Outbreak of Invasive *Serratia marcescens* among Persons Incarcerated in a State Prison, California, USA, March 2020–December 2022

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Serratia marcescens is an environmental gram-negative bacterium that causes invasive disease in rare cases. During 2020–2022, an outbreak of 21 invasive *Serratia* infections occurred in a prison in California, USA. Most (95%) patients had a history of recent injection drug use (IDU). We performed whole-genome sequencing and found isolates from 8 patients and 2 pieces of IDU equipment were closely related. We also identified social interactions among patients. We recovered *S. marcescens* from multiple environmental samples throughout the prison, including personal containers storing Cell Block 64 (CB64), a quaternary ammonium disinfectant solution. CB64 preparation and storage conditions were suboptimal for *S. marcescens* disinfection. The outbreak was likely caused by contaminated CB64 and propagated by shared IDU equipment and social connections. Ensuring appropriate preparation, storage, and availability of disinfectants and enacting interventions to counteract disease spread through IDU can reduce risks for invasive *Serratia* infections in California prisons.

Serratia marcescens, a gram-negative environmental bacterium (*1*,*2*), is an opportunistic pathogen that in rare cases causes invasive diseases, including bacteremia and endocarditis (*1*,*3*–*7*). Reported outbreaks have been linked to contaminated environmental sources, such as water, soap, intravenous fluids, and compounded drugs (*8*–*16*) in nosocomial settings (*17*–*19*). Invasive *S. marcescens* infections have occurred among persons who inject drugs (*5*,*6*,*20*–*22*). Given the high prevalence of injection drug use (IDU) in prisons and lack of access to sterile needles (*23*–*25*), risks for transmission of bloodborne pathogens are higher than among the general population (*25*). Cell Block 64 (CB64) solution, produced by California Prison Industry (CALPIA, https://www.calpia.ca.gov), is a quaternary ammonium concentrate (https://catalog.calpia.ca.gov/custom/assets/Files/view-current-sds-information-16.pdf) used as the primary disinfectant in prisons in California, USA. However, *S. marcescens* can survive in improperly prepared disinfection solutions, including quaternary ammonium disinfectants (*18*,*19*,*26*).

We describe a multiyear outbreak of invasive *S. marcescens* infections driven by widespread environmental contamination, improperly prepared and maintained disinfection solution, IDU, and social connections at a California state prison. Prison A is a maximum-security state prison housing ≈3,000 male incarcerated persons. In October 2020, the primary hospital affiliated with prison A notified the California Correctional Health Care System (CCHCS) that multiple incarcerated persons had been admitted with invasive *S. marcescens* infections. CCHCS, Monterey County Public Health Laboratory (MCPHL), and California Department of Public Health (CDPH) began a multidisciplinary investigation to identify additional cases, determine risk factors for infection, and provide recommendations for mitigation and

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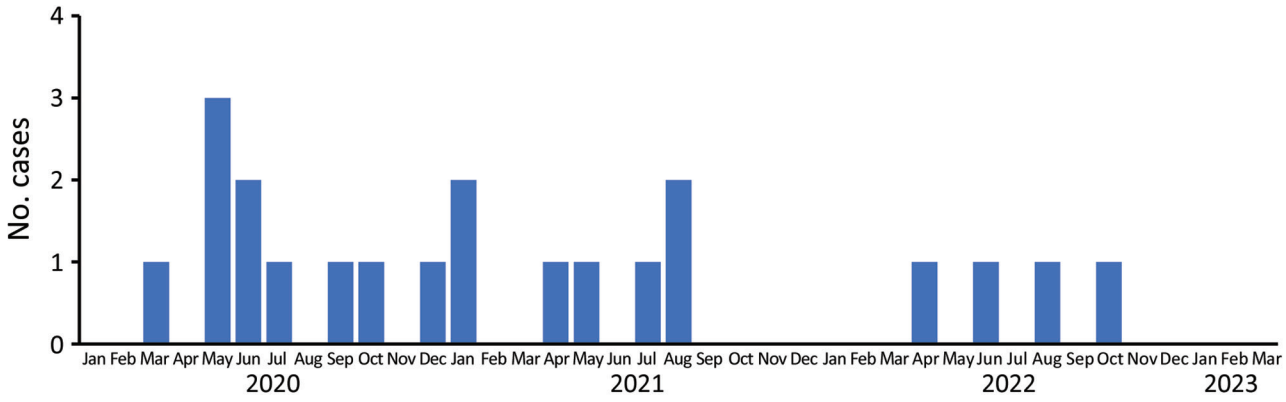

Figure 1. Epidemiologic curve of patients hospitalized with invasive Serratia marcescens infections at prison A, by sampling month of positive isolate, California, USA, January 2020–March 2023.

prevention. This project was determined to be nonresearch by the Centers for Disease Control and Prevention because it involved public health surveillance.

