Systematic review of invasive Acinetobacter infections in children

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INTRODUCTION: Clinicians are generally familiar with Acinetobacter as an etiological agent for serious nosocomial infections in intensive care units. However, there are no previous reviews of the full spectrum of invasive infections in children.

METHODS: A systematic review of the literature was completed up to December 2008 for reports of invasive Acinetobacter infections in children.

RESULTS: There were 101 studies that met the inclusion criteria including 18 possible outbreaks, 33 case series and 49 case reports. Suspected outbreaks were concentrated in neonatal intensive care units (16 of 18 outbreaks) and involved bacteremia or meningitis. Proof of isolate clonality or identification of the source of the outbreak was seldom established. Case series were primarily of children younger than five years of age presenting with bacteremia (sometimes multiresistant), meningitis, endocarditis or endophthalmitis, with many community-acquired infections being reported from India. Case reports consisted of unique presentations of disease or the use of novel therapies. Attributable mortality in the outbreaks and case series combined was 68 of 469 (14.5%).

DISCUSSION: Invasive Acinetobacter infections in children usually manifest as bacteremia, meningitis or both, but can result in a wide variety of clinical presentations. Outbreaks are primarily a problem in newborns with underlying medical conditions. Most reports of community-acquired infections are from tropical countries. The study of the mechanism of colonization and infection of children in intensive care units and of neonates in tropical countries may provide some insight into prevention of invasive infections.

Key Words: Acinetobacter infections; Bacteremia; Disease outbreak; Meningitis

The Acinetobacter genus is a group of immobile, aerobic, non-fermenting Gram-negative coccobacilli found in soil and fresh water (1). Acinetobacter species have become an important culprit in nosocomial infection (1) and, in recent years, have displayed increasing resistance to a broad range of antimicrobials (2-4). The purpose of the present study was to perform a systematic review of the literature on Acinetobacter invasive infection in pediatric patients to describe the epidemiology and outcome of reported cases. This may aid clinicians in outlining the prognosis for children with invasive infections and guide them when they suspect an outbreak due to Acinetobacter species.

METHODS

Inclusion criteria
All studies that provided information on the clinical course of one or more cases of Acinetobacter infection isolated from a normally sterile site in children up to 18 years of age were included in the present review (studies till December 2008). There was no date or foreign language restrictions. Translation was only available for French language articles; otherwise data were mainly derived from an English abstract if provided. Reports that described colonization, pneumonia or soft tissue infections were excluded, unless the organism was also grown from blood cultures or from a normally sterile site. Studies that involved both children and adults were included if the clinical information on pediatric patients could be ascertained.

Classification of studies
Studies were classified into one of three categories: outbreaks, case series or case reports. Studies describing nosocomial Acinetobacter infections or colonization (with a minimum of one case of invasive disease) that were believed by the study...
authors to be epidemiologically linked were classified as outbreaks. Studies describing two or more cases (including at least one child) that were not believed to have a common source were classified as a case series. The remaining studies, generally individual reports of interesting manifestations of Acinetobacter infection, were classified as case reports.

Search strategy
The English and foreign-language literature on Acinetobacter species was searched using MEDLINE, EMBASE, PUBMED, and SCOPUS databases in December 2008. For MEDLINE, all subject headings were checked off when terms were mapped. The study was limited to “all children, 0-18 years”. For EMBASE, all subject headings were checked off when terms were mapped. The study was limited to “infant”, “child”, “preschool child”, “school child” and “adolescent”. For PUBMED, the study was limited to “all child: 0 to 18 years”. For SCOPUS, an advanced search was conducted with “school child” and “adolescent”. For PUBMED, the study was limited to “all children, 0-18 years”. For EMBASE, all subject headings were checked off when terms were mapped.

For the above four database searches, “Acinetobacter” was used as the first search term. The nomenclature for Acinetobacter species has changed over the decades, and all other known terms for any species of the bacteria were also searched with the four databases – these were Mima polymorpha, Herellea vagincola, BSW, Bacterium antratrum, Achromobacter haemolyticus var. glucidolytica, Achromobacter conjunctivae, Moraxella glucidolytica, Achromobacter antratrus, Neisseria winogradskyi, Micrococcus calcoaceticus, Diplococcus mucosus, Achromobacter citroalcaligenes, Achromobacter haemolyticus var. alcaligenes, Alcaligenes metalcaligenes, Achromobacter lwoffi, Moraxella lwoffi and Alcaligenes hemolysis.

