

Breaches in Infection Prevention and Controls Discovered During an Outbreak Investigation of Two Unlinked Cases of *Pseudomonas aeruginosa* Bloodstream Infections in a Cardiovascular Thoracic Surgery Unit

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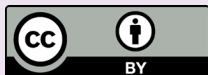
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ABSTRACT

Two patients with *Pseudomonas aeruginosa* bloodstream infections were diagnosed a week apart in a cardiovascular thoracic (CVT) surgery unit where there had been no cases of *P. aeruginosa* infections in the preceding 6 months. An outbreak investigation was conducted. Medical records were reviewed to identify potential common exposure in both patients. Outbreak investigation procedures included cultures of intravenous infusions and various solutions in the operating theatre and the general CVT surgery unit, the intensive care unit and the intermediate care unit, and monitoring compliance with the central line associated bloodstream infection prevention bundle. Both the blood cultures of the two patients as well as the liquid soap used for hand washing in the unit grew *P. aeruginosa*. However, there were three clonalities of isolates, the first from patient A, the second from patient B, and the third from the liquid soap. Other intravenous infusions and various solutions, i.e., normal saline solution, lactate ringer solutions, solutions for cardiopulmonary bypass circuits, and skin antisepsis, did not grow potential pathogens. In conclusion, although these were unlinked cases, investigation of the cases uncovered breaches in infection control practices and provided an opportunity to improve the infection control strategies in our institution..

KEYWORDS *P. aeruginosa*, bloodstream infection, outbreak, outbreak investigation, infection control

INTRODUCTION

Pseudomonas aeruginosa is an aerobic gram-negative bacterium that is ubiquitous in the environment, including in soil, water and plants (1). It is one of the pathogens most frequently implicated in healthcare-associated infections (1). Outbreaks of *P. aeruginosa* related to the hospital environment have been reported (2-7). Here we present two cases of *P. aeruginosa* bloodstream infections

(BSIs) which occurred in July 2020, a week apart, in the general cardiovascular thoracic (CVT) surgery unit. As there had been no cases of *P. aeruginosa* BSI in the previous 6 months in this unit, we suspected a common source of the outbreak, prompting an investigation to identify possible reservoirs and modes of transmission as well as to implement infection control measures to prevent future outbreaks.

METHODS

Maharaj Nakorn Chiang Mai Hospital is a 1,400-bed, tertiary-care, university-affiliated hospital. The Division of Cardiovascular Thoracic (CVT) surgery performs approximately 700–800 cardiac surgeries a year. The detection of *P. aeruginosa* in blood cultures of two patients within a week triggered an investigation by the infection control team. Both patients had clinical signs and symptoms of bloodstream infection. We reviewed the medical records and identified potential sources of exposure common to both patients.

Outbreak investigation procedures

1. Compliance with CLABSI prevention bundle

As the patients had bloodstream infections and it was unproven if they were central venous catheter (CVC) related, we focused on infection control measures for CVC insertion and dressings. To that end, we randomly observed the practice of central line insertion after this occurrence.

2. Cultures of intravenous infusions and various solutions

Intravenous infusions, including NSS, lactate ringer solution (LRS), solutions used in operating procedures, and solutions used with surgical wound dressings in the affected units, i.e., liquid soap for hand washing and antiseptic solutions for wound dressings, were randomly sampling for cultures.

Microbiology

Culture and drug susceptibility testing were performed at the Microbiology Unit, Diagnostic Laboratory, Maharaj Nakorn Chiang Mai Hospital. Colonies were identified by MALDI-TOF (VITEK MS, Biomerieux, Marcy l'Etoile, France). Antimicrobial susceptibility testing was performed using broth microdilution techniques (THAN2F, Sensititre, ThermoFisher, Massachusetts, USA). In addition to the two isolates from hemocultures, all specimens that grew *P. aeruginosa* from environmental samples were sent for genotypic study using the multilocus sequence typing (MLST) method at the microbiology laboratory, Department of Pathology, Faculty of Medicine, Ramathibodi Hospital.

