Clinical and Epidemiological Investigations of Acinetobacter Genomospecies 3 in a Neonatal Intensive Care Unit

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A prospective study of Acinetobacter isolates from a neonatal intensive care unit was performed for 24 months. Fifty-six isolates were obtained from 21 patients, and another eight were obtained from environmental specimens. Infection due to Acinetobacter organisms was established for 16 patients, 6 with septicemia, 9 with pneumonia, and 1 with a wound infection. Further investigations were performed with 38 representative isolates. Twenty-nine isolates were identified as unnamed DNA-DNA hybridization group (genomospecies) 3, three were identified as genomospecies 2 (Acinetobacter baumannii), one was identified as genomospecies 5 (Acinetobacter junii), three were identified as genomospecies 14, and two were unclassified. Eight distinguishable protein profiles, coded I through VIII, were found by cell envelope protein electrophoresis. Profile V, a common profile, was observed for 17 isolates that had been recovered from 11 patients and 1 dust specimen. These isolates, all of which belonged to genomospecies 3, had similar antibiograms and biotypes. This study has revealed that genomospecies 3 can be associated with infection and be spread in hospitals.

Acinetobacters are ubiquitous organisms which can be easily isolated from water and soil and have also been recovered from a variety of specimens of biotic origin (20). In general, these bacteria are relatively harmless, but in the last two decades, they have emerged as nosocomial pathogens and numerous reports of epidemic spread of multiresistant Acinetobacter strains have appeared (4, 5, 10, 21, 30). Colonization is more common than infection, and careful clinical judgment is required to assess whether isolations represent disease (25). A comprehensive study by Glew et al., published in 1977 (19), has shown that severe and fatal infections occur, especially in patients who require intensive treatment in special care units. Now, patients in these units may be even more at risk from infections because of considerable advances in medical treatment.

The genus Acinetobacter has a complex history, and it has long been difficult to find criteria for speciation (38). Since 1986, this genus has been found to consist of at least 17 species which can be identified by DNA-DNA hybridization (6, 8, 35). Seven species have names that are included in the Index of the Bacterial and Yeast Nomenclatural Changes (22), A. calcoaceticus (genomospecies 1), A. baumannii (genomospecies 2), A. haemolyticus (genomospecies 4), A. junii (genomospecies 5), A. johnsonii (genomospecies 7), A. lwofii (genomospecies 8), and A. radiolarians (genomospecies 12). A phenotypic scheme for identification of genomospecies 1 to 12 has previously been described (6, 7); however, by using this system, discrepancies with identifications by DNA-DNA hybridization have been found (18). The ecological niches and relation to disease of various species are not yet well-known, although there are indications that genomospecies 2 (A. baumannii) and unnamed genomospecies 3 are of clinical significance (6, 7, 35).

A variety of methods for differentiation of clinical strains, including antibiogram and plasmid typing (29, 37), biotyping (7), phage typing (9), protein electrophoretic typing (1, 12), bacteriocin typing (2), serotyping (36), and ribotyping (17), have been used. Differences between strains can be small (7, 12, 15), and the combined use of typing methods has been advocated (9, 11).

In 1988, acinetobacters were isolated in a neonatal intensive care unit (NICU) from three patients with extraventricular drains in adjoining incubators. Microorganisms were isolated from the extraventricular drain systems of two patients (patients a and b) who were considered to have been colonized. In the third patient (patient iii), Acinetobacter organisms were cultured from cerebrospinal fluid and the drain insertion site. This patient developed a fatal case of ventriculitis. Prior to these isolations, acinetobacters had been recovered from two other patients, in a blood specimen of one and a bronchial aspirate of the other. A review of microbiological data showed that a total of 19 Acinetobacter isolates had been recovered from clinical specimens in this ward during 1988, all of which came from these five patients. These observations gave rise to a prospective study of Acinetobacter organisms in this NICU.

The aims of this study were threefold. First, the clinical significance of Acinetobacter isolates in patients was analyzed. Secondly, epidemiology was investigated by using a combination of typing methods. Thirdly, it was established which genomospecies were involved.

