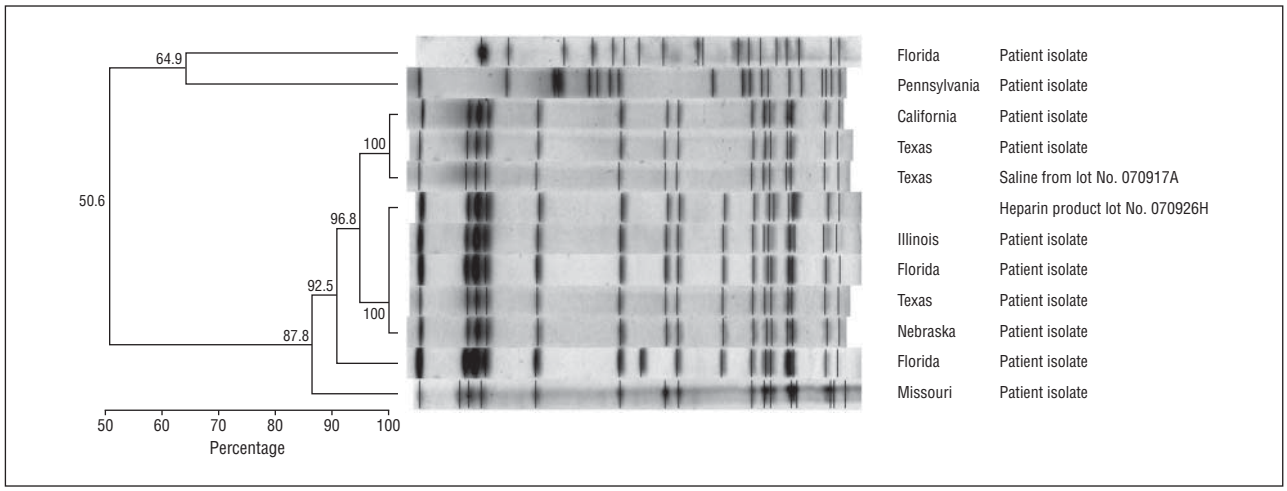

Figure 1. Dendrogram demonstrating the genetic relatedness of representative *Serratia marcescens* patient isolates from 7 states to the outbreak strain recovered from prefilled syringes manufactured by company X. The data are given as percentages; each branch shows the percentage of relatedness to other strains.

were identified among patients who had not been exposed to a heparin flush but who had been exposed to prefilled saline syringes manufactured by company X for distribution by another company. This product bore the label of the distributing company but also bore the National Drug Code number of company X.

CULTURES OF SYRINGES

Unopened prefilled heparin syringes from the chemotherapy infusion center in Texas, from which culture samples were taken by company X as well as by the TDSHS laboratory, grew no bacteria. *Serratia marcescens* was first isolated by a hospital laboratory in Chicago from unopened, prefilled heparin syringes of the lot associated with cases at the infusion center in Texas and in Chicago. *Serratia marcescens* was also recovered from culture samples from the unopened heparin syringes of this lot taken at the CDC laboratory. Cultures of 3 other lots of heparin flushes showed no growth. The DNA testing of the unopened prefilled heparin syringe from this lot tested positive for SM DNA by the T5000 Biosensor System Bacterial Surveillance Assay. *Serratia marcescens* was also isolated from the broth-filled heparin syringes sent to the CDC by company X. The cancer referral center in Texas recovered SM from an unopened saline flush syringe. The CDC laboratory took culture samples from unopened saline syringes from this lot but did not recover SM or detect SM DNA by the T5000 Biosensor System Bacterial Surveillance Assay. The CDC also took culture samples of 3 other lots of unopened saline syringes but did not recover bacteria from any of them.

MOLECULAR TYPING OF ISOLATES

Serratia marcescens isolates obtained from the unopened and broth-filled heparin syringes were genetically indistinguishable by PFGE (100% similarity). We defined these isolates as the "outbreak strain" (**Figure 1**). The isolate recovered from the unopened saline syringe in Texas was genetically related to the outbreak strain (>95% similarity).