Ethical approval

This study was exempt from review by Research Ethics Committee of Faculty of Medicine,

Chiang Mai University (certificate of exemption MED 7555/2020). Informed consent regarding the case details for publication in medical journals was obtained from the parent of patient A (as patient A had died) and from patient B.

RESULTS

Description of the cases

Patient A was a 20-year-old male admitted to the general CVT surgery unit due to a sternal wound infection from *S. aureus* on April 27th, 2020 following a Bentall procedure in January 2020. He underwent surgery in operating room (OR) “A” by surgeon team “A” on June 30th, 2020 where the Bentall operation was re-performed. Two central venous catheters were inserted, the first of which was inserted in the intermediate care unit (IMCU) and the second in the OR. He was subsequently transferred from the intensive care unit (ICU) to IMCU on July 8th, 2020 and then to the general CVT surgery unit, bed number 14, on July 9th, 2020. The tip of the first central venous catheter, collected on July 10th, 2020, grew *P. aeruginosa*. His blood cultures were collected on July 11th, 2020 also grew *P. aeruginosa*.

Patient B was a 61-year-old female admitted to the general CVT surgery unit on July 3rd, 2020 for tricuspid valve annuloplasty. She underwent surgery in OR “B” by surgeon team “B” on July 9th, 2020 and was transferred from the ICU to IMCU on July 10th, 2020 then to the general CVT surgery unit, bed number 15, on July 11th, 2020. Her blood cultures were collected on July 18th, 2020 grew *P. aeruginosa*. Echocardiography performed on July 23th, 2020 revealed vegetation at the anterolateral tricuspid valve annulus which was identified as prosthetic valve endocarditis.

All wound dressings for both patients were applied by the same surgical team. There were no other patients diagnosed with *P. aeruginosa* pneumonia or UTI in the general CVT surgery unit in the preceding 6 months. Both patients recovered from BSI following catheter removal and a course of antibiotics and were discharged from the hospital. The timelines for both patients are shown in Figure 1 and the room maps of the general CVT surgery unit and IMCU are shown in Figure 2.