Materials and Methods

Epidemiologic Investigation

We defined a case-patient as a person diagnosed with an invasive *S. marcescens* infection who resided at prison A for ≥1 month before symptom onset during January 1, 2020–December 31, 2022. We defined infections as invasive if occurring at normally sterile body sites or in a case-patient manifesting critical illness with severe soft tissue infection. We reviewed patient hospitalization and prison medical records, including social histories, for IDU and other risk-elevating behaviors. We interviewed patients using a standardized questionnaire that included questions about cell cleaning practices, IDU, and other risk factors.

Table 1. Demographic data and other characteristics of 21 patients infected with invasive *Serratia marcescens* at prison A, California, USA, 2020–2022*

Characteristic	Value
Median age, y (range)	44 (22–66)
Race and ethnicity	
White	9 (43)
Black	2 (10)
Hispanic	8 (38)
Other	2 (10)
Serratia diagnosis†	
Bacteremia	11 (52)
Endocarditis	2 (10)
Epidural abscess	9 (43)
Osteomyelitis	6 (29)
Pseudoaneurysm	1 (5)
Severe soft tissue infection	4 (19)
Type of injection drug used,† n = 21	
Heroin	18 (86)
Suboxone	12 (57)
Methamphetamine	8 (38)
Opiates (by hospital urine toxicology screen)	5 (24)

*Values are no. (%) patients except as indicated.
†Not mutually exclusive.

Environmental Investigation

Prison A public health and infection control, CCHCS public health, CDPH, and MCPHL staff evaluated the water system and cleaning practices and procedures at prison A. In 2020 and 2021, MCPHL tested water from different sources at prison A, including holding tanks and wells. MCPHL also tested sinks and communal showers, faucets in patients' cells, personal items, hand-rinsate from a cellmate, 2 syringes used for injecting drugs, objects used for mixing, storing, or applying disinfectant, dilution machines, reused containers, and commercial bottles.

Laboratory Investigation

MCPHL streaked swabs onto *Serratia* CHROMagar (https://www.chromagar.com) MacConkey and blood agar plates and incubated them in brain heart infusion broth for up to 5 days. Needles and syringes were placed directly into brain heart infusion broth. Cultures with growth were subcultured on CHROMagar plates. Liquids, including water, disinfectant cleaning solutions, and rinsates, were filtered onto 47 mm 0.45 μm–pore sized mixed cellulose ester membranes and placed onto CHROMagar plates. MCPHL forwarded *S. marcescens* isolates to CDPH Center for Laboratory Science Microbial Diseases Laboratory for whole genome sequencing (WGS) using the validated in-house protocol with Illumina MiSeq (https://www.illumina.com) (Appendix, https://wwwnc.cdc.gov/EID/article/30/13/23-0801-App1.pdf) (*27*).

Results

Epidemiologic Investigation

As of December 2022, we had identified 21 cases: 17 identified during March 2020–August 2021 and 4 during April–October 2022 (Figure 1). All 21 case-patients were hospitalized and recovered; however, 1 patient later died of a cause unrelated to *S. marcescens*. Median patient age was 44 years (range 22–66 years). We grouped patients by race/ethnicity as non-Hispanic White (9 [43%]), non-Hispanic Black (2 [10%]), Hispanic (8 [38%]), or other (2 [10%]). Diagnoses were not mutually exclusive and included bacteremia in 11 (52%) patients; endocarditis in 2 (10%); epidural abscess in 9 (43%); osteomyelitis in 6 (29%); pseudoaneurysm in 1 (5%); and soft tissue infections in 4 (19%), including 2 (10%) with muscle abscess (Table 1). Of the nonbacteremic patients, 2 had polymicrobial cultures, including viridans streptococci (*1*), *Staphylococcus aureus* (2), and *Raoutella panticola* (*1*).

