"Down the drain": carbapenem-resistant bacteria in intensive care unit patients and handwashing sinks

Despina Kotsanas
BSc(Hons), MClinEpi, Scientist[1]

WRPLI Wijesooriya
MB BS, MD, MPhil, Medical Microbiologist[1]

Tony M Korman
MB BS, FRACP, FRCPA, Director[1]

Elizabeth E Gillespie
BN, MPubHlth, Nursing Director[2]

Louise Wright
BN, Infection Control Consultant[2]

Kylie Snook
BN, Infection Control Consultant[2]

Natalie Williams
BN, Infection Control Consultant[2]

Jan M Bell
BSc, Scientist[3]

Hua Y Li
MMed, Research Fellow[4]

Rhonda L Stuart
MB BS, PhD, FRACP, Infectious Diseases Physician,[1] and Adjunct Clinical Associate Professor[5]

1 Monash Infectious Diseases, Southern Health, Melbourne, VIC.

2 Infection Control and Epidemiology, Southern Health, Melbourne, VIC.

3 Microbiology and Infectious Diseases, Women's and Children's Hospital, Adelaide, SA.

4 Microbiological Diagnostic Unit, University of Melbourne, Melbourne, VIC.

5 Department of Medicine, Southern Clinical School, Monash University, Melbourne, VIC.

rhonda.stuart@southernhealth.org.au

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Abstract

Objectives: Clinical utility of carbapenem antibiotics is under threat because of the emergence of acquired metallo-β-lactamase (MBL) genes. We describe an outbreak in an intensive care unit (ICU) possibly associated with contaminated sinks.

Design, setting and participants: Four clusters of gram-negative bacteria harbouring the MBL gene bla_{IMP-4} were detected in the ICU at Dandenong Hospital between November 2009 and July 2012. Epidemiological investigations were undertaken in order to identify a common point source. During September 2012, screening using rectal swabs for all ICU patients, and environmental swabs targeting all ICU handwashing sinks and taps were collected. Samples were cultured onto selective carbapenem-resistant Enterobacteriaceae (CRE) agar. Suspected CRE isolates were further characterised using the modified Hodge test and VITEK 2 and confirmed by polymerase chain reaction and sequencing of MBL genes. Clinical and environmental CRE isolates were typed by pulsed-field gel electrophoresis.

Results: Ten clinical isolates and one screening isolate of CRE (consisting of *Klebsiella pneumoniae* [5], *Serratia marcescens* [4], *Enterobacter cloacae* [1] and *Escherichia coli* [1]) were detected with the bla_{IMP-4} gene over the 30-month period. *S. marcescens* was isolated persistently from the grating and drain of eight central sinks. Molecular typing confirmed that clinical and environmental isolates were related. Tap water cultures were negative. Several attempts to clean and decontaminate the sinks using detergents and steam cleaning proved unsuccessful.

Conclusion: This report highlights the importance of identification of potential environmental reservoirs, such as sinks, for control of outbreaks of environmentally hardy multiresistant organisms.

One of the most concerning emerging resistance traits among gram-negative bacteria is the ability of these organisms to produce carbapenem-hydrolysing β-lactamases, which confer resistance to almost all β-lactams.[1] Carbapenem-resistant Enterobacteriaceae (CRE) are increasing in prevalence worldwide, causing growing concern, as they are often combined with non-β-lactam resistance to produce isolates that are multidrug resistant, have few treatment options available and are associated with high mortality rates.[2]

Although multiple resistance mechanisms have been identified, carbapenem resistance is often plasmid-encoded, allowing gene dissemination and a propensity to cause nosocomial outbreaks.[3-6]

We describe a CRE outbreak due to the presence of the metallo-β-lactamase gene bla_{IMP-4} in an intensive care unit (ICU) associated with contaminated sinks. This report highlights the key role of bacterial environmental contamination and sink design and usage in the propagation of CRE outbreaks.

Methods

Dandenong Hospital is a 440-bed tertiary referral hospital in Melbourne, Australia. The ICU has a 14-bed capacity, admitting both medical and surgical patients and averaging 1400 admissions yearly.

Ten ICU patients were found to have clinical specimens with Enterobacteriaceae harbouring the bla_{IMP-4} gene between November 2009 and July 2012. The ICU routinely screens for vancomycin-resistant enterococci (VRE) carriage using rectal swabs on admission, weekly and on discharge. During the 4-week period from 6 September to 4 October 2012, CRE screening was performed in addition to the routine screen for VRE.

