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Multicenter Outbreak of Gram-Negative Bloodstream Infections in Hemodialysis Patients

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Abstract

Rationale & Objective—Contaminated water and other fluids are increasingly recognized to be associated with health care–associated infections. We investigated an outbreak of Gram-negative bloodstream infections at 3 outpatient hemodialysis facilities.

Study Design—Matched case-control investigations.

Setting & Participants—Patients who received hemodialysis at Facility A, B, or C from July 2015 to November 2016.

Exposures—Infection control practices, sources of water, dialyzer reuse, injection medication handling, dialysis circuit priming, water and dialysate test findings, environmental reservoirs such as wall boxes, vascular access care practices, pulsed-field gel electrophoresis, and whole-genome sequencing of bacterial isolates.

Outcomes—Cases were defined by a positive blood culture for any Gram-negative bacteria drawn July 1, 2015 to November 30, 2016 from a patient who had received hemodialysis at Facility A, B, or C.

Analytical Approach—Exposures in cases and controls were compared using matched univariate conditional logistic regression.

Results—58 cases of Gram-negative bloodstream infection occurred; 48 (83%) required hospitalization. The predominant organisms were *Serratia marcescens* (n = 21) and *Pseudomonas aeruginosa* (n = 12). Compared with controls, cases had higher odds of using a central venous catheter for dialysis (matched odds ratio, 54.32; lower bound of the 95% CI, 12.19). Facility staff reported pooling and regurgitation of waste fluid at recessed wall boxes that house connections for dialysate components and the effluent drain within dialysis treatment stations. Environmental samples yielded *S marcescens* and *P aeruginosa* from wall boxes. *S marcescens* isolated from wall boxes and case-patients from the same facilities were closely related by pulsed-field gel electrophoresis and whole-genome sequencing. We identified opportunities for health care workers' hands to contaminate central venous catheters with contaminated fluid from the wall boxes.

Limitations—Limited patient isolates for testing, on-site investigation occurred after peak of infections.

Conclusions—This large outbreak was linked to wall boxes, a previously undescribed source of contaminated fluid and biofilms in the immediate patient care environment.

More than 6,500 outpatient centers provide hemodialysis to more than 450,000 patients in the United States.[1] Morbidity and mortality are high in this population.[1] In 2014, there were 29,516 bloodstream infections (BSIs) among hemodialysis outpatients reported to the Centers for Disease Control and Prevention (CDC).[2] BSIs in hemodialysis patients are most commonly caused by Gram-positive organisms.[2] BSIs caused by Gram-negative organisms are less common. However, there are reports of outbreaks due to these organisms in outpatient hemodialysis facilities attributed to water sources including contaminated reprocessed dialyzers,[3–6] improperly handled medications,[7] hemodialysis equipment,[8–11] and dialysate.[12]

Water reservoirs, including waste water systems, have been increasingly associated with health care–associated infections.[13–17] Dialysis effluent is a liquid waste product of the hemodialysis process. We describe a large outbreak of Gram-negative BSIs linked to dialysis effluent drains located in wall boxes.

In August 2016, CDC detected a cluster of 5 BSIs caused by *Serratia marcescens* in an outpatient hemodialysis facility (Facility A) through review of routine surveillance data reported to the National Healthcare Safety Network (NHSN).[18] During subsequent consultations with state health departments, we learned that 2 additional outpatient hemodialysis facilities (Facilities B and C) owned by the same company had experienced BSIs caused by similar Gram-negative organisms.[19] Multiple Gram-negative organisms were identified, most commonly *S marcescens, Pseudomonas aeruginosa*, and *Enterobacter cloacae*. In October to November 2016, at the states' request, CDC participated in an on-site investigation to determine the extent of the outbreak and source of infections.

Methods

Case Definitions and Characteristics

A case was defined as a blood culture from which any Gram-negative bacteria was identified during July 1, 2015 to November 30, 2016 from a patient who received hemodialysis at Facility A, B, or C. There must have been at least 21 days between positive cultures for more than 1 case to occur in a single patient.

To identify additional cases, we reviewed Facility A, B, and C electronic medical records and surveillance data submitted to NHSN. Infection preventionists at select area hospitals were also queried to identify cases diagnosed on admission to other facilities.

We developed a standardized data abstraction form and extracted patient demographics, medical history, blood culture results, and clinical course. Information abstracted from the dialysis session on the date of the event (earliest of the following: date of positive blood culture, symptom onset, or outpatient dialysis session closest to date of positive blood culture if culture was collected upon hospitalization) and the 2 prior sessions included time of dialysis (shift), staff caring for the patient, dialysate information, and medications received.

