An Outbreak of Multidrug-Resistant Acinetobacter baumannii Associated With Pulsatile Lavage Wound Treatment

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Multidrug-resistant Acinetobacter baumannii (MDR-Ab) has emerged worldwide as an important health care–associated pathogen, causing infections such as ventilator-associated pneumonia, bloodstream infections, and wound infections.1-4 The organism can survive on environmental surfaces for months, making nosocomial transmission extremely difficult to prevent and control.5-7 Many Acinetobacter isolates demonstrate extensive resistance to antimicrobial agents, including carbapenems, which greatly complicates treatment of these infections.3,7,8 Previously reported outbreaks of MDR-Ab have frequently been associated with respiratory care equipment and water sources such as humidifiers.5,0,12

In October 2003, the Department of Hospital Epidemiology and Infection Control at Johns Hopkins Hospital became aware of a cluster of 5 patients infected or colonized with MDR-Ab. The

Context Pulsatile lavage is a high-pressure irrigation treatment used increasingly in a variety of health care settings to debride wounds. Infection control precautions are not routinely used during the procedure and are not included in pulsatile lavage equipment package labeling.

Objectives To investigate an outbreak of multidrug-resistant Acinetobacter baumannii and to test the hypothesis that pulsatile lavage wound treatment was the mode of transmission for the organism.

Design Outbreak case-control investigation including case identification, review of medical records, environmental cultures, and pulsed-field gel electrophoresis.

Setting A 1000-bed tertiary care hospital in Baltimore, Md, during September and October 2003.

Patients The investigation included 11 patients infected or colonized with multidrug-resistant A baumannii. Seven of these patients met the case definition for the case-control study and were compared with 28 controls randomly selected from a list of inpatients without multidrug-resistant A baumannii who had a wound care consultation.

Main Outcome Measure Infection or colonization with multidrug-resistant A baumannii.

Results Eleven patients had cultures that grew multidrug-resistant A baumannii during the outbreak period. Of the 10 health care–associated cases, 8 had received pulsatile lavage treatment. One strain of multidrug-resistant A baumannii was recovered from all 6 pulsatile lavage patients who had isolates available for pulsed-field gel electrophoresis analysis and from multiple surfaces in the wound care area. Six of 7 cases (86%) were treated with pulsatile lavage vs 4 of 28 controls (14%) (odds ratio, 36; 95% confidence interval, 2.8-1721; P<.001). These results confirm that pulsatile lavage was a significant risk factor for acquisition of multidrug-resistant A baumannii.

Conclusions Transmission was apparently caused by dissemination of multidrug-resistant A baumannii during the pulsatile lavage procedure, resulting in environmental contamination. Appropriate infection control precautions should be used during pulsatile lavage therapy and should be included in pulsatile lavage equipment labeling.
number of cases of MDR-Ab was approximately 5 times the usual rate (FIGURE 1) and the isolates were particularly resistant, susceptible only to colistin. The patients had different primary diagnoses and were located in various units throughout the hospital. Four of the 5 original cluster patients had wounds and 3 had received pulsatile lavage therapy, a water-based, high-pressure irrigation treatment with concurrent suction used for cleansing and debridement of wounds.13 The technique originated in the 1960s for use in the operating room and is now performed widely in hospitals, rehabilitation centers, outpatient clinics, and long-term care facilities. This is the first report of a nosocomial outbreak related to pulsatile lavage treatment.

METHODS
Setting
The Johns Hopkins Hospital is a 1000-bed tertiary care hospital in Baltimore, Md. Prior to this outbreak, physical therapists performed wound care, including pulsatile lavage, for inpatients and outpatients in a single procedure room. The room was a large, open area with 3 whirlpools, 1 sink, and 2 stretchers. It contained curtains for patient privacy, wound care carts, and open supply shelves. There was minimal ventilation and high humidity.