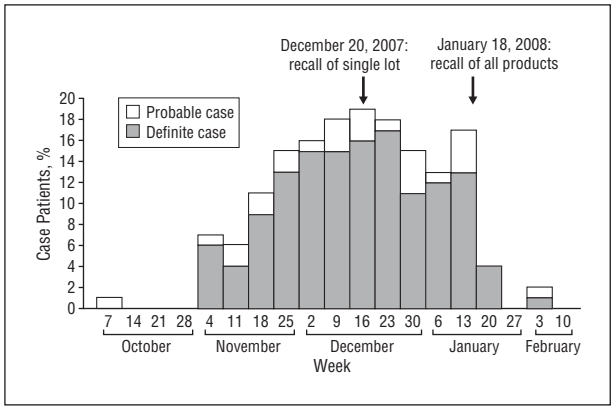

Figure 2. Epidemic curve of *Serratia marcescens* bloodstream infections reported to the Centers for Disease Control and Prevention (N=162) that met the definition for a probable or definite case, by first day of week of onset, from October 7, 2007, through February 10, 2008.

The CDC laboratory personnel typed 83 SM blood isolates from 7 states. Of these, 70 (84%), from 6 of the states, were genetically related to the outbreak strain (>80% similarity).

CLINICAL DESCRIPTION OF ALL CASES

From October 7, 2007, through February 17, 2008, 162 probable or definite cases of SM BSIs were reported to the CDC (**Figure 2**). Most of the cases occurred from November 4, 2007, to January 27, 2008. In 4 cases (2 definite cases and 2 probable cases), clinicians indicated that an SM BSI may have contributed to a patient's death.

The **Table** shows the clinical characteristics of the 162 patients with SM BSIs that were associated with patients' exposure to prefilled syringes manufactured by company X. Fifty percent of them were patients with cancer who were receiving chemotherapy, and 91.2% of them had had a central venous catheter (CVC). An elevated temperature (mean maximum temperature, 39.1°C [102.3°F]) was the most common symptom. In 13.0% of SM BSIs, symptoms began during an intravenous infusion.

Table. Clinical Features of 162 Patients With *Serratia marcescens* Bloodstream Infections (SM BSIs) Associated With Exposure to Contaminated Prefilled Syringes From Company X

Characteristic	No. (%)		
	Probable Cases[a] (n=26)	Definite Cases[a] (n=136)	Total (N=162)
Age, mean (SD), y	56.6 (18.7)	54.4 (18.8)	54.7 (18.7)
Sex			
Male	11 (42.3)	55 (40.4)	66 (40.7)
Female	15 (57.7)	77 (56.6)	92 (56.8)
Unknown	0	4 (2.9)	4 (2.5)
Primary diagnosis			
Cancer	3 (11.5)	78 (57.4)	81 (50.0)
End-stage renal disease	0	8 (5.9)	8 (4.9)
Infection	10 (38.5)	24 (17.7)	34 (21.0)
Other	13 (50.0)	21 (15.4)	34 (21.0)
Unknown	0	5 (3.7)	5 (3.1)
Port type[b]			
Temporary CVC	6 (23.1)	12 (8.8)	18 (11.1)
Peripherally inserted central catheter	14 (53.9)	48 (35.3)	62 (38.3)
Other long-term CVC	3 (11.5)	58 (42.7)	61 (37.7)
Multiple CVCs	0	6 (4.4)	6 (3.7)
Peripheral intravenous catheter	3 (11.5)	3 (2.2)	6 (3.7)
Unknown	0	9 (6.6)	7 (4.3)
Reported syringe exposures			
Prefilled heparin syringe	12 (46.2)	64 (47.1)	76 (46.9)
Prefilled saline syringe[c]	13 (50.0)	44 (32.4)	57 (35.2)
Both heparin and saline syringes[c]	1 (3.9)	22 (16.2)	23 (14.2)
Unknown	0	6 (4.4)	6 (3.7)
Onset of symptoms			
During infusion	2 (7.7)	19 (14.0)	21 (13.0)
Not during infusion	17 (65.4)	36 (26.5)	53 (32.7)
Unknown	7 (26.9)	36 (59.5)	88 (54.3)
Clinical manifestations			
Temperature >100.4°F (38.0°C)	19 (73.1)	66 (48.5)	85 (52.5)
Mean maximum temperature, °F (SD)	102.5 (1.6)	102.2 (1.5)	102.3 (1.5)
Chills	10 (38.5)	48 (35.3)	58 (35.8)
Night sweats	2 (7.7)	6 (4.4)	8 (4.9)
Myalgias	7 (26.9)	8 (5.9)	14 (8.6)
Headache	5 (19.2)	7 (5.2)	12 (7.4)
Poor appetite	5 (19.2)	6 (4.4)	11 (6.8)
Nausea	8 (30.8)	11 (8.1)	19 (11.7)
Vomiting	5 (19.2)	10 (7.4)	15 (9.3)
Fatigue	7 (26.9)	18 (13.2)	25 (15.4)
Follow-up care[d]			
Hospitalization	24 (92.3)	75 (55.1)	99 (61.1)
Emergency department evaluation	7 (26.9)	21 (15.4)	28 (17.3)
Outpatient visit	1 (3.9)	6 (4.4)	7 (4.3)
Outcomes			
Death	2 (7.7)	2 (1.5)	4 (2.5)