Environmental screening for CRE targeting all 28 wet area locations (including 11 sinks and taps, as well as water fountains and ice machines) was performed. Samples were recollected from CRE positive locations after successive decontamination attempts. A total of 97 samples were collected from taps, water, grates and drains (10 cm down and above the water trap interface where biofilm may be expected to persist).

All environmental and patient screening swabs were cultured onto chromogenic agar (*Brilliance* CRE Agar, Oxoid). Suspect colonies were further characterised using the modified Hodge test and VITEK 2 (Biomérieux). All isolates with a meropenem minimum inhibitory concentration (MIC) ≥ 0.25 mg/L and a positive modified Hodge test result were forwarded for confirmation by polymerase chain reaction and molecular sequencing. Molecular typing using pulsed field gel electrophoresis (PFGE) was conducted on clinical and environmental isolates and interpreted as per the reference guidelines.[7]

Guidelines on ICU handwashing sink styles were reviewed to establish whether sinks met clinical design standards.[8]

Results

Ten clinical isolates (*Klebsiella pneumoniae* [$n = 5$], *Serratia marcescens* [$n = 4$] and *Enterobacter cloacae* [$n = 1$]) and one screening isolate (*Escherichia coli*) containing the bla_{IMP-4} gene were detected over the 30-month period. There were four distinct CRE clusters, commencing with three cases of *K. pneumoniae* in November 2009, followed by two cases of *S. marcescens* 6 months later, three cases (two *S. marcescens* and one *E. cloacae*) after another 11 months, and three cases of *K. pneumoniae* in July 2012.

Clinical characteristics, patient demographics and ICU admission details of all 11 patients are summarised in Box 1. Patients acquired CRE after a median length of stay in ICU of 10 days (range, 3–134 days). No

1 Demographics and intensive care unit (ICU) admissions for patients with carbapenem-resistant Enterobacteriaceae isolates

Patient	Underlying condition	Year of first positive culture	Culture type	Organism	Total hospital stay (days)	ICU stay (days)	ICU admissions in past 12 months	Total carbapenem therapy (days)	Outcome
1	Small bowel perforation, post-hernia repair	2009	Blood	*Klebsiella pneumoniae*	229	134	0	14	Discharged
2	Urosepsis, multiorgan failure	2010	Urine	*K. pneumoniae*	44	16	0	0	Discharged
3	Bilateral pneumonia	2010	Bronchial washings	*K. pneumoniae*	61	33	0	0	Discharged
4	Pneumonia	2010	Intercostal catheter swab	*Serratia marcescens*	44	32	0	2	Discharged
5	Pneumonia	2010	Endotracheal aspirate	*S. marcescens*	46	6	0	0	Discharged
6	Buttock abscess	2011	Urine	*S. marcescens*	49	10	0	0	Discharged
7	Pneumonia	2011	Penile swab	*S. marcescens*	46	22	0	3	Discharged
8	Congestive cardiac failure	2011	Sputum	*Enterobacter cloacae*	57	4	0	0	Died
9	Ischaemic stroke	2012	Sputum	*K. pneumoniae*	31	3	0	3	Died
10	Periprosthetic hip fracture	2012	Urine	*K. pneumoniae*	46	8	0	0	Discharged
11	Ketoacidosis	2012	Rectal screen swab	*Escherichia coli*	11	4	2	0	Discharged

patient died due to clinical CRE infection. Patient 1 had a prolonged CRE bacteraemia that responded to removal of a central venous catheter, the presumed source of infection.

A total of 111 rectal swabs were collected from 71 patients. Only one patient (Patient 11) was CRE-positive with an *E. coli* isolate detected.

Antibiotic resistance profiles of clinical isolates indicated resistance to β-lactams and meropenem with MICs ⩾1 mg/L. All *S. marcescens* clinical isolates were sensitive to piperacillin/tazobactam, ciprofloxacin and amikacin, while *K. pneumoniae* and *E. coli* were only sensitive to amikacin. *S. marcescens* environmental isolates showed a higher meropenem MIC of ⩾16 mg/L.

S. marcescens was the only species recovered from environmental samples and was isolated persistently, even after six attempts to decontaminate the grates and drains of eight of the 11 central sinks in the ICU. Tap spout and water cultures were negative for CRE.

Three of the four *S. marcescens* clinical isolates from 2010 and 2011 were indistinguishable or closely related by PFGE to four isolates from sinks. *S. marcescens* was isolated from an intercostal catheter swab of Patient 4, matching two sink isolates; Patient 5 had an endotracheal aspirate identical to two different sink locations; and the urine isolate from Patient 6 was closely related to a different sink. The isolate from Patient 7 was unable to be typed by PFGE.