Pulsatile Lavage Procedure
Pulsatile lavage treatment is used to debride wounds of devitalized tissue and debris. Pulsatile lavage devices are class 2 devices, which are exempt from premarket notification or approval by the US Food and Drug Administration (FDA). A battery-powered device that resembles a water gun is used to deliver pressurized sterile saline to the wound. A small shield at the tip of the device is placed in contact with the wound bed so that suction is created and splash is minimized. Tubing connects the device to irrigation fluid and to a suction pump. The water gun, splash shield, and tubing are for single use and are disposable. In 2003, 2947 pulsatile lavage procedures were performed at Johns Hopkins Hospital.

Epidemiologic Investigation
Microbiology records were reviewed to identify cases and to define the baseline rate of MDR-Ab prior to the outbreak. A case was defined as any patient infected or colonized with MDR-Ab susceptible to no more than 1 class of antimicrobial agents, excluding colistin. The baseline rate of MDR-Ab for the 4 years prior to the outbreak was a mean of 2 cases per quarter (range, 0-4). There were only 2 cases of MDR-Ab between January 2003 and the beginning of the outbreak in September 2003 (Figure 1). Medical records were reviewed, including paper and electronic charts, the microbiology database, and physical therapy wound care records. The pulsatile lavage procedure was observed and multiple surfaces in the wound care room were cultured. Given prior reports of MDR-Ab outbreaks associated with mechanical ventilation, respiratory care records were also reviewed and respiratory care equipment was cultured.

Surveillance
After identifying pulsatile lavage therapy as a potential risk factor for transmission of MDR-Ab, certified letters were sent to all 58 patients who received pulsatile lavage or whirlpool therapy in the wound care room from September 1 through October 31, 2003. Patients were asked to return for a surveillance wound culture. For patients who did not reply to the certified letter, at least 2 attempts were made to contact them by telephone.

Microbiologic Methods
Clinical cultures were performed using standard practices on routine media. Susceptibility testing was performed by the agar dilution method. Environmental samples were cultured on brain-heart infusion plates supplemented with 5% sheep blood and gentamicin at a concentration of 10 µg/mL. Pulsed-field gel electrophoresis (PFGE) (Bio-Rad Gen Path, Hercules, Calif) was performed on all available isolates. DNA was digested with Smal and gels were analyzed with Molecular Analyst Fingerprinting Plus software (Bio-Rad, Hercules). Isolates were considered genetically related if their PFGE patterns differed by 3 or fewer bands.14

Case-Control Study
We conducted a case-control study to assess risk factors for acquisition of the outbreak strain of MDR-Ab in our institution. The case definition was any patient who had the outbreak strain or unidentified strain of MDR-Ab in a clinical culture taken at least 48 hours after admission, during an inpatient hospitalization between September 1 and October 31, 2003. This study definition did not include patients with strains other than the outbreak strain by PFGE or patients admitted to our institution already harboring MDR-Ab. Patients whose MDR-Ab was detected by surveillance culture during the epidemiologic investigation were not included to avoid biasing the study toward pulsatile lavage as a risk factor. Controls were randomly selected from the list of inpatients without MDR-Ab who were seen for wound care consultation during the outbreak period. The ratio of controls to cases was 4 to 1. All controls had wounds and at least 1 clinical culture of urine, sputum, wound, or...
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Table 1. Case Summaries of 11 Patients Infected or Colonized With MDR-Ab Between September 1 and October 31, 2003