Data extraction
Data extraction was performed by both authors. Relevant clinical information on the course of Acinetobacter infection was collected.

RESULTS
There were 101 studies that met the inclusion criteria including 18 outbreaks, 33 case series, and 49 case reports. There were 28 studies up to 1970, 13 from 1971 to 1990, and 70 from 1991 to 2008.

Outbreaks
Eighteen of the studies (5-22) described outbreaks, beginning in 1982 (Table 1). The frequency of outbreak reports has been increasing, with nine of the 18 outbreaks reported within the past 10 years. Outbreaks were reported from Europe (seven studies), Asia (three studies), South America (three studies), Africa (two studies), the Middle East (two studies) and the Caribbean (one study).

Fifteen of the 18 outbreaks occurred in neonatal intensive care units (NICUs) with another occurring in a combined NICU and pediatric intensive care unit (PICU). There was an outbreak reported from a burn unit (21) and from a pediatric oncology ward (13). The number of cases of invasive Acinetobacter infection varied from one to 36 per outbreak (median: seven cases), with colonized patients also being reported in many outbreaks.

A variety of Acinetobacter species were implicated in the outbreaks: Acinetobacter baumannii (six studies), Acinetobacter calcoaceticus (five studies), Acinetobacter junii (two studies), Acinetobacter lwoffi (one study) and unspecified species (two studies). Two studies described cases with novel strains of Acinetobacter, including Acinetobacter septicus (5) and Acinetobacter RUH 1139 strain (7). In most studies, the authors assumed an outbreak based solely on an increased number of children with Acinetobacter colonization or infection in a medical unit over a period of weeks to months. Typing of isolates was described in only one study (11), identifying six of nine strains in bacteraemic neonates as identical.

The source of the outbreak was proven only in one study in which an Acinetobacter RUH 1139 strain caused bacteraemia infections in 16 neonates and was isolated from the total parenteral nutrition solution (7). Many studies described isolation of