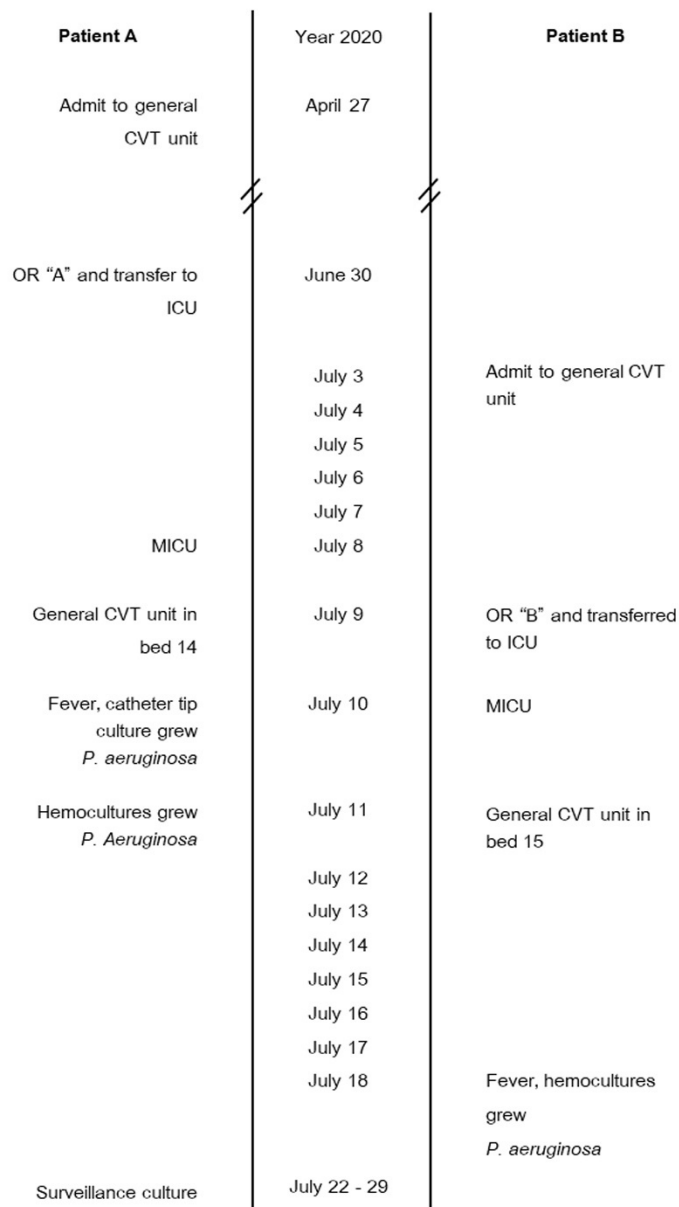


Figure 1. Timeline of the two patients with *P. aeruginosa* bloodstream infections

Antibiotic susceptibility patterns of clinical isolates

Antibiotic susceptibility (DST) patterns of *P. aeruginosa* isolates from patients A and B are shown in [Table 1](#). Two peripheral blood cultures from patient A had the same DST pattern, whereas cultures of from the catheter tip had a different DST pattern for imipenem. In the case of patient B, DST was the same for the peripheral blood cultures. No catheter tips were sent for culture.

Multilocus Sequence Typing (MLST) profile for *P. aeruginosa*

There were 3 clonalities of isolates: ST918 was discovered in the isolates from patient A, ST3393

from patient B, and ST381 from liquid soap in the general CVT surgical unit. The results are shown in [Table 2](#).

Compliance with central line-associated bloodstream infection (CLABSI) bundles

Fifteen central venous catheter insertions were investigated after this outbreak. All but one followed the CLABSI bundles, including having only well-trained healthcare personnel performing the procedure, following appropriate hand hygiene practices, using 2% alcoholic chlorhexidine for skin antisepsis, use of maximum sterile barriers, selecting optimal sites (avoiding the femoral vein), and the wearing of appropriate personal protective

