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ORIGINAL ARTICLE

Nosocomial outbreak of multidrug-resistant *Pseudomonas aeruginosa* caused by damaged transesophageal echocardiogram probe used in cardiovascular surgical operations

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Abstract Multidrug-resistant *Pseudomonas aeruginosa* (MDRP) is a major problem among hospital-acquired infections. We had a one-month outbreak of this strain at a university hospital in Osaka, Japan, from May to June 2004. To determine the cause of the outbreak, we collected and analyzed epidemiological information about the patients from whom MDRP was isolated, and performed microbiological investigations. MDRP was detected in respiratory specimens from eight patients in the intensive care unit. One of these patients developed severe lethal pneumonia accompanied by septicemia, and two contracted less severe non-lethal pneumonia. All the MDRP patients had been monitored with a contaminated transesophageal echocardiography (TOE) probe during their cardiac surgery. The TOE probe proved to have a defect 5 mm in diameter at the surface near the transducer, and the MDRP strain was traced to this defect. Pulsed-field gel electrophoresis showed that the strain isolated from the patients and from the TOE probe were genetically indistinguishable. After use of the damaged TOE probe was terminated, MDRP was not isolated from any patients who underwent cardiac surgery in the subsequent 8 years. In conclusion, TOE is routinely used during cardiac surgery and has been shown to have a significant clinical effect. Prevention of similar post-operative pneumonia outbreaks will require thorough infection control of TOE probes used for monitoring during cardiovascular surgery.

Keywords Intensive care unit (ICU) · Pulsed-field gel electrophoresis · Multidrug-resistant *Pseudomonas aeruginosa* (MDRP) · Transesophageal echocardiography (TOE) · Nosocomial infection

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Introduction

Pseudomonas aeruginosa is endemic among critically ill patients, and multidrug-resistant strains are increasingly being isolated in intensive care units (ICUs) [1]. The main origin of patients' pulmonary colonization with *P. aeruginosa* seems to be endogenous, but a contaminated device or environment has been responsible for transmission of the pathogen in some outbreaks [2]. Because *P. aeruginosa* is a virulent organism susceptible to only a limited number of antibiotic agents, infections caused by this organism are difficult to cure and often require combination therapy. Multidrug-resistant *P. aeruginosa* (MDRP) has been defined as *P. aeruginosa* resistant to ceftazidime, ciprofloxacin, piperacillin, imipenem, and amikacin [3, 4], although this definition has not been agreed internationally. In Japan, it is usually defined by the Japan Nosocomial Infections Surveillance (JANIS) [5], a program of the Ministry of Health Labour and Welfare, as *P. aeruginosa* resistant to carbapenems, for example imipenem or meropenem, fluoroquinolones, and amikacin. The increasing resistance of *P. aeruginosa* is a growing threat to clinical management of such infections [1].

Use of transesophageal echocardiography (TOE) during cardiac surgery continues to increase. In typical surgical use, the TOE probe is inserted after induction of anesthesia

and left in place for the duration of the operation, typically from 3 to 5 h. Because the probe and related equipment are not designed primarily for use in the operating room, this application leads to an increased risk of TOE probe damage [6].

In this report, we describe an outbreak of nosocomial MDRP in patients who underwent cardiac surgery at a university hospital, and identification of a damaged TOE probe as the source of the infection.

Materials and methods

Outbreak investigation

During 1 month, from May to June 2004, MDRP was isolated from cultures of respiratory specimens from eight patients who had undergone cardiovascular surgery at a 1076-bed university hospital in Osaka. Surveillance of hospital-acquired infections, using one-year data from April 2003 to March 2004, revealed the average number of MDRP strains isolated in this hospital was 1.08 ± 0.67 per month. As soon as the hospital's infection-control team recognized that an outbreak of MDRP had occurred in the 8-bed surgical ICU, epidemiological information was collected and analyzed. Environmental specimens and medical devices were subjected to bacteriological examination in an effort to identify possible sources of infection.

Microbiological investigation

Transesophageal echocardiographs and their damaged parts were swabbed and wiped with a piece of premoistened gauze, which was wrung out to provide the specimen. Each specimen was either inoculated directly, or the specimen was centrifuged and the resulting pellets were inoculated, on to 5 % sheep blood agar and BTB agar plates. Environmental species were also investigated by similar methods.

