Epidemiology of Bacteremia in Febrile Infants in the United States

WHAT’S KNOWN ON THIS SUBJECT: Bacteremia occurs in 2.2% of febrile infants who have a blood culture drawn. Regional data suggest that Escherichia coli, group B Streptococcus, and Staphylococcus aureus are leading causes; however, the geographic boundaries of these data limit universal applicability.

WHAT THIS STUDY ADDS: This is the first national study examining epidemiology of bacteremia in febrile infants admitted to a general inpatient unit. The most common pathogens were Escherichia coli (42%), group B Streptococcus (23%), and Streptococcus pneumoniae (6%). No Listeria monocytogenes was identified.

abstract

BACKGROUND: Fever in infants is a common clinical dilemma. The objective of this study was to present data from hospital systems across the northeast, southeast, mid-west, and western United States to identify the pathogens causing bacteremia in febrile infants admitted to general care units.

METHODS: This was a retrospective review of positive blood culture results in febrile infants aged ≤90 days admitted to a general care unit across 6 hospital systems. Data were collected from January 1, 2006 through December 31, 2012 from emergency departments and general inpatient units. Cultures from ICUs, central lines, or infants who had complex comorbidities were excluded, as were repeat cultures positive for the same bacteria. Common contaminants were considered pathogens if they were treated as such.

RESULTS: We identified 181 cases of bacteremia in 177 infants. The most common pathogen was Escherichia coli (42%), followed by group B Streptococcus (23%). Streptococcus pneumoniae was more likely in older infants (P = .01). Non-low-risk bacteremic infants were more likely to have E coli or group B Streptococcus than low-risk bacteremic infants. We identified no cases of L monocytogenes. Variation between sites was minimal.

CONCLUSIONS: This is the largest and most geographically diverse study to date examining the epidemiology of bacteremia in infants. We suggest E coli is the most common cause of bacteremia in previously healthy febrile infants admitted to a general inpatient unit. We identified no cases of L monocytogenes and question whether empirical therapy remains necessary for this pathogen. Pediatrics 2013;132:990–996

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KEY WORDS: febrile infant, bacteremia, Escherichia coli, epidemiology, antibiotic use

ABBREVIATIONS

AMC—Albany Medical Center
GCHS—Golisano Children’s Hospital of Strong
GHCM—Children’s Hospitals and Clinics of Minnesota
GHKD—The Children’s Hospital of The King’s Daughters
GHLA—Children’s Hospital Los Angeles
GHOI—Children’s Hospital of Illinois
CoNS—coagulase-negative staphylococcus
CSF—cerebrospinal fluid
GBS—group B Streptococcus
GCHS—Golisano Children’s Hospital at Strong
SBI—serious bacterial infection
SSTI—skin or soft-tissue infection
UTI—urinary tract infection

Dr Biondi conceptualized and designed the study, collected data, served as the central site principal investigator, coordinated data collection at all 6 study sites, drafted much of the initial manuscript, and participated in statistical analysis; Dr Evans aided in study conceptualization and design, collected data at her institution, served as participating site principal investigator, and drafted parts of the initial manuscript; Dr Mischler aided in study conceptualization and design, collected data at his institution, served as participating site principal investigator, and drafted parts of the initial manuscript; Dr Horstmann aided in study conceptualization and design, collected data at her institution, served as participating site principal investigator, and drafted parts of the initial manuscript; Dr Lee aided in data collection, served as principal investigator at his institution, and reviewed drafts of this manuscript; Dr Aldag provided statistical analysis of the compiled data and critically reviewed and drafted aspects of the methodology and results sections; Dr Gigliotti aided in conceptualization and study design, provided supervision and mentorship at the central site, and critically reviewed the manuscript; and all authors approved the final manuscript as submitted.

(Continued on last page)
Fever in infants is a common problem faced by pediatricians and is often the only sign of serious bacterial infection (SBI) in this age group. It is estimated that 2% of infants presenting with fever without a source will have bacteremia, but it is often difficult to clinically predict which infants have bacteremia before obtaining blood culture results. For this reason, empirical broad spectrum antibiotic coverage is classically recommended until specific pathogens can be isolated or excluded; however, the recommended antibiotics have changed very little in the last few decades.