MATERIALS AND METHODS

Patients. A prospective study of Acinetobacter isolates was performed in a 24-bed NICU of a 900-bed university hospital from January 1989 until December 1990. The records and clinical conditions of all patients with Acinetobacter organisms during this period were studied.

Definition of neonatal nosocomial infections. The Centers for Disease Control and Prevention definitions for nosocomial infections (16) were amended to specify infection or colonization in neonates, including preterms.

Blood stream infection by Acinetobacter organisms was diagnosed when one of the following criteria was met: fever, or hypothermia, spells of apnea or bradycardia, and isolation of this organism from one or more blood cultures. Pneumonia due to Acinetobacter organisms was diagnosed when physical findings that are consistent with pneumonia were present; production of respiratory secretions
were observed and these organisms were isolated from one or more cerebrospinal fluid specimens. Insertion site infection by Acinetobacter organisms was diagnosed if a patient had erythema and/or serous or purulent umbilical drainage were present and Acinetobacter organisms were isolated from the absence of other possible pathogens. Patients were said to have omphalitis if erythema and/or serous or purulent umbilical drainage were present and Acinetobacter organisms was cultured from a specimen without any sign of infection. All definitions were made in connection with parameters such as temperature, leukocyte and C-reactive protein.

**Isolation of Acinetobacter organisms.** Specimens were taken from suspected sites of infection, and in addition, routine throat swabs were taken from patients twice a week. During two surveys in 1989 and 1990, 70 and 56 environmental specimens, respectively, were taken from dry and wet sites in this ward, including mattresses, pillows, cleaning equipment, cupboards, sinks, taps, artificial ventilatory equipment, air humidifiers, stock solutions, and air. These specimens also included those of the skin and clothes of staff members. Fluid samples were centrifuged, and these sediments as well as other specimens were cultured on blood agar and MacConkey agar and after 18 h of incubation at 35°C inspected for growth. Isolates were identified as belonging to the genus Acinetobacter by the following criteria: gram-negative, coccoid, oxidase-negative, nonmotile, and nonfermenting bacteria.

**Susceptibility tests.** Bacterial susceptibilities to antimicrobial agents were measured by agar disk diffusion according to standard procedures (3). The susceptibilities of isolates to amoxicillin, piperacillin, cefuroxime, imipenem, ceftazidime, gentamicin, tobramycin, co-trimoxazole, and ciprofloxacin were tested.

**Typing studies.** Thirty-eight isolates (3 from patients i, ii, and iii in 1988; 29 from 21 patients from 1989 to 1990; and 6 environmental isolates) were typed by the following three methods.

(i) **Cell envelope protein electrophoretic typing.** Sodium dodecyl sulfate-polyacrylamide gel electrophoresis (SDS-PAGE) of cell envelope protein was performed as described before (12), with minor modifications (13). Briefly, cell envelope fractions were obtained by ultrasonic disruption of cells and subsequent centrifugation. SDS-PAGE was performed with a stacking gel of 3% acrylamide and a running gel of 11% acrylamide. After fast green FC (Sigma Chemical Co., St. Louis, Mo.) staining, profiles were examined visually.

(ii) **Antibiogram typing combined with cluster analysis.** Iso-Sensitest agar (CM 471; Oxoid, Basingstoke, Hampshire, United Kingdom) plates were inoculated with a bacterial suspension in saline of standardized density (10\(^{-3}\) × 0.5 McFarland) that had been prepared from a 24-h culture on blood agar, yielding confluent or almost confluent growth. After inoculation, antibiotic disks (Oxoid) were placed: amoxicillin (25 µg), piperacillin (100 µg), imipenem (10 µg), ticarcillin-clavulanic acid (75 and 10 µg, respectively), cefuroxime (30 µg), cefadolin (30 µg), cephalaxine (30 µg), cefazidime (30 µg), aztreonam (30 µg), tobramycin (10 µg), amikacin (30 µg), norfloxacin (10 µg), ciprofloxacin (5 µg), chloramphenicol (30 µg), trimethoprim-sulfamethoxazole (1.25 and 23.75 µg, respectively), and colistin sulfate (10 µg). Plates were incubated for 24 h at 30°C, after which inhibition zones were read. Isolates were comparatively typed on the basis of similarities in inhibition zones of antibiotics. The diameters of inhibition zones were normalized and subjected to cluster analysis. By this method, isolates were grouped on the basis of their antibiotic profiles. A dendrogram, derived from the antibiotic disks (Oxoid) used were amoxicillin, piperacillin, cefuroxime, imipenem, ticarcillin-clavulanic acid, cefazidime, aztreonam, tobramycin, amikacin, norfloxacin, ciprofloxacin, chloramphenicol, trimethoprim-sulfamethoxazole, and colistin. Bacteriophages were prepared from a 24-h culture on a blood agar plate by the method of McFarland. Strips were inoculated at 30°C and read after 48 h, except for glucosidate acidification, which was read after 24 h. All strips were inoculated on the same day by one individual, incubated for the same period, and read by the same individual.