Twenty (95%) patients had a history of IDU <6 months before infection and one >6 months before infection. Of patients with recent IDU, 18/20 (86%) had injected heroin, 12 (57%) suboxone, and 8 (38%) methamphetamines. Among patients who had urine toxicology performed at admission, 4/9 were positive for opiates. Nine patients reported consuming >1 drug; 5 patients used 2 and 4 patients used 3 drugs. Of patients interviewed, 5/16 (31%) used CB64 to clean IDU equipment. Of PWID patients, 9/21 (43%) were enrolled in the prison A substance use disorder treatment (SUDT) program before *S. marcescens* infection occurred.

Although some patients resided throughout the 4 physically separated yards at the facility, 11 (52%) were housed in yard 1; 2 patients in other yards at time of illness onset had previously been housed in yard 1. Interviews identified social connections among >9 patients. We used WGS to identify the predominant *S. marcescens* outbreak strain as the cause of infection in 6 (66%) patients and a different strain in 1 patient; we had no isolates available for 4 patients (Figures 2, 3). Among patients who revealed social connections, 6 shared needles, 4 shared cells, 3 had attended the urgent care clinic at the same time, and

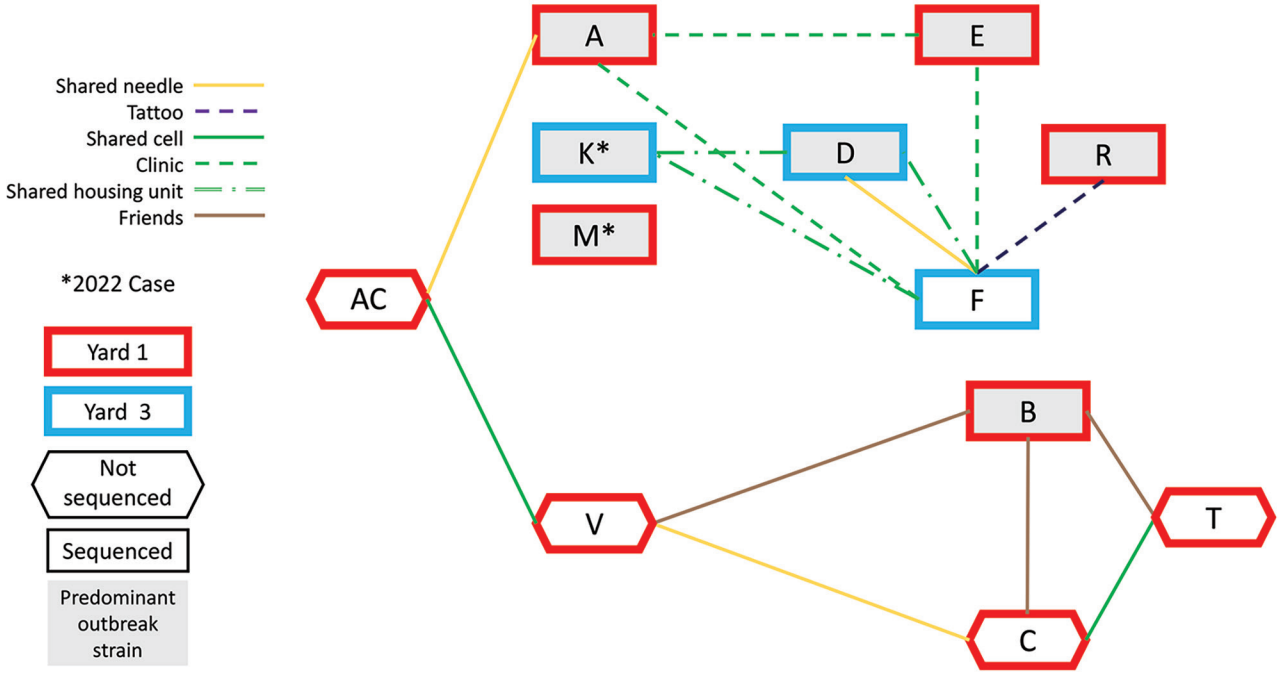

Figure 2. Social network analysis of patients and whole genome sequencing results for patients hospitalized with invasive *Serratia marcescens* infections at prison A, California, USA, January 2020–March 2023. All patients were identified in 2021, except patients K and M, identified in 2022. Patients A, B, D, E, R, K, and M all had isolates in the predominant outbreak strain. Patients D, F, and K were in yard 3, all others in yard 1. Patients C, T, and V did not have isolates available for sequencing. Patient AC had a *S. marcescens* infection in 2019 outside of the outbreak period; however, he had multiple social connections with case-patients and so is included in this figure. Patient F shared a housing unit with D and K, was in the clinic at the same time as A and E, reported sharing needles with D, and might have been tattooed by R. Patient D also shared a housing unit with K. Patient A was in the clinic the same time as E and reported sharing a needle with AC. Patient V shared a cell with AC, was friends with D, and reported sharing needles with C. Patient T shared a cell with C and was friends with B. Patients B and C were also friends.