Epidemiologic Investigation

Two 1:1–matched case-control investigations were performed at Facilities A and B to examine risk factors for becoming a case.

The first investigation focused on patient-specific risk factors (eg, age and comorbid conditions). Case-patients were compared with randomly selected control-patients matched by facility. Control-patients received hemodialysis at Facility A or B and did not develop a Gram-negative BSI during the investigation period.

The second investigation examined factors that were specific to a patient during a particular treatment (ie, session-specific factors; eg, medications received). For each case-patient, a session date of interest was selected that corresponded to the date of the event. Each case-patient's selected treatment session was matched to a randomly selected control-patient's treatment session by date and facility. Control sessions were excluded if any of the following criteria were met: patient had blood cultures collected 7 days before or after the treatment session date, received intravenous antibiotics during the session, or had signs or symptoms of a BSI during the treatment session.

All statistical analyses were performed using SAS, version 9.3 (SAS Institute Inc). Matched odds ratios (mORs) and 95% confidence intervals (CIs) were calculated using matched univariate conditional logistic regression with exact analysis. Two-sided $P < 0.05$ was considered significant. For select continuous and ordinal variables, the median value or quartiles were used to create categorical variables.

Review of Practices

We conducted site visits at Facilities A, B, and C and interviewed staff and administrators at each facility. We focused on opportunities for water exposure, including dialyzer reuse; injection medication handling; and dialysis circuit priming. We examined results of routine monthly water and dialysate testing, including endotoxin and bacterial colony counts, and environmental reservoirs such as wall boxes. We also evaluated central venous catheter (CVC) and vascular access care and maintenance practices.

Wall boxes are frames recessed into the wall at each dialysis treatment station that house connections for the dialysis machine to receive reverse-osmosis water, acid, and bicarbonate concentrates that are proportioned in the machine to produce dialysate. Wall boxes also contain a connection to a drain line, through which effluent (ie, spent dialysate or waste) from the dialysis machine empties into the sanitary sewer system (Fig 1).

Clinic Observations

Using standardized tools,[20] we observed infection control practices, including dialysis machine and station disinfection, CVC and vascular access care practices, injectable medication preparation and administration, priming procedures, and hand hygiene.

Laboratory Testing and Environmental Sampling

Collection and Processing of Surface and Water Samples—One-liter water samples from individual sinks and reverse-osmosis tanks were collected. We used 3M Sponge-Sticks and swabs to obtain environmental surface samples from sink faucets, counters, dialysis machine prime buckets, and wall boxes. Sponge-Sticks and swabs were processed using methods previously described.[3] Water bacterial quality was evaluated using heterotrophic plate counts as previously described.[21]

Organism Identification and Strain Typing—The identity of organisms isolated from environmental samples and available case-patient isolates was confirmed using matrix-assisted laser desorption/ionization time-of-flight (MALDI-TOF) mass spectrometry. Pulsed-field gel electrophoresis (PFGE) was performed on all *S marcescens*, *P aeruginosa*, and *E cloacae* isolates. Isolates with >90% and 99% similarity in PFGE band patterns were considered closely related and indistinguishable, respectively.

For greater resolution of a possible point source, whole-genome sequencing of the environmental and patient isolates of *S marcescens* was performed to determine relatedness. DNA was extracted from isolates using an automated nucleic acid purification system (Maxwell 16 MDx Instrument; Promega). High-quality input genomic DNA was fragmented using Covaris ultrasonic fragmentation. Sample libraries were prepared using the NuGen Ovation Ultralow DR Multiplex System 1–96 kit. Sequencing was done with an Illumina MiSeq, producing 250–base pair paired-end reads.

Genome assemblies were constructed from high-quality sequencing reads using a de novo assembly algorithm. Species IDs were verified using Kraken.[22] To determine the relatedness between *S marcescens* isolates, phylogenetic analysis was performed using high-quality

single-nucleotide polymorphisms (SNPs) from a reference mapping approach,[23] using A3 as the reference sequence given that it had the highest quality assembly as determined by N50 length (a measure of assembly contiguity).

Ethics and Informed Consent

This activity underwent human subjects review at CDC and was determined to constitute a nonresearch urgent public health response. Therefore, individual-level informed consent was not obtained.

Results

Epidemiologic Investigation

Facilities A, B, and C were located in close geographic proximity (<20 miles apart). The facilities had between 12 and 36 dialysis treatment stations. The 3 facilities shared corporate ownership, and some products such as medications, dialyzers, acid, and bicarbonate came from the same distributors. Facilities A and B shared the same municipal water supply, while Facility C had a different supply. Staff were not commonly shared across the 3 facilities.