Abbreviation: CVC, central venous catheter.

[a] Definite cases were SM BSIs that occurred in facilities using prefilled syringes made by company X in which the isolate was related to the outbreak strain by pulsed-field gel electrophoresis. Probable cases were SM BSIs that occurred at facilities that used the syringes but in which isolates were not available for molecular typing.

[b] A CVC was defined as a catheter that entered a central vein, whether directly or through extension (peripherally inserted central catheter). A temporary CVC was defined as one that was placed with the intention of short-term use. A long-term CVC was defined as one that was placed with the intention of extended use.

[c] "Saline" indicates isotonic sodium chloride solution.

[d] Some patients received more than 1 type of follow-up care.

Two delayed infections were reported to the CDC. The first occurred in a patient exposed to the contaminated lot of prefilled heparin syringes in November 2007 who developed an SM BSI in February 2008. The second occurred in a patient exposed to the contaminated lot of prefilled heparin syringes who developed an SM BSI in November 2007. Although the latter patient was treated with antibiotics, a previously implanted CVC was not removed. This patient developed a second SM BSI when the CVC was flushed in February 2008.

Of all case patients, 46.9% were reported to have been exposed to prefilled heparin syringes, 35.2% to prefilled saline syringes, and 14.2% to both. An additional 3.7% had been patients in a health care facility that used prefilled syringes from company X, but personnel could not determine which type of syringes the case patients had

received. Investigators in Chicago, who had information on lot numbers of syringes that patients used, found that 22 of 121 patients (18.2%) exposed to the contaminated lot developed SM BSIs.

TERMINATION OF THE OUTBREAK

Based on the results of this investigation, the company issued a voluntary national recall of the contaminated lot of prefilled heparin syringes on December 18, 2007.[14] The subsequent identification of cases associated with prefilled saline syringes prompted the company to expand their recall to include all of their prefilled syringes on January 18, 2008.[15] Reporting of SM BSIs to the CDC decreased precipitously after the January recall, as demonstrated in Figure 1. An FDA inspection of the facility where the syringes were produced found "that the firm is not in compliance with the Quality System regulation and failed to have adequate controls to ensure necessary sterility of its prefilled syringes."[14]

COMMENT

We identified a multistate outbreak of 162 SM BSIs associated with contaminated prefilled syringes manufactured by a single company from October 7, 2007, to February 17, 2008. Epidemiologic and laboratory findings indicated that the infections were associated with exposure to prefilled heparin or saline syringes made by this company. Case reports ended quickly after a nationwide recall of all prefilled syringes manufactured by company X. An onsite inspection of the manufacturer by the FDA revealed poor compliance with the FDA's Good Manufacturing Practices (GMPs) and quality system regulations (21 Code of Federal Regulations [CFR] §820[16]). Within days of this inspection, company X discontinued production of all medical products.