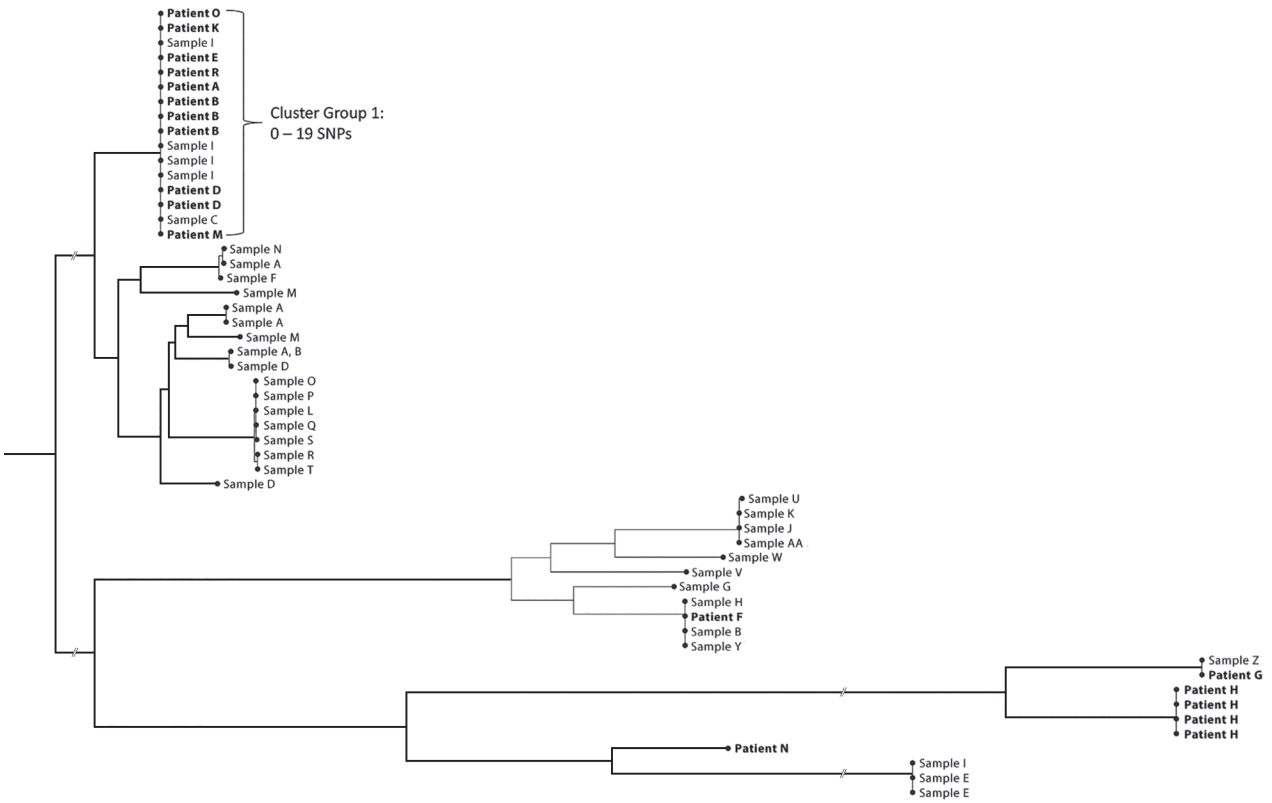

Figure 3. Phylogenetic tree representing patients hospitalized with invasive *Serratia marcescens* infections and whole-genome sequencing for environmental and clinical isolates at prison A, California, USA, January 2020–March 2023. The predominant outbreak cluster included patients A, B, D, E, K, M, O, and R and environmental samples C (needle/syringe) and sample I (nasal spray bottle) from patient D. These sequences had 0–19 single-nucleotide polymorphism (SNP) differences. Patient F, sample B (coffee cup) found in patient D's cell, sample H (hand rinsate) from the cellmate of patient D, and sample Y (doorway swab) from the cell occupied at different times by both patient A and AC are grouped together within a 11–17 SNP range.

2 might have shared tattoo needles (Figure 2). Patient AC, diagnosed with an invasive *S. marcescens* infection at a different prison in 2019 and later transferred to prison A, was found to have multiple social connections with patients identified in 2020 and beyond but we did not include him in the outbreak cohort (Figure 2).

Environmental Investigation

Inspection of the potable water system at prison A did not identify any deficiencies or areas of concern, and we found large-volume water samples negative for *Serratia.* Each housing unit has a machine for diluting the CB64 solution (Figure 4). Machines in multiple units had exposed tubing touching the machine surface, maintenance schedules were not documented, and dilution of CB64 occurred in large containers outside the dilution machines. Prison A allowed incarcerated persons to keep CB64 in their cells after the COVID-19 pandemic started. Some incarcerated persons described using their own repurposed containers (e.g., shampoo bottles) to scoop diluted CB64 from the large containers.

Laboratory Investigation

Eleven patients had isolates available for WGS; 8 (73%) patients, including 3 identified in 2022, had isolates that differed from one another by 0–19 single-nucleotide polymorphisms (SNPs) on WGS. Those isolates clustered within the predominant strain group (Figure 3). Of 152 environmental samples collected and analyzed, 27 (18%) were positive for *S. marcescens*, including a needle and syringe combination (sample I) and a reused nasal spray bottle (sample C) storing methamphetamines from patient D (Table 2). Both specimens matched the predominant outbreak strain (Figure 3). The *S. marcescens* isolate from patient F grouped within 11–17 SNPs with isolates from a coffee cup (sample B) found in patient D's cell, hand-rinsate (sample H) from patient D's cellmate, and a doorway swab (sample Y) from a cell occupied at different times

