



ELSEVIER

Available online at [www.sciencedirect.com](http://www.sciencedirect.com)

## Infection Prevention in Practice

journal homepage: [www.elsevier.com/locate/ijip](http://www.elsevier.com/locate/ijip)

# Outbreak of *Acinetobacter baumannii* associated with extrinsic contamination of ultrasound gel in a tertiary centre burn unit

Kruti J. Yagnik<sup>a</sup>, Gautam Kalyatanda<sup>b</sup>, Anthony P. Cannella<sup>b,c,d,e</sup>,  
Lennox K. Archibald<sup>b,c,\*</sup>

<sup>a</sup> University of Florida College of Medicine, Department of Medicine, Gainesville, FL, USA

<sup>b</sup> University of Florida College of Medicine, Department of Medicine, Division of Infectious Diseases & Global Medicine, Gainesville, FL, USA

<sup>c</sup> Malcolm Randall Veterans Health Administration Medical Centre, Gainesville, FL, USA

<sup>d</sup> University of Florida College of Medicine, Department of Molecular Genetics & Microbiology, Gainesville, FL, USA

<sup>e</sup> University of Florida College of Medicine, Emerging Pathogens Institute, Gainesville, FL, USA

## ARTICLE INFO

**Article history:**

Received 4 March 2019

Accepted 20 June 2019

Available online 27 June 2019

**Keywords:***Acinetobacter baumannii*

Ultrasound gel

Outbreak

Nosocomial infection

Burn unit



## SUMMARY

**Background:** During 2011 and 2012, an increase in occurrence of multidrug-resistant *Acinetobacter baumannii* infections was recorded in the Shands Hospital Burn Intensive Care Unit (BICU). An epidemic curve together with strain typing was consistent with an intermittent common source outbreak. An investigation was therefore initiated.

**Aim:** To identify risk factors for *A. baumannii* infection, characterize the source of the pathogen, implement control measures to terminate the outbreak, and institute preventive measures.

**Methods:** We conducted a retrospective case-control study; reviewed BICU infection control policies, practices and procedures, and patient exposure to healthcare workers (HCWs), and obtained epidemiologically-directed environmental cultures.

**Findings:** Eleven patients met the case definition. On multivariate analysis, case-patients were more likely to have undergone an ultrasound procedure in the BICU (adjusted odds ratio [AOR]: 19.5; confidence interval [CI]: 2.4–435) or have a FlexiSeal™ device (AOR: 11.9, CI:1.3–276). Epidemiologically-directed cultures of the environment, ultrasound equipment, and ultrasound gel from opened containers on the ultrasound trolley and in the Ultrasound Department were negative for the outbreak pathogen. Culture of an open ultrasound gel dispenser stored in the Ultrasound Department yielded an *A. baumannii* strain with DNA banding patterns identical to the outbreak strain.

**Conclusions:** Based on data from our epidemiologic, microbiologic, and observational studies, we believe that inadvertent extrinsic contamination of the gel dispenser occurred in the Ultrasound Department. Contaminated gel was then dispensed into multiuse vials of gel stored on the mobile carts. The outbreak was stemmed by instituting changes in practices in the Ultrasound Department, including introduction of single-use ultrasound vials and storage of ultrasound gel.

\* Corresponding author. Address: Malcolm Randall Veterans Administration Medical Centre 1601 SW Archer Road, Gainesville, FL 32608, USA. Tel.: +1(352) 494-2224.

E-mail address: [lennox.archibald@medicine.ufl.edu](mailto:lennox.archibald@medicine.ufl.edu) (L.K. Archibald).

## Introduction

*Acinetobacter* species are ubiquitous environmental, non-motile, strictly aerobic, Gram-negative coccobacilli that have become significant causes of healthcare-associated infections in medical facilities across the globe [1–3]. The organism naturally inhabits freshwater and soil and flourishes in tropical and temperate climates [1]. *Acinetobacter* spp. have become endemic in hospital environments, including isolation from tap water, nebulizers, irrigating solutions, and intravenous infusions [1,4,5]. In the intensive care unit (ICU), *Acinetobacter* spp. commonly colonize following sites of patients: skin, respiratory secretions, ventilator circuits and reservoirs, intravascular lines or monitoring devices, indwelling urinary catheters, wounds, or surgical drains [1,5]. Thus, *Acinetobacter* spp. can readily be disseminated in ICUs via direct contact (e.g., person-to-person) or indirect contact transmission with fomites, such as work surfaces, bed rails, door-knobs, telephones, or computer keyboards. Furthermore, *Acinetobacter* spp. can be both inherently resistant as well as be able to acquire resistance to multiple classes of available antimicrobial agents (fluoroquinolones, aminoglycosides, carbapenems, and polymyxins) [1–8]. These properties highlight the potential for *Acinetobacter* to cause serious or intractable infection in seriously ill or immunocompromised patients; this underscores the increasing clinical and public health importance of this healthcare-associated pathogen.