### Table 1: Characteristics of pediatric Acinetobacter outbreaks with at least one case of invasive infection

<table>
<thead>
<tr>
<th>Ref</th>
<th>Year</th>
<th>Country</th>
<th>Cases of invasive infection, n</th>
<th>Setting</th>
<th>Bacteremia, n</th>
<th>Meningitis, n</th>
<th>Deaths from any cause, n</th>
<th>Deaths from Acinetobacter, n</th>
<th>Species</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>2008</td>
<td>Turkey</td>
<td>5</td>
<td>NICU</td>
<td>5 NR NR</td>
<td>NR NR</td>
<td>2 A septicus</td>
<td></td>
<td>A septicus</td>
</tr>
<tr>
<td>6</td>
<td>2007</td>
<td>Taiwan</td>
<td>1</td>
<td>NICU</td>
<td>1 NR NR</td>
<td>0</td>
<td>0 A baumannii</td>
<td></td>
<td>A baumannii</td>
</tr>
<tr>
<td>7</td>
<td>2006</td>
<td>Venezuela</td>
<td>16</td>
<td>NICU</td>
<td>16 2 NR</td>
<td>NR NR</td>
<td>2 A RUH 1139</td>
<td></td>
<td>A baumannii</td>
</tr>
<tr>
<td>8</td>
<td>2005</td>
<td>Brazil</td>
<td>11</td>
<td>NICU</td>
<td>11 NR NR</td>
<td>3 3</td>
<td>3 A baumannii</td>
<td></td>
<td>A baumannii</td>
</tr>
<tr>
<td>9</td>
<td>2003</td>
<td>India</td>
<td>36</td>
<td>NICU</td>
<td>36 9 13 NR</td>
<td>NR NR</td>
<td>3 A baumannii</td>
<td></td>
<td>A baumannii</td>
</tr>
<tr>
<td>10</td>
<td>2003</td>
<td>Israel</td>
<td>9</td>
<td>NICU</td>
<td>9 2 3 NR</td>
<td>NR NR</td>
<td>2 A baumannii</td>
<td></td>
<td>A baumannii</td>
</tr>
<tr>
<td>11</td>
<td>2002</td>
<td>Taiwan</td>
<td>9</td>
<td>NICU</td>
<td>9 NR NR</td>
<td>3 0</td>
<td>2 A baumannii</td>
<td></td>
<td>A baumannii</td>
</tr>
<tr>
<td>12</td>
<td>2001</td>
<td>South Africa</td>
<td>7</td>
<td>PICU/NICU</td>
<td>5 NR NR NR</td>
<td>NR NR</td>
<td>3 A calcoaceticus</td>
<td></td>
<td>A calcoaceticus</td>
</tr>
<tr>
<td>13</td>
<td>2000</td>
<td>Germany</td>
<td>3</td>
<td>Pediatric oncology ward</td>
<td>3 0 NR 0</td>
<td>NR NR</td>
<td>1 A junii</td>
<td></td>
<td>A junii</td>
</tr>
<tr>
<td>14</td>
<td>1999</td>
<td>Netherlands</td>
<td>6</td>
<td>NICU</td>
<td>6 NR NR</td>
<td>0</td>
<td>0 A junii</td>
<td></td>
<td>A junii</td>
</tr>
<tr>
<td>15</td>
<td>1999</td>
<td>South Africa</td>
<td>4</td>
<td>NICU</td>
<td>4 NR NR</td>
<td>1 1</td>
<td>1 Not specified</td>
<td></td>
<td>A calcoaceticus</td>
</tr>
<tr>
<td>16</td>
<td>1998</td>
<td>Bahamas</td>
<td>8</td>
<td>NICU</td>
<td>8 0 6 3</td>
<td>3</td>
<td>3 A baumannii</td>
<td></td>
<td>A baumannii</td>
</tr>
<tr>
<td>17</td>
<td>1993</td>
<td>Israel</td>
<td>9</td>
<td>NICU</td>
<td>9 0 4 4</td>
<td>4 4</td>
<td>4 Not specified</td>
<td></td>
<td>A calcoaceticus</td>
</tr>
<tr>
<td>18</td>
<td>1991</td>
<td>Chile</td>
<td>21</td>
<td>NICU</td>
<td>21 NR NR NR</td>
<td>NR NR</td>
<td>3 A calcoaceticus</td>
<td></td>
<td>A calcoaceticus</td>
</tr>
<tr>
<td>19</td>
<td>1990</td>
<td>Germany</td>
<td>6</td>
<td>NICU</td>
<td>6 NR NR</td>
<td>0 0</td>
<td>0 A calcoaceticus</td>
<td></td>
<td>A calcoaceticus</td>
</tr>
<tr>
<td>20</td>
<td>1989</td>
<td>United Kingdom</td>
<td>7</td>
<td>NICU</td>
<td>7 NR 0 0</td>
<td>0</td>
<td>0 A lwoffi</td>
<td></td>
<td>A lwoffi</td>
</tr>
<tr>
<td>21</td>
<td>1983</td>
<td>United Kingdom</td>
<td>2</td>
<td>Burn unit</td>
<td>2 NR 2 NR</td>
<td>NR NR</td>
<td>2 A calcoaceticus</td>
<td></td>
<td>A calcoaceticus</td>
</tr>
<tr>
<td>22</td>
<td>1982</td>
<td>United Kingdom</td>
<td>4</td>
<td>NICU</td>
<td>4 NR NR</td>
<td>0 0</td>
<td>0 A calcoaceticus</td>
<td></td>
<td>A calcoaceticus</td>
</tr>
</tbody>
</table>

All species belong to the Acinetobacter genus. NICU Neonatal intensive care unit; NR Not reported; PICU Pediatric intensive care unit; Ref Reference.
Acinetobacter from environmental sources, air conditioners, aerotors, dressings, suction catheters or the hands of health care workers; however, typing was never performed to confirm whether the patient and environmental strains were identical.

The vast majority of patients in the outbreaks had Acinetobacter bloodstream infections. Of the 18 studies, 17 described at least one bacteraemic patient. The other study (22) did not report blood culture results in four preterm infants with Acinetobacter meningitis. Meningitis was the second most common infection after bacteremia, with four of the 18 studies describing patients with Acinetobacter meningitis with or without bacteremia. There were no other sites of proven invasive infection described in the outbreak studies.

