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ORIGINAL PAPER

Dialysis drains as a possible source for carbapenem-resistant pathogens causing an ICU outbreak

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Abstract

Objective design We describe a case series of patients colonized with KPC-producing *Enterobacteriaceae* related to dialysis drains at patient's bedside.

Setting The study was set at the intensive care unit (ICU) of a tertiary referral hospital.

Patients In March 2016, we discovered four ICU patients to be colonized with KPC-producing *Enterobacteriaceae* in routine screening. All of these patients had already received contact isolation, and all of them were treated with continuous veno-venous dialysis. Environmental examinations showed KPC-producing *Enterobacteriaceae* in dialysis drains in different ICU rooms and even in rooms not hosting KPC-colonized patients.

Interventions Based on our findings, we suspected the dialysis drains as a reservoir of KPC-producing *Enterobacteriaceae* with a potential risk for the patients. Therefore, we decided to change the dialysis waste management.

Results As a result, no KCP-producing *Enterobacteriaceae* were detected during the following weekly screening of the patients.

Conclusions Installation of dialysis connection units including a drain system at the patient's bedside is a comfortable way to provide water supply. In many ICUs, such dialysis drains are installed near the patients' head and directly besides the infusion systems. When the drains are not used properly, in our opinion, they pose a risk of transmission of pathogens from the drain to the patient. Our findings support the need of specific precautions.

Keywords Dialysis drains · Dialysis wastewater · Carbapenem resistance · ICU

Introduction

Carbapenem-resistant *Enterobacteriaceae* are of great concern worldwide. Above all, hospital water and water-related devices are known to be important for their distribution in the environment. Many outbreak reports describe an association between sewages and the colonization or infection of patients with multidrug-resistant *Enterobacteriaceae* [1]. Therefore, water-bearing systems in hospitals always have to be considered when an outbreak caused by *Enterobacteriaceae* occurs.

Background

One of the procedures in hospitals that need a high-quality water supply is renal replacement therapy such as hemodialysis. Renal failure is a common condition in the intensive care unit (ICU). According to recent data, 5–25% of ICU patients develop acute kidney injury and of these, approximately 6% require renal replacement therapy [2–5]. The usual treatment for acute renal failure is intermittent

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hemodialysis to rapidly remove solutes and fluids, usually this process takes 4–5 h.

However, particularly in ICU patients, it frequently results in significant arterial hypotension. Accordingly, pump-driven veno-venous hemodialysis/hemofiltration (CVVHD) at constant blood flow over 24 h is often preferred to intermittent dialysis in the ICU.

CVVHD is an on-site dialysis and requires special equipment on the ward and a water source for the CVVHD machines. It is preferable to have water line connectors and drains for the dialysis equipment immediately at the patient's bedside. However, the convenience of having a water supply nearby may cause potential contamination of the environment with waterborne bacteria.

We describe an outbreak related to the dialysis water supply and drains in an ICU.

Outbreak description

In March 2016, four patients in an ICU of a tertiary referral hospital were diagnosed to be colonized with various *Klebsiella pneumoniae* carbapenemase (KPC)-producing *Enterobacteriaceae*. All of these patients had a long and complex medical history with an ICU stay of minimum 8 days prior to the diagnosis of the colonization, so nosocomial transmission was suspected.

Multispecies outbreaks of KPC-forming *Enterobacteriaceae* in Germany have been previously reported [6–8], but KPC had very rarely been detected in our hospital. So, we were concerned about these findings in our patients.

Accordingly, we classified this scenario as a multispecies outbreak with KPC-producing *Enterobactericeae* and investigations were performed immediately as follows.

Materials and methods

Analysis of ICU ward structure, patient care, and cleaning procedures was carried out by the Infection control team using standard observation tools according to the German recommendations.

Routine microbiological surveillance

It was already implemented before the outbreak to perform swabs once a week on all patients to screen for multidrug-resistant gram-negative pathogens. A microbiological examination of tracheal secretions was performed on all ventilated patients at least once per week. This procedure was continued during the outbreak investigations.

Environmental investigations

Flexible bronchoscopes: Since all patients frequently required bronchoscopy, the bronchoscopes were considered a likely source of the KPC-producing *Enterobacteriaceae*. Therefore, the equipment was checked in the hospital's centralized high-level disinfection unit for endoscopes. However, no positive cultures were revealed (data not shown).

Surfaces: Samples were taken from surfaces both within and outside the patients' rooms with a total of 174 imprints and swab tests taken. Particular attention was given to water supply systems and typical hand contact surfaces.

Microbiological techniques: We used Replicate Organism Detection and Counting plates (RODAC™), an established system for environmental surface sampling, to check for microorganisms measuring colony-forming units (CFU) per square centimeter.