Recent regional data suggest that the epidemiology of bacteremia in term infants is shifting, and that *Escherichia coli* is now the most common cause of bacteremia in febrile infants ≤90 days old. Once considered the most common cause of bacteremia in infants, estimates suggest that group B *Streptococcus* (GBS) may now account for as few as 16% of cases and was only the third most common cause of bacteremia in 1 study. Early-onset GBS has declined dramatically since the early 1980s from 1.7 cases per 1000 live births to 0.34 to 0.37 in recent years. Additionally, although evidence-based guidelines regarding empirical antibiotics continue to include coverage for *Listeria monocytogenes*, there is evidence that the incidence of listeriosis has been decreasing.

The subpopulation of febrile infants who are well-appearing enough to be admitted to a general inpatient unit is important. These infants are exposed to empirical antibiotic coverage pending culture results, colloquially termed the "rule out sepsis" evaluation, but rarely demonstrate true bacteremia. A review of the literature identified no multicenter studies examining this issue, and regional studies were limited to <100 cases of bacteremia. The low prevalence of bacteremia in this group, and potential geographic variability, make it difficult for regional or single-site studies to provide generalizable epidemiological data, and thus warrant a national examination. Furthermore, although patients stratified as low or non-low risk by the Rochester criteria can differ in risk for SBI by greater than eightfold, a literature review did not identify a study examining bacterial epidemiology by risk.

The purpose of this study was to provide geographically diverse data on the epidemiology of bacteremia in previously healthy, febrile infants admitted to a general inpatient unit; to determine the incidence of *L monocytogenes* in this population; and to determine whether age or infant risk can predict the epidemiology of bacteremia.

**METHODS**

This was a multicenter, retrospective review of positive, pathogenic blood cultures in previously healthy, febrile infants aged ≤90 days admitted to a general inpatient unit between January 1, 2006 and December 31, 2012. This study was independently approved by the Institutional Review Boards at all 6 participating institutions. Informed consent was waived.

**Study Design**

The central site for this study was Golisano Children’s Hospital at Strong (GCHS) at the University of Rochester Medical Center, a tertiary care children’s hospital located in Rochester, New York. Participating sites included The Children’s Hospital of Illinois (CHOI), The Children’s Hospital of The King’s Daughters (CHKD), Children’s Hospitals and Clinics of Minnesota (CHCM), The Children’s Hospital at Albany Medical Center (AMC), and Children’s Hospital Los Angeles (CHLA). Table 1 describes the demographic attributes of the participating sites. All sites use a BACTEC automated blood culture detection system.

Each participating site obtained from their microbiology laboratory an initial database of all positive blood cultures drawn from infants ≤90 days old within their hospital system. Inter-site study dates varied secondary to availability of data and feasibility of collection.

A preliminary review of culture data allowed exclusion of cultures drawn in an ICU and a full chart review was then performed on the remaining cultures to determine whether study criteria were met. To qualify for inclusion, cultures must have been positive for bacteria, drawn from an infant ≤90 days of age, treated as a pathogen, and drawn from a patient who had either a fever per history or a recorded temperature of ≥38.0°C. Cultures drawn in any manner other than peripheral venipuncture, from children requiring an ICU level of care (defined as drawn in an ICU or from a patient admitted directly to an ICU), from patients with central lines, intra-abdominal, intracranial, or intra-thoracic surgical histories, or repeat cultures growing the same bacteria from the same infant were excluded. Cultures that grew common contaminants such as diphtheroids, *Propionibacterium* sp., or coagulase-negative *Staphylococcus* (CoNS) were generally excluded unless the culture was treated by the attending physician as a pathogen (eg, a full course of antibiotic therapy).