by patients AA and AC (Table 2; Figure 3). All other isolates differed from the predominant strain by thousands of SNPs (Figure 3). We sequenced multiple isolates from some samples. Samples from all unopened bottles of CB64 tested negative for *S. marcescens*.

Discussion

During March 2020–December 2022, a total of 21 persons incarcerated at prison A required hospitalization for invasive *Serratia* infections. Factors contributing to this outbreak included widespread environmental contamination with *Serratia,* including in CB64, the sole disinfectant used within the prison, and complex social networks that involved IDU.

Of note, 5 environmental samples that tested positive for *Serratia* were associated with diluted CB64. CB64 is used throughout California state prisons as a disinfectant because it is less caustic than other disinfectants (e.g., bleach). Quaternary ammonium compounds like CB64 have previously been linked to outbreaks (*18*,*19*,*26*). Prison A had documented nonadherence to CB64 manufacturer dilution and storage protocols. In addition, incarcerated persons stored diluted CB64 in cells after the COVID-19 pandemic began, a change in procedure occurring at approximately the same time as initial cases. Repeatedly finding *Serratia* in CB64 indicates that improper use and storage of the disinfectant likely contributed to the spread.

The invasive nature of the *Serratia* infections, including manifestations such as bacteremia and severe soft-tissue infection, suggests introduction of the bacteria directly into the bloodstream or soft tissues, highlighting the role of IDU in the prison outbreak. The predominant outbreak strain of *Serratia* was recovered from a needle obtained from 1 patient. In prisons, there is no access to new needles; some patients reported sharing needles, and most reported reusing needles multiple times themselves. Some patients reported using CB64 to clean their needles.

In August 2021, prison A implemented mitigation measures, including extensive staff training, instituting maintenance logs, recalibrating dilution machines, ensuring regular changing of tubing in dilution devices, and providing dedicated bottles of CB64 for incarcerated persons to check out and return within 24 hours for in-cell cleaning. Additional education on IDU risks and SUDT (begun in 2020) were also provided to incarcerated persons. No new cases were identified until spring 2022, at which time lapses in staff and resident education on use, maintenance, and storage of CB64 solution and dilution devices were recognized.