Fourteen of the 18 studies provided information on patient outcome, with all these studies involving only neonates. For the 11 studies that reported deaths attributable to Acinetobacter, mortality varied from 0% to 44%; 13 of 70 neonates (19%) died.

Case series
Thirty-three of the studies (23-56) were case series dating back to 1953 (Table 2). As with the outbreaks, the number of case series also seems to be increasing, with 15 of 33 (45%) occurring within the past 10 years. Case series were concentrated in India (seven studies [21%]), Slovakia (four studies [12%]) and the United States (four studies [12%]).

The number of children per case series ranged from one to 138 (median: nine cases). For 12 of the 33 studies (36%), all cases were from the same setting: five studies were from an NICU (15%), two were from neurosurgery wards (6%), one was from a PICU (3%), one was from a general pediatric ward (3%) and three (all from India) described only community-acquired infections (9%). A study (26) from Philadelphia (USA) investigating risk factors for bacteremia with Acinetobacter found that almost 50% of infections were acquired at home in children with central venous catheters, many of whom had malignancies.

In terms of types of infection, five of the 33 (15%) studies included cases of neonatal (younger than one month of age) meningitis, 10 (30%) included cases of pediatric (older than one month of age) meningitis and four (12%) included cases of postsurgical meningitis. Fifteen of the 33 (45%) studies reported cases of bacteremia with no meningitis, one reported cases of endophthalmitis and one reported cases of postmeningitis. Meningitis was the second most common infection dating back to 1950. Unlike the outbreaks or the case series, a relatively smaller fraction of the case reports were reported recently, with only 12 from the past 10 years. The geographical distribution of the case reports also differs from the outbreaks and case series in that only 12 of the 44 that provided the location were from developing countries.

Case reports
There were 49 case reports of invasive pediatric Acinetobacter infection dating back to 1950. Unlike the outbreaks or the case series, a relatively smaller fraction of the case reports were reported recently, with only 12 from the past 10 years. The geographical distribution of the case reports also differs from the outbreaks and case series in that only 12 of the 44 that provided the location were from developing countries.

Case reports described unusual presentations including multiple nodules in the spleen and lung mimicking fungal infection in a child with leukemia (57), a mediastinal mass in a child with chronic granulomatous disease (58), skin abscesses in a neonate (59), osteomyelitis of a phalanx following a hammer bite (60), gangrene of the toes in an infant (61,62) and corneal perforation with iris prolapse in a child (63). Novel aspects of therapy from the case reports included responses to parenteral colistin (64-66), netilmicin (65), tigecycline (67) and intrathecal polymyxin (68).

DISCUSSION
A systematic literature review of pediatric Acinetobacter infection yielded 18 descriptions of possible outbreaks, 33 case series and 49 case reports from around the globe dating back to 1950. Early publications were case reports of primarily meningitis, followed by case series of infections that occurred in specific settings (such as intensive care units, burn units or oncology wards). The first possible outbreak from a United Kingdom NICU was reported in 1982 (22). None of the outbreaks occurred in North America, but a NICU outbreak was reported from New York (USA) in 2009 after the literature search was completed (69).

One of the striking features of the outbreaks was that the vast majority (89%) occurred in NICUs, suggesting that neonates with a complicated course are at particular risk of Acinetobacter infection. However, it is important to realize that outbreaks may be easier to recognize in a NICU because infection control surveillance is more likely in this setting, with patients often staying in a NICU until discharge; consequently, almost all nosocomial infections are detected. In settings with no surveillance, linked cases may not be noted if different physicians are caring for the patient. Evidence for an outbreak was simply based on clustering of cases in the majority of studies; therefore, it is very difficult to determine whether they were truly outbreaks. The source of infection was definitely proven in only one study (7); therefore, it was difficult to make specific recommendations to prevent such outbreaks in the future. In fact, one study (12) reported that although all isolates were A calcoaceticus, susceptibility patterns varied, which would make one question if this truly was an outbreak.

Among the 33 case series, it is interesting to note that a significant number were from India (eight studies), with four of these case series including community-acquired cases. It is possible that Acinetobacter is more predominant in the normal flora of this population or in warm humid climates and, therefore, causes more community-acquired infections.