In addition, swab samples were collected by moving the swabs across the sampling site several times. The swabs were then placed into transport medium. Agar plates were inoculated and incubated at 37 °C for 48 h.

Afterwards, bacteria were identified to the species level according to standard methods (VITEK MS and VITEK 2, bioMérieux, Nürtlingen Germany). Phenotypic detection of carbapenem resistance resulted in molecular investigation, using the Xpert Carba-R-Kit (Cepheid, Sunnyval, CA, USA) in which sequences coding for KPC, NDM, VIM, OXA 48, and IMP-1 can be detected.

Results

Analysis of ICU ward structure

This ICU had received extensive refurbishment in 2015 with newly designed one-bed rooms. It had excellent structural facilities and had maintained a high compliance with infection control measures. Its use of hand disinfectant averaged 180 ml per patient day, which exceeded the 90th percentile of the German National Reference Center data for interdisciplinary ICUs [9]. Not all of the ICU patient rooms were occupied at the time of the outbreak.

ICU room layout

The interior of the ICU one-bed rooms is shown in Fig. 1. Each room is equipped with a sink and a dialysis unit, which is located behind the bed near the infusion system. These dialysis units consist of a water supply connection and a drain which is covered by an inspection flap.

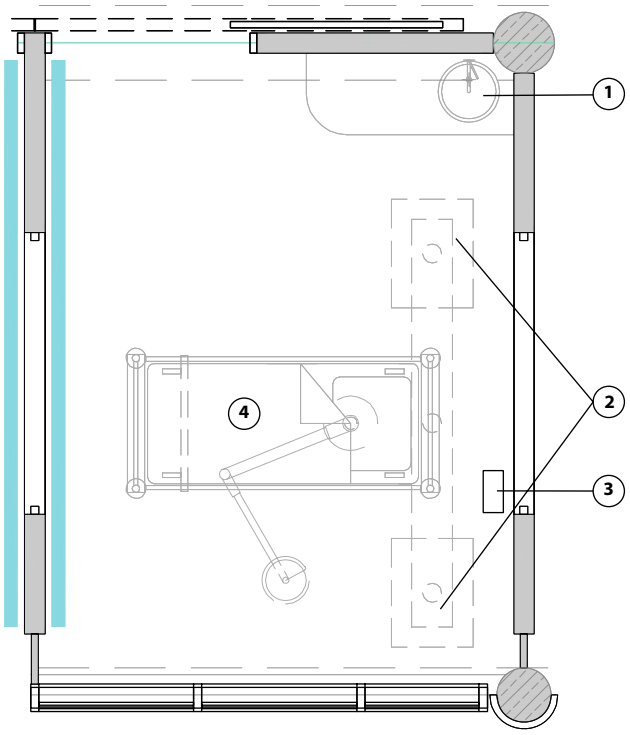

Fig. 1 Patient's room (ICU). (1) sink, (2) syringe pumps, infusion pumps, (3) dialysis unit, (4) patient's bed

Patient characteristics

Five patients were identified to be colonized with different KPC-producing *Enterobacteriaceae* in routine screening. All of them had a long stay in the ICU (8–87 days, see Table 1), the routine screening had not shown any carbapenem organisms before. Four of those patients were transferred to these ICU from other hospitals with a known influenza infection to receive an extracorporal membrane oxygenation (ECMO) therapy.

Three of the patients were found to be colonized with carbapenem-resistant *Enterobacteriaceae* in tracheal secretions and another carrier was identified by a screening swab (anal smear) after a minimum of an 8 day stay. Screening on admission and on a weekly basis for *Enterobacteriaceae* was already in effect, however, no additional positive cultures were found.

One additional patient was identified retrospectively (Table 1). This patient had been hospitalized in this ICU 3 months previously. He was treated under isolation precautions, too.

Analysis of patient care

Staff members wore complete personal protective equipment (PPE) while caring for these isolated patients because of the known influenza infection. The PPE consisted of protective gown, gloves, hood, and a FFP3 mask. All influenza patients were treated with extracorporeal membrane oxygenation (ECMO) because of severe lung failure. Additionally, CVVHD was performed on all five patients. Multiple use ultrafiltrate bags were used and emptied five times a day into the dialysis drains of the patients' room using a plastic hose. One of these ultrafiltrate bags included 10 l fluid. To avoid the effort to carry the heavy bags across the hallway into the