We identified 58 cases from July 2015 through November 2016 (Fig 2) occurring in 51 patients. The majority (n = 52; 90%) occurred at Facilities A and B. For comparison, during the preceding year, 12 Gram-negative BSIs were identified at the 3 facilities. The monthly patient census in the 3 facilities remained stable and did not increase between July 2014 and November 2016. The Gram-negative organisms most commonly identified were *S marcescens* (n = 21; 36%), *P aeruginosa* (n = 12; 21%), and *E cloacae* (n = 11; 19%). Sixteen (28%) cases had multiple Gram-negative organisms isolated. Forty-eight (83%) cases resulted in hospitalization, with a median length of stay of 8 (interquartile range, 4–11) days. The majority of cases had a CVC for dialysis access (n = 50; 86%; Table 1). No individual staff members were associated with infections across or within facilities and no single dialysis machine was associated with a majority of infections.

When patient-specific risk factors were examined, case-patients and matched control-patients were similar in age, sex, and comorbid conditions (Table 2). Longer dialysis vintage was associated with lower odds of infection (mOR, 0.19; 95% CI, 0.05–0.57).

Among session-specific risk factors, using a CVC for dialysis access was significantly associated with increased BSI odds (mOR, 54.32; lower bound of the 95% CI, 12.19). Dialyzing after the first treatment shift (mOR, 2.83; 95% CI, 1.07–8.78) and having more than 3 staff members involved in the patient's care during the session (mOR, 3.75; 95% CI, 1.20–15.52) were more common among case-patients than control-patients.

Clinic Observations and Review of Practices

Infection control deficiencies were noted at all 3 facilities. Inadequate aseptic technique during CVC care was observed; for example, during 2 of 6 (33%) observed CVC connections, the CVC was not connected to the blood tubing aseptically. Although 44 of 51 (86%) hand hygiene opportunities were successful, we still observed multiple missed hand hygiene opportunities, particularly as staff moved between "dirty" and "clean" areas at

the dialysis stations, most frequently not changing gloves or not performing hand hygiene when changing gloves. We observed more than 20 separate machine and station cleaning and disinfection processes. At all 3 facilities, we found multiple lapses, including not applying disinfectant to all surfaces (83%) or applying an inadequate amount of disinfectant (61%). Regarding prime buckets, we observed multiple staff members not applying disinfectant to them or rinsing them with tap water after disinfection. We found clean supplies stored in close proximity to sinks at all 3 facilities. In Facilities B and C, medication preparation areas were adjacent to sinks without a splash guard in place.

Reuse of dialyzers was practiced at some facilities at the start of the outbreak but had ceased at all facilities before the on-site investigation (Fig 2). Hemodialysis machines underwent daily heat disinfection and chemical disinfection with bleach every 72 hours. Routine testing of the water distribution loop and machines revealed endotoxin levels and bacterial colony counts below action levels set by the Association for the Advancement of Medical Instrumentation (AAMI).[24]

Staff at Facility A reported problems with wall boxes that became apparent in early 2016 and peaked in summer 2016. This included clogging and regurgitation of fluid from the drain, odors, and insect infestation. Administrators also observed that staff would touch wall boxes (eg, to change acid concentrate) and then proceed directly to CVC or other patient care without performing hand hygiene. At all 3 facilities, we observed that wall box basins were damp and frequently had visible pools of fluid, foaming, and waste fluid backing out of the drain. Sediment clogging the waste drains was also noted (Fig S1).

Laboratory Testing and Environmental Sampling

In total, 43 environmental samples from the 3 facilities underwent testing (Table S1). Gram-negative bacteria were found in multiple environmental sources, including tap water, sinks, and surfaces. Notably, all wall box samples grew at least 1 of the 3 most common outbreak pathogens, *S marcescens*, *P aeruginosa*, and *E cloacae*. These organisms were infrequently isolated from sinks, water, or other surfaces at the facilities.

Eighteen patient isolates were available for testing, including 9 *S marcescens*, 5 *P aeruginosa*, and 1 each of the following: *Escherichia coli*, *Burkholderia cepacia*, *E cloacae*, and *Klebsiella pneumoniae*. PFGE identified 2 clusters of *S marcescens* in Facility B (clusters B and C; Fig S2) and 1 cluster of *P aeruginosa* in Facility A (cluster B; Fig S2). There were no related clinical isolates across different facilities by PFGE or whole-genome sequencing. There were clusters of *S marcescens* isolates within facilities differing by 4 to 227 SNPs, while unrelated isolates across facilities differed by more than 18,000 SNPs (Fig 3).