<table>
<thead>
<tr>
<th>Patient No./Sex/Age, y</th>
<th>Primary Diagnosis/Procedure</th>
<th>Infected/Colonized</th>
<th>Health Care Associated</th>
<th>Pulsatile Lavage</th>
<th>Mechanical Ventilation</th>
<th>MDR-Ab Culture Sites</th>
<th>MDR-Ab Strain†</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/M/46§</td>
<td>Solid organ transplant</td>
<td>Infected</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Blood, sputum, wound</td>
<td>A</td>
</tr>
<tr>
<td>2/F/79</td>
<td>CABG</td>
<td>Infected</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Wound</td>
<td>A</td>
</tr>
<tr>
<td>3/M/59§</td>
<td>DM, ESRD</td>
<td>Infected</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Blood, sputum, wound</td>
<td>A</td>
</tr>
<tr>
<td>4/M/74</td>
<td>Sarcoma resection</td>
<td>Infected</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Wound</td>
<td>B</td>
</tr>
<tr>
<td>5/M/71</td>
<td>Stroke</td>
<td>Colonized</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Sputum</td>
<td>C</td>
</tr>
<tr>
<td>6/F/25][[</td>
<td>Paraplegia</td>
<td>Infected</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Urine</td>
<td>A</td>
</tr>
<tr>
<td>7/F/53</td>
<td>Abdominal hernia</td>
<td>Infected</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Wound</td>
<td>A</td>
</tr>
<tr>
<td>8/M/63§</td>
<td>DM, ESRD</td>
<td>Infected</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Blood, sputum, wound</td>
<td>A</td>
</tr>
<tr>
<td>9/M/57‡</td>
<td>HIV</td>
<td>Infected</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Wound</td>
<td>A</td>
</tr>
<tr>
<td>10/F/83‡</td>
<td>CABG</td>
<td>Infected</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Wound</td>
<td>NA</td>
</tr>
<tr>
<td>11/M/24</td>
<td>Paraplegia</td>
<td>Infected</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Urine</td>
<td>NA</td>
</tr>
</tbody>
</table>

Abbreviations: CABG, coronary artery bypass graft surgery; DM, diabetes mellitus; ESRD, end-stage renal disease; HIV, human immunodeficiency virus; MDR-Ab, multidrug-resistant Acinetobacter baumannii; NA, isolate not available for analysis.
*Mechanical ventilation during the period September 1, 2003, to the date of the patient’s first culture that grew MDR-Ab.
†Strain A was the outbreak strain.
‡Patients who met case definition.
§Patients receiving hemodialysis.
||Patients who were in nursing homes.

Figure 2. Outbreak Timeline Showing 11 Case Patients’ Pulsatile Lavage Treatments and Cultures That Grew MDR-Ab

This timeline depicts the 11 patients identified as infected with multidrug-resistant Acinetobacter baumannii (MDR-Ab) at Johns Hopkins Hospital during September and October 2003. Eight of the 11 patients had pulsatile lavage therapy, as indicated by the bars. Circles denote cultures that grew MDR-Ab. During the outbreak investigation, it was discovered retrospectively that patient 11 had a urine culture that grew MDR-Ab in July 2003. This isolate was not available for pulsed-field gel electrophoresis analysis.

Multivariate logistic regression was not performed because of small sample size. All statistical analyses were performed with Stata software, version 7 (Stata Corp, College Station, Tex).

RESULTS
Epidemiologic Investigation
A total of 11 case patients infected or colonized with MDR-Ab were identified between September 1 and October 31, 2003 (TABLE 1 and FIGURE 2). This includes the 5 original cluster patients and 6 other patients who were identified during the outbreak investigation. The patients had different primary diagnoses and were located in various units throughout the hospital. Isolates of MDR-Ab were found in blood, sputum, urine, and wounds. All MDR-Ab isolates were susceptible to colistin but were otherwise either completely resistant or showed only intermediate susceptibility to amikacin. The mean age of case patients was 59 years (range, 24-83 years). One patient was culture-positive for MDR-Ab on admission, but this strain of MDR-Ab was unrelated to the outbreak strain by PFGE. Of the 10 patients who acquired the organism in the hospital, all had wounds and 8 had received pulsatile lavage treatment. Thirty-one (53%) of 58 wound care patients returned for surveillance cultures and 1 patient (2%)
had MDR-Ab grown from the surveillance culture.

Eight of the case patients had wound infections and 3 had both bloodstream infections and pneumonia. Three patients required admission to the intensive care unit for sepsis and respiratory distress, and 2 patient deaths were possibly related to their infections.