WGS results for 3 patient isolates identified at the prison in 2022 were closely related to 2021 patient isolates, indicating that the predominant outbreak strain of *S. marcescens* persisted >1 year. Given the diversity of *S. marcescens* strains in the environment, the predominance of a single strain suggests the likely existence of a persistent, but unknown, nidus of the outbreak strain. A single contaminated drug or CB64 source is unlikely to account for the persistence. An incarcerated person colonized with this strain or an unrecognized fomite in the environment are possible sources. Although *S. marcescens* is not a normal part of human flora, colonization of skin and gut has been documented (*10*,*27*). In addition, the hand-rinsate from a patient's cellmate yielded *S. marcescens*, indicating the potential for persistence on skin. After identification of additional cases in 2022, intervention included reeducating staff and incarcerated persons on proper use of CB64, including performing dilution within dilution devices only, and education on risks for *S. marcescens* infection through IDU equipment. No further cases had been documented as of July 2023, 8 months after the last identified case. Additional education has been provided to institutions throughout the state (Appendix).

One limitation of this study is that, given drug use is prohibited in prison, patients might have

Figure 4. Device calibrated to dilute Cell Block 64 solution and other cleaners to correct concentrations. Device pictured shows dangling tubing touching the machine surface, a possible route of contamination in outbreak of invasive *Serratia marcescens* infections at prison A, California, USA, January 2020–March 2023

Table 2. Environmental specimens positive for *Serratia marcescens* associated with patients hospitalized with invasive *Serratia marcescens* infections at prison A, California, USA, January 2020–March 2023

Identifier	Sample description	Sample location, yard no.	Matched a patient isolate
A	Swab of water pooled in Cell Block 64 solution dilution machine tubes	2	No
B	Coffee from plastic cup	3	Yes
C	Nasal spray bottle	3	Yes, patients B and D
D	Scrub pad 1: porter closet	1	No
E	Scrub pad 2: used to clean cell	1	No
F	Scrub pad 3: beside toilet	1	No
G	Shower floor swab	1	No
H	Hand rinsate of cellmate to patient D (sterile saline)	3	No
I	Used needle or syringe 1	1	Yes, patients A and B
J	Water and laundry detergent from body wash bottle	1	No
K	Cleaner stored in hand sanitizer bottle	1	No
L	Diluted cell block 64 solution in spray bottle	1	No
M	Mop bucket	1	No
N	Cell Block 64 solution stored in shampoo bottle	1	No
O	Cell Block 64 solution stored in chili sauce bottle	2	No
P	Cell Block 64 solution stored in coffee container	2	No
Q	Empty bottle, used to store Cell Block 64 solution	1	No
R	Diluted breakout from trash can 1	1	No
S	Doorway 4 floor swab	1	No
T	Doorway 3 floor swab	1	No
U	Drinking water in bottle	2	No
V	Breakout from container originally used to store Cell Block 64 solution	2	No
W	Doorway 2 floor swab	1	No
Y	Doorway 1 floor swab	1	Yes
Z	Plastic sports drink bottle, used to store water	1	No
AA	Plastic bottle used as urinal	1	No
AB	Diluted breakout from trash can 2	1	No

provided incomplete information regarding drug preparation and sharing, and therefore some common sources of drugs or drug equipment may not have been identified. In addition, only 2 needles or syringes were available for testing. A comprehensive environmental sampling survey of the entire prison population and structure was unfeasible, so we focused testing on areas where cases were identified. Additional sources of environmental contamination, including water sources such as cell toilet water and shower and sink drains and traps, where biofilm may have formed, were unable to be tested. A limited number of patient isolates from 2021 and 2022 were available for WGS; testing of all isolates might have further clarified patient connections. Patients might have been infected with >1 *S. marcescens* strain. Most environmental isolates positive for *S. marcescens* did not match patient strains, and so direct correlation between environmental contamination and patient illness was not possible. Finally, our investigation focused on invasive infections and excluded milder illness.

