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Interpretation of cerebrospinal fluid white blood cell counts in young infants with a traumatic lumbar puncture

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Abstract

Study Objective—To determine the optimal correction factor for cerebrospinal fluid (CSF) white blood cell (WBC) counts in infants with traumatic lumbar punctures (LPs).

Methods—We performed a secondary analysis of a retrospective cohort of infants 60–days-old with a traumatic LP [CSF red blood cell (RBC) count 10,000 cells/mm³] at 20 participating centers. CSF pleocytosis was defined as a CSF WBC count 20 cells/mm³ for infants 28 days, 10 cells/mm³ for infants 29–60 day and bacterial meningitis as growth of pathogenic bacteria from CSF culture. Using linear regression, we derived a CSF WBC correction factor and compared the uncorrected to the corrected CSF WBC count for the detection of bacterial meningitis.

Results—Of the eligible 20,319 LPs, 2,880 (14%) were traumatic of whom 33 (1.1%) had bacterial meningitis. The derived CSF RBCs:WBCs ratio was 877:1 [95% confidence interval (CI) 805–961:1]. Compared with the uncorrected CSF WBC count, the corrected CSF WBC count had lower sensitivity for bacterial meningitis [88% uncorrected vs. 67% corrected; difference 21%, 95% CI 10–37%] but resulted in fewer infants with CSF pleocytosis [78% uncorrected vs. 33% corrected; difference 45%, 95% CI 43–47%]. CSF WBC count correction resulted in 7 additional infants with bacterial meningitis being misclassified as not having CSF pleocytosis; only one of these infants was > 28-days-old.

Conclusion—Correction of the CSF WBC count substantially reduced the number of infants with CSF pleocytosis while misclassifying only one infant with bacterial meningitis 29 to 60 days of age.

INTRODUCTION

Background and Importance

The evaluation of febrile infants in the first 2 months of life is challenging as up to 10% of well-appearing febrile infants can have bacterial infections such as meningitis.¹ Consequently, the vast majority of such infants undergo a lumbar puncture (LP) as part of their initial clinical evaluation. Of those infants who have an LP performed, a substantial proportion (15–40%) will have a traumatic LP.^{2–5} As introduction of blood into the cerebrospinal fluid (CSF) complicates the interpretation of CSF results, infants with traumatic LPs have higher rates of hospitalization and are more likely to receive parenteral antibiotics than infants with non-traumatic LPs.^{2,6,7} Although several methods for correction of the CSF white blood cell (WBC) count for the presence of red blood cells (RBCs) have been investigated,^{8–14} these approaches have not been extensively evaluated in the youngest infants and remain controversial.^{4,10}

Goals of This Investigation

Our primary objective was to determine the optimal correction factor for cerebrospinal fluid (CSF) white blood cell (WBC) counts in infants 60 days-old with traumatic lumbar punctures (LP). We derived a traumatic LP correction factor to adjust the CSF WBC count for the presence of CSF RBCs and compared this derived correction factor, as well as other

commonly used correction factors, to the uncorrected CSF WBC count for the detection of bacterial meningitis.

MATERIALS AND METHODS

Study Design and Setting

We performed a retrospective cohort study of infants who underwent LPs at 20 participating centers that contributed CSF cell counts and culture results for analysis. This study was a planned secondary analysis of the Pediatric Emergency Medicine Clinical Research Committee (PEM CRC) herpes simplex virus (HSV) study. The parent HSV study sought to determine the incidence of HSV disease in infants < 60 days undergoing evaluation for central nervous system infection. Of the 23 pediatric hospitals included in this HSV study, we limited our analysis to the 20 sites which contributed CSF white blood cell (WBC) and red blood cell (RBC) counts. The study protocol was approved by each of the participating institutional review boards with permission for data sharing.

Selection of Participants

Infants were eligible for inclusion in our study if they were 60 days or younger, presented to a participating emergency department (ED) between January 1, 2005 and December 31, 2013, had a CSF culture obtained within 24 hours of ED presentation and had CSF cell counts available for analysis. We identified eligible infants using electronic search strategies optimized for each study site. Infants with > one eligible ED visit in which an LP was performed were included for each eligible encounter. Infants without cell counts available were excluded. We defined a traumatic LP as a CSF RBC $\geq 10,000$ cells/mm³, to reflect a level of blood contamination making the CSF WBC truly difficult to interpret.^{3,10} We categorized LPs with a CSF RBC < 10,000 cells/mm³ as non-traumatic.