Shands Hospital at the University of Florida Health is a 996-bed, tertiary care, teaching hospital with over 200 ICU beds, serving a catchment area that covers both North Florida and South Georgia. The facility had an eight-bed Burn Intensive Care Unit (BICU) that provided care for skin and pulmonary burn injuries, severe skin disorders, and chronic intractable wound issues. BICU infection control practices and procedures met the standards set out in guidelines established by the Centres for Disease Control and Prevention (CDC) including surveillance of common healthcare-associated infections (HAI) as required by the Joint Commission [9–11]. During March 2012, BICU nursing and medical personnel reported an increase in the occurrence of multidrug-resistant *Acinetobacter baumannii* infections among BICU inpatients during 2011. BICU surveillance data had documented just two patients with *A. baumannii* infection during 2010. Patients with infection and colonization were placed on contact isolation precautions, patients and nursing staff were appropriately cohorted, and all medical, nursing and ancillary personnel in the BICU worked with the Infection Control Department to ensure scrupulous hand hygiene, and adherence to infection control guidelines for practices and procedures in the BICU by all personnel. In addition, the Environmental Services Department increased the frequency of enhanced environmental cleaning of the BICU and weekly point prevalence surveillance cultures from BICU patients were instituted. Despite these measures, BICU patients continued to acquire *A. baumannii* infection and point prevalence surveillance cultures demonstrated persistence of *A. baumannii* in the BICU environment.

A full investigation was therefore initiated and comprised four integrated components: a) analytic epidemiologic investigation; b) microbiologic studies; c) review of practices and procedures in the BICU, and d) observational studies. The objectives of the investigation were to characterize and identify the source of the *A. baumannii* infections; identify factors facilitating persistence of the organism in the BICU environment; assess risk factors for *A. baumannii* infection or colonization of BICU patients; implement control measures to terminate this outbreak; and institute appropriate preventive measures.

## Methods

To confirm the existence of an outbreak, we carried out preliminary analyses of BICU surveillance data on healthcare-associated infections.

### Case definition and case ascertainment

A case-patient was defined as any patient in the BICU infected or colonized with the outbreak strain of *A. baumannii* as determined by culture of clinical or screening samples during January 2011 through March 2012. Case-patients were ascertained by review of the hospital's clinical microbiology laboratory line listings, infection control surveillance data, and patient medical records from the epidemic period. To determine whether the cluster of case-patients represented an outbreak, comparison was done of *A. baumannii* infection in the BICU during the epidemic and pre-epidemic periods.

### Case-control study

To identify and characterize risk factors for infection with *A. baumannii*, we compared case-patients with randomly selected, unmatched, control-patients who were in the BICU during the study period, and who did not acquire infection from any pathogen, including *A. baumannii* during their stay in the BICU. Comprehensive clinical, microbiologic, and epidemiologic data were aggregated and documented in a standardized questionnaire and included the following: patient demographics (e.g., age, race, and sex); type, cause, and severity of burns; hospital ward and room number before transfer to the BICU; BICU room number; duration of stay in the BICU; underlying comorbidities, including cardiopulmonary disease, diabetes, metabolic complications; type and duration of surgical procedures, if any; types of grafts used for burn surgery (e.g., autograft, allograft, xenograft); exposure to nasogastric tube, mechanical ventilation, urinary catheterization with Foley catheters; types and duration of vascular access, including intracardiac devices and central lines, chest tube; haemodialysis or continuous veno-venous hemofiltration; types and duration of intravenous antimicrobial therapy, electrolyte infusions, blood products, and parenteral nutrition; glucocorticoid therapy; patient's nutrition (prealbumin, diet, supplementary nutrition); procedures performed during

hospitalization (bronchoscopy, upper gastrointestinal endoscopy, cardiac catheterization, blood transfusion). The completion of data forms included in-depth interviews with patients, relatives, clinical care staff, and thorough examination of medical records.

### Personnel studies

Interaction of case- and control-patients with various BICU healthcare personnel were determined from the time of admission to the BICU to the first positive culture for case-patients and to the end of BICU stay for control-patients. We documented interaction of each BICU patient with healthcare workers, including nursing staff, physiotherapists and occupational therapists, case managers, radiologists, and radiology technicians, nutritionists, individuals from consultant teams (e.g., surgery, infectious disease, cardiology, pulmonary), medical students, residents, and attendings. Patient exposures to BICU personnel and ancillary staff were ascertained from the daily nursing assignment logs, and patient medical records. To assess whether the nurse-to-patient ratio in the BICU during the study period was a risk-factor in acquiring *A. baumannii* infection or colonization, time sheets were examined, and monthly nursing-hours/patient-day ratios were determined for the BICU.

### Clinical audit

We carried out reviews of the following in the BICU: housekeeping; hand hygiene adherence among nursing, medical and ancillary staff; infusion and medication preparation practices; practices and procedures of nutritional services. Furthermore, BICU personnel were interviewed about customary handwashing and infection control practices, patient care duties, and policies regarding prevention of transmission of multidrug-resistant pathogens in the BICU. To assess handwashing practices, a brief survey was administered to BICU personnel using a standardized questionnaire. During the investigation, the Infection Control Department and the Hospital Epidemiologist carried out multiple impromptu visits to the BICU to evaluate infection control practices and procedures and check compliance with hand hygiene and adherence to existing hospital policies.