Sink inspection revealed aged and deteriorating porcelain, even though sinks were only installed in 2005. Sink design did not comply with Australasian clinical design standards,[8] with a small, shallow sink and a tap that directed water over the drain (Box 2). The design of the ICU sinks led to poor use for hand hygiene (although measured hand hygiene compliance using alcoholic hand rub was around 70% within the unit) and the potential for organisms residing down the drain to be splashed back onto staff hands or contaminate patient areas. It was also revealed that the handwashing sinks had been used incorrectly, with staff disposing clinical waste and residual antibiotics directly into drains. Further enquiry also revealed that a single brush had been used to clean down the drains of all sinks in the ICU without disinfection between sinks.

Cleaning was attempted in an effort to rid the organisms from the sinks.

2 Existing design of intensive care unit sink compared with a design that complies with Australasian standards[8]

A: Existing sink, showing water spray directly over drain. **B:** Compliant sink design, showing larger basin and less forceful water flow directed away from drain, to prevent splash back and contamination with drain contents. ◆

First, cleaning of grates and drains using single-use, soft brushes was attempted, but repeat screening revealed continued CRE growth. Next, in addition to the brushes, hypochlorite deep cleaning was used after the scrub; however, heavy CRE growth was again evident 1 week later. Finally, an attempt using pressurised steam decontamination (Jetsteam Maxi with plunger tool attachment, Duplex) for 1 minute at 170°C on grates and drains appeared to eradicate almost all CRE at Day 1 (one sink remained colonised); however, repeat testing 3 days after steam treatment showed re-emergence of CRE in all previously affected sinks.

Discussion

We report an outbreak of CRE in an ICU with identical organisms isolated from patients and an environmental source (sinks).

Dissemination of carbapenemase-resistant bacteria has been reported previously in an ICU in Australia, with 62 patients infected or colonised with gram-negative bacteria from multiple genera containing the bla_{IMP-4} gene.[9] The gene is carried on a highly mobile plasmid making it efficient for nosocomial transmission. The gene can reside in multiple genera of hardy environmental organisms that can establish a reservoir within biofilm.

Identifying the outbreak using molecular methods allowed us to establish clonality between clinical and environmental isolates and to propose a mechanism whereby patient contamination may have occurred. Although we cannot prove that the sinks were the source of patient infection, the persistence of the organism within the environment was a concern. Attempts at sink sterilisation were futile, and complete eradication will require future sink removal and replacement with appropriately designed sinks.

Others have reported outbreaks of multiresistant bacteria such as extended-spectrum β-lactamase-producing *K. pneumoniae* linked to imperfect sink design requiring sink cleaning, replacement and/or improved sink practices to successfully control the outbreaks.[10]

Our data should act as a reminder on the importance of appropriate hospital design, adequate environmental cleaning and antimicrobial stewardship in the hospital setting.

Competing interests: No relevant disclosures.

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Stamps of greatness

Karl Landsteiner (1868–1943)

LANDSTEINER was born on 14 June 1868 in Vienna, Austria. He studied medicine at the University of Vienna and graduated in 1891. For 5 years he studied chemistry in Wurzburg (with Emil Fischer) and Munich, but then returned to Vienna and transferred his interest to pathological anatomy.

In 1898 he became an assistant to the institute of pathological anatomy in Vienna, in 1908 the prosector at the Wilhelminaspital, and in 1911 professor of pathology at the University of Vienna. After the upheavals of World War I he went first to Holland and then, in 1922, to the Rockefeller Institute for medical research in New York, where he continued work even after being made Emeritus Professor in 1939.

From 1900 he studied the agglutination of blood from different individuals, and in 1909 he outlined the human blood types, thus making blood transfusion possible. Landsteiner received the Nobel Prize in Medicine in 1930 for this work, which he continued at the Rockefeller Institute.

During his time in Vienna he also studied (in collaboration with others) poliomyelitis, first showing that the disease was infectious, and then isolating the causative virus.

In the early 1940s at the Rockefeller Institute, he was part of the team that discovered the Rh factor in blood, adding to his work on blood transfusion and compatibility of donors.

Throughout his career he contributed many fundamental principles to the science of immunology and knowledge of antigens and anaphylaxis, and was the recipient of many academic honours and awards. He died on 26 June 1943 after suffering a heart attack while working in his laboratory two days earlier.

Philatelically he was honoured on the centenary of his birth in 1968 by both Austria and Germany.

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John Roche
Moss Vale, NSW
roche.araleuen@westnet.com.au

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