Methods and Measurements

Data were abstracted electronically at 17 sites and manually at 3 sites. All site abstractors received standardized training through conference calls and bi-annual in-person meetings.^{15,16} The following data elements were abstracted: demographics (age, gender), visit level data (study site, date of visit, disposition), triage temperature, and laboratory data [complete blood count (CBC) with differential, CSF cell counts, CSF glucose and protein and CSF Gram stain]. We manually abstracted the following microbiology results: bacterial cultures (blood, urine, CSF), viral cultures (CSF), as well as HSV polymerase chain reaction (PCR) CSF testing.

Outcome measures

Our primary outcome was a case of bacterial meningitis defined as an infant with a CSF culture (standard or broth) positive for a pathogenic organism as previously described.¹⁷ The following bacterial organisms were classified *a priori* as contaminants: coagulase-negative *Staphylococci*, *Streptococcus viridans*, *Propionibacterium acnes*, and *Corynebacterium species*.

Analysis

The unit of analysis was the LP. Standard descriptive statistics were used to describe infants with and without a traumatic LP. The relationship between CSF RBCs and CSF WBCs was explored using linear regression with CSF RBC as the independent variable and CSF WBC as the dependent variable using our *a priori* understanding of the relation between these CSF parameters. The slope of the regression line (i.e. β -coefficient) was used to derive the CSF WBC correction factor. We then utilized a generalized estimating equation to adjust for post-natal age and to cluster by hospital center.

We next evaluated the performance of CSF pleocytosis for the detection of bacterial meningitis in traumatic LPs. We defined CSF pleocytosis as a CSF WBC count ≥ 20 cells/mm³ for infants 0–28 days and ≥ 10 cells/mm³ for infants 29–60 days.^{6,18} We evaluated the following five approaches to interpretation of the CSF WBC count: 1). uncorrected CSF WBC count, 2). the regression-based correction factor 3) a 1000:1 CSF RBCs:CSF WBCs correction factor, 4) a 500:1 CSF RBCs:CSF WBCs correction factor and 5) an correction factor based on using the peripheral RBC to WBC ratio [CSF WBC corrected = CSF WBC – (CSF RBC $\times$ Peripheral WBC/Peripheral RBC)].⁴ The area under the curve (AUC) for the receiver operator characteristic curve was determined for each of these five strategies using CSF WBC count as a continuous variable. For purposes of comparison, we assessed the ability the CSF WBC count to detect bacterial meningitis in infants with a non-traumatic LP. Given the potential for outpatient management for low-risk febrile infants 29 to 60 days of age, we planned *a priori* to also report the performance of the five approaches to CSF WBC correction in this sub-group.

Last, we calculated the number needed to treat, as the number of infants without bacterial meningitis who would need to be treated for every misclassified infant with bacterial meningitis if we corrected the CSF WBC for the presence of CSF RBCs. This number represents the number of infants without bacterial meningitis who would need to be treated to avoid one misclassified case of bacterial meningitis using the uncorrected CSF WBC count instead of the derived correction factor.

Statistical analyses were performed using the Statistical Program for the Social Sciences (SPSS) version 23.0 (Armonk, NY: IBM Corporation).

RESULTS

Characteristics of Study Subjects

We identified 23,618 LPs with CSF culture obtained, of which 20,319 (86%) had CSF cell counts available. Of these, 14% (2,880/20,319) were traumatic (FIGURE 1). Among infants with a traumatic LP, 1.1% (33/2882) had bacterial meningitis. We identified the following bacterial meningitis pathogens in infants with traumatic LPs: GBS (8), *Staphylococcus aureus* (8), *Escherichia coli* (7), *Enterococcus* species (3), *Klebsiella* species (2), *Listeria* (1), *Neisseria meningitidis* (1), *Moraxella catarrhalis* (1), *Proteus* species (1), *Streptococcus pneumoniae* (1). Rates of traumatic LP varied significantly by study center (range 6% to 23%). Overall, children with a traumatic LP were younger and more likely to be hospitalized (TABLE 1). Rates of hospitalization were higher for infants 29–60 days with traumatic LPs

(87.7%, 1,055/1,203) compared to those with non-traumatic LPs [82.0%, 7,137/8704; difference 5.7%, 95% confidence interval (CI) 3.5–7.7%].