For cultures meeting study criteria, clinical and demographic information was collected using a standardized extraction tool. Abstracted information included age at the time of culture, gender of the infant, bacterial species isolated from the blood, and infant risk based on modified Rochester Criteria similar to that used by others. Each infant was stratified as either low risk or non-low risk. Low risk infants were defined as those without evidence of focal infection, previous antibiotic administration, treatment of hyperbilirubinemia, previous hospitalization, history
of preterm birth (<37 weeks), chronic medical conditions, abnormal white cell count (<5000 or >15 000 white blood cells per mm$^3$), absolute band cell count of >1500 per mm$^3$, or urinalysis results (>10 white blood cells/high power field). As in previous studies, patients who did not meet all of the low risk criteria, or who had classifying data that were unavailable, were placed in the non-low risk group. When available, cerebrospinal fluid (CSF) and urine culture results were recorded if drawn within 24 hours of the positive blood culture to assess for concurrent urinary tract infection (UTI) and/or meningitis. In cases of *Staphylococcus aureus* bacteremia, a further chart review was done to determine whether there was concern for skin or soft-tissue infection (SSTI) at the time of blood culture. The principal investigator at each site was responsible for ensuring that cultures from their site met study criteria and data were reported to GCHS for analysis.

**Data Analysis**

Prevalence of bacterial species among infants was calculated and reported along with a basic statistical summary. $\chi^2$ was used to determine variance in bacterial prevalence among the 6 sites (the 2 smallest sites were combined) for prevalence of *E coli* compared with all other bacterial species and GBS compared with all other bacterial species. The 95% confidence interval for *L monocytogenes* was determined by using a method proposed for numerators of zero, $\chi^2$ or Fisher’s exact tests were used to test dichotomous variables, with statistical significance set at $P < .05$. The statistical program used was SPSS version 21 (IBM SPSS Statistics, IBM Corporation).

**RESULTS**

We identified 2901 positive blood cultures from infants ≤90 days of age within the study period (Fig 1). Eighteen hundred were excluded because they were drawn from patients who were in a neonatal or pediatric ICU, admitted directly to the ICU, or who had central lines. Of the remaining cultures, 811 were either identified as a contaminant or not treated as a pathogen and therefore did not meet inclusion criteria, the majority of which were CoNS (59%). Because of complex comorbidities, an additional 96 cultures were excluded. Of the remaining 194 cultures, 9 were not obtained from an infant who had a fever history and 4 were duplicate cultures growing the same bacteria from the same patient, leaving 181 cultures for analysis obtained from 177 infants. Table 2 displays demographic information for cultures by site and in total. *E coli* was the most prevalent pathogen in all but 1 hospital system. There was no statistically significant difference in the prevalence of *E coli*, GBS, or all other bacteria species between sites ($\chi^2 = 9.9, P = .28$). Nineteen different bacterial species were identified (Table 3). The most common pathogen recovered from all blood cultures was *E coli* (76/181, 42%), followed by GBS (41/181, 23%), *Streptococcus pneumoniae* (10/181, 6%), and *S aureus* (9/181, 5%). Of the infants we identified with *S aureus* bacteremia, 56% (5/9) had evidence of SSTI on presentation. There were no cases of *L monocytogenes* (95% confidence interval, 0%–2% of total cases).

Urine cultures were obtained in 172 (95%) cases and 85 (49%) of these were...
positive for bacteria. Of the 76 blood cultures that grew *E. coli*, 75 (99%) had an associated urine culture collected and 68 (91%) of these were found to have concurrent *E. coli* UTI. Of the 105 blood cultures positive for other bacterial species, 97 (92%) had associated urine cultures and 16 (15%) had concurrent UTI.

CSF cultures were obtained in 151 (83%) cases, 20 (13%) of which were positive for bacteria. GBS was the bacterial species most likely to cause concurrent meningitis (10/37, 27%). There was also 1 case of *Pantoea* sp. bacteremia with concurrent GBS meningitis. Of the 76 cases of *E. coli* bacteremia, 63 had CSF cultures obtained and 5 (7%) had concurrent meningitis. Two infants who had *E. coli* bacteremia and *E. coli* UTI also had concurrent *E. coli* meningitis (2/68, 3%). Of the 10 cases of *S. pneumoniae* bacteremia, 4 had CSF cultures obtained and 1 of these had concurrent meningitis.