Table 1 Patients' characteristics

Patient no.	Multidrug-resistant organism	First record First record of KPC in regular weekly screening (day of stay)[a]	Duration of hospitalization	Diagnosis/procedures/precautions[a]
1	*Klebsiella oxytoca* (KPC)	11th Dec 2015 (day 87)	9th Sep 2015–19 th Jan 2016 (+)	Sepsis, multi-organ-failure/ CVVHD/single room isolation precautions
2	*Citrobacter freundii* (KPC)	4th Mar 2016 (day 30)	3th Feb–1th June 2016	ARDS, Influenza/CVVHD, ECMO/ single room isolation precautions
3	*Klebsiella pneumoniae* (KPC)	22th Mar 2016 (day 8)	14th Mar–18th Apr 2016	ARDS, influenza/CVVHD, ECMO /single room isolation precautions
4	*Klebsiella pneumoniae* (KPC)	20th Mar 2016 (day 27)	22th Feb–23th Mar 2016	ARDS, influenza/CVVHD, ECMO /single room isolation precautions
5	*Citrobacter freundii* (KPC)	29th Mar 2016 (day 26)	3th Mar–6th Jul 2016	ARDS, influenza/ CVVHD, ECMO /single room isolation precautions

CVVHD continuous veno-venous hemodialysis, *ECMO* extracorporeal membrane oxygenation, *ARDS* adult respiratory distress syndrome

[a]All patients were isolated in single rooms during their stay in the ICU

impure working room, the drains in the patient rooms were used for emptying the bags. This procedure included touching the drains directly with gloved hands. However, hand disinfection compliance was not 100%. Gloves were rarely changed and not always disinfected.

Analysis of cleaning procedures

Cleaning of all the ward's surfaces was carried out with an oxygen-producing disinfectant (Perform® 0.5%) twice per day. Observation of the cleaning process did not reveal evidence of any practice errors.

Environmental investigations

We performed extended environmental investigations outside the patients' rooms focusing on hand-touch sites and bronchoscope equipment to get an idea of the mode of transmission of KPC.

Microorganisms, mainly non-pathogenic microorganisms like coagulase-negative *Staphylococci* or non-pathogenic *Corynebacteriae* in low or moderate concentrations, were detected on various surfaces, but KPC-producing *Enterobacteriaceae* could not be identified despite targeted search.

However, KPC-producing *Enterobacteriaceae* were found in the drains of the patients' rooms, mainly in the drains of the dialysis units (five times) and in the siphons of the sinks (twice) (Table 2). Investigations were not limited to rooms with KPC-colonized patients but also performed in rooms of non-colonized patients. However, no KPC-producing *Enterobacteriaceae* were detected outside the patients' rooms.

Measures

Since KPC-producing *Enterobacteriaceae* could be found mainly in the dialysis drains, we assumed them a as a reservoir of these pathogens. A transfer from the drains to the patients had to be strictly avoided. The drain use was discontinued and the dialysis regimen was changed to single use ultrafiltrate bags which could be discarded into the garbage. Disinfection of the dialysis and sink drains was performed using inorganic hypochlorite (bleach). Follow-up investigations showed decreased number of bacteria and less evidence of gram-negative pathogens 1 week later, but bacteria were not eliminated since two dialysis drains and two sink drains were still found to be contaminated. On the basis of

Table 2 Detection of KPC-producing *Enterobacteriaceae* in patients' rooms

Room number	Dialysis drains	Sink drains	Patient with proven colonization with KPC
2	Skin flora	Skin flora	–
3	Skin flora	Skin flora	–
4	Skin flora	Skin flora	–
7	Skin flora	Skin flora	–
11	***K. oxytoca* KPC**	***K. oxytoca* KPC**	+ ***Citrobacter freundii KPC***
12	*S. maltophilia* Skin flora	Skin flora	–
13	***C. freundii KPC***	*P. fluorescens* Skin flora	–
14	*S. maltophilia* Skin flora	Skin flora	–
15	***K. oxytoca KPC***	Skin flora	+ ***Klebsiella pneumoniae* KPC**
16	*P. putida* Skin flora	*K. oxytoca* (susceptible) Skin flora	–
17	*P. putida, P. fluorescens* Skin flora	*P. putida* Skin flora	–
18	*Ps. putida, P. fluorescens* Skin flora	***K. oxytoca, C.freundii KPC***	+ ***Citrobacter freundii KPPC***
19	***K.oxytoca, C.freundii KPC***	Skin flora	–
20	Skin flora	*P. aeruginosa* (susceptible)	–
21	*S. maltophilia* Skin flora	Skin flora	–
22	***E. cloacae, KPC***	Skin flora	–

Bold indicates KPC-producing *Enterobacteriaceae*

these findings, the dialysis drains were taken out of use and the sinks were treated daily with inorganic hypochlorite.

