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Brief Report

Outbreak investigation of *Pseudomonas aeruginosa* infections in a neonatal intensive care unit



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Outbreak

A *Pseudomonas aeruginosa* outbreak was investigated in a neonatal intensive care unit that had experienced a prior similar outbreak. The 8 cases identified included 2 deaths. An investigation found the cause of the outbreak: tap water from contaminated hospital plumbing which was used for humidifier reservoirs, neonatal bathing, and nutritional preparation. Our findings reinforce a recent Centers for Medicare & Medicaid Services memo recommending increased attention to water management to improve awareness, identification, mitigation, and prevention of water-associated, health care–associated infections.

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INTRODUCTION

Pseudomonas aeruginosa is a Gram-negative bacterium commonly found in water and soil. Prior *P aeruginosa* outbreaks in health care settings, including neonatal intensive care units (NICUs), have been linked to environmental sources such as biofilms in hospital plumbing systems.¹ Underdeveloped neonatal immune systems and invasive devices contribute to the susceptibility of NICU patients to infections.

In 1999, *P aeruginosa* transmission at a Maryland NICU was controlled through improved practices in hand hygiene and cleaning of surfaces and equipment;² however, in March 2016 in the same NICU (Level III, 18 beds, census 8–10 patients), a new outbreak resulted in 2 deaths. Initial interventions begun in August 2016 included enhanced

hospital water management (eg, hyperchlorination) and installation of point-of-use filters at NICU taps, but these measures did not eliminate transmission. Therefore, in November 2016, under consultation with public health authorities, the hospital voluntarily closed the NICU to further evaluate infection prevention and control (IPC) practices and to identify additional control measures.

METHODS

A case was considered to be any clinical or surveillance culture that was positive for *P aeruginosa* in a specimen collected from a patient admitted to the NICU at the time of specimen collection from March to October 2016.

Epidemiology methods

We reviewed medical and laboratory records to identify and describe cases. We interviewed personnel from hospital administration, infection control, nursing, facilities management, environmental services, and respiratory therapy departments. We reviewed the hospital's water management plan and assessed plumbing fixtures and uses of water in the NICU. The NICU closure precluded real-time

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observation of patient care and IPC practices; however, demonstrations of equipment usage were assessed in situ. Active surveillance for *P aeruginosa* among patients was implemented after the NICU reopened in April 2017. Rectal swabs were performed on patients upon admission and weekly for at least 6 weeks; if no additional cases were identified, then monthly rectal swabs of all patients present in the unit were performed, for 6 months of negative swabs.

Laboratory methods

We performed environmental sampling on high-touch surfaces and water taps. We used heterotrophic plate counts (HPCs) and cultures of hospital water to assess water quality. Environmental cultures of NICU equipment, stored breast milk, environmental surfaces, and tap water were guided by epidemiologic findings. *P aeruginosa* isolates were identified by matrix-assisted laser desorption/ionization time-of-flight mass spectrometry using MicrobeNet databases.³ Pulsed-field gel electrophoresis (PFGE) band patterns of isolates were classified as indistinguishable (100% similar) or closely related (≤ 3 band difference).⁴ Isolates with $\geq 90\%$ similarity in PFGE band patterns were considered closely related.

RESULTS

Epidemiology results

Complete data on all hospital-associated infections in the NICU were not available; however, the hospital central line-associated bloodstream infection standardized infection ratio was 1.94 for 2016, and *P aeruginosa* infection rates in the NICU showed a marked increase from 0 per 1000 patient days in 2015 to 1.96 in 2016. The investigation team identified 8 cases, 2 of whom died. Most patients were born preterm, required invasive or noninvasive mechanical ventilation, and received breast milk (Table 1). At the time of onsite assessment in November 2016, point-of-use filters had already been installed at all 10 sink faucets. When sink faucets were run at maximum flow, splashing was observed onto adjacent countertops including those designated for preparation of breast milk and infant formula. Humidifier reservoirs of incubators were filled with tap water, despite manufacturer instructions recommending distilled water. Patients were bathed in tap water. Parents cleaned reusable breast pump equipment in sinks that were also used for handwashing and other medical purposes. Breast shields and tubing from the breast pump kit were not consistently air dried per manufacturer instructions before storage and reuse. Active surveillance after the NICU

Table 1

Characteristics of patients in an outbreak of *Pseudomonas aeruginosa* in a neonatal intensive care unit in Maryland in 2016 (N = 8)

Characteristic	n
Female	3
Invasive or noninvasive mechanical ventilation	7
Received breast milk*	8
Born in hospital [†]	7
Infected [‡]	4
Colonized [§]	4
Died	2

Median gestational age was 27 weeks.