### Microbiological investigations

We reviewed hospital epidemiology and microbiology line listings in the SafetySurveillor™ (Premier, Inc, Charlotte, North Carolina, USA) database, between 2010 and 2012. Multilocus sequence typing [MLST] of the isolates from case-patients was carried out. Based on preliminary analyses of epidemiologic data selected environmental cultures were obtained. The processing of cultures was carried out in the Clinical Microbiology Laboratory at UF Health Shands Hospital. Microbiologic identification and characterization were carried out using traditional culture and Gram stain) and the VITEK® 2 system (bioMérieux-Vitek). Automated mass spectrometry microbial identification using Matrix Assisted Laser Desorption Ionization Time-of-Flight (MALDI-TOF) was performed with VITEK® MS using the SARAMIS™ microorganism identification database with SuperSpectra™ and ReferenceSpectra algorithms. Out-break and non-outbreak strains were run in duplicate.

Multilocus sequence typing (MLST) was performed using the primer sets and sequence database at <http://pubmlst.org/abaumannii>.

### Statistical analysis

Raw data were first recorded on a standardized questionnaire, and then entered in an Excel spreadsheet. Data were prepared, and analysed using SAS statistical software (version 6.12, SAS Institute, Cary, NC, USA). Categorical variables were compared using the  $\chi^2$ -Square test or, when appropriate, Fisher's exact test. Medians of continuous variables were compared using the Wilcoxon two-sample test. Univariate analysis was carried out and odd ratios (OR) and 95% confidence intervals (CI) were calculated. To control for confounding variables and effect modification, we performed multivariate and logistic regression analyses: variables with a  $P$ -value  $\leq 0.05$  were included in a logistic regression model and the adjusted OR (AOR) calculated.

### Results

Preliminary analyses of BICU surveillance data revealed a statistically significant increase in the rate of *A. baumannii* infection in BICU patients from January 2011 through March 2012 (epidemic period) compared with the previous 12 months–2010 (pre-epidemic period).

### Case characteristics

Eleven patients met the case definition (the epidemic curve is shown in [Figure 1](#)). Case-patient characteristics were as follows: six (54%) were women and seven (64%) were Caucasian; median age was 39 (range: 28–58) years and median body mass index was 25.2 (range: 18.2–36.8) kg/m<sup>2</sup> ([Table I](#)). Four case-patients had been transferred from outside hospitals. The median time to the first positive culture for *A. baumannii* was 29 (range: 17–49) days. The median length of stay of case-patients in the BICU was 77 (range: 27–237) days. The percentage of body surface area that had burn injuries ranged from 23% to 92% with a median of 42%. Three case-patients died during their inpatient stay ([Table I](#)).

### Case-control study

Twenty-two control-patients were selected for a total of thirty-three study-patients. Control-patients were unmatched. Case- and control-patients were similar in sex, age, body mass index, APACHE scores on admission, underlying comorbidities, being transferred from another facility, receipt of antibiotics before hospitalization or admission to the BICU, type and duration of medical device usage, frequency of placement of intravascular devices, duration of antimicrobial therapy during BICU stay, type of nutrition and mode of administration, exposure to haemodialysis, receipt of infusates, plasma, or blood transfusions. The monthly nurse-to-patient ratio did not change during the pre-epidemic and epidemic periods.

In contrast, on univariate analysis ([Table II](#)), case-patients had a longer median duration of BICU stay (77 days vs. 16.5 days,  $P < 0.001$ ), to have an inhalational burn injury to the lungs ( $P < 0.05$ ), to have received dermal allograft ( $P < 0.015$ ), to have

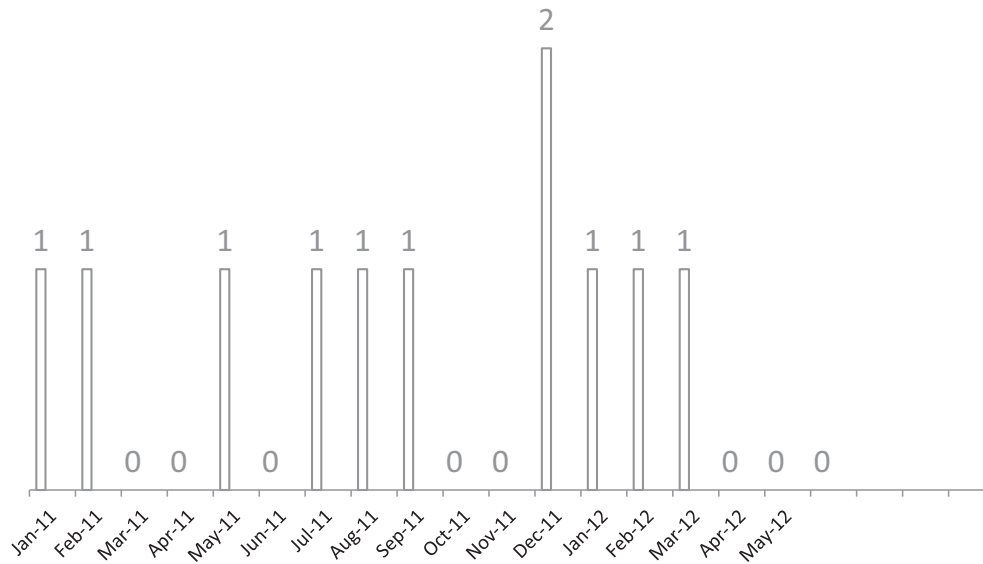


Figure 1. Epidemic Curve Number of cases by month: January 2011 through May 2012.