Isolates were available from 6 of the case patients who had undergone pulsatile lavage treatment and from 3 case patients who did not have pulsatile lavage. Pulsed-field gel electrophoresis of the isolates from all 6 patients who received pulsatile lavage demonstrated 1 identical strain of MDR-Ab that was distinct from isolates obtained from 2 patients who did not have pulsatile lavage (Figure 3). One patient who did not receive pulsatile lavage had the outbreak strain of MDR-Ab in her urine. No risk factor for transmission was identified for this patient. The disposable pulsatile lavage gun and suction canister insert grew the outbreak strain of MDR-Ab after being used to treat 1 of the case patients at the time of the outbreak investigation. Environmental cultures from a cleaned stretcher, the sink, and a supply shelf above the treatment area all grew the outbreak strain of MDR-Ab, as confirmed by PFGE (Figure 3).

Investigation revealed that a change in pulsatile lavage procedure had occurred approximately 2 months prior to the cluster of cases that brought the outbreak to our attention. As a cost-saving measure, the disposable suction canister inserts that were previously discarded after each patient was treated were changed once a day or when full.

**Case-Control Study**

Seven patients met the case definition of the case-control study. Of the 4 patients who did not meet the definition, 1 grew MDR-Ab within 48 hours of admission, 1 was detected by surveillance culture, and 2 had MDR-Ab strains different from the outbreak strain. The cases and controls were similar with respect to age, race, sex, smoking status, McCabe disease severity score, and mean number of cultures performed (Table 2). The mean number of hospital days was greater for the patients with MDR-Ab than for the controls (50 days vs 33 days); the difference was not statistically significant. Univariate analysis confirmed that pulsatile lavage was a significant risk factor for acquisition of MDR-Ab. Six (86%) of 7 cases vs 4 (14%) of 28 controls were treated with pulsatile lavage (OR, 36; 95% CI, 2.8-1721; P<.001). Prior residence in a nursing home was also a significant risk factor. Four (57%) of 7 cases vs 1 (4%) of 28 controls resided in a long-term care facility in the 6 months prior to admission (OR, 36; 95% CI, 2.2-1833;
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P = .003). Three (43%) of 7 cases vs 3 (11%) of 28 controls received hemodialysis, which approached but did not achieve statistical significance (OR, 6.3; 95% CI, 0.9-42.5; P = .08). All other variables tested, including mechanical ventilation and administration of antimicrobial agents, were not significantly different between case and control patients (Table 2).

Termination of the Outbreak

All pulsatile lavage treatment was stopped on October 24, 2003. The outbreak was halted by aggressive infection control measures, including temporary closure of the wound care treatment room, thorough cleaning and disinfection of environmental surfaces, strict isolation of infected and colonized patients, and termination of pulsatile lavage wound care until renovation of the wound care area and procedural changes occurred. When pulsatile lavage resumed on November 18, treatments occurred in newly constructed private rooms and patients known to be colonized or infected with MDR-Ab were scheduled at the end of the day whenever possible. After these interventions, MDR-Ab cases remained slightly elevated in the final months of 2003; however, no further cases of the outbreak strain were detected. Follow-up environmental cultures of surfaces in the new private rooms constructed for pulsatile lavage treatment have been performed monthly for 11 months and none has grown MDR-Ab.

COMMENT

This report describes the first recognized nosocomial outbreak associated with pulsatile lavage wound care and identifies a novel mode of transmission for A baumannii. Six (13%) of 46 patients treated with pulsatile lavage during the outbreak period were infected or colonized with a single strain of MDR-Ab that was also cultured from multiple environmental surfaces in the wound care room. Only 1 patient acquired the outbreak strain of MDR-Ab without known exposure to pulsatile lavage treatment. The attributable risk of acquisition of MDR-Ab in patients receiving pulsatile lavage therapy was approximately 12.4%. Prior to the outbreak, the manufacturer of our pulsatile lavage equipment did not include any infection control information in its product insert. Based on our findings in this outbreak, 1 equipment manufacturer added information on infection control measures to the product insert. However, other manufacturers of pulsatile lavage equipment are not currently required to include infection control information with their product.

The extensive resistance of the organism and the severity of the patient outcomes make this outbreak significant, though it involved a small number of patients. Three case patients required admission to the intensive care unit for sepsis, and MDR-Ab infections possibly contributed to 2 deaths.