S marcescens isolates from a wall box (C3) and a patient (C4) at Facility C were found to be indistinguishable by PFGE; whole-genome sequencing showed that these 2 isolates differed by only 4 SNPs from a core of 85.94% of the reference genome (Figs 3 and S2). SNP analysis revealed related wall box (A2) and patient (A3) *S marcescens* isolates at Facility A that differed by 34 SNPs (from a core of 46.47%) and were unrelated to those at Facility C (Fig 3).

Control Measures

During summer 2016, before the start of the on-site investigation, facility administrators implemented a wall box drain care protocol at Facilities A and B, educated staff on the importance of performing hand hygiene after touching wall boxes, and had increased their frequency of hand hygiene audits. Patients at Facilities A and B received a letter informing them of increased infections and the steps that facility administrators were taking to decrease infections. At the time of our on-site investigation, these interventions had not been introduced at Facility C.

We recommended remedying the infection control lapses identified, including improving aseptic technique during CVC access, care, and maintenance; machine and station cleaning and disinfection; and hand hygiene, with particular emphasis on hand hygiene after wall box contact. Facility C initiated a wall box drain care protocol similar to that at Facilities A and B. Staff at all facilities were re-educated and received training regarding the importance of hand hygiene, aseptic technique during CVC care, and station disinfection. Between December 2016 and May 2017, 3 Gram-negative BSIs were reported by the 3 facilities.

Discussion

In this investigation, we determined that wall boxes were contaminated with Gram-negative organisms and contributed to a large outbreak of BSIs. Although wall boxes have not previously been identified as a cause of health care–associated infections; water-related biofilms have been associated with health care–associated infections across the spectrum of health care[13–16,25,26] with risk that is not limited to Gram-negative infections.[27] Contaminated sink faucets, aerators, or drains can serve as a reservoir of organisms and be associated with infections through splashing or contact with the hands of health care personnel.[28–31] Medications may become contaminated with water during preparation or administration.[32,33] Waterborne organisms can be dispersed through devices that do not come into direct contact with patients but contain contaminated water.[34,35] Sources of contaminated water, fluids, and biofilms that can cause infections are still being identified, as illustrated in this investigation and the recent discovery of *Mycobacterium chimera* infections associated with heater-cooler units used in coronary bypass procedures.[36,37]

In this outbreak, Gram-negative organisms commonly found in water-related biofilms (*S marcescens*, *P aeruginosa*, and *E cloacae*) caused a large number of infections. In almost one-third of cases, more than 1 Gram-negative organism was identified, further supporting the conclusion that an environmental reservoir was the source. Gram-negative organisms were found in the environment, notably at dialysis station wall boxes. Matching patient and wall box isolates were identified within facilities. Infection control breaches, primarily poor hand hygiene, provided a mechanism of pathogen spread from wall boxes to patients. Routine testing performed monthly by the facilities failed to show excessive contamination of reverse-osmosis water or bicarbonate solutions.

We found that CVC use was strongly associated with becoming a case, likely due to higher risk for contamination during CVC care and a propensity toward biofilm formation.[38] Being on dialysis for fewer months was associated with being a case, possibly related to

a high CVC prevalence among newer hemodialysis patients.[1] Dialyzing later in the day (when environmental surfaces are likely to have greater levels of contamination), and more staff involved in a patient's care were risk factors for BSI, suggesting that environmental contamination and infection control breaches played a role in transmission of infections. Although the close proximity and common ownership of facilities initially suggested a possible point source, we believe this was unlikely due to the lack of related isolates between facilities and variety of organisms causing infections.

There are no standards for wall box configuration, yet they are generally similar in design. Multiple connections are present that allow the dialysis machine to receive reverse-osmosis water, bicarbonate, and acid (Fig 1). The waste line leaving the dialysis machine connects and empties into the sanitary sewer system, functioning as any other drain with the resulting formation of biofilms and subsequent proliferation of organisms including the bacteria that were implicated in this outbreak. Typically, the "clean" side of the wall box device (connections for treated water, dialysate, and bicarbonate) is not separated from the "dirty" side (waste line and drain).

Although malfunctioning wall boxes (eg, with foam or fluid regurgitation) make it nearly impossible for health care personnel to manipulate connections without directly contacting the waste fluid, our investigation suggested that even properly functioning wall boxes can serve as a source for transmission. The dialysate effluent or waste that drains into the wall box is rich in nutrients and might facilitate the formation of biofilms and proliferation of Gram-negative organisms. Facilities A and B had a p-trap and large visible air gap at each dialysis station wall box, and these wall boxes appeared to be more prone to fluid splashing and foaming. By contrast, Facility C had traps located distal to floor drains, with several wall boxes emptying into each floor drain and less reported clogging and foaming. Regardless of the plumbing features in place, contamination with Gram-negative organisms was present. We found related *S marcescens* isolates in wall boxes at Facility C despite no overt signs of wall box dysfunction.