Bacteremia and meningitis were the most common presentations of pediatric Acinetobacter infection, with dissemination to other sites being rare. There were five case reports (69-74) and
### TABLE 2
Characteristics of pediatric *Acinetobacter* case series involving at least one child with invasive infection

<table>
<thead>
<tr>
<th>Ref</th>
<th>Year</th>
<th>Country</th>
<th>Cases of invasive infection, n</th>
<th>Age range</th>
<th>Setting</th>
<th>Primary infection</th>
<th>Deaths from <em>Acinetobacter</em>, n</th>
<th>Species</th>
</tr>
</thead>
<tbody>
<tr>
<td>23</td>
<td>2008</td>
<td>Iran</td>
<td>40</td>
<td>&lt;28 days</td>
<td>NICU</td>
<td>Bacteremia</td>
<td>NR</td>
<td>A baumannii</td>
</tr>
<tr>
<td>24</td>
<td>2007</td>
<td>Taiwan</td>
<td>52</td>
<td>3 years to 27 years, mean: 6 years</td>
<td>wards, PICU, NICU</td>
<td>Bacteremia</td>
<td>NR</td>
<td>A baumannii</td>
</tr>
<tr>
<td>25</td>
<td>2007</td>
<td>Slovak Republic</td>
<td>25</td>
<td>NR</td>
<td>Children's hospital general wards, ICUs</td>
<td>Meningitis</td>
<td>5</td>
<td>A baumannii</td>
</tr>
<tr>
<td>26</td>
<td>2007</td>
<td>United States</td>
<td>92</td>
<td>IQR: 1.8 to 13.2</td>
<td>Children's hospital general wards, ICUs, outpatients</td>
<td>Bacteremia</td>
<td>4</td>
<td>A baumannii, A lwofii, A calcoaceticus, unidentified species</td>
</tr>
<tr>
<td>27</td>
<td>2006</td>
<td>Greece</td>
<td>26</td>
<td>Mean: 7.6 years</td>
<td>PICU</td>
<td>Bacteremia</td>
<td>NR</td>
<td>A baumannii</td>
</tr>
<tr>
<td>28</td>
<td>2006</td>
<td>India</td>
<td>23</td>
<td>NR</td>
<td>7 community acquired, 16 hospital acquired</td>
<td>Bacteremia</td>
<td>NR</td>
<td>A baumannii, A lwofii</td>
</tr>
<tr>
<td>29</td>
<td>2006</td>
<td>India</td>
<td>42</td>
<td>34 were &lt;12 h old</td>
<td>9 community acquired, 33 hospital acquired</td>
<td>Bacteremia and meningitis</td>
<td>NR</td>
<td>A baumannii, A lwofii</td>
</tr>
<tr>
<td>30</td>
<td>2005</td>
<td>Greece</td>
<td>2</td>
<td>14 years, 16 years</td>
<td>NR</td>
<td>Meningitis</td>
<td>0</td>
<td>A baumannii</td>
</tr>
<tr>
<td>31</td>
<td>2004</td>
<td>India</td>
<td>78</td>
<td>NR</td>
<td>Bacteremia and meningitis</td>
<td>NR</td>
<td>A baumannii, A lwofii</td>
<td></td>
</tr>
<tr>
<td>32</td>
<td>2003</td>
<td>Morocco</td>
<td>20</td>
<td>&lt;28 days old</td>
<td>NICU</td>
<td>Bacteremia and meningitis</td>
<td>NR</td>
<td></td>
</tr>
<tr>
<td>33</td>
<td>2003</td>
<td>India</td>
<td>4</td>
<td>7 years, 14 years, 14 years, 18 years</td>
<td>NR</td>
<td>Endophthalmitis</td>
<td>0</td>
<td>A calcoaceticus</td>
</tr>
<tr>
<td>34,35</td>
<td>2001</td>
<td>Slovak Republic</td>
<td>48</td>
<td>0 to 12 years</td>
<td>Multiple wards across 8 teaching hospitals</td>
<td>Bacteremia</td>
<td>6</td>
<td>A baumannii</td>
</tr>
<tr>
<td>36</td>
<td>2000</td>
<td>Slovak Republic</td>
<td>10</td>
<td>1 to 36 months</td>
<td>NR</td>
<td>Meningitis</td>
<td>4</td>
<td>A calcoaceticus</td>
</tr>
<tr>
<td>37</td>
<td>2000</td>
<td>Taiwan</td>
<td>3</td>
<td>3 years, 3 years and 6 years</td>
<td>NR</td>
<td>Meningitis</td>
<td>2</td>
<td>A lwofii</td>
</tr>
<tr>
<td>38</td>
<td>2000</td>
<td>Slovak Republic</td>
<td>14</td>
<td>1 to 36 months</td>
<td>3 pediatric hospitals</td>
<td>Meningitis</td>
<td>0</td>
<td>A baumannii</td>