Main Results

Among the 2880 infants with traumatic LPs the median CSF WBC count was 46 cell/mm³ (IQR 17–128 cell/mm³) and CSF RBC count was 43,050 cell/mm³ (IQR 19,050–114,397 cell/mm³). CSF WBCs increased with CSF RBCs in traumatic LPs (FIGURE 2). Using linear regression, the crude ratio of CSF RBCs to CSF WBCs was determined to be 877:1 [95% CI 805–961:1] which did not change significantly after adjustment for patient age and hospital center (874:1, 95%CI 803–958:1).

When compared with the uncorrected CSF WBC count, the 877:1 correction factor had lower sensitivity but higher specificity but the AUC for the detection of bacterial meningitis did not differ (TABLE 2). The derived correction factor classified 45% (1305/2880, 95%CI: 43–47%) more infants with traumatic LPs as not having CSF pleocytosis. Among infants 29–60 days, the derived correction factor had similar sensitivity to the uncorrected CSF WBC count, but classified 48% (590/1221, 95%CI 46–51%) more infants as not having CSF pleocytosis (TABLE 3). Overall and in the subgroup of infants 29 to 60 days of age, the 1000:1 correction factor performed similarly to the 877:1 correction factor.

Of the thirty-three infants with a traumatic LP and bacterial meningitis, four had an uncorrected CSF WBC that did not meet the definition of CSF pleocytosis. All four of these infants were 0–28 days old. Application of the derived correction factor misclassified an additional 7 infants with bacterial meningitis (TABLE 4). Of these, the one infant 29–60 days of age grew *Staphylococcus aureus* from CSF broth culture. As the *S. aureus* was considered by the treating clinical team to be a contaminant, the child received only 48 hours of parenteral antibiotics.

For infants < 28 days of age, application of the 877:1 correction factor classified 118 infants (95% CI: 59–253 infants) without bacterial meningitis as not having CSF pleocytosis for every misclassified infant with bacterial meningitis. For infants 29 to 60-days-old, application of the 877:1 correction factor classified 589 (95%CI 106–2,439 infants) infants without bacterial meningitis as not having CSF pleocytosis for every misclassified infant with bacterial meningitis. The more easily usable 1000:1 correction factor performed similarly. For infants < 28 days application of 1000:1 correction factor classified 109 infants (95% CI 50–233 infants) as not having CSF pleocytosis for every misclassified case of bacterial meningitis. For infants 29 to 60-days-old application of a 1000:1 correction factor classified 532 infants (95% CI 96–2,202 infants) infants without CSF pleocytosis for every misclassified infant with bacterial meningitis. Thus, for every 109 infants < 28 days classified as lacking pleocytosis and for every 532 infants 29–60 days classified as lacking pleocytosis using the 1000:1 correction, one had bacterial meningitis. In our cohort, for every 223 infants (95%CI 162–318) 0–29 days and 219 infants (95% CI 158–314) 29–60 days with non-traumatic LPs who were classified as not having CSF pleocytosis, one had bacterial meningitis.