Our outbreak investigation identified a common procedure as a previously unrecognized means for transmission of a multidrug-resistant nosocomial pathogen. Although MDR-Ab was responsible for this outbreak, it is reasonable to hypothesize that other aquaphilic organisms such as Pseudomonas might be spread by this means.

The case-control study confirmed that pulsatile lavage was a significant risk factor for acquisition of MDR-Ab. The results must be interpreted with caution given the small sample size and wide 95% CIs. Case-control studies can demonstrate an association between factors such as pulsatile lavage therapy and acquisition of MDR-Ab but cannot lead to conclusions regarding causality. When taken with the results of the epidemiologic investigation, however, these data suggest a strong association between pulsatile lavage wound care and the acquisition of MDR-Ab in this outbreak.

The association of pulsatile lavage with this outbreak highlights the need for appropriate infection control measures when using this method of wound care. We hypothesize that MDR-Ab was disseminated during the pulsatile lavage treatments leading to contamination of the surrounding environmental surfaces. Two of the case patients in this outbreak presented with MDR-Ab pneumonia and sepsis, suggesting an inhalational route of exposure. The change in procedure allowing suction canister inserts to fill before replacing them may have played a role in transmission of the organism. It is likely that multiple factors contributed to the development of this outbreak, including simultaneous treatment of patients on adjacent stretchers, open supply shelves that make cleaning and disinfection difficult, and high room humidity from the whirlpools. The outbreak strain of MDR-Ab may have been introduced into this environment by one of the case patients or, possibly, by an unidentified patient.

Manufacturers of pulsatile lavage equipment note that proper technique requires close proximity of the device’s suction tip with the wound bed at all times. Practically speaking, however, uneven wound contour, momentary breaches in technique, or patients pulling away from the device will certainly lead to the chance for splash and environmental contamination during these procedures. Aerosolization during pulsatile lavage treatment was previously reported in a study in which organisms from wounds were recovered by air samplers at 3 ft and 8 ft from patients during the procedure. In addition, 2 recent published reports recognize that there is often splash during pulsatile lavage treatment and describe barrier precautions to reduce it.

Our findings emphasize that pulsatile lavage treatment must be performed under controlled circumstances with appropriate infection control measures in place. The Centers for Disease Control and Prevention (CDC) now recommend that health care workers performing pulsatile lavage procedures use appropriate infection control procedures to minimize aerosols and protect themselves and their patients from potentially infectious materials. Because of the risks of splash, health care workers performing pulsatile lavage should use personal protective equipment, includ-
ing fluid-resistant gowns, gloves, surgical masks, eye protection, and shoe and hair covers. In addition, patients receiving pulsatile lavage treatment should wear surgical masks and all intravenous lines and other wounds must be covered during the treatment. The procedure should be performed in a private room with easily washable surfaces, only essential equipment in the room, and no open supply shelves. Thorough cleaning and disinfection of the room must occur after each procedure and at the end of the day. As with any medical procedure, all staff performing pulsatile lavage treatment should be thoroughly trained in proper technique for use of the device.

In addition to pulsatile lavage, our case-control study found that residence in a nursing home within the previous 6 months was a significant risk factor for acquisition of MDR-Ab. Antimicrobial-resistant pathogens are known to be present in long-term care facilities. The 4 case patients who had recent residence in a nursing home were in 4 different facilities, and it is unclear what role nursing home residence played in this outbreak. Because wound care, including pulsatile lavage, is frequently performed in long-term care facilities, practitioners in these facilities must be cognizant of appropriate infection control procedures to help prevent transmission of resistant organisms.

Finally, this outbreak highlights the importance of careful evaluation of the infection control implications of new therapies, existing therapies used in a new way, and cost-saving procedural changes. Manufacturers must ensure that product labeling for new medical devices includes infection control information and recommendations on appropriate precautions, proper storage, cleaning and disinfection, and potential infectious risks. Pulsatile lavage is an emerging technology that is being used with increasing frequency throughout the United States in a variety of inpatient, long-term care, and outpatient settings. Infection control information and recommendations must be disseminated to the health care workers who perform these procedures in diverse settings.

**Author Contributions:** Dr Maragakis had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

**REFERENCES**