### TABLE 2 Inter-Site Characteristics of Positive Cultures Drawn From Infants

<table>
<thead>
<tr>
<th>Site</th>
<th>n</th>
<th>Male (%)</th>
<th>Median Age in Days (Range)</th>
<th>Non-Low Risk (%)</th>
<th>Most Common Organisms (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHCM</td>
<td>86</td>
<td>44 (51)</td>
<td>38 (7–88)</td>
<td>69 (80)</td>
<td><em>E. coli</em> (50)</td>
</tr>
<tr>
<td>CHKD</td>
<td>29</td>
<td>13 (45)</td>
<td>36 (10–81)</td>
<td>26 (90)</td>
<td><em>E. coli</em> (41)</td>
</tr>
<tr>
<td>CHLA</td>
<td>24</td>
<td>16 (64)</td>
<td>39 (6–90)</td>
<td>21 (84)</td>
<td><em>E. coli</em> (44)</td>
</tr>
<tr>
<td>CHOI</td>
<td>23</td>
<td>12 (52)</td>
<td>42 (3–81)</td>
<td>15 (65)</td>
<td><em>E. coli</em> (39)</td>
</tr>
<tr>
<td>GCHS</td>
<td>14</td>
<td>3 (20)</td>
<td>23 (15–66)</td>
<td>6 (60)</td>
<td><em>E. coli</em> (34)</td>
</tr>
<tr>
<td>AMC</td>
<td>18</td>
<td>3 (16)</td>
<td>33 (9–73)</td>
<td>7 (88)</td>
<td><em>E. coli</em> (40)</td>
</tr>
<tr>
<td>Total</td>
<td>181</td>
<td>91 (50)</td>
<td>34 (3–90)</td>
<td>144 (80)</td>
<td><em>E. coli</em> (42)</td>
</tr>
</tbody>
</table>

Percentages may not add to 100 owing to rounding.

* AMC also had *Neisseria* sp. (13) and *S. aureus* (15).

**DISCUSSION**

This multiregional study examined the epidemiology of bacteremia in previously healthy febrile infants outside of the ICU. A national approach is particularly salient to the question of bacterial epidemiology in our patient population for 2 reasons. First, bacteremia in this group is a rare event and combining data from 6 centers allows us a more rigorous examination than would otherwise be possible. Second, patterns of bacterial prevalence may vary geographically, potentially limiting generalizability of regional data.

Our study demonstrates an increasingly prominent role for *E. coli* as a cause of bacteremia in febrile infants in the United States. These results are largely consistent with single-region observations, although we do demonstrate a slightly lower percentage of bacteremia caused by Gram-negative organisms (53%) than previous studies (63%–80%).

The majority of infants who had *E. coli* bacteremia had concurrent UTI. It has been suggested that infants who have *E. coli* UTI may not require a lumbar puncture to establish the diagnosis of concurrent meningitis.
puncture.18 However, in infants who had *E coli* UTI and bacteremia, we identified 2 cases (3%) of concurrent meningitis. GBS remains a common cause of bacteremia and was the most common bacteria to cause concurrent meningitis (27%).