CDC is communicating with AAMI, state health departments, and dialysis providers to better understand how wall boxes contribute to patient infections, as well as design features and disinfection strategies to help mitigate these risks. It is unknown how often wall boxes contribute to infections. The findings of this investigation suggest that it is perhaps occurring in other facilities without being recognized. All dialysis facilities should perform routine cleaning and disinfection of wall boxes, as part of the immediate patient care environment, at least daily (Table 3).[39] Centers with overtly malfunctioning wall boxes should take immediate steps to remediate clogged drain pipes and improve outflow. In some centers, wall box design improvements might be necessary. New dialysis facilities should consider installing wall boxes that separate the waste line and drain from the area in which clean supply ports are housed and minimize splashing at air gaps. Improved adherence to basic infection control practices such as hand hygiene and aseptic technique is critical in all dialysis facilities and can help mitigate potential risk for infection from wall boxes.

Our investigation has strengths and limitations. We investigated infections at 3 different facilities, illustrating that our findings were not isolated to a single facility. We

performed a multipronged investigation that included epidemiologic studies, infection control observations, environmental sampling, and molecular analysis that led to our final conclusions. On-site observations and environmental sampling took place after the peak of infections at Facilities A and B. Facility B also underwent renovations before the start of the investigation. We had a limited number of patient isolates available for testing and although we were able to visually inspect all wall boxes, we were unable to sample every wall box or water source. We sampled wall boxes in areas of the facility at which most of the case-patients dialyzed; 75% of the wall boxes sampled were located in a station at which a case-patient had dialyzed. Although the overall evidence suggests that contamination from wall boxes combined with poor hand hygiene practices was the cause of this outbreak, we observed other breaches that could have contributed to the infections (eg, preparation of medications near sinks) and many lapses in station disinfection. Therefore, it was critical that these other infection control challenges were addressed, in addition to remediation of the wall boxes. Although dialyzer reuse was ongoing at the start of the outbreak and may have contributed to some infections, at least 47 infections occurred after reuse was discontinued.

Providers should be aware that wall boxes are a potential source of Gram-negative BSIs in dialysis settings. Infections with Gram-negative organisms commonly found in water-related biofilms should prompt investigation into water and sources of waste fluid serving as potential reservoirs in the health care environment. Infection prevention and control practices should be regularly assessed and incorporated into routine quality improvement activities in all health care settings to decrease the likelihood of pathogen transmission from the environment to patients.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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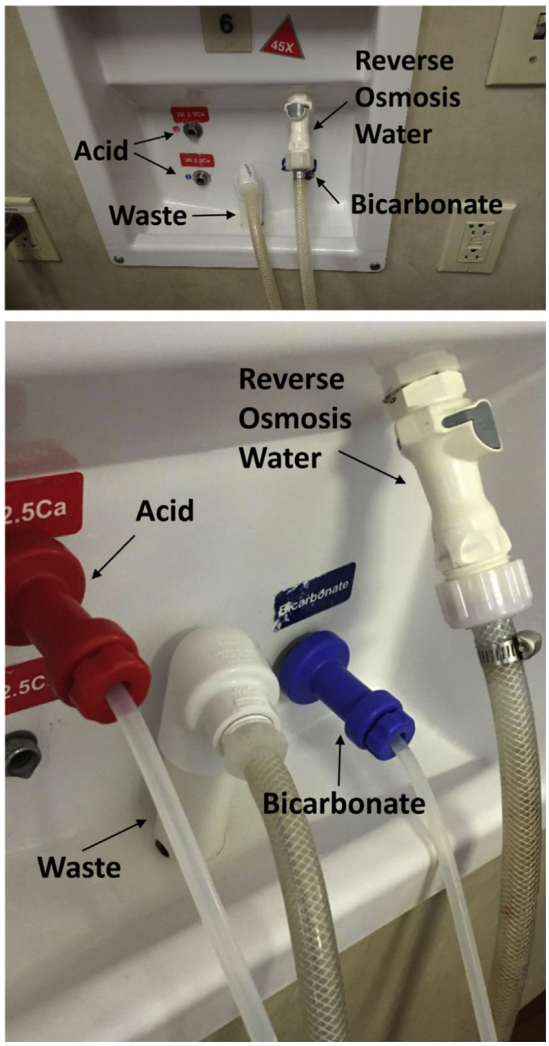

Figure 1.
Dialysis station wall boxes with bicarbonate, acid, reverse osmosis water, and waste connections and lines labeled.