*Two patients consumed breast milk exclusively while in the neonatal intensive care unit.

[†]One infant was born in the car, en route to the hospital.

[‡]Infectious signs/symptoms present with positive culture from eye (1), blood (2), or sputum/tracheal aspirate (2); 1 case had multiple positive cultures.

[§]Positive culture from nares (3) or perirectal swab (1) without signs/symptoms of infection.

reopened identified no additional cases over 1 year after implementation of recommended control measures.

Laboratory results

Before hyperchlorination of the plumbing system, *P aeruginosa* was isolated from swabs or bulk water from 4 of 7 NICU sinks sampled. Swabs or bulk water from 3 of 10 sinks sampled also showed HPCs of >1000 colony-forming units (CFU)/mL. After hyperchlorination and filter placement, post-filter water samples had HPCs of <3 CFU/mL but *P aeruginosa* was still cultured from first-catch faucet water samples from 3 of 5 NICU faucets sampled. Analysis of patient, sink, and stored breast milk isolates indicated multiple strains of *P aeruginosa* (Fig 1). Several environmental and patient isolates were indistinguishable by PFGE. Not all breast milk isolates remained available for testing from mothers of all patients.

Hospital IPC interventions

Hospital water was hyperchlorinated with calcium hypochlorite at 200 parts per million (ppm) for 2 hours. Supplemental hypochlorite added at municipal water intakes yielded residual chlorine levels of 2 ppm at distal sites, until a monochloramine system was installed. Additional changes included preparing infant formula and breast milk away from splash zones near sinks, bathing patients in sterile water, and following manufacturer instructions for using breast pump equipment and refilling and maintaining humidifier reservoirs of incubators. At the conclusion of our investigation, the plumbing proximal to NICU sinks was replaced to mitigate infection risks while construction of a new hospital, planned prior to this outbreak, could be completed.

DISCUSSION

This outbreak was associated with contaminated hospital plumbing and use of contaminated tap water in a neonatal care environment. Interruption of transmission required a multidisciplinary approach to water management, such that supplemental disinfection of the hospital plumbing system was combined with unit-level filtration and improved adherence to recommended health care practices for the use of tap water and cleaning and disinfection of breast pump equipment.

In June 2017, the Centers for Medicare & Medicare Services (CMS) directed all hospitals and nursing facilities to establish water management plans that include risk assessments to identify areas where *Legionella* and other opportunistic waterborne pathogens (eg, *Pseudomonas*) could spread in the facility water system.⁵ These assessments should include consideration of how patients might be exposed to contaminated water and identify when tap water should not be used, such as during invasive procedures or while using certain medical devices.

This investigation illustrates challenges in controlling water-associated outbreaks in health care settings. Although initial HPC levels exceeded Environmental Protection Agency limits for potable water (<500 CFU/mL), an upper CFU limit that would ensure the safety of specific patient populations has not been established. Also, the presence of *P aeruginosa* on the surfaces of some sink faucets despite supplemental chlorination and filtration is an example of the potential difficulty in eliminating water-associated pathogens when they have established environmental reservoirs such as plumbing fixtures, drains, and adjacent surfaces.

Limitations of our investigation include the unavailability of some patient isolates for testing. Not all patient isolates were definitively linked to the hospital water system, but exposures to contaminated