Intrinsic contamination of heparin and saline products has been reported in the past, but more recent episodes of infection associated with exposure to contaminated products have involved products contaminated during pharmaceutical compounding rather than during the manufacturing process.[17-19] For example, in 2005, the CDC reported a nationwide outbreak of *Pseudomonas fluorescens* BSIs associated with exposure to prefilled heparin syringes that were contaminated during product preparation, either at the manufacturer or at a compounding pharmacy that mixed concentrated heparin.[17] More recently, an outbreak of *Pseudomonas putida* and *Stenotrophomonas maltophilia* infections was traced to a compounding pharmacy in Brazil that prepared heparin catheter-lock solution.[18] In the outbreak we investigated, however, no compounding pharmacy was involved in the production of the syringes. This distinction is important because compounded pharmaceuticals are not held to the same regulatory standards as manufactured ones.[20] To ensure the sterility of manufactured medical products, companies must adhere to the FDA's GMPs, a comprehensive body of regulations that govern all aspects of production.[21] An FDA inspection of company X revealed that the firm was not in compliance with the quality system regulation or the GMPs (21 CFR §820[16]) and failed to have adequate controls to ensure necessary sterility of its prefilled syringes.[14]

Virtually all (91.2%) of the case patients in this outbreak had CVCs. Because CVCs are in place for extended periods and have to be flushed with saline and heparin frequently to maintain their patency, patients with CVCs are at increased risk of developing BSIs as a result of contaminated flushes. This outbreak demonstrates, however, that the time from contaminated flush exposure to BSI can vary substantially. Although most patients developed BSIs within days of exposure to a contaminated syringe, 2 developed BSIs several weeks after exposure. Delayed infections such as these have been observed in other situations in which medications contaminated with bacteria have been infused through CVCs, perhaps owing to the contamination of biofilms on the catheters.[17]

We encountered several challenges while conducting this investigation. First, our attempts to track specific lots of prefilled syringes were complicated by the number of distributors that acted as intermediaries between the manufacturer and the health care facilities that used the products (ie, the end users). For example, the prefilled heparin syringes were sent to 1 primary distributor, which sent them to pharmacies and home care companies, which in turn supplied them to clinics in other states. Distribution was even more complicated for the saline syringes, which were sent by a primary distributor to various subdistributors, some of whom supplied products to large national product distribution companies. As a result, some syringes might have gone through 3 distribution steps before reaching the end user. Unfortunately, the distributors of the syringes did not have detailed records of the product lot numbers they distributed, which posed challenges during the recall.

A second challenge was that even though company X manufactured all of the syringes implicated in this outbreak, none of these syringes actually bore the company's name on the label. The heparin syringes bore the name of a subsidiary of company X, and the prefilled saline syringes bore the name of a different company (company Y) that was not related in any way to company X. Company Y also distributed prefilled saline syringes manufactured by other companies that were not part of the company X product recall. Ultimately, the most reliable way to identify syringes made by company X was by their National Drug Code.[22] This numeric code is a universal product identifier for medications; each product made by a company is assigned a specific number that is displayed on the product, even if is the product is relabeled. The National Drug Code proved invaluable, not only during our investigation, but also in helping facilities identify which prefilled syringes needed to be removed from use.

A third challenge was that the syringe contamination was likely intermittent. This probably affected our ability to identify contaminated syringes and might have been a substantial factor in the CDC's inability to recover SM from the saline syringes, which were made in much larger lots than the heparin syringes. The intermittent nature of product contamination and resultant difficulty in identifying contaminated syringes solely on the basis of laboratory results underscore the importance of pairing epi-

demiologic and microbiologic data during investigations. For example, although initial culture samples of prefilled heparin syringes from the chemotherapy infusion center in Texas showed no evidence of contamination, the syringes remained suspect because of the epidemiologic findings. The finding of intermittent contamination also lent support to company X's decision to recall all products, even those from lots that had not been found to be contaminated.