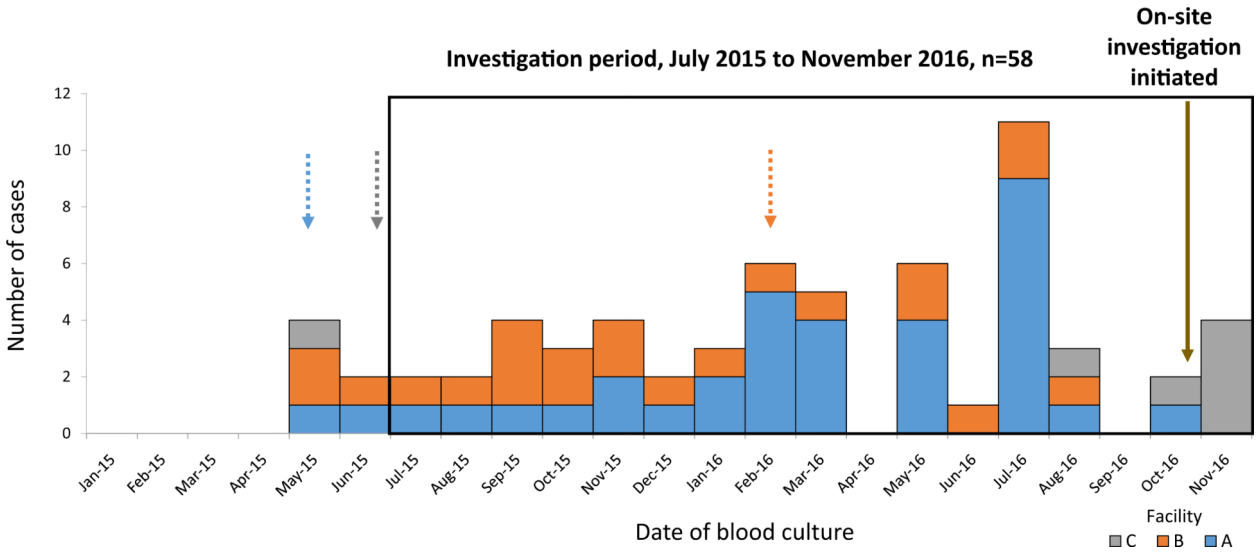

Figure 2.

Epidemic curve of Gram-negative bloodstream infections in hemodialysis patients at Facilities A, B, and C (n = 64). Solid box indicates investigation period from July 2015 to November 2016; n = 58. Dashed arrows indicate date reuse of dialyzers ceased at each facility.

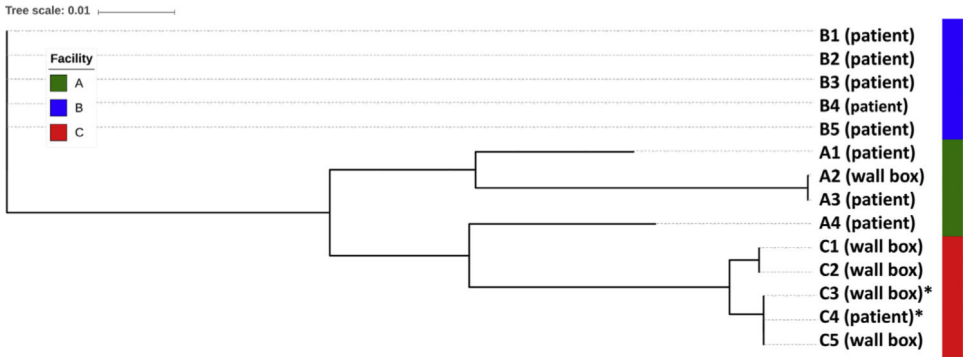

Figure 3.

Phylogenetic trees of reference-based single-nucleotide polymorphism (SNP) analysis comparing *Serratia marcescens* case-patient and wall box isolates from 3 different outpatient hemodialysis facilities (A, B, and C; SNPs from core genome size of 29.87%). The phylogenetic tree represents genetic distances based on branch length; that is, isolates A2 and A3 (which have short branches between one another) are closely related to one another and more distantly related to isolates A1 and A4; *C3 and C4 were found to be indistinguishable using pulsed-field gel electrophoresis. Core genome size of isolates for individual facility whole genome sequencing comparisons are as follows: Facility A, 46.47%; Facility B, 78.46%; Facility C, 85.94%. The sequence reads generated as part of this study are available at National Center for Biotechnology Information BioProject ID PRJNA454492.

Table 1.