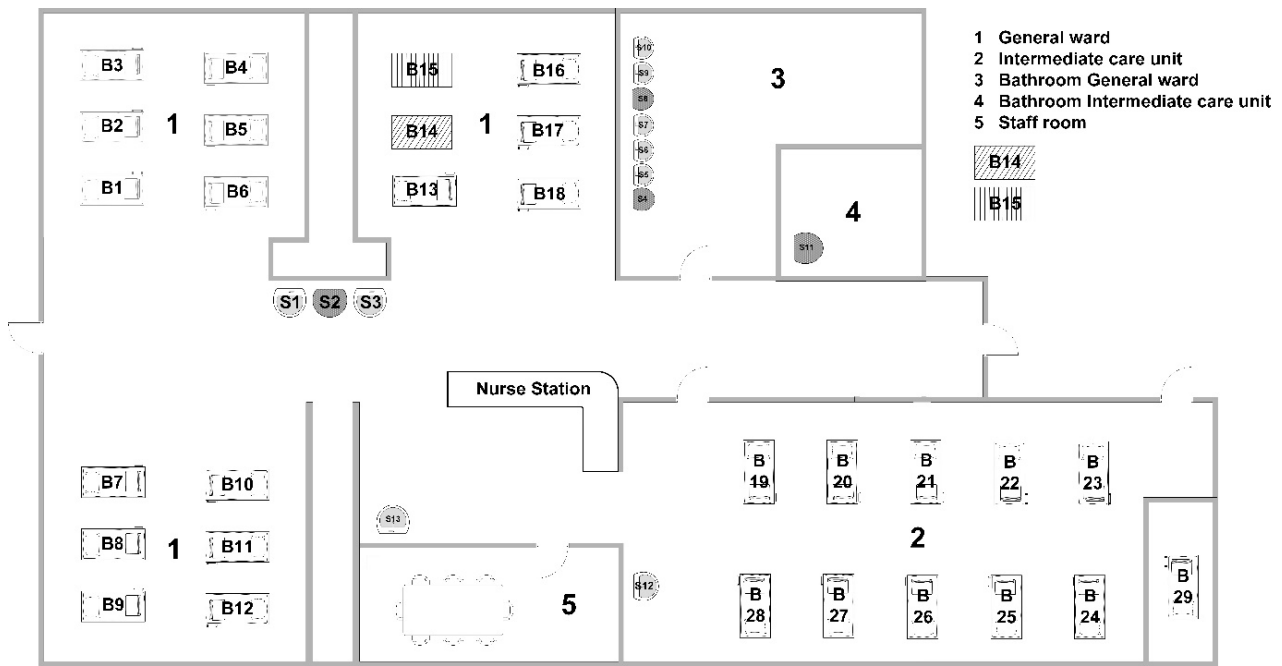


Figure 2. Room map of the general cardiovascular thoracic surgery and intermediate care units

Notes:

1. Patient A occupied bed 14 (hemocultures grew *P. aeruginosa* on July 11th, 2020) and patient B occupied bed 15 (hemocultures grew *P. aeruginosa* on July 18th, 2020)
2. Liquid soap above sink 2 (S2) grew *P. aeruginosa* > 100 CFU/mL
3. Liquid soap between S4 and S5 grew *P. aeruginosa* >100 CFU/mL
4. Liquid soap between S8 and S9 grew *Enterobacter cloacae* >100 CFU/mL, and *Klebsiella pneumoniae* >100 CFU/mL
5. Liquid soap between S4 and S5 grew *P. aeruginosa* >100 CFU/mL, and *Enterococcus faecalis* >100 CFU/mL

Table 1. Antibiotic susceptibility pattern of *P. aeruginosa* isolated from patients

Patient	Specimen	AMK	CPO	COL	CTZ	IMI	LFX	MEM	TAZ
A	Tip of CVC	S (<=8)	S (0.25)	I (2)	S (2)	S (2)	S (0.5)	S (<=0.5)	S (<=8)
A	Blood	S (<=8)	S (0.25)	I (2)	S (2)	I (4)	S (0.5)	S (<=0.5)	S (<=8)
A	Blood	S (<=8)	S (0.25)	I (2)	S (2)	I (4)	S (0.5)	S (<=0.5)	S (<=8)
B	Blood	S (<=8)	S (0.12)	I (2)	S (2)	S (2)	S (0.5)	S (<=0.5)	S (<=8)
B	Blood	S (<=8)	S (0.12)	I (2)	S (2)	S (2)	S (0.5)	S (<=0.5)	S (<=8)

AMK, amikacin; CPO, ciprofloxacin; COL, colistin; CTZ, ceftazidime; CVC, central venous catheter; IMI, imipenem; I, intermediate resistant; LFX, levofloxacin; MEM, meropenem; S, susceptible; TAZ, piperacillin/tazobactam

Table 2. Multilocus Sequence Typing (MLST) profile for *P. aeruginosa*

Samples	Allelic profile							Sequence type
	acsA	aroE	guaA	mutL	nuoD	ppsA	trpE	
Blood patient A	15	5	1	3	15	12	2	918
Tip CVC patient A	15	5	1	3	15	12	2	918
Blood patient B	11	2	6	3	15	38	3	3,393
Liquid soap	11	20	1	65	4	4	10	381
Liquid soap	11	20	1	65	4	4	10	381
Liquid soap	11	20	1	65	4	4	10	381
Liquid soap	11	20	1	65	4	4	10	381

CVC, central venous catheter

equipment. On one occasion, maximal sterile barrier was not followed. However, regarding catheter maintenance, the transparent dressings were changed regularly every 7 days, but were not changed when damp.