had a tunneled subclavian line placed in the BICU ( $P=0.05$ ), to be fitted with a Flexi-Seal™ device ( $P<0.01$ ), to have received a tracheostomy, or to be on a probiotic containing *Lactobacillus* ( $P<0.01$ ), treated with metronidazole ( $P<0.05$ ), or to have had an ultrasound scan in the BICU (10/11 vs 6/22,  $P=0.0007$ ). The median percentage body area burns for cases was 42% (range: 23%–92%) versus 18.8% (range: 2%–59%) for controls ( $P<0.001$ ). Persons with surface areas burns  $>30\%$  were significantly more likely to be a case (8/11 vs 6/22,  $P=0.013$ ).

On logistic regression analysis, having an ultrasound procedure in the BICU (AOR= 19.5; CI: 2.4–435;  $P=0.0006$ ) or having a Flexi-Seal™ device (a temporary containment device used for immobilized, incontinent patients with liquid or semi-liquid stool) (AOR=11.9; CI: 1.3–276;  $P=0.025$ ) were the two independent risk factors associated with case-patients (Table III).

### Clinical audit

Informal observation of infection control practices revealed that compliance and adherence to the CDC guidelines for

**Table I**  
Characteristic of case-patients, BICU, Shands Hospital

Case no.	Sex	Age	Time to first positive culture (days)	% TBSA* with burns	Outcome
1	M	40	43	28.5	-
2	M	33	17	30.5	-
3	F	42	31	92	Died
4	F	39	24	55	-
5	F	58	47	26	Died
6	F	28	19	65	Died
7	F	32	45	34	-
8	M	45	49	65	-
9	F	39	26	40	-
10	M	38	22	43	-
11	M	48	29	23	-

\*TBSA= total body surface area.

contact precautions and hand hygiene before patient contact were excellent and consistent. During our investigation, enhanced environmental cleaning in the BICU had been ongoing for at least 3 months and patients infected or colonized with *A. baumannii* and BICU nurses had already been cohorted, and work and sink areas were kept dry and disinfected.

### Microbiological investigations

Multilocus sequence typing [MLST] of the isolates from case-patients revealed a single genotype (type 208) of *A. baumannii* that was multi-drug resistant and accounted for infection in all case-patients. This was consistent with a common (point) source exposure and reflected in the profile of the epidemic curve.

Based on analyses of epidemiologic data that indicated significant association between being a case-patient and having an ultrasound procedure, cultures were obtained from the ultrasound carts, unopened probes, and ultrasound gel from an open jar that had been found on the ultrasound carts. In addition, selected environmental cultures were obtained from work surfaces surrounding case-patients' beds and bedrails, sink areas, moisture from ventilator tubing and reservoirs, hot and cold tap water in the individual rooms. BICU personnel had already carried out arbitrary culturing of work surfaces, door-knobs, desks and phones (none of these cultures had yielded *A. baumannii*). Environmental sampling of specific surfaces around case-patients (beds and bedrails, sink areas, moisture from ventilator tubing and reservoirs, hot and cold tap water, doorknobs) did not yield the outbreak strain of *A. baumannii*. Cultures of work surfaces and equipment found on mobile ultrasound trolleys, including ultrasound probes and transducers, and opened multiuse vials of ultrasound gel found on these trolleys were all negative for bacterial and fungal growth. However, culture of ultrasound gel from the supply container kept in a cupboard in the Ultrasound Department yielded growth of *A. baumannii* with strain typing profile (MLST 208) identical to the outbreak strain. Cultures of some gel containers was not possible as these had already been

**Table II**  
Comparison of case- and control-patients, BICU, Shands Hospital (Univariate analysis)

Categorical variable	Case-patients (N=11)	Control-patients (N=22)	Odds ratio (95% CI)	P-value
Allograft	8	6	7.1 (1.4–36.1)	0.013
Metronidazole	6	3	7.6 (1.4–41.6)	0.013
Flexi-Seal™	10	8	17.5 (1.9–163)	0.003
Inhalational burn injury	6	4	5.4 (1.1–27.0)	0.03
Probiotic	5	2	8.3 (1.3–54.0)	0.016
Tunnelled subclavian	7	5	6.0 (1.2–29.0)	0.02
Ultrasound scan	10	6	26.7 (2.8–255)	0.0007
Xenograft	1	15	0.05 (0.005–0.4)	0.05
<b>Continuous variables</b>				
Median age	39 (28–58) years	51.5 (17–82) years	–	0.06
Percent body surface area burns	42% (23–92%)	19% (2–59%)	–	0.0009

discarded by the time the epidemiologic analyses had identified having an ultrasound procedure as a risk factor for *A. baumannii* infection or colonization.