Beginning in January 2020, screening and referral for SUDT became available in California prisons to all newly incarcerated persons, those transitioning into the community, and patients with IDU-related complications (*28*). As of January 2022, >64,600 incarcerated persons had been screened for SUD and medication-assisted treatment provided to >22,500 patients, leading to a significantly decline in overdoses and infectious disease complications since the program started (*29*).

After this outbreak, queries have identified additional cases of invasive *S. marcescens* infections in other California prisons. Similar concerns related to disinfection, including improper storage, device calibration, and usage, and IDU practices have been reported. Environmental mitigation through extensive cleaning and strict adherence to disinfectant guidelines might not eliminate all environmental sources of *Serratia* but might decrease the environmental microbial burden, thereby decreasing potential exposures to *S. marcescens* and other pathogens. IDU among incarcerated persons should be addressed through promotion of harm reduction practices and education, including access to appropriate disinfection supplies and sterile needles, and referral to SUDT programs.

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About the Author

Dr. Kamali is a medical epidemiologist and infectious disease physician with California Correctional Health Care Services and California Department of Public Health whose interests include outbreak investigation.

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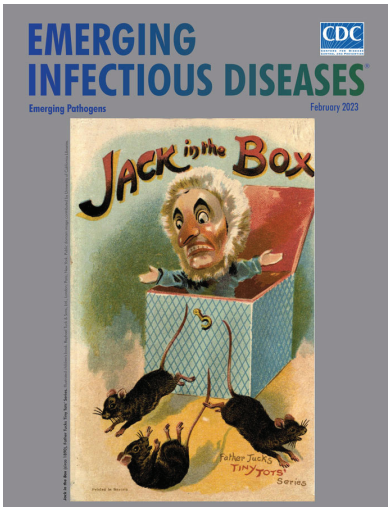
February 2023

Emerging Pathogens

- Infant Botulism, Israel, 2007–2021
- Sentinel Surveillance System Implementation and Evaluation for SARS-CoV-2 Genomic Data, Washington, USA, 2020–2021
- Crimean-Congo Hemorrhagic Fever, Spain, 2013–2021
- *Streptococcus dysgalactiae* Bloodstream Infections, Norway, 1999–2021
- Changing Disease Course of Crimean-Congo Hemorrhagic Fever in Children, Turkey
- Relationship between Telework Experience and Presenteeism during COVID-19 Pandemic, United States, March–November 2020
- Circovirus Hepatitis Infection in Heart-Lung Transplant Patient, France
- Incidence and Transmission Dynamics of *Bordetella pertussis* Infection in Rural and Urban Communities, South Africa, 2016–2018
- Influence of Landscape Patterns on Exposure to Lassa Fever Virus, Guinea
- Increased Multidrug-Resistant *Salmonella enterica* I Serotype 4,[5],12:i:- Infections Associated with Pork, United States, 2009–2018
- Novel Prion Strain as Cause of Chronic Wasting Disease in a Moose, Finland
- Novel Species of *Brucella* Causing Human Brucellosis, French Guiana
- Early Introduction and Community Transmission of SARS-CoV-2 Omicron Variant, New York, New York, USA



- Penicillin and Cefotaxime Resistance of Quinolone-Resistant *Neisseria meningitidis* Clonal Complex 4821, Shanghai, China, 1965–2020
- Combined Phylogeographic Analyses and Epidemiologic Contact Tracing to Characterize Atypically Pathogenic Avian Influenza (H3N1) Epidemic, Belgium, 2019
- Age-Stratified Model to Assess Health Outcomes of COVID-19 Vaccination Strategies, Ghana
- Correlates of Protection, Thresholds of Protection, and Immunobridging among Persons with SARS-CoV-2 Infection
- Longitudinal Analysis of Electronic Health Information to Identify Possible COVID-19 Sequelae

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- Molecular Detection of *Candidatus* Orientia chuto in Wildlife, Saudi Arabia
- Neoehrlichiosis in Symptomatic Immunocompetent Child, South Africa
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- Next-Generation Sequencing for Identifying Unknown Pathogens in Sentinel Immunocompromised Hosts
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- Occupational Monkeypox Virus Transmission to Healthcare Worker, California, USA, 2022

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Outbreak of Invasive *Serratia marcescens* among Persons Incarcerated in a State Prison, California, USA, March 2020–December 2022

Appendix.