(iii) **Biotyping.** Isolates were biotyped by using the API20NE system (bio-Mérieux, Marcy l’Etoile, France) according to the manufacturer's instructions. In short, standardized bacterial suspensions that corresponded to an optical density of 0.5 McFarland were prepared from 24-h blood agar cultures grown at 30°C with a pH of 7.5. Strips were incubated at 30°C and read after 48 h, except for glucosidate acidification, which was read after 24 h. All strips were inoculated on the same day by one individual, incubated for the same period, and read by the same individual.

**Taxonomic identification by DNA-DNA hybridization.** Typed isolates were identified to genomospecies level by a quantitative dot filter method, as described previously (34). Briefly, bacterial preparations were hybridized on a filter with \(^{32}\)P-labeled DNAs from reference strains and the stabilities of duplexes were determined by thermal denaturation. The reference strains and labeling procedures were the same ones that had been used before (35). Criteria for inclusion of an isolate in a given genomospecies were based on the difference in thermal denaturation between homologous and heterologous DNA-DNA duplexes or the percentage of DNA removed at a temperature 7°C below the thermal denaturation midpoint of homologous duplexes (34). Each isolate included in a species had a thermal denaturation that was equal to or smaller than 3.0 or a percentage of DNA removed that was equal to or smaller than 17%.

**RESULTS**

**Isolation of acinetobacters.** During this prospective study (1989 and 1990), a total of 796 neonates were nursed in this unit. Fifty-six Acinetobacter strains were isolated from 21 patients, and another eight were isolated from the environment (Table 1). Most clinical isolates were obtained from bronchial aspirates and blood samples. Environmental isolates were obtained from both wet and dry sources.

**Susceptibilities.** All isolates were fully susceptible to piperacillin, ceftazidime, imipenem, gentamicin, tobramycin, co-trimoxazole, and ciprofloxacin. Resistance to amoxicillin and cefuroxime was found in 65 and 85% of the isolates tested, respectively.

**Patients.** Clinical data for the patients in this prospective study (patients A through G from 1989 and patients H through U from 1990) are summarized in Table 2. There were twice as many female neonates as male neonates. Eleven neonates had gestational ages of less than 32 weeks, with 10 having birth weights of less than 1,500 g. All but one patient (patient U) had one or more underlying diseases. Fourteen patients had infant respiratory distress syndrome.

The length of NICU stay before first isolation of Acinetobacter organisms ranged from 1 to 76 days, with an average of 21.5 days. Twenty patients were mechanically ventilated at the time of Acinetobacter isolation from one or more specimens. The duration of ventilation before first isolation ranged from 1 to 76 days, with an average of 17.5 days.

Antibiotics had been administered or were being given to 17 of these 21 patients before or at the time of the first Acinetobacter isolation. Two patients had received a penicillin derivative as a single agent. A penicillin derivative in combination with an aminoglycoside was given to 15 patients. For four of these patients, this regimen was replaced by an expanded-spectrum cephalosporin in combination with an aminoglycoside or a glycopeptide.