LIMITATIONS

Our study has limitations. First, many LPs performed only provided adequate sample for culture and not cell counts and were not included in our analysis. These infants present considerable diagnostic uncertainty for treating clinicians. Second, we selected no upper limit of CSF RBCs in our study definition and therefore cannot ensure that the sample contains CSF and not just peripheral blood. However, the sample was identified as CSF, representing a clinician's interpretation of the fluid obtained. Third, we utilized an electronic database and individual medical records were not reviewed. While laboratory and microbiology results could be completely abstracted from existing sources, the clinical appearance of study participants could not be assessed. However, ill appearing infants should be appropriately evaluated and treated for meningitis regardless of their CSF results. Fourth, we were unable to determine whether study infants had received antibiotics prior to diagnostic LP, potentially rendering bacterial cultures falsely negative.¹⁹ However, clinicians rarely administer antibiotics to the youngest infants prior to obtaining a CSF culture.^{20,21} Additionally, we were unable to determine whether a child with a traumatic LP and bacteremia had bacterial meningitis.¹⁷ However, as the rate of bacteremia for study infants was quite low, significant under-reporting of bacterial meningitis is unlikely.²² Fifth, we did not evaluate the performance of CSF pleocytosis for the detection of viral meningitis as utilization of viral testing in clinical practice varied substantially. However, viral meningitis is usually a self-limited infection requiring only supportive care. Sixth, we were unable to determine whether all study infants had a fever as only half had a triage temperature $\geq 38.0^{\circ}\text{C}$. However, infants who were afebrile at triage may have been febrile at home or after initial ED triage. Moreover, the treating clinician deemed it necessary to evaluate all infants for central nervous system infection. Seventh, we were underpowered to detect small difference in bacterial meningitis rates due to the small number of cases of bacterial meningitis. However, the rate of bacterial meningitis in our cohort is consistent to what has been reported in current literature and does reflect the clinical reality in the era of both widespread conjugate vaccination and maternal antibiotic prophylaxis.²³ Lastly, we examined only CSF WBC count as an isolated predictor of bacterial meningitis. Clinicians caring for these infants must consider the CSF WBC count in the context of other clinical and laboratory variables when assessing an infant's overall risk of bacterial meningitis.

DISCUSSION

In our large multi-center sample of infants undergoing LP as part of their ED evaluation, traumatic LPs were very common. We focused our analysis on infants with bloody spinal fluid (defined as a CSF RBCs $\geq 10,000$ cells/mm³), as interpretation of bloody CSF can be the most challenging to clinicians. Application of the derived 877 CSF RBCs per 1 CSF WBC correction factor to infants with a traumatic LP substantially reduced the number of infants classified as having CSF pleocytosis while misclassifying only a few cases of bacterial meningitis. The 1000:1 to correction factor performed similarly and was considerably easier to apply. Although CSF correction factors should be used with caution in the evaluation of the youngest infants, correction of the CSF WBC count for the presence of peripheral RBCs in older infants has the potential to decrease the number of infants

classified as having CSF pleocytosis without substantial misclassification of infants with bacterial meningitis.

Traumatic LPs occur commonly in infants,³ yet there is no uniform approach to the interpretation of cell counts in traumatic CSF to identify infants at risk of bacterial meningitis.¹⁰ The presence of peripheral blood in the CSF makes interpretation of CSF cell counts challenging. Prior studies have investigated methods of correcting CSF WBC for the presence of CSF RBCs in children with a traumatic LP.^{4,11,12,14} Heterogeneity of patient populations, varying traumatic LP definitions and changes in bacterial meningitis epidemiology due to widespread conjugate vaccination limit the applicability to our study population.²³ The largest study to date included 2519 infants < 30 days of age in the neonatal intensive care unit.⁴ Similar to our study, correction for a traumatic LP using a 1000:1 correction substantially reduced the sensitivity of CSF WBC for bacterial meningitis. However, this study did not include infants in the second month of life where our correction formula performed with greater accuracy. In a second single-center study of 92 children older than one month, CSF abnormalities associated with bacterial meningitis including CSF pleocytosis were rarely obscured by the presence of CSF RBCs.¹³ Our study was the largest to date to evaluate approaches to correction of CSF WBC count in a large sample of young infants with bloody CSF.

Consistent with previous work, application of our derived correction factor reduced the number of infants with CSF pleocytosis, at the cost of misclassifying a few additional infants with bacterial meningitis as not having CSF pleocytosis.⁴ Each of the approaches to correction of the CSF WBC count for the presence of CSF RBCs that we evaluated demonstrates the trade-offs between sensitivity and specificity for bacterial meningitis. Because adjustment of CSF WBC count for the presence of CSF RBCs reduces the corrected CSF WBC count, any approach to correction will reduce sensitivity and increase specificity for bacterial meningitis. When compared to the uncorrected CSF WBC count, our derived 877:1 correction factor missed the fewest cases of bacterial meningitis, while appropriately classifying nearly 50% more infants as not having CSF pleocytosis. However, the 1000:1 correction factor may be the preferred approach as the correction factor performed similarly and would be considerably easier to apply in clinical practice.