</tr>
<tr>
<td>39</td>
<td>1999</td>
<td>Taiwan</td>
<td>1</td>
<td>17 years</td>
<td>Neurosurgery ward</td>
<td>Meningitis</td>
<td>0</td>
<td>Unidentified species</td>
</tr>
<tr>
<td>40</td>
<td>1998</td>
<td>India</td>
<td>79</td>
<td>NR</td>
<td>55 nursery, 24 community acquired</td>
<td>Bacteremia</td>
<td>NR</td>
<td></td>
</tr>
<tr>
<td>41</td>
<td>1998</td>
<td>Bangladesh</td>
<td>138</td>
<td>82% were 5 years or younger</td>
<td>Community and hospital acquired</td>
<td>Bacteremia</td>
<td>22</td>
<td>A baumannii, A lwofii, A hemolyticus, A junii, genomospecies 3, genomospecies 14, unidentified species</td>
</tr>
<tr>
<td>42</td>
<td>1995</td>
<td>Netherlands</td>
<td>6</td>
<td>1, 3, 8, 13, 20 and 29 days</td>
<td>NICU</td>
<td>Bacteremia</td>
<td>5</td>
<td>A calcoaceticus</td>
</tr>
<tr>
<td>43</td>
<td>1993</td>
<td>India</td>
<td>26</td>
<td>NR</td>
<td>NICU</td>
<td>Bacteremia</td>
<td>NR</td>
<td></td>
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<td>44</td>
<td>1993</td>
<td>Israel</td>
<td>3</td>
<td>2 months, 3 months, 1 year</td>
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<td>Meningitis</td>
<td>0</td>
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</tr>
<tr>
<td>45</td>
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<td>Nigeria</td>
<td>2</td>
<td>NR</td>
<td>NR</td>
<td>Endocarditis</td>
<td>NR</td>
<td></td>
</tr>
<tr>
<td>46</td>
<td>1989</td>
<td>Japan</td>
<td>19</td>
<td>4 to 22 days</td>
<td>NICU</td>
<td>Bacteremia</td>
<td>NR</td>
<td>A calcoaceticus</td>
</tr>
<tr>
<td>47</td>
<td>1986</td>
<td>United States</td>
<td>29</td>
<td>NR</td>
<td>Oncology ward</td>
<td>Bacteremia</td>
<td>0</td>
<td>A lwofii, A calcoaceticus, unidentified species</td>
</tr>
<tr>
<td>48</td>
<td>1973</td>
<td>Israel</td>
<td>2</td>
<td>2 years, 3 years</td>
<td>NR</td>
<td>Bacteremia</td>
<td>NR</td>
<td>A lwofii</td>
</tr>
<tr>
<td>49</td>
<td>1969</td>
<td>India</td>
<td>2</td>
<td>2 years, 2 years</td>
<td>NR</td>
<td>Meningitis</td>
<td>NR</td>
<td>A lwofii</td>
</tr>
<tr>
<td>50</td>
<td>1965</td>
<td>United States</td>
<td>2</td>
<td>23 months, 6 years</td>
<td>Community acquired</td>
<td>Meningitis</td>
<td>1</td>
<td>A lwofii</td>
</tr>
<tr>
<td>51</td>
<td>1965</td>
<td>United States</td>
<td>2</td>
<td>4 years, 16 years</td>
<td>Community acquired</td>
<td>Meningitis</td>
<td>1</td>
<td>A lwofii</td>
</tr>
<tr>
<td>52</td>
<td>1965</td>
<td>India</td>
<td>2</td>
<td>4 years, 18 years</td>
<td>Community acquired</td>
<td>Meningitis</td>
<td>0</td>
<td>A lwofii</td>
</tr>
<tr>
<td>53</td>
<td>1965</td>
<td>Uganda</td>
<td>5</td>
<td>1 month, 1 year, 1 year, 6 years, 7 years</td>
<td>NR</td>
<td>Bacteremia and meningitis</td>
<td>0</td>
<td>A lwofii, A calcoaceticus</td>
</tr>
<tr>
<td>54</td>
<td>1961</td>
<td>Puerto Rico</td>
<td>7</td>
<td>4 days to 2 years</td>
<td>NR</td>
<td>Bacteremia and meningitis</td>
<td>3</td>
<td>A lwofii, A calcoaceticus</td>
</tr>
<tr>
<td>55</td>
<td>1957</td>
<td>Canada</td>
<td>2</td>
<td>4 days, 6 days</td>
<td>NR</td>
<td>Meningitis</td>
<td>1</td>
<td>A calcoaceticus</td>
</tr>
<tr>
<td>56</td>
<td>1953</td>
<td>Unknown</td>
<td>2</td>
<td>11 days, 21 days</td>
<td>NR</td>
<td>Meningitis</td>
<td>0</td>
<td>A calcoaceticus</td>
</tr>
</tbody>
</table>