#### Evaluation of the role of ultrasound in transmission of *A. baumannii* in the BICU

Results from our case-control epidemiologic study identified having an ultrasound procedure in the BICU was unequivocally the single independent risk factor for infection or colonization with *A. baumannii*. For this reason, our investigation eventually focused on the practices and standard operating procedures for ultrasound procedures in the BICU. All case-patients had severe burns >30% body surface area and had undergone non-invasive ultrasound scans that involved passage of the probe across non-intact burnt skin areas. Before communicating the epidemiologic results of our investigation, we carried out impromptu observational studies of ultrasound procedures in the BICU. In addition, Ultrasound Department personnel were questioned about ultrasound use hospital-wide, and decontamination and disinfection of ultrasound probes. All observed ultrasound procedures were non-invasive and largely involved scans of the thorax and abdomen; none of the observed procedures involved ultrasound-guided intravascular device placement or biopsies. A special mobile trolley was used for transporting the ultrasound equipment to various wards and units. Personnel scrupulously adhered to CDC guidelines for standard, and contact precautions, where deemed appropriate, and attention to aseptic technique was most satisfactory. Sterile sheaths were used on the probes for all procedures observed in the BICU. After individual use, probes were sent for high-level disinfection processing per hospital policy. The single variance ascertained was the practice of filling multiuse vials with coupling gel from a dispenser that was kept in a cupboard in the Ultrasound Department; usage of

single-use gel vials was not the norm. Mobile carts that housed the portable equipment had one or more multiuse bottles that had been filled in the Ultrasound Department and obviously had been used for multiple patients in the BICU and perhaps hospital-wide. Although we did not identify any break in infection control practices and procedures, more ultrasound procedures were carried out during the period from December 2011 through March 2012 than the previous nine months. However, no ultrasound personnel were found to be associated with case-patients in the analytic epidemiologic component of our investigation and therefore could not be implicated directly in the chain of *A. baumannii* transmission.

## Discussion

Our investigation provides epidemiologic evidence that patients with severe burns in our BICU, who also underwent an ultrasound procedure, were more likely to acquire infection with a single strain of *A. baumannii*. Moreover, the outbreak pathogen was isolated only from a central dispenser that was stored in a cupboard in the Ultrasound Department and used to refill multiuse vials of ultrasound gel. Use of a Flexi-Seal™ device was the other independent risk factor associated with case-patients. Presence of this device was likely a surrogate marker for severity of illness rather than a risk factor for direct *A. baumannii* infection.

Based on the data from our epidemiologic, microbiologic, and observational studies, we hypothesize that inadvertent extrinsic contamination of the central gel dispenser occurred in the Ultrasound Department due to a lapse in aseptic technique or infection control procedure. Contaminated gel would have been dispensed into the multiuse vials, which would then be stored on the mobile carts used for ultrasound equipment leading to BICU patient exposure whenever an ultrasound procedure was carried out. Several factors support this assertion: a) only burn patients in the BICU were affected; b) exposure to ultrasound equipment or gel were the only common factors associated with case-patients; c) intrinsic contamination of multiuse gel vials should have resulted in more widespread *A. baumannii* infections in other hospital areas (there were no other occurrences of epidemic strain infections in other hospital areas or units); d) the overall homogeneity of the outbreak *A. baumannii* strains found on molecular typing suggested a common source; e) sterile sheaths were used on

**Table III**  
Independent risk factors for *Acinetobacter baumannii* infection, BICU, Shands Hospital following multivariate analysis using logistic regression

	Adjusted Odds Ratio	Confidence Interval	P-value
Ultrasound scan	19.5	2.4–435	0.0006
Flexi-Seal® device	11.9	1.3–276	0.025

ultrasound probes during each patient encounter; thus exposure to the outbreak pathogen would more likely have originated in the gel vial versus probe contamination; f) no individuals in the Ultrasound Department were found to be epidemiologically linked with direct contact transmission of the outbreak pathogen to case-patients; g) there were no new episodes of infections with the epidemic strain in the BICU after replacing the central dispenser system and multiuse gel vials with single-use gel vials and instituting an educational module that stressed the importance of compliance with isolation and cleaning and disinfection of high touch areas on ultrasound mobile trolleys and adherence to aseptic technique during all patient encounters.

The pathogenesis of *A. baumannii* infections that occurred in case-patients is almost certainly linked to the chain of transmission from contaminated ultrasound coupling gel to non-intact burnt skin in case-patients. The combination of high-level disinfection and a sterile covering sheath rendered the probe itself less likely to be the source of the outbreak pathogen. There is a myriad of published outbreak investigations in which ultrasound played a role in the transmission of an outbreak pathogen; in most of these outbreaks, the critical instruments were largely those that penetrated skin or mucous membranes (e.g., prostate biopsies) or used for internal gynaecological examination. These types of procedures require sterilized probes. In less critical settings where the ultrasound probe meets mucous membranes (e.g., transoesophageal echocardiograms; upper or lower fibreoptic gastrointestinal endoscopy), high-level disinfection of probes or transducers is the norm. External probes that only encounter clean, intact skin are considered noncritical devices and require cleaning with low level disinfectant [12]. There are relatively fewer publications in which ultrasound coupling gel plays an essential role in the chain of transmission [13–27]. But even in these outbreaks, invasive procedures (e.g., transrectal biopsies, intraoperative transoesophageal echocardiography or insertion of intravascular devices) played key roles in the chain of transmission.