Cultures from various solutions in the units and operation theatres

Intravenous fluid and various solutions from the OR and from other hospital units were randomly sampled for bacterial cultures. The results are shown in Tables 3 and 4. The liquid soap used for hand washing in the general CVT surgery unit and the IMCU was commercial soap, brand A and

brand B. Due to the viscosity of the commercial liquid soap, the patient support staff mixed the commercial soap with water to make it easier to wash out. They first transferred commercial liquid soap to a non-sterile container and mixing it with tap water, or water for irrigation without following a specific formula for the mixture and not recording the date of the mixture on the container labels.

DISCUSSION

We described 2 cases of *P. aeruginosa* BSIs which occurred in patients in the same surgical unit within 1 week. They were initially believed to

Table 3. Cultures from specimens in the intensive care unit, intermediate care unit, and general cardiothoracic surgical unit

Unit	Specimens	Culture result (CFU/mL)
ICU	4% alcoholic chlorhexidine	< 10
ICU	10% povidone-iodine	< 10
ICU	2% alcoholic chlorhexidine	< 10
IMCU	4% alcoholic chlorhexidine gluconate	< 10
IMCU	Liquid soap brand A	< 10
IMCU	Liquid soap brand A mixed with water for irrigation*	< 10
IMCU (bathroom)	Liquid soap brand B mixed with tap water*	2 specimens < 10 1 specimen grew <i>P. aeruginosa</i> > 100 and <i>Enterococcus faecalis</i> > 100
IMCU	10% povidone-iodine	< 10
IMCU	2% alcoholic chlorhexidine	< 10
General	Liquid soap brand B	< 10
General	Tap water (sinks 1-4)	4 specimens < 10
General	Liquid soap brand A mixed with hot water (sink 2)	4 specimens < 10 1 specimen grew <i>P. aeruginosa</i> > 100
General (bathroom)	Liquid soap brand B mixed with tap water (sink 4)	1 specimen grew <i>P. aeruginosa</i> > 100
General (bathroom)	Liquid soap brand B mixed with tap water (sink 8)	6 specimens < 10 1 specimen grew <i>P. aeruginosa</i> > 100 1 specimen grew <i>Enterobacter cloacae</i> complex >100 and <i>Klebsiella pneumoniae</i> > 100
General	Alcohol handrub	< 10
General	10% povidone-iodine	< 10
General	0.5% alcoholic chlorhexidine	< 10
General	2% alcoholic chlorhexidine	< 10
OR	NSS in bag	< 10
OR	LRS in a bag, soak ring, soak ring holder	< 10
OR	A solution from the cardiopulmonary bypass circuit	< 10
OR	Cardioplegia solution	< 10
OR	2% alcoholic chlorhexidine	< 10
OR	4% alcoholic chlorhexidine	< 10

CFR, colony-forming unit; ICU, intensive care unit; IMCU, intermediate care unit; OR, operating room

Note: There was no formula for mixing liquid soap with water, and no date of mixing labeled on the liquid soap bottle.

Table 4. Cultures from the heater-cooler of the cardiopulmonary bypass machine in the operating rooms

Operating room	Specimen	Culture result (CFU/mL)
A	Heater cooler 1	< 10
A	Heater cooler 2 before changing distilled water	<i>Cupriavidus pauculus</i> > 100
A	Heater cooler 2 after changing distilled water	<i>Sphingomonas paucimobilis</i> > 100 <i>Cupriavidus pauculus</i> > 100
A	Heater cooler 3 before changing distilled water	<i>Sphingomonas paucimobilis</i> > 100 <i>Cupriavidus pauculus</i> > 100
A	Heater cooler 3 after changing distilled water	<i>Cupriavidus pauculus</i> > 40
B	Heater cooler 1	< 10

be of the same clonality, triggering an outbreak investigation. Once *P. aeruginosa* was isolated from blood, we focused on an infused solution. Cultures of various solutions were then performed as part of this investigation. Initially, we hypothesized that there was potential for contamination of an infused solution used in the operating procedure or in the surgical field. However, we were unable to determine whether either the intravenous infusions or the solutions used in the operating procedures were contaminated as some of the solutions sampled for testing were not from the same lot as those used on the patients. The other hypothesis regarding the source of the infection was linked to the central line insertion and maintenance procedures. However, we failed to demonstrate contamination of skin antiseptic and normal saline solution (NSS) from the same lot used with the patients. Although *P. aeruginosa* was found in the cultures from the liquid soap in which the healthcare workers wash their hands, the MLST profile of isolates from patient A, patient B, and the liquid soap were different.