Consistent with previous regional data, we found no cases of *L monocytogenes* bacteremia.2,10,17 There has been an overall decrease in laboratory-confirmed listeriosis in recent decades, likely owing to prohibitions regarding the sale of potentially contaminated food and public education campaigns targeted at high-risk populations, including pregnant women.19 Although *L monocytogenes* is generally considered a cyclical pathogen, making it possible that our data were gathered during a “lull” in incidence, we collected geographically diverse data over several years during which time there were several nationally reported outbreaks of listeriosis.20 Historically, physicians have been taught that bacteremia in young infants is caused by GBS, *E coli*, and *L monocytogenes*.21,22 This classic teaching stems from studies performed decades ago when *L monocytogenes* was a more common cause of food-borne infection.23,24 Based on our data and regional studies performed previously, we suggest that the etiologies of SBI remains the same, although this is not the first time that treatment has been used in some way to determine contamination.2 Although there are bacteria that should always represent a true infection,28 and some that almost always represent contamination in an otherwise healthy child,26,29 using bacterial species alone to determine contamination is unlikely to be sufficient, because many common contaminants can also represent true bacteremia.28–30 For this reason we feel that, although we did potentially exclude up to 3 cases of true bacteremia (1 culture grew several species including *S aureus*, and 2 others grew *E coli* per chart review, none were treated and all did well), our method of determining contaminants allowed us to avoid including many cases that likely did not represent true bacteremia. One example was a febrile infant sent home from the emergency department without antibiotics after having blood cultures drawn that eventually grew *Enterococcus* sp. Further review revealed that the repeat cultures from the outpatient office showed no growth, and that the child was afebrile and doing well at 1 week follow-up. Our study criteria allowed us to exclude this patient, who would otherwise have been mistakenly included. Our study had several limitations. First, the retrospective nature of the review and incidence may confirm that empirical monotherapy with a third-generation cephalosporin, such as ceftaxime, may be adequate. Cefotaxime is well tolerated in young infants and should provide coverage for the vast majority of pathogens we identified.26,27 This study also highlights the emergence of *S aureus* as a leading pathogen in bacteremia in young infants, similar to that seen previously,2,10 and it should be considered particularly for febrile infants in whom SSTI is suspected.

Our decision to use treatment with a full course of antibiotics as an aspect of our study criteria warrants some explanation, although this is not the first time that treatment has been used in some way to determine contamination.2 Although there are bacteria that should always represent a true infection,28 and some that almost always represent contamination in an otherwise healthy child,26,29 using bacterial species alone to determine contamination is unlikely to be sufficient, because many common contaminants can also represent true bacteremia.28–30 For this reason we feel that, although we did potentially exclude up to 3 cases of true bacteremia (1 culture grew several species including *S aureus*, and 2 others grew *E coli* per chart review, none were treated and all did well), our method of determining contaminants allowed us to avoid including many cases that likely did not represent true bacteremia. One example was a febrile infant sent home from the emergency department without antibiotics after having blood cultures drawn that eventually grew *Enterococcus* sp. Further review revealed that the repeat cultures from the outpatient office showed no growth, and that the child was afebrile and doing well at 1 week follow-up. Our study criteria allowed us to exclude this patient, who would otherwise have been mistakenly included. Our study had several limitations. First, the retrospective nature of the review

### TABLE 4 Characteristics of Infants by the Most Common Pathogenic Blood Culture Species

<table>
<thead>
<tr>
<th>Variable</th>
<th>Male (P)</th>
<th>Non-Low Risk (P)</th>
<th>0–30 d</th>
<th>31–60 d</th>
<th>61–90 d</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>E coli</em></td>
<td>44 (0.08)</td>
<td>68 (0.01)</td>
<td>37</td>
<td>22</td>
<td>17</td>
<td>.48</td>
</tr>
<tr>
<td>GBS</td>
<td>10 (0.01)</td>
<td>27 (0.01)</td>
<td>18</td>
<td>15</td>
<td>10</td>
<td>.86</td>
</tr>
<tr>
<td><em>S pneumoniae</em></td>
<td>3 (0.01)</td>
<td>8 (0.01)</td>
<td>2</td>
<td>2</td>
<td>6</td>
<td>.01</td>
</tr>
<tr>
<td><em>S aureus</em></td>
<td>3 (0.01)</td>
<td>8 (0.01)</td>
<td>2</td>
<td>2</td>
<td>6</td>
<td>.01</td>
</tr>
<tr>
<td><em>Klebsiella</em> sp.</td>
<td>5 (0.01)</td>
<td>8 (0.01)</td>
<td>4</td>
<td>2</td>
<td>2</td>
<td>.37</td>
</tr>
<tr>
<td>All other</td>
<td>18 (0.02)</td>
<td>26 (0.12)</td>
<td>16</td>
<td>14</td>
<td>7</td>
<td>.80</td>
</tr>
</tbody>
</table>
inhibited our ability to identify negative blood cultures, so we are unable to provide information regarding the overall risk for bacteremia. This limits our ability to provide firm recommendations regarding empirical antibiotic therapy and a prospective, national study is necessary. Second, criteria for ICU admission vary from institution to institution and this may have introduced some unidentified heterogeneity in our patient population. Third, when analyzing the difference in bacterial species between risk cohorts, statistical significance of some individual species was limited by small sample sizes (eg, *Klebsiella* sp.). Additionally, we assigned risk retrospectively after the infant was known to have bacteremia; risk classification is typically employed as a way to predict which infants will have an SBI before 1 being identified. Finally, the start date of data collection varied between sites by up to 14 months owing to limitations in the availability of data within each institution’s microbiology database. However, our analysis found no statistically significant variability in the prevalence of *E coli*, GBS, or all other species (*P* = .28), which suggests uniformity across the dates of study.