In addition, the personnel were trained in proper hand disinfection. All patients were removed from the rooms with the affected drains, then the rooms were cleaned as per protocol with high concentrations of the oxygen-producing disinfectant (Perform® 3%). Additionally, surfaces were disinfected with hydrogen peroxide. Above all, it was trained that after the contact with the drains a glove change and a hand disinfection necessarily had to take place. Subsequently, no KCP-producing *Enterobacteriaceae* were detected during the weekly screenings.

Discussion

Colonization with KPC-producing *Enterobacteriaceae* is a grave finding in ICU patients and mortality from invasive infections with carbapenem-resistant pathogens is high [10].

Our analysis of this small epidemic demonstrates that dialysis drains in ICUs may be a potential source of outbreaks with waterborne pathogens, especially with improper use of the drains.

Reducing the risk of pathogen transmission from contaminated sinks, already described as a source of gram-negative pathogens [1], needs consistent hand hygiene after contact with wastewater. Our investigations showed KPC-producing gram-negative bacteria in the sinks of patients' rooms. These rooms were occupied by patients who were known to be colonized. We interpreted this finding as a secondary contamination caused by the water which was used for the basic care of the patients. To prevent the colonization of the entire water system of the ICU, we used bleach for the disinfection of the drains.

But how did the KPC-producing *Enterobacteriaceae* colonize the dialysis drains? An entry via the dialysis water seemed unlikely—the filtrate is usually bacteria-free, but may contain residues of drugs, including antibiotics. This may support contamination by waterborne pathogens with drug resistance. In our opinion, direct hand contact between the patient's environment and the drains might have "infected" the drains.

Process observations revealed a good compliance with hand hygiene when the sink was used, therefore, it did not seem likely that the pathogens were transferred from the sink to the patient. So, we did not suspect the sink drains as the source of KPC.

The presence of KPC-producing *Enterobacteriaceae* in the dialysis drain units and, in particular, its relevance as a bacterial reservoir for transmissions of pathogens was more difficult to interpret and only further observations revealed a possible link between the dialysis units and the patients' environment:

This ICU was equipped with dialysis units and a water supply beside each patient's bed. (Fig. 1) Dialysis units had separate couplings for fresh water and waste water which could be used to connect mobile osmosis systems as well as dialysis machines. The main advantage of this design is the avoidance of water transfer over long distances. Dialysis filtrate can also be discharged directly into the sink via the wall connection.

CVVHD produces significantly less filtrate than intermittent dialysis. Therefore, it is customary to dispose the filtrate via collection in 10 l filtrate bags. Filtrate bags are available both as single and multiple use models. On average, these bags must be changed 4–5 times daily. The exchange process causes difficulties, regardless of whether single or multiple use bags are used, since the nursing staff must lift these heavy bags to take it to the ICU's waste room. This is not only physically challenging but may also evoke contamination of the ICU's environment.

All potential procedural changes have distinct disadvantages. The filtrate bags can either be emptied into the washing basin of the patients' room, possibly causing outbreaks as recently published by Salm et al. [11] or thrown into the garbage, which is inconvenient and costly. In the affected ICU, the filtrate bags were emptied via the wall drains of the dialysis units in the patient room immediately next to the headboard of the bed. During this procedure, bags were attached to infusion poles above the dialysis units, and a catheter had been used to establish a bypass to the drain. This process required the nursing staff to touch the drains and to get in contact with the siphon. The lifting of the heavy filtrate bags in protective clothing also was a physically exhausting task, evoking handling errors that resulted in spilling contaminated material from the drains to the environmental surfaces. This issue, combined with the aforementioned difficulties with hand disinfection in protective clothing (especially with gloves), likely resulted in bacterial contamination.

After these observations, all dialysis drains were closed and the filtrate bags were now disposed of directly into the garbage without prior emptying. While this approach required considerable changes in waste management logistics, no KPC-producing *Enterbacteriaceae* were detected thereafter by the ongoing weekly screening program.

From a hygienic point of view, the correct handling of filtrate bags is a challenge and better technical solutions are needed. As an alternative to bag-based systems, dialysis machines are available which allow a direct introduction of the filtrate into a wall connection. However, these machines have technical disadvantages in ICU patients. Another alternative is a bag coupled to the dialysis unit without the risk of opening and touching potentially contaminated siphons. Preliminary observations using this system are promising and this approach is widely accepted by the staff in our hospital.

In our opinion, significant risks result from the use of a water supply for dialysis in ICUs due to their need for drains. The proximity of potentially contaminated siphons to the patients' head, often next to infusion lines and central venous catheters, also is a cause for concern and minor handling errors may evoke grave consequences.

Dialysis drains in patient rooms in ICUs may be potential sources of outbreaks with waterborne pathogens, especially with improper use of the drains and should considered in routine ICU surveillance.

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Compliance with ethical standards

Conflict of interest All authors report no conflicts of interest relevant to this article.

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