We did, however observe breaches in the hospital infection control practices, including the following:

1. Practices to prevent CLABSI were not strictly adhered to, in particular, the use of maximal sterile barriers and the replacement of dressings that are wet, soiled, or dislodged. Although the compliance rate was 93.3% for 15 observed catheter insertions, this rate may have been elevated due to the Hawthorne effect as during the observation, the surgical care team was aware of the two cases of BSIs.

2. The soap and water used for washing hands was unclear in many locations because the liquid soap was mixed with tap water to liquefy the mixture to make it less viscous, thus making it easier to wipe off.

3. The heater-cooler of the cardiopulmonary bypass (CPB) machine, although not directly related to the surgical area, was contaminated with bacteria that can inhabit water. The investigation revealed that the circuit had not been regularly maintained, mainly due to the COVID-19 pandemic, which restricted the operation and visiting of the hospital by people (including the staff performing the maintenance of the circuit).

The hospital administrative department responded immediately to the results of this investigation by revising the regulation for maintenance of the heater-cooler of the CPB machine and by supplying more appropriate materials, i.e., user-friendly liquid soap which does not need to be mixed with water, limiting the potential for contamination, making increased use of single-use towels, increasing emphasis on the systematic monitoring of adherence to prevention bundles, not only of CLABSI bundles but also bundles to prevent other hospital-acquired infections. In addition, as the culture of the tip of central venous catheter in patient A and the blood culture taken from peripheral veins were performed on the different days, we used the opportunity to emphasize appropriate blood collection for diagnosis of catheter-related bloodstream infection (CRBSI) to enable identification of the infection and to facilitate speedy, effective treatment.

These two cases were co-incident and were not epidemiologically linked, as they had different sequence types. In addition, during the investigation, four similar strains found in liquid soap used in the general CVT unit were different from those isolated from the patients in this study. This emphasizes the usefulness of molecular study to determine whether samples from different patients are caused by the same infectious agent. When conducting antibiotic susceptibility testing (DST) of *P. aeruginosa* isolated from the tip of CVC and

blood from patient A, we noticed a one-dilution difference in the minimum inhibitory concentration (MIC) of the isolates to imipenem which raised the question of whether they were the same strain. The MLST confirmed the same clonality of isolates from patient A and distinguished it from that of patient B and the liquid soap. The MLST of liquid soap samples from various locations shown in Table 3 show similar sequence types. The contamination of liquid soap can occur during the preparation process prior to distribution to various locations.

Previous studies have found that *P. aeruginosa* can be prevalent in a hospital environment, occurring in potable water, faucets/taps, sinks, cleansing equipment, and hydrotherapy equipment (1). It can also colonize liquid antiseptics, e.g., quaternary ammonium compounds, infusion fluids and soap solutions, and can be transmitted causing infections in hospitalized patients (2–7). These bacteria can form biofilms which make them resistant to antibiotics and which allow them to adhere to catheters (1, 8). *P. aeruginosa* is a significant pathogen among hospital-acquired infections and can cause morbidity and mortality, particularly in the case of multidrug-resistant strains (9). However, acknowledgment of this being a hospital-acquired pathogen enabled the hospital to improve measures to avoid infection despite it not having been an actual outbreak. It motivated taking action to identify potential reservoirs and modes of transmission to help prevent future outbreaks.