P. aeruginosa identification and susceptibility tests were performed by use of MicroScan WalkAway systems (Siemens, Munich, Germany), and MDRP was defined as *P. aeruginosa* resistant to carbapenems, for example imipenem or meropenem, fluoroquinolones, and amikacin [5].

Pulsed-field gel electrophoresis (PFGE)

The isolates underwent molecular typing by PFGE using the GenePath kit (Bio-Rad, Hercules, CA, USA) and the restriction enzyme *Spe*I. Pairwise comparisons of isolates by PFGE were interpreted on the basis of the criteria of Tenover et al. [7]. Isolates were considered identical if none of their bands differed, closely related if one to three of their bands differed, and possibly related if four to six of their bands differed. Isolates differing by more than six bands were assumed to arise from different strains.

Results

Because the hospital has an active surveillance program for hospital-acquired infections, all patients treated postoperatively in the ICU are closely monitored by means of routine bacteriological examination of pharyngeal swabs or sputum at least once per week. These surveillance data revealed the presence of an unusually large number of MDRP-infected patients in the ICU during the 1 month from May to June 2004. Eight patients had MDRP, which was isolated from respiratory specimens after cardiac surgery. The period from the operation to isolation of MDRP ranged from 3 to 6 days. All of the patients with MDRP had undergone cardiovascular surgery—one coronary artery bypass graft and open-heart surgery on seven occasions. Accompanying persistent or transient MDRP bacteremia was discovered in two of the three patients who had acquired MDRP pneumonia. One patient subsequently died from severe MDRP pneumonia and septicemia 6 days postoperatively. The patients developed pneumonia only 1 day after cardiovascular surgery, which strongly suggested artificial effects, including device-related infection (Fig. 1). The other five patients from whom MDRP was isolated did not develop infection.

Surgery on the eight MDRP patients had not been performed by the same surgeon, and not all had undergone a bronchoscopic procedure. None of the patients had used humidifiers during and/or after their surgery. We did not perform a case–control study; we did, however, discover that the same TOE probe had been used for all these patients, either to monitor cardiac function or to observe morphological changes during surgery.

Three TOE probes had been used for the cardiovascular operations. During the study period, 39 patients had undergone cardiovascular surgery. Of these, 23 had been monitored intraoperatively with one specific TOE probe; another five patients had been monitored with one of the two other TOE probes available; the remaining 11 patients had not been subjected to TOE monitoring during their operations.

Inspection revealed that the probe that had been used for most of the operations had a defect, 5 mm in diameter, on the surface of the flexible portion of the insertion tube near the echocardiogram transducer, 15 cm from the end of the probe (Fig. 2).

After a routine cycle of cleaning and disinfection performed by the staff in the operating theaters with sponges and the other devices, the defect on the surface of the