Acinetobacter organisms were isolated from the blood samples of 6 patients and the bronchial aspirates of 15 patients. For three patients, Acinetobacter organisms were cultured from multiple specimens (patients D, K, and U). In 16 of 21 cases,
TABLE 2. Clinical and microbiological data of patients (n = 21)

<table>
<thead>
<tr>
<th>Patient</th>
<th>Sex¹/gestational age (wk)</th>
<th>Birth wt (g)</th>
<th>NICU stay before first isolation/total NICU stay (days)</th>
<th>Duration of ventilation before first isolation/total duration of ventilation (days)</th>
<th>Source(s) of culture⁵ (no. of isolates)</th>
<th>Protein profile(s)</th>
<th>Clinical feature(s)c</th>
<th>Colonization or infection⁴</th>
<th>Clinical picture affected by Acinetobacter organisms</th>
<th>Clinical outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>F/38</td>
<td>3,310</td>
<td>1/9</td>
<td>1/8</td>
<td>B (2)</td>
<td>I</td>
<td>ASPH, SE, MOF</td>
<td>I</td>
<td>Yes</td>
<td>Died</td>
</tr>
<tr>
<td>B</td>
<td>F/30</td>
<td>1,365</td>
<td>8/38</td>
<td>1/3</td>
<td>B (2)</td>
<td>II</td>
<td>IRDS, ODB, PVH, SE</td>
<td>I</td>
<td>Yes</td>
<td>Survived</td>
</tr>
<tr>
<td>C</td>
<td>F/25</td>
<td>1,005</td>
<td>13/71</td>
<td>13/24</td>
<td>BA (1)</td>
<td>III</td>
<td>IRDS, ODB, PVH, BPD</td>
<td>C</td>
<td>No</td>
<td>Survived</td>
</tr>
<tr>
<td>D</td>
<td>F/28</td>
<td>1,040</td>
<td>13/47</td>
<td>13/47</td>
<td>BA (5), SK (1)</td>
<td>IV</td>
<td>IRDS, ODB, BPD, PN</td>
<td>I</td>
<td>Yes</td>
<td>Died</td>
</tr>
<tr>
<td>E</td>
<td>M/33</td>
<td>2,350</td>
<td>35/49</td>
<td>35/39</td>
<td>BA (1)</td>
<td>IV</td>
<td>IRDS, ODB, ASPH, PVH</td>
<td>C</td>
<td>No</td>
<td>Died</td>
</tr>
<tr>
<td>F</td>
<td>F/38</td>
<td>2,950</td>
<td>4/7</td>
<td>4/5</td>
<td>BA (1)</td>
<td>II</td>
<td>RI</td>
<td>C</td>
<td>No</td>
<td>Died</td>
</tr>
<tr>
<td>G</td>
<td>M/36</td>
<td>2,250</td>
<td>6/14</td>
<td>6/8</td>
<td>BA (1)</td>
<td>V</td>
<td>ASPH, ODB, PN</td>
<td>I</td>
<td>Yes</td>
<td>Survived</td>
</tr>
<tr>
<td>H</td>
<td>F/28</td>
<td>1,565</td>
<td>36/46</td>
<td>36/46</td>
<td>BA (4)</td>
<td>VI</td>
<td>IRDS, PFC, PVH, BPD, PN</td>
<td>I</td>
<td>Yes</td>
<td>Survived</td>
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<tr>
<td>I</td>
<td>M/30</td>
<td>1,680</td>
<td>35/112</td>
<td>25/112</td>
<td>BA (14)</td>
<td>V, VI</td>
<td>IRDS, CD, ODB, PN</td>
<td>I</td>
<td>Yes</td>
<td>Died</td>
</tr>
<tr>
<td>J</td>
<td>M/31</td>
<td>1,340</td>
<td>23/25</td>
<td>23/25</td>
<td>BA (2)</td>
<td>IV</td>
<td>IRDS, ODB, BPD, PN</td>
<td>I</td>
<td>Yes</td>
<td>Died</td>
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<tr>
<td>K</td>
<td>M/32</td>
<td>1,560</td>
<td>13/19</td>
<td>13/19</td>
<td>B (1), ID (2)</td>
<td>VIII</td>
<td>IRDS, PFC, SE</td>
<td>I</td>
<td>Yes</td>
<td>Died</td>
</tr>
<tr>
<td>L</td>
<td>F/27</td>
<td>1,080</td>
<td>7/46</td>
<td>7/20</td>
<td>BA (1)</td>
<td>V</td>
<td>IRDS, ODB, BPD, PN</td>
<td>I</td>
<td>Yes</td>
<td>Survived</td>
</tr>
<tr>
<td>M</td>
<td>F/31</td>
<td>1,900</td>
<td>3/4</td>
<td>3/4</td>
<td>B (1)</td>
<td>V</td>
<td>IRDS, PFC, SE</td>
<td>I</td>
<td>Yes</td>
<td>Survived</td>
</tr>
<tr>
<td>N</td>
<td>F/29</td>
<td>3,050</td>
<td>39/46</td>
<td>39/46</td>
<td>BA (2)</td>
<td>V</td>
<td>RI, CD, MA</td>
<td>C</td>
<td>No</td>
<td>Died</td>
</tr>
<tr>
<td>O</td>
<td>F/28</td>
<td>1,110</td>
<td>76/191</td>
<td>76/78</td>
<td>BA (1)</td>
<td>V</td>
<td>IRDS, BPD</td>
<td>C</td>
<td>No</td>
<td>Survived</td>
</tr>
<tr>
<td>P</td>
<td>M/34</td>
<td>2,250</td>
<td>19/27</td>
<td>19/19</td>
<td>BA (2)</td>
<td>V</td>
<td>IRDS, PFC, MA, PN</td>
<td>I</td>
<td>Yes</td>
<td>Died</td>
</tr>
<tr>
<td>Q</td>
<td>M/28</td>
<td>1,135</td>
<td>36/57</td>
<td>16/24</td>
<td>BA (4)</td>
<td>V</td>
<td>IRDS, ODB, BPD, PN</td>
<td>I</td>
<td>Yes</td>
<td>Survived</td>
</tr>
<tr>
<td>R</td>
<td>F/34</td>
<td>1,480</td>
<td>20/46</td>
<td>5/19</td>
<td>B (1), BA (2)</td>
<td>V</td>
<td>RI, CD, ODB, SE</td>
<td>I</td>
<td>Yes</td>
<td>Died</td>
</tr>
<tr>
<td>S</td>
<td>F/38</td>
<td>2,805</td>
<td>22/35</td>
<td>22/35</td>
<td>BA (3)</td>
<td>V</td>
<td>RI, CD, PN</td>
<td>I</td>
<td>Yes</td>
<td>Died</td>
</tr>
<tr>
<td>T</td>
<td>F/27</td>
<td>590</td>
<td>29/62</td>
<td>1/22</td>
<td>B (1)</td>
<td>IV</td>
<td>IRDS, ODB, VCSS, SE</td>
<td>I</td>
<td>Yes</td>
<td>Died</td>
</tr>
<tr>
<td>U</td>
<td>F/35</td>
<td>1,450</td>
<td>12/64</td>
<td>-/</td>
<td>W (1)</td>
<td>V</td>
<td>WI</td>
<td>I</td>
<td>No</td>
<td>Survived</td>
</tr>
</tbody>
</table>