Appendix Table. Data on patient serosamples from study of persons incarcerated in a California state prison (BioProject no. PRJNA981498)

Patient identifier	Fastq file name	BioSample accession no.	Sequence read run no.
Patient F	PatientF	SAMN35676889	SRR24876887
Patient A	PatientA	SAMN35676882	SRR24876944
Patient E	PatientE	SAMN35676888	SRR24876888
Sample A	SampleA-2	SAMN35676907	SRR24876926
Sample A	SampleA-3	SAMN35676908	SRR24876925
Sample A	SampleA-1	SAMN35676906	SRR24876927
Patient I	PatientI	SAMN35676895	SRR24876939
Patient J	PatientJ	SAMN35676896	SRR24876938
Patient H	PatientH-1	SAMN35676891	SRR24876885
Patient H	PatientH-2	SAMN35676892	SRR24876942
Patient H	PatientH-3	SAMN35676893	SRR24876941
Patient H	PatientH-4	SAMN35676894	SRR24876940
Sample U	SampleU	SAMN35676937	SRR24876893
Sample O	SampleO	SAMN35676931	SRR24876900
Sample P	SampleP	SAMN35676932	SRR24876898
Patient B	PatientB-1	SAMN35676883	SRR24876943
Sample V	SampleV	SAMN35676938	SRR24876892
Sample M	SampleM-2	SAMN35676929	SRR24876902
Sample M	SampleM-1	SAMN35676928	SRR24876903
Sample D	SampleD-2	SAMN35676914	SRR24876918
Sample D	SampleD-1	SAMN35676913	SRR24876919
Patient B	PatientB-2	SAMN35676884	SRR24876932
Patient B	PatientB-3	SAMN35676885	SRR24876921
Sample E	SampleE-1	SAMN35676915	SRR24876917
Sample E	SampleE-2	SAMN35676916	SRR24876916
Sample I	SampleI-1	SAMN35676920	SRR24876912
Sample I	SampleI-2	SAMN35676921	SRR24876911
Sample I	SampleI-3	SAMN35676922	SRR24876909
Sample I	SampleI-4	SAMN35676923	SRR24876908
Sample F	SampleF	SAMN35676917	SRR24876915
Sample I	SampleI-5	SAMN35676924	SRR24876907
Sample N	SampleN	SAMN35676930	SRR24876901
Sample Q	SampleQ	SAMN35676933	SRR24876897
Patient S	PatientS	SAMN35676905	SRR24876928
Patient D	PatientD-1	SAMN35676886	SRR24876910
Patient D	PatientD-2	SAMN35676887	SRR24876899
Sample H	SampleH	SAMN35676919	SRR24876913
Sample B	SampleB	SAMN35676911	SRR24876922
Sample C	SampleC	SAMN35676912	SRR24876920
Patient R	PatientR	SAMN35676904	SRR24876929

Patient identifier	Fastq file name	BioSample accession no.	Sequence read run no.
Patient G	PatientG	SAMN35676890	SRR24876886
Sample W	SampleW	SAMN35676939	SRR24876891
Sample Y	SampleY	SAMN35676940	SRR24876890
Sample G	SampleG	SAMN35676918	SRR24876914
Sample R	SampleR	SAMN35676934	SRR24876896
Sample Z	SampleZ	SAMN35676941	SRR24876889
Sample S	SampleS	SAMN35676935	SRR24876895
Sample T	SampleT	SAMN35676936	SRR24876894
Sample AB	SampleAB	SAMN35676910	SRR24876923
Sample J	SampleJ	SAMN35676925	SRR24876906
Sample AA	SampleAA	SAMN35676909	SRR24876924
Sample K	SampleK	SAMN35676926	SRR24876905
Sample L	SampleL	SAMN35676927	SRR24876904
Patient N	PatientN	SAMN35676900	SRR24876934
Patient K	PatientK	SAMN35676897	SRR24876937
Patient L	PatientL	SAMN35676898	SRR24876936
Patient M	PatientM	SAMN35676899	SRR24876935
Patient P	PatientP	SAMN35676902	SRR24876931
Patient O	PatientO	SAMN35676901	SRR24876933
Patient Q	PatientQ	SAMN35676903	SRR24876930

Appendix Figure. Injection safety poster from study of persons incarcerated in a California state prison.