This investigation has several limitations. First, cases of SM BSIs in patients exposed to these syringes may have been underreported. Although we attempted to identify additional cases by posting requests for case reports on various electronic communication networks and through state health departments, we do not know how widely those messages were disseminated or if they reached the proper audiences. The broad distribution of the saline syringes precluded making direct contact with all receiving facilities. In addition, even when cases of SM BSI among patients exposed to contaminated syringes were identified, they may not have been associated with the use of these syringes because SM is a cause of health care–associated BSIs and may have been attributed to other risk factors, such as the presence of a CVC. For these reasons, the 162 cases described herein are likely to be an underestimate. Another limitation is that we were not able to determine why there were some differences between probable and definite cases. Both groups of patients met criteria for SM BSI, but, to be conservative, we classified cases in which there were not isolates available as probable cases. We do not know if these differences represent true differences between the probable and definite cases or if they are due to the fact that the number of probable cases (n=26) was small compared with the number of definite cases (n=136). However, we believe this to be a minor limitation, given that 84% of the cases were definite. A final limitation is that we were often not able to determine with certainty the exact lot or lots of syringes to which infected patients were exposed because specific lot numbers of medications received by patients are seldom available in either medical or pharmacy records. A notable exception was if the syringes came from home care companies or outpatient pharmacies, which frequently did record the lot numbers of syringes they distributed. When lot numbers of syringes to which patients were exposed were not available, we were, however, usually able to use billing inventories to determine which lots had been used at a facility.

Despite these limitations, we believe that the results of our investigation highlight several important issues concerning the safety of pharmaceutical products. First, companies that manufacture these products must ensure that they are familiar with, and in full compliance with, all of the requirements set forth by the FDA's GMPs. Compliance with these measures may well have averted this outbreak altogether. Second, communication with public health officials can help identify common outbreaks in different locations and facilitate the timely identification of and response to an outbreak associated with a widely distributed medical product. Third, distributors and subdistributors of pharmaceutical products should follow the example of home care companies and outpatient pharmacies and record lot numbers of products that they distribute. Likewise, receiving departments or pharmacies at health care facilities should record lot numbers of products received by the facility. Such tracking of lot numbers would help to quickly identify where defective pharmaceuticals have been sent and expedite the recall of these products, potentially averting additional cases. Tracking lot numbers of products used by patients would also be very helpful during investigations of possible adverse drug events. Unfortunately, this type of tracking is labor intensive. However, investigations like the one described herein demonstrate the importance of efforts to improve medication tracking through the use of improved technology like bar coding. Fourth, investigations of possible adverse drug events must include both epidemiologic and laboratory components. Like the investigators of nationwide outbreaks of *Fusarium keratitis* associated with a contact lens solution in 2005[23] and adverse reactions associated with contaminated heparin in 2008,[24] we established an epidemiologic association between cases of disease and exposure to a medical product before we could confirm the link with laboratory findings. In each of these investigations, establishment of an epidemiologic association led to more rapid action in removing the implicated products from circulation. A final issue highlighted by our investigation is that, given the complexity of pharmaceutical manufacturing and distribution in the United States, clinicians and those who handle medical supplies for health care facilities should be aware of the National Drug Code. As we found in this investigation, this code is the most reliable piece of information for identifying a pharmaceutical product associated with an adverse drug event.

In summary, we identified a large outbreak of SM BSIs, which we determined to be associated with contaminated, prefilled heparin and saline syringes manufactured by a single company. Close collaboration among federal agencies, public health authorities, and clinicians was critical to the identification of the cause of this outbreak. In the course of the investigation, we also identified several challenges to medical product tracking that should be addressed promptly so that disease outbreaks caused by exposure to contaminated medications can be dealt with more efficiently in the future.

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