¹ F, female; M, male.

² B, blood; BA, bronchial aspirate; SK, skin; ID, intravascular device; W, wound.

³ ASPH, asphyxia; SE, septicemia; MOF, multiple organ failure; IRDS, infant respiratory distress syndrome; ODB, open ductus Botalli; PVH, periventricular hemorrhagiae; BPD, bronchopulmonary dysplasia; PN, pneumonia; RI, respiratory insufficiency; PFC, persistent fetal circulation; CD, congenital disorder; MA, malignancy; VCSS, vena cava superior syndrome; WI, wound infection.

⁴ I, infection; C, colonization.
Twenty-nine isolates were identified as unnamed genomospecies. 1570 HORREVORTS ET AL.

In the last 2 decades, the genus Acinetobacter has been increasingly associated with hospital infection and colonization. Most outbreaks of nosocomial Acinetobacter infections have occurred in adult intensive care units, with the respiratory tract as the predominant site of infection, but other sites have also been described (14, 19, 23, 31). In reported outbreaks in NICUs, Acinetobacter organisms have been associated with sepsis and pulmonary infection (24, 27, 28, 33). Intravenous nutritional fluids, intestinal flora, air humidifiers, and resuscitation bags have been found to be reservoirs, and the spread of Acinetobacter organisms by hands or air humidifiers has been suggested.