In two outbreaks, *Burkholderia cepacia* complex bacteraemia was attributed to contaminated sterile gel used for central line insertion under ultrasound guidance [13,15]. And in 2011, an outbreak of *Pseudomonas aeruginosa* respiratory tract infections carried out by the Department of Epidemiology at Beaumont Health System (BHS) in Michigan found an association with use of ultrasound gel from a single manufacturer during transoesophageal echocardiography. The chain of transmission was linked to ultrasound gel in multiuse bottles. This outbreak was controlled after multiuse bottles were removed from BHS facilities and replaced with a single-use product [25].

Because of the increased infection risk, outbreaks, and death associated with improper infection prevention in ultrasound procedures, Carrico and colleagues recently published the results of an anonymous national survey among U.S. infection preventionists regarding ultrasound probe use and reprocessing in the United States [14]. The results of their survey are disturbing and include the following findings: (a) there is a high degree of noncompliance with U.S. guidelines; (b) surface ultrasound probes used in invasive procedures often did not undergo high-level disinfection or sterilization where

deemed appropriate; (c) surface probes were not high-level disinfected or sterilized 15% and 78% of the time for invasive procedures and peripheral line placements, respectively; moreover, 5% and 47% did not use sterile gel for the same procedures, respectively.

Our investigation had a few limitations: First, by the time our investigation established a significant association between case-patient and having an ultrasound procedure, most of the opened multiuse containers of coupling gel that were in use during the hospitalization of case-patients in the BICU had already been discarded. Thus, it remains unknown how many multiuse coupling gel containers might have been contaminated with the outbreak pathogen. Second, we were not able to establish how the outbreak pathogen was introduced into the central dispenser in the Ultrasound Department or at what time coupling gel vials carried on the portable trolleys became contaminated. We believe that a limited number of multiuse containers might have been contaminated; this would explain the intermittent nature of exposure to the outbreak pathogen, underscored by the irregular pattern of the epidemic curve (Figure 1). Third, we were not able to ascertain the risks associated with colonization among BICU patients before hospital admission. Although this investigation was carried out in 2012, the findings of the recent national survey on ultrasound probe use and reprocessing, carried out by Carrico *et al.* and addressed earlier in this paper, render our findings even more relevant to patient safety in 2019 [14]. Indeed, it is now well recognized that *Acinetobacter* species are widely distributed in the environment and may be common commensals in humans with rates of skin colonization between 25 to 40% for healthy ambulatory individuals and up to 75% for hospitalized patients [1,4,28,29].

This investigation employed a classic, stepwise process in conducting an outbreak investigation in a tertiary healthcare facility. First, we confirmed the existence of an outbreak. This was followed by the following steps: creation of a case definition that reflected person, time, and place; case ascertainment and establishment of a line listing and an epidemic curve for preliminary analyses; development of a detailed questionnaire and conduct of analytic epidemiologic studies; appropriate microbiologic sampling and audits that were directed by the epidemiologic data; development of a hypothesis to explain the possible chain of transmission; drawing conclusions and inferences from the findings of the investigation; and finally, communication and explanation of all the findings to BICU personnel with recommendations for appropriate control and preventive measures and continuation of post-outbreak surveillance for new cases.

This investigation is a good example of how analytic epidemiologic studies can be integrated with strain typing to characterize an outbreak. There are basically two different approaches to the investigation of healthcare-associated outbreaks: (a) the conduct of extensive culture surveys to identify the source of the outbreak; or (b) conduct of an epidemiologic investigation with subsequent epidemiologically-directed environmental or personnel cultures (i.e., epidemiologic investigation with laboratory confirmation) [30]. Initial culture surveys of personnel or the environment without epidemiologic linkage is expensive, a waste of resources, and may lead to treatment or interventions that are inappropriate or way off

**Table IV**

Summary of strategies instituted by the Ultrasound Department and the Burn Intensive Care Unit to prevent transmission of *Acinetobacter baumannii*

1. Changes in practices in the Ultrasound Department, including discontinuation of the practice of dispensing coupling ultrasound gel from a centrally stored container; discontinuation of use of multiuse ultrasound gel vials; and regular cleaning of equipment and trolleys with a high-level disinfectant.
2. Modification of infection control policy to stipulate single-use coupling gel vials and sterile probe/transducer covers in the BICU.
3. Continuation of surveillance cultures from all BICU patients.
4. Presentation of educational modules developed by the Infection Control Department that stressed the importance of compliance with isolation and cleaning and disinfection of high-touch areas. BICU staff attendance to in-service presentations was deemed mandatory by BICU Leadership.

course [30]. Moreover, a positive culture without epidemiologic linkage might merely reflect colonization before, during, or after the outbreak without the individual being part of the chain of transmission. Also, use of culturing and molecular typing on their own often can lead to uninterpretable results [30]. Our investigation highlights how appropriate and sensible use of molecular typing integrated with the findings of an analytic epidemiologic investigation are essential to the characterization of the chain of transmission of an outbreak pathogen.