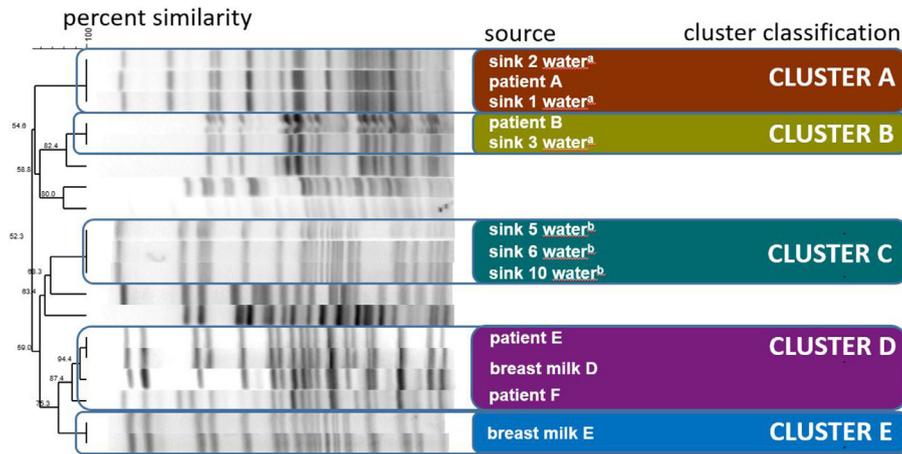


Fig 1. Pulsed-field gel electrophoresis strain typing showed the following neonatal intensive care unit clusters of closely related environmental and clinical *Pseudomonas* isolates. ^aWater sampled prior to hyperchlorination and filter installation. ^bWater sampled after hyperchlorination and filter installation.

water in the NICU likely explain most cases elucidated via other epidemiologic techniques described above. NICU closure during the investigation prevented real-time observations of normal NICU workflow.

CONCLUSIONS

A comprehensive water management strategy and strict adherence to IPC practices remain key components in managing infection risks associated with hospital water systems. As a result of the continued occurrence of health care–associated outbreaks of *Legionella* and other water-associated pathogens, such as *P aeruginosa*, *Acinetobacter*, *Burkholderia*, *Stenotrophomonas*, nontuberculous mycobacteria, and fungi, CMS surveyors have required compliance with recommended water management policies and procedures in hospitals and nursing facilities since June 2017.^{5,6} It is unknown if the CMS requirements for water management plans and resources for *Legionella* control⁷ are sufficient for control of these other pathogens in hospital plumbing systems;⁸ however, our report demonstrates that this increased attention to water management can improve the recognition and prevention of water-associated, health care–associated infections.⁸

References

1. Jefferies JMC, Cooper T, Yam T, Clarke SC. *Pseudomonas aeruginosa* outbreaks in the neonatal intensive care unit—a systematic review of risk factors and environmental sources. *J Med Microbiol* 2012;61:1052–61.
2. Zafar AB, Sylvester LK, Beidas SO. *Pseudomonas aeruginosa* infections in a neonatal intensive care unit. *Am J Infect Control* 2002;30:425–9.
3. Centers for Disease Control and Prevention. MicrobeNet. Available from: <https://www.cdc.gov/microbenet/index.html>. Accessed March 25, 2019.
4. Tenover FC, Arbeit RD, Goering RV, Mickelsen PA, Murray BE, Persing DH, et al. Interpreting chromosomal DNA restriction patterns produced by pulsed-field gel electrophoresis: criteria for bacterial strain typing. *J Clin Microbiol* 1995;33:2233–9.
5. Centers for Medicare & Medicaid Services. Requirement to Reduce *Legionella* Risk in Healthcare Facility Water Systems to Prevent Cases and Outbreaks of Legionnaires' Disease (LD). Available from: <https://www.cms.gov/Medicare/Provider-Enrollment-and-Certification/SurveyCertificationGenInfo/Downloads/QSO17-30-HospitalCAH-NH-REVISED-.pdf>. Accessed March 25, 2019.
6. Centers for Medicare & Medicaid Services. Infection Control Pilot: 2017 Update. Available from: <https://www.cms.gov/medicare/provider-enrollment-and-certification/surveycertificationgeninfo/downloads/survey-and-cert-letter-17-09.pdf>. Accessed March 25, 2019.
7. Centers for Disease Control and Prevention. Developing a Water Management Program to Reduce *Legionella* Growth & Spread in Buildings: A Practical Guide to Implementing Industry Standards. Available from: <https://www.cdc.gov/legionella/downloads/toolkit.pdf>. Accessed March 25, 2019.
8. Centers for Disease Control and Prevention. From Plumbing to Patients: Water Management Programs for Healthcare Facilities. Available from: <https://www.cdc.gov/hai/prevent/water-management.html>. Accessed March 25, 2019.