Characteristics of Cases With Gram-Negative Bloodstream Infections at Outpatient Hemodialysis Facilities A, B, and C

Parameter	Value
Patient Characteristics (n = 51) [a]	
Age, y	62 [49–72]
Female sex	29 (57%)
Race	
Black	36 (71%)
White	14 (27%)
Missing	1 (2%)
Charlson comorbidity index score	
0	0 (0%)
1–2	1 (2%)
3–4	20 (39%)
≥5	30 (59%)
Current or former IV drug user	4 (8%)
Facility	
A	29 (57%)
B	17 (33%)
C	5 (10%)
Dialysis vintage, mo	11 [4–33]
Case Treatment Characteristics (n = 58)	
Acid delivery method	
Jug (via container not attached to wall box)	31 (53%)
Standard (via wall box)	26 (45%)
Missing	1 (2%)
Dialysis treatment shift	
First	16 (27%)
Second	17 (29%)
Third	23 (40%)
Nocturnal	1 (2%)
Missing	1 (2%)
Dialysis treatment schedule	
Monday/Wednesday/Friday	24 (41%)
Tuesday/Thursday/Saturday	32 (55%)
Nocturnal	1 (2%)
Missing	1 (2%)
Vascular access type used	

Parameter	Value
Central venous catheter	50 (86%)
Arteriovenous fistula/graft	7 (12%)
Missing	1 (2%)
No. of staff involved in patient's treatment session	
≤3	24 (41%)
>3	33 (57%)
Missing	1 (2%)
Infections and Outcomes (n = 58)	
Gram-negative organisms	
Serratia marcescens	21 (36%)
Pseudomonas aeruginosa	12 (21%)
Enterobacter cloacae	11 (19%)
Klebsiella spp[b]	9 (16%)
Escherichia coli	4 (7%)
Stenotrophomonas maltophilia	4 (7%)
Pantoea spp	2 (3%)
Providencia stuartii	2 (3%)
Other[c]	9 (16%)
>1 Gram-negative organism isolated	16 (28%)
Hospitalized	48 (83%)
Hospital length of stay, d	8 [4–11]
Central venous catheter removed[d]	29 (58%)
Died ≤2 weeks after positive blood culture	1 (2%)

Note: Values for continuous variables given as median [interquartile range]; for categorical variables, as count (percentage). Abbreviation: IV, intravenous.

[a] In 51 patients, 58 cases occurred.

[b] *Klebsiella oxytoca* (n = 5), *Klebsiella pneumoniae* (n=4).

[c] One each of the following: *Achromobacter dentrificans, Acinetobacter* spp, *Aeromonas hydrophila, Burkholderia cepacia, Citrobacter koseri, Delftia acidovorans, Empedobacter brevus, Pseudomonas stutzeri*, and *Sphingomonas paucimobilis*

[d] Of 50 cases that occurred in patients with a central venous catheter.

Table 2.

Risk Factors for Gram-Negative Bloodstream Infections in Patients at Outpatient Hemodialysis Facilities A and B

	Cases	Controls	mOR (95% CI)	*P* [a]
Patient-Specific Risk Factors [b]				
No. of patients	46	46		
Age category				
18–44 y	8 (17%)	6 (13%)	1.00 (reference)	
45–64 y	20 (44%)	19 (41%)	0.82 (0.21–3.00)	0.9
≥65 y	18 (39%)	21 (46%)	0.71 (0.19–2.46)	0.7
Male sex	18 (39%)	26 (57%)	1.90 (0.84–4.58)	0.1
Race				
White	12 (26%)	6 (13%)	1.00 (reference)	
Black	33 (72%)	40 (87%)	0.33 (0.06–1.34)	0.2
Missing	1 (2%)	0 (0%)		
Charlson comorbidity index score				
0–2	1 (2%)	6 (13%)	1.00 (reference)	
3–4	19 (41%)	17 (37%)	5.93 (0.66–53.51)	0.1
≥5	26 (57%)	23 (50%)	6.05 (0.69–52.78)	0.1
Dialysis vintage				
<26 mo	29 (63%)	15 (33%)	1.00 (reference)	
≥26 mo	12 (26%)	31 (67%)	0.19 (0.05–0.57)	<0.001[c]
Missing	5 (11%)	0		
Session-Specific Risk Factors [b]				
No. of sessions	52	52		
Acid delivery method				
Jug (via container not attached to wall box)	30 (58%)	34 (65%)	1.00 (reference)	
Standard (via wall box)	21 (40%)	18 (35%)	1.33 (0.52–3.58)	0.7
Missing	1 (2%)	0 (0%)		
Dialysis treatment shift				