In summary, extrinsically contaminated ultrasound coupling gel in a central dispenser in an Ultrasound Department led to an outbreak of multidrug-resistant *A. baumannii* infection in a BICU. The outbreak was controlled by replacing multiuse gel vials with single-use sterile gel vials (Table IV). If a patient known to be colonized with a multi-drug-resistant microorganism on a burn unit needs to have non-invasive ultrasound scan, the ultrasound operator must maintain strict contact precautions, and scrupulous attention and adherence to aseptic technique and hand hygiene. Probes or transducers (considered semicritical instruments) that meet mucous non-intact or burned skin require high-level disinfection at a minimum and should be used only after covered with a single-use sterile probe sheath [12,31]. With the expansion of ultrasound services in US hospitals documented by Carrico and colleagues [14], the onus is now on healthcare personnel, including administrators, infection preventionists, and ultrasound department managers to review and update policies and guidelines for the maintenance of ultrasound machines, proper use and reprocessing of ultrasound probes, and to ensure single-use gel vials is the rule for all external ultrasound procedures.

### Conflict of interest statement

None of the authors have any conflict of interest.

### Acknowledgements

We are indebted to the Infection Control Department at Shands Hospital, especially Ms. Amanda Aspilcueta, Mr. Robert Kelly, Mrs. Maryanne Gross, and Ms. Charlene Ruse (the latter two persons have now retired); and to Dr. Kenneth Rand, Director of the Clinical Microbiology Laboratory for carrying out molecular typing of outbreak isolates. Finally, we are grateful to the patients and medical and nursing staff for facilitating the conduct of this investigation.

### References

- [1] Fournier PE, Richet H. The epidemiology and control of *Acinetobacter baumannii* in health care facilities. *Clin Infect Dis* 2006;42(5):692–9.
- [2] Lee CR, Lee JH, Park M, Park KS, Bae IK, Kim YB, et al. Biology of *Acinetobacter baumannii*: Pathogenesis, Antibiotic Resistance Mechanisms, and Prospective Treatment Options. *Front Cell Infect Microbiol* 2017;7:55.
- [3] Peleg AY, Seifert H, Paterson DL. *Acinetobacter baumannii*: emergence of a successful pathogen. *Clin Microbiol Rev* 2008;21(3):538–82.
- [4] Abbo A, Navon-Venezia S, Hammer-Muntz O, Krichali T, Siegmán-Igra Y, Carmeli Y. Multidrug-resistant *Acinetobacter baumannii*. *Emerg Infect Dis* 2005;11(1):22–9.
- [5] Garnacho-Montero J, Amaya-Villar R. *Multiresistant Acinetobacter baumannii* infections: epidemiology and management. *Curr Opin Infect Dis* 2010;23(4):332–9.
- [6] Girerd-Genessay I, Benet T, Vanhems P. Multidrug-Resistant Bacterial Outbreaks in Burn Units: A Synthesis of the Literature According to the ORION Statement. *J Burn Care Res* 2016;37(3):172–80.
- [7] Marchaim D, Navon-Venezia S, Schwartz D, Tarabeia J, Fefer I, Schwaber MJ, et al. Surveillance cultures and duration of carriage of multidrug-resistant *Acinetobacter baumannii*. *J Clin Microbiol* 2007;45(5):1551–5.
- [8] Munier AL, Biard L, Legrand M, Rousseau C, Lafaurie M, Donay JL, et al. Incidence, risk factors and outcome of multi-drug resistant *Acinetobacter baumannii* nosocomial infections during an outbreak in a burn unit. *Int J Infect Dis* 2019;79:179–84.
- [9] Sehulster L, Chinn RY. Guidelines for environmental infection control in health-care facilities. Recommendations of CDC and the Healthcare Infection Control Practices Advisory Committee (HICPAC). *MMWR Recomm Rep* 2003;52(RR-10):1–42.
- [10] Siegel JD, Rhinehart E, Jackson M, Chiarello L. Guideline for Isolation Precautions: Preventing Transmission of Infectious Agents in Health Care Settings. *Am J Infect Control* 2007 2007;35(10 Suppl 2):S65–164.
- [11] Siegel JD, Rhinehart E, Jackson M, Chiarello L. Management of multidrug-resistant organisms in health care settings. *Am J Infect Control* 2007 2006;35(10 Suppl 2):S165–93.
- [12] Rutala WA, Weber DJ. Sterilization, high-level disinfection, and environmental cleaning. *Infect Dis Clin North Am* 2011;25(1):45–76.
- [13] Abdelfattah R, Al-Jumaah S, Al-Qahtani A, Al-Thawadi S, Barron I, Al-Mofada S. Outbreak of *Burkholderia cepacia* bacteraemia in a tertiary care centre due to contaminated ultrasound probe gel. *J Hosp Infect* 2018;98(3):289–94.
- [14] Carrico RM, Furmanek S, English C. Ultrasound probe use and reprocessing: Results from a national survey among U.S. infection preventionists. *Am J Infect Control* 2018;46(8):913–20.
- [15] Shaban RZ, Maloney S, Gerrard J, Collignon P, Macbeth D, Cruickshank M, et al. Outbreak of health care-associated