**CONCLUSIONS**

We present the largest study to date examining the question of bacterial epidemiology in infants admitted to the general care unit with bacteremia. These data support the trend seen in previous regional publications that *E coli* has become the most common cause of bacteremia in febrile infants admitted to the general care unit, with GBS and *S pneumoniae* the second and third most common causes, respectively. Together, these 3 species account for 71% of positive blood cultures in our patient population. Not a single case of *L monocytogenes* was identified. In infants who have bacteremia, *E coli* and GBS are more likely to be identified as the cause in non-low risk than in low risk infants and *S pneumoniae* is more likely to be found in older infants. We suggest a prospective evaluation to determine whether a change in typical empirical antibiotic regimens is necessary.

**REFERENCES**

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An error occurred in the article by Eric Biondi et al, titled “Epidemiology of Bacteremia in Febrile Infants in the United States” published in the December 2013 issue of *Pediatrics* (2013;132[6]:990–996; originally published online November 11, 2013; doi:10.1542/peds.2013-1759). On page 990, in Authors, this reads: “Vivan Lee; Children’s Hospital of Los Angeles.” This should have read: “Vivian Lee; Children’s Hospital Los Angeles.”

doi:10.1542/peds.2013-4017


An error occurred in this article by Pickering et al, titled “The Red Book Through the Ages” published in the November 2013 issue of *Pediatrics* (2013;132[5]:898–906; originally published online October 14, 2013; doi:10.1542/peds.2013-2538). On page 899, under Early History of the COID, the first line reads: “After the establishment of the AAP in 1930 in the library of Harber Hospital....” This should have read: “After the establishment of the AAP in 1930 in the library of Harper Hospital....”

doi:10.1542/peds.2013-4105


doi:10.1542/peds.2014-0173


Two errors occurred in the article by Simpson et al, titled “A New Leukocyte Hyperadhesion Syndrome of Delayed Cord Separation, Skin Infection, and Nephrosis” published in the January 2014 issue of *Pediatrics* (2014;133[1]:e257–e262; doi:10.1542/2013-0884). On page e261, under Treatment With Glucocorticoids on line 31, this reads: “Whereas the exact mechanism causing the hyperadhesiveness of the integrins is not known, the symptoms bear resemblance to mice expressing constitutively active LFA-1 in which excessive adhesion prevents leukocytes from entering injured tissues and, when tested in vitro, causes increased adhesion and stalled migration.15,16” This should have not been inserted. Additionally, on the same page (e261) in the next section, Leukocyte Hyperadhesiveness, on line 12, this reads: “Whereas the exact mechanism causing the hyperadhesiveness of the integrins is not known, the symptoms bear resemblance to mice expressing constitutively active LFA-1 in which excessive adhesion prevents leukocytes from entering injured tissues and, when tested in vitro, causes increased adhesion and
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An erratum has been published regarding this article. Please see the attached page for:
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