	Cases	Controls	mOR (95% CI)	*P* [a]
First shift	14 (27%)	26 (50%)	1.00 (reference)	
After first shift	37 (71%)	26 (50%)	2.83 (1.07–8.78)	0.03[c]
Missing	1 (2%)	0 (0%)		
Dialysis treatment schedule				
Monday/Wednesday/Friday or nocturnal	23 (44%)	22 (42%)	1.00 (reference)	
Tuesday/Thursday/Saturday	28 (54%)	30 (58%)	0.50 (0.01–9.61)	0.9
Missing	1 (2%)	0 (0%)		
IV medications				
Epoetin alfa	39 (75%)	45 (87%)	0.50 (0.13–1.61)	0.3
Doxercalciferol	36 (69%)	39 (75%)	0.70 (0.23–2.04)	0.6
Heparin	39 (75%)	44 (85%)	0.67 (0.24–1.77)	0.5
Iron sucrose	23 (44%)	16 (31%)	2.75 (0.82–11.84)	0.1
Dialysis access				
Arteriovenous fistula/graft	6 (11%)	45 (87%)	1.00 (reference)	
Central venous catheter	45 (87%)	7 (13%)	54.32 (12.19-∞)	<0.001[c]
Missing	1 (2%)	0 (0%)		
No. of staff involved in treatment session				
≤3	22 (42%)	34 (65%)	1.00 (reference)	
>3	29 (56%)	18 (35%)	3.75 (1.20–15.52)	0.02[c]
Missing	1 (2%)	0 (0%)		

Abbreviations: CI, confidence interval; IV, intravenous; mOR, matched odds ratio.

[a] *P* value for mOR.

[b] Two case-control studies were performed to examine both patient- and session-specific risk factors; 52 cases occurred in 46 patients. Patient-specific controls were matched on facility. Session-specific controls were matched on facility and date of event.

[c] $P < 0.05$.

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Table 3.

Suggested Approaches to Dialysis Wall Box Maintenance and Interventions for Infection Prevention

Issue	Steps and Strategies
Staff may lack awareness of infectious risks associated with wall boxes and necessary infection prevention and control measures	• Educate staff on the risks associated with wall boxes and practices to prevent wall box–related infections • Hand hygiene should be performed after coming into contact with wall box or any of its components; reinforce and regularly assess compliance with hand hygiene
Wall boxes are part of the immediate patient care environment and are considered contaminated or dirty	• Each facility should develop policies about the specific frequency and methods for wall box surface disinfection[a,b] • Wall box surfaces should be disinfected at least daily (eg, at the end of the day after all patients have dialyzed); cleaning and disinfection might be needed more frequently (eg, when visibly dirty) • Cleaning and disinfection of the wall box should be performed after the patient has left the station and not concomitant with patient care activities • An EPA-registered hospital disinfectant should be applied to all surfaces of the wall box and any attached hoses[c] • Ensure high-touch surfaces (eg, connections for acid, bicarbonate, and reverse osmosis water) are disinfected • Wipes or other supplies used to disinfect the wall box should be discarded after use and not used to disinfect other surfaces in the dialysis station • More than 1 disinfectant wipe or application may be needed to ensure all wall box surfaces are visibly wet with disinfectant to achieve the contact time specified by the manufacturer
Wall boxes contain drains that are predisposed to the development of biofilms	• Interventions to decrease the rate of biofilm formation should be considered as a preventive measure on a routine schedule for drains and traps (eg, drain cleaners, drain gels, enzymatic cleaners)[c]
Wall box drains may become clogged; splashing and foaming at the wall box may occur	• Interventions performed by a qualified plumber aimed at removing clogs should be used; the frequency or type of these interventions may need to be modified over time to address the clogging if there is not an adequate response • Alternative wall box designs that separate dirty (waste line and drain) from clean (acid, bicarbonate, and reverse osmosis water supply connections) areas and relocate or reconfigure the air gap may be needed if foaming or splashing are a persistent problem
Biofilms in wall box drains may contain opportunistic pathogens that can cause HAIs	• Conduct routine surveillance (eg, monthly) for HAIs, including bloodstream infections, and regularly review results • Blood cultures positive for Gram-negative organisms commonly found in water-related biofilms should prompt investigation into possible reservoirs in the patient environment, including wall boxes • Contact local or state public health authorities to help investigate potential wall box–related infections and clusters

Abbreviations: EPA, Environmental Protection Agency; HAIs, health care–associated infections.

[a]Follow the manufacturer's label instructions for proper dilution, preparation, contact time, and use of disinfectant.

[b]Suggestions for disinfectant selection and use are described within the Centers for Disease Control and Prevention Environmental Surface Disinfection in Dialysis Facilities: Notes for Clinical Managers document.[40]

[c]Chemicals should not be mixed; follow product instructions for use.