**TABLE 3. Identification by DNA-DNA hybridization, typing by cell envelope protein electrophoresis, and biotyping of 38 Acinetobacter isolates**

<table>
<thead>
<tr>
<th>Genomospecies</th>
<th>Protein profile (no. of isolates)</th>
<th>API20NE profile* (no. of isolates)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 (A. baumannii)</td>
<td>II (2)</td>
<td>1000051 (2)</td>
</tr>
<tr>
<td>3 (unnamed)</td>
<td>I (1)</td>
<td>0010101 (1)</td>
</tr>
<tr>
<td>4 (A. baumannii)</td>
<td>I (1)</td>
<td>0010101 (1)</td>
</tr>
<tr>
<td>5 (A. junii)</td>
<td>III (1)</td>
<td>0000051 (1)</td>
</tr>
<tr>
<td>14 (unnamed)</td>
<td>VI (3)</td>
<td>4010053 (2)</td>
</tr>
<tr>
<td>Unclassified</td>
<td>VIII (2)</td>
<td>0000071 (2)</td>
</tr>
</tbody>
</table>

* According to the API20NE profile index, profiles 1000051, 0001051, 0000051, and 0000071 correspond to A. baumannii (genomospecies 2), and all other profiles listed correspond to A. baumannii (genomospecies 2).
Our report has been concerned with Acinetobacter organisms in an NICU, with most clinical isolates coming from bronchial aspirations and blood samples. To discriminate between colonization and infection, the Centers for Disease Control and Prevention criteria for nosocomial infections in patients under the age of 12 months were adapted to specifically define infections in very young neonates, including preterms. Using a cluster analysis, we found 17 patients were infected with Acinetobacter organisms and that in 16 of these cases, the clinical picture was affected by this organism. This illustrates that in these vulnerable patients, Acinetobacter strains can be a serious threat.

A combination of typing methods must be used to discriminate between the Acinetobacter strains that are involved in outbreaks (9, 11). We used three typing methods. Cross-colonization or infection was suggested when strains that were indistinguishable by cell envelope protein profile and highly similar in biotype and antibiogram were recovered over a short period. In this study, a number of these cases were confirmed and one strain seemed to have spread epidemically. Several environmental isolates with traits that were common to clinical isolates were obtained during these surveys. These isolates were found at both wet and dry sites. Because of the isolation of Acinetobacter organisms from dust, sink basins, and pillows, procedures for cleaning and disinfection of the environment have been reinforced. In addition, the use of alcohol dispensers in hand washing has been introduced. Supporting pillows filled with foam grains have been more frequently changed, and washing temperatures have been increased from 60 to 90°C. In 1991, the number of Acinetobacter isolations in this ward dropped to 5, compared with 17 and 47 during 1989 and 1990, respectively. The reservoir and mode of spread have not been elucidated.

Identification by DNA-DNA hybridization showed that most of the isolates in our study belonged to the unnamed genomospecies 3, which is closely related to genomospecies 2 (A. baumannii). Genomospecies 2 is usually implicated in nosocomial outbreaks and infections (6, 7, 9). Because of the lack of sufficient phenotypic discriminating criteria (18), unambiguous identification of genomospecies must be performed by DNA-DNA hybridization. It is possible that isolates of genomospecies 3 have been incorrectly identified as genomospecies 2 (A. baumannii), as was the case with APIZONE in this study. This may have resulted in a general underestimation of the clinical significance of genomospecies 3.

Many studies of nosocomial Acinetobacter outbreaks have focused on the epidemiology of the strains involved. We have combined clinical aspects with epidemiology and taxonomy to obtain a comprehensive picture of Acinetobacter organisms in an NICU. The strains involved gave rise to a high number of infections and spread through the ward; most of the isolates belonged to the unnamed genomospecies 3. To elucidate the clinical impact of this entity, rapid and reliable methods for identification need to be developed.

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