One may question whether in this case it was too early to start an outbreak investigation as those two cases may have occurred by chance and an outbreak investigation results in the loss of hospital resources. However, in the authors' point of view, the definition of an outbreak was met, i.e., an increase in the disease incidence beyond the expected number of cases in a particular area within a defined period of time (10). In addition, if there really was a reservoir, it would be harmful to patients, particularly those undergoing cardiac valvular surgery and who then develop prosthetic valve endocarditis. In such a case, the outcome could be devastating, both from the perspective of the patient and from that of the hospital. In general, any outbreak is an emergency condition and stopping it early can potentially limit the impact and the number of cases involved.

The major limitation of this investigation was that the specimens were prospectively collected only after the two cases had been detected. As a result, some of the solutions sampled for testing were not from the same batch as those used on the patients. Therefore, the negative culture results obtained from these samples as a source of infection cannot be completely excluded.

CONCLUSIONS

We present two unlinked cases of *P. aeruginosa* bloodstream infection along with contamination of liquid soap with *P. aeruginosa*. Although this was not an actual outbreak, investigation of these two cases uncovered breaches in infection control practices and provided an opportunity to improve the infection control strategies in our institution.

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CONFLICTS OF INTEREST

The authors have no conflicts of interest to report.

ADDITIONAL INFORMATION

Author contributions

Conceptualization, R.C.; methodology, R.C., A.G.; investigation, N.N., A.G., P.K., S.K., U.T.; data curation, N.N., A.G.; writing—original draft preparation, N.N., R.C.; original draft preparation, review and editing, R.C.; supervision, A.P.; funding acquisition, R.C.

REFERENCES

1. Moradali MF, Ghods S, Rehm BHA. *Pseudomonas aeruginosa* lifestyle: a paradigm for adaptation, survival, and persistence. *Front Cell Infect Microbiol*. 2017;7:39. PubMed PMID: 28261568

2. Farmer JJ, 3rd, Weinstein RA, Zierdt CH, Brokopp CD. Hospital outbreaks caused by *Pseudomonas aeruginosa*: importance of serogroup O11. *J Clin Microbiol.* 1982;16: 266-70.
3. Eckmanns T, Oppert M, Martin M, Amorosa R, Zuschneid I, Frei U, et al. An outbreak of hospital-acquired *Pseudomonas aeruginosa* infection caused by contaminated bottled water in intensive care units. *Clin Microbiol Infect.* 2008;14:454-8.
4. Quick J, Cumley N, Wearn CM, Niebel M, Constantidou C, Thomas CM, et al. Seeking the source of *Pseudomonas aeruginosa* infections in a recently opened hospital: an observational study using whole-genome sequencing. *BMJ Open.* 2014;4:e006278. PubMed PMID: 25371418
5. Blanc DS, Nahimana I, Petignat C, Wenger A, Bille J, Francioli P. Faucets as a reservoir of endemic *Pseudomonas aeruginosa* colonization/infections in intensive care units. *Intensive Care Med.* 2004;30:1964-8.
6. DiazGranados CA, Jones MY, Kongphet-Tran T, White N, Shapiro M, Wang Y F, et al. Outbreak of *Pseudomonas aeruginosa* infection associated with contamination of a flexible bronchoscope. *Infect Control Hosp Epidemiol.* 2009;30:550-5.
7. Reuter S, Sigge A, Wiedeck H, Trautmann M. Analysis of transmission pathways of *Pseudomonas aeruginosa* between patients and tap water outlets. *Crit Care Med.* 2002;30:2222-8.
8. Ciofu O, Tolker-Nielsen T. Tolerance and resistance of *Pseudomonas aeruginosa* biofilms to antimicrobial agents-how *P. aeruginosa* can escape antibiotics. *Front Microbiol.* 2019;10:913. PubMed PMID: 31130925
9. Pachori P, Gothwal R, Gandhi P. Emergence of antibiotic resistance *Pseudomonas aeruginosa* in intensive care unit; a critical review. *Genes Dis.* 2019;6:109-19.
10. Reintjes R, Zanuzdana A. Outbreak Investigations. In: Krämer A, Kretzschmar M, Krickeberg K, editors. *Modern infectious disease epidemiology. Statistics for biology and health.* New York: Springer. 2009. p. 159-76.