- Burkholderia cenocepacia* bacteremia and infection attributed to contaminated sterile gel used for central line insertion under ultrasound guidance and other procedures. *Am J Infect Control* 2017;45(9):954–8.
- [16] Yamunadevi VR, Ramasubramanian V, Senthur Nambi P, Samundewari P, Ramakrishnan N. Outbreak of *Burkholderia cepacia* bacteraemia in a tertiary care centre due to contaminated ultrasound probe gel. *J Hosp Infect* 2018;100(4):e257–8.
- [17] Scott D, Fletcher E, Kane H, Malcolm W, Kavanagh K, Banks AL, et al. Risk of infection following semi-invasive ultrasound procedures in Scotland, 2010 to 2016: A retrospective cohort study using linked national datasets. *Ultrasound* 2018;26(3):168–77.
- [18] Cheng A, Sheng WH, Huang YC, Sun HY, Tsai YT, Chen ML, et al. Prolonged postprocedural outbreak of *Mycobacterium massiliense* infections associated with ultrasound transmission gel. *Clin Microbiol Infect* 2016;22(4). 382.e1–.e11.
- [19] Chittick P, Russo V, Sims M, Robinson-Dunn B, Oleszkowicz S, Sawarynski K, et al. An outbreak of *Pseudomonas aeruginosa* respiratory tract infections associated with intrinsically contaminated ultrasound transmission gel. *Infect Control Hosp Epidemiol* 2013;34(8):850–3.
- [20] Gillespie JL, Arnold KE, Noble-Wang J, Jensen B, Arduino M, Hageman J, et al. Outbreak of *Pseudomonas aeruginosa* infections after transrectal ultrasound-guided prostate biopsy. *Urology* 2007;69(5):912–4.
- [21] Hutchinson J, Runge W, Mulvey M, Norris G, Yetman M, Valkova N, et al. *Burkholderia cepacia* infections associated with intrinsically contaminated ultrasound gel: the role of microbial degradation of parabens. *Infect Control Hosp Epidemiol* 2004;25(4):291–6.
- [22] Jacobson M, Wray R, Kovach D, Henry D, Speert D, Matlow A. Sustained endemicity of *Burkholderia cepacia* complex in a pediatric institution, associated with contaminated ultrasound gel. *Infect Control Hosp Epidemiol* 2006;27(4):362–6.
- [23] Nannini EC, Ponessa A, Muratori R, Marchiaro P, Ballerini V, Flynn L, et al. Polyclonal outbreak of bacteremia caused by *Burkholderia cepacia* complex and the presumptive role of ultrasound gel. *Braz J Infect Dis* 2015;19(5):543–5.
- [24] Olshtain-Pops K, Block C, Temper V, Hidalgo-Grass C, Gross I, Moses AE, et al. An outbreak of *Achromobacter xylosoxidans* associated with ultrasound gel used during transrectal ultrasound guided prostate biopsy. *J Urol* 2011;185(1):144–7.
- [25] Centers for Disease Control and Prevention. *Pseudomonas aeruginosa* respiratory tract infections associated with contaminated ultrasound gel used for transesophageal echocardiography - Michigan, December 2011-January 2012. *MMWR Morb Mortal Wkly Rep* 2012;262–4.
- [26] Weist K, Wendt C, Petersen LR, Versmold H, Ruden H. An outbreak of pyodermas among neonates caused by ultrasound gel contaminated with methicillin-susceptible *Staphylococcus aureus*. *Infect Control Hosp Epidemiol* 2000;21(12):761–4.
- [27] Gaillot O, Maruejols C, Abachin E, Lecuru F, Arlet G, Simonet M, et al. Nosocomial outbreak of *Klebsiella pneumoniae* producing SHV-5 extended-spectrum beta-lactamase, originating from a contaminated ultrasonography coupling gel. *J Clin Microbiol* 1998;36(5):1357–60.
- [28] Berlau J, Aucken H, Malnick H, Pitt T. Distribution of *Acinetobacter* species on skin of healthy humans. *Eur J Clin Microbiol Infect Dis* 1999;18(3):179–83.
- [29] Gauzere C, Godon JJ, Blanquart H, Ferreira S, Moularat S, Robine E, et al. Core species' in three sources of indoor air belonging to the human micro-environment to the exclusion of outdoor air. *Sci Total Environ* 2014;485–486:508–17.
- [30] Jarvis WR. Usefulness of molecular epidemiology for outbreak investigations. *Infect Control Hosp Epidemiol* 1994;15(7):500–3.
- [31] Rutala WA, Weber DJ. Reprocessing semicritical items: Current issues and new technologies. *Am J Infect Control* 2016;44(5 Suppl):e53–62.