All species belong to the *Acinetobacter* genus. ICU Intensive care unit; IQR Interquartile range; NICU Neonatal ICU; NR Not reported; PICU Pediatric ICU; Ref Reference
one case series that described endocarditis (45). There was one case series with four patients with endophthalmitis (33). There were only three cases reports of well-documented pulmonary involvement with isolation of Acinetobacter from pleural fluid (75), pulmonary lymph node (58) and lung at autopsy (76). However, it is important to recognize that ventilator-associated pneumonia Acinetobacter may also be common in children, but such cases would have been excluded from the current study because Acinetobacter is typically isolated from pulmonary secretions in the absence of a tissue diagnosis. Acinetobacter grew from superficial abscesses in two cases (59,77) and from an intra-abdominal abscess in one case (78), but was otherwise not implicated in abscess formation. This distribution of infections suggests that Acinetobacter is more likely to be part of skin rather than respiratory or gastrointestinal flora.

Acinetobacter taxonomy has changed markedly over time. As of 2008, there were 31 genomic species of which 17 had valid species names (79). It remains controversial whether A. calcoaceticus and A. baumannii should be regarded as the same species because they are difficult to differentiate. A. calcoaceticus appears to be more common from environmental sources and A. baumannii from human sources (79). To clarify some of the terms used in older literature, A. anitratus is actually a subtype of A. calcoaceticus and is more accurately written as A. calcoaceticus var anitratus. Mima polymorpha is an older name for A. lucifii, while B. anitratum, D. mucosus, M. glaciolytica and H. vaginicola are all A. calcoaceticus. A wide variety of species have been described as etiological agents of invasive disease, with A. baumannii traditionally being considered to be of greatest clinical significance, although A. lucifii and A. calcoaceticus were commonly implicated in the published pediatric literature.

The outcome of infection with multiresistant or panresistant Acinetobacter in children remains unclear because it is probable that authors are more likely to publish cases of success than of failure. There are few published cases (64-66) in which the only reasonable therapeutic option was colistin. Fortunately, it appears that ill children develop less nephrotoxicity from colistin than adults (80).

The primary limitation of the present study is that infections reported in the literature may not mirror the relative incidence, spectrum and severity of infection, especially in developed countries or nonacademic centers where clinicians may not have the opportunity to report unusual infections or outbreaks. Pediatric cases that were reported as part of adult series may have been missed. Identification and speciation of Acinetobacter is complex, and may not always be accurately reported.

**CONCLUSION**

Reported invasive Acinetobacter infections in children generally manifest as bacteremia or meningitis. Ventilator-associated pneumonia may also be a common presentation, but this could not be ascertained from the current study. Infections that have been reported from developed countries are usually nosocomial, with community-acquired infections often being reported from India. Outbreaks appear to most likely occur in NICUs, with the source usually remaining unknown. A large multicentre, prospective study concentrating on NICUs and PICUs would be beneficial to further characterize risk factors for and current outcome of invasive infection with this organism. A study of colonisation of normal newborns in tropical countries would also be of value.

**REFERENCES**

Hu and Robinson