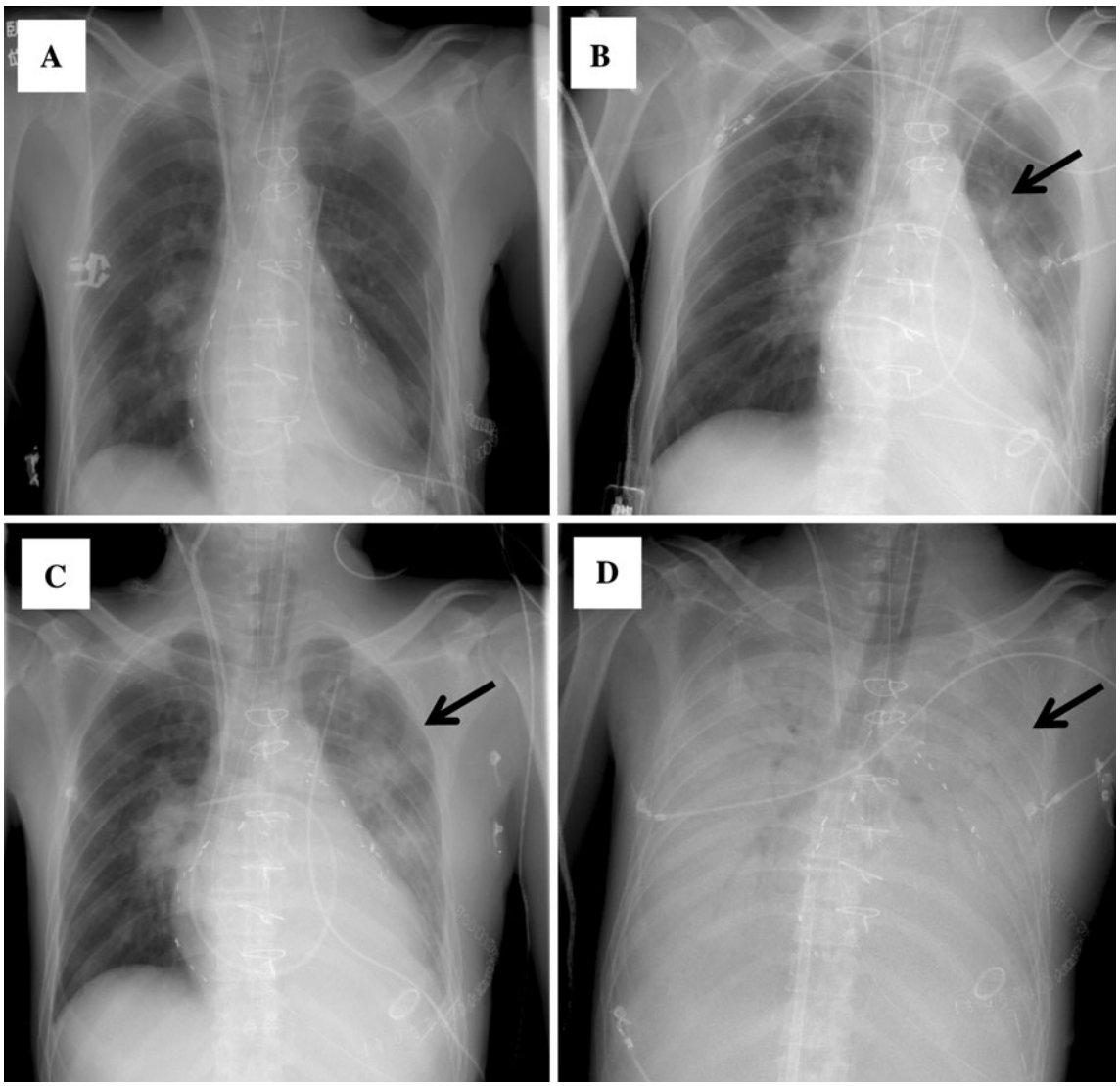

Fig. 1 Clinical course of chest X-ray findings of a representative patient who developed pneumonia because of multidrug-resistant *Pseudomonas aeruginosa* (MDRP) after cardiovascular surgery. **a** Day 0, **b** Day 1, **c** Day 2, and **d** Day 3 after surgery. *Arrows* indicate infiltration shadows, which suggested pneumonia

damaged TOE probe was swabbed and MDRP was readily recovered from this swab. In contrast, no MDRP was isolated from the environment, including lavatory, flooring, corridor, and cardiovascular wards, or from devices stored in the ICU/ER or operating theaters, for example bronchoscopes, ventilators, or the xylocaine gel that was used for insertion of the TOE probe (data not shown). The damaged TOE probe had been used for all the patients from whom MDRP was subsequently isolated. No MDRP was isolated postoperatively from the patients monitored with either of the other TOE probes or for whom TOE monitoring was not used. Although the period of durability was within the limit and no obvious problems had been observed during sterilization procedures, TOE probes were used without a sheath.

The strains isolated from the patients and from the surface defect of the TOE probe were compared via PFGE of digested chromosomal DNA. All of these isolates proved to be genetically indistinguishable (Fig. 3). Two other *Pseudomonas* strains, both of which had been isolated from water taps in the ICU, were also subjected to PFGE analysis; these tap-derived strains were distinctly different genotypes, both from each other and from the outbreak-associated strains.

On the basis of the results from these tests, use of the damaged TOE probe was terminated, but with use of single-use sheaths in TOE examinations was recommended. Centralized sterilization was also enforced to monitor the disinfection process to discover TOE probe damage early. In the subsequent 8 years, no more MDRP strains were

Fig. 2 Defect on the transesophageal echocardiogram probe. A biofilm was detected inside the damaged area. Specimens obtained by swabbing this area were positive for multidrug-resistant *Pseudomonas aeruginosa* (MDRP)

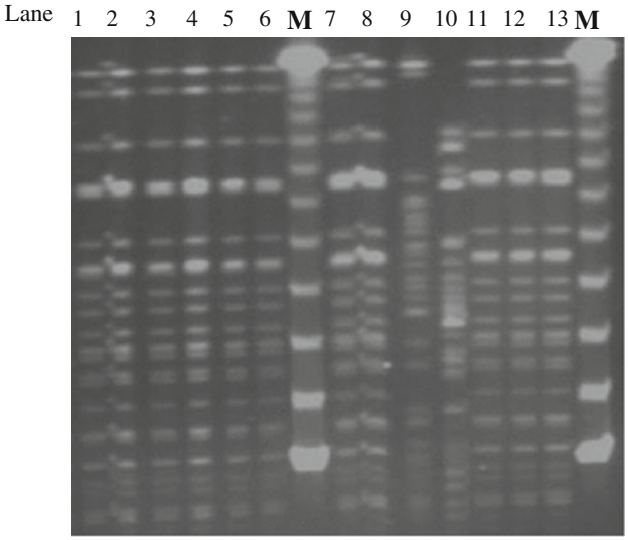

Fig. 3 Pulsed-field gel electrophoresis analysis of the multidrug-resistant *Pseudomonas aeruginosa* (MDRP) isolates. *Lanes 1–8*, isolates from patients with MDRP in the ICU; *lanes 9 and 10*, isolates from water taps in the ICU; *lanes 11–13*, isolates from the damaged TEE probe; *M*, size marker

isolated from any patients who underwent cardiac surgery at this facility.

Discussion

Transesophageal echocardiography is used to monitor cardiac function; the probe is placed in the esophagus to monitor the heart's valves. Recently, TOE has often been used during cardiovascular surgery. It has been suggested that contamination resulting from use of TOE probes is a result of transfer of endogenous oral or esophageal flora to the circulation [8, 9]. Levy et al. [10] have previously reported a TOE probe as a potential source of infection; those researchers demonstrated transmission of *Legionella pneumophila* pneumonia in a case–control study.

Gastrointestinal endoscopy, which similarly requires placement of a probe through the esophagus and into the stomach, has also been reported as a source of contamination. Examples include exogenous transmission of contaminating hepatitis B virus [11], *Helicobacter pylori* [12, 13], and *Salmonella* spp. [14], but such endoscopy is rarely associated with pneumonia. Contamination of the TOE probe itself has, therefore, rarely been considered as a potential source of nosocomial pneumonia. Although the TOE probe is regarded as part of endoscopy, there are no clear guidelines for prevention and control of probe-associated infection in the operating theater.

Mechanical cleaning might be needed to remove any biofilm that could interfere with probe disinfection [15]. However, in the outbreak described here, the contaminated defect on the surface of the insertion probe, and the depressions on the side and the pockets below the surface cover, could not be cleaned mechanically. Microbe-containing organic matter was presumably retained in the depressions and pockets of the defective probe, thus preventing penetration of germicides and contributing to disinfection failure [16, 17]. Persistent bacterial contamination of the surface defect of our hospital's TOE probe was also probably not removed, despite cleaning and disinfection by automated devices.

Prolonged intraoperative use of a contaminated TOE probe may facilitate MDRP colonization of the oral cavity or esophagus of patients. Additionally, keeping the intubation tube in place for management of the ventilator, both intra and postoperatively, is likely to interfere with clearance of MDRP from the oral cavity and pharynx, potentially contributing to MDRP invasion of the lower respiratory tract.

In our case, although the period of durability was within the limit and no obvious problems had been observed during sterilization procedures, the TOE probe was used without a sheath. Therefore, we recommended use of single-use sheaths for TOE examinations, and thorough centralized sterilization with monitoring of the disinfection process, which should enable early discovery of TOE probe damage. Kanemitsu et al. [18] have reported that outbreaks of *Enterobacter cloacae* in a cardiovascular ward were improved by similar measures.

Furthermore, the patients developed pneumonia only 1 day after cardiovascular surgery, which strongly suggested artificial effects, including device-related infection. Although we did not perform a case–control study, we found all patients underwent TOE examinations. Our results suggest careful examination and management are needed after surgery, and experienced clinicians should be

included in infection control teams and participate in outbreak investigations.

In conclusion, we had an outbreak of MDRP as a result of use of a contaminated TOE probe during cardiovascular surgery. Identical patterns were obtained from PFGE analysis of MDRP isolated from the damaged site of the TOE probe and from the patients. We have had no MDRP outbreaks as a result of TOE probes since this problem. Our experience makes it clear that great care must be exercised to prevent damage and contamination of the surface of TOE probes. This recommendation is critical for prevention of post-surgical pneumonia and is in accord with recommendations derived from clinical experience in gastrointestinal endoscopy.

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