Bacterial meningitis can be very challenging to diagnosis before the results of bacterial cultures are available, especially in the youngest infants where the clinical examination may not provide adequate discrimination. Even infants with non-traumatic LPs and normal CSF WBC counts can have bacterial meningitis.^{4,24,25} The presence of peripheral blood in the CSF makes clinical decisions about an infant's risk of bacterial meningitis while CSF cultures are pending even more challenging. Therefore, clinicians must consider CSF WBC count in the context of the infant's other clinical and laboratory factors. Utilization of the uncorrected CSF WBC count will result in increased rates of antibiotic and antiviral exposure, increased hospitalizations and increased cost for many infants without bacterial meningitis.² Moreover, hospitalization of these infants increases the potential of nosocomial infections, adverse reactions to antibiotics, as well as hospital errors.^{26–28} Clinical decisions for an individual patient should be made after balancing the risk of infection against the risks of hospitalization for the particular infant.

While most febrile infants < 28 days of age are hospitalized regardless of the results of screening tests, infants 29–60 days may be treated as outpatients if determined to be low-risk based upon clinical and laboratory criteria.²⁹ Similar to previous work, we observed a significantly higher admission rate for older infants with a traumatic LP compared to those without.² Our CSF WBC count correction factor would allow almost 600 additional infants age 29–60 days without bacterial meningitis to be appropriately classified as not having CSF pleocytosis for every misclassified case of bacterial meningitis. Infants 29–60 days with traumatic LPs who lack pleocytosis after correction of their CSF WBC count may potentially be managed as outpatients. However, given they may still be at risk of other serious bacterial infections, clinicians should strongly consider empiric treatment with a long-acting parenteral antibiotic (e.g. ceftriaxone) pending culture results. The one misclassified infant > 28 days with bacterial meningitis grew a contaminant from the CSF broth culture and was not treated clinically for bacterial meningitis. Therefore, we suggest correction of the CSF WBC count for the presence of RBCs for otherwise well-appearing infants age 29–60 days without other findings suggestive of bacterial infection.

In conclusion, in our large multi-center sample of infants < 60 days with a traumatic LP, application of a 1000 CSF RBCs per 1 CSF WBC correction factor significantly reduced the number of infants with CSF pleocytosis while misclassifying 7 additional infants with bacterial meningitis as not having CSF pleocytosis of which only one was between 29 and 60 days of age. Application of a 1000:1 CSF RBC:WBC correction factor in infants 29–60 days would result in the classification of more than 500 infants without CSF pleocytosis for every infant with bacterial meningitis. Clinicians should consider this trade-off when determining how to interpret CSF WBC counts in infants 29–60 days with traumatic LPs.

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FIGURE 1.
Flow diagram of enrollment

FIGURE 2. Relationship between CSF WBC count and CSF RBC count in infants with traumatic LPs

The shaded area represents the 95% confidence interval for estimate of the best fit line

Line derived using linear regression with CSF WBC count as the dependent variable and CSF RBC count as the independent variable

$\beta = 0.00114036$ corresponding to 877 CSF RBCs for every 1 CSF WBC

TABLE 1

Comparison between infants with a traumatic and a non-traumatic LP

Characteristic	Non-Traumatic LP N = 17,439	Traumatic LP N = 2,880
Demographics		
Age (days) ^a	29.0 (16.0, 42.0)	25.0 (13.0, 39.0)
Age 0–28 days, n/N (%)	8628/17,439 (49.5)	1665/2880 (57.8)
Age 29–60 days, n/N (%)	8811/17,439 (50.5)	1215/2880 (42.2)
Male	9813/17439 (56.3)	1578/2880 (54.8)
Clinical		
Triage temperature (°C) ^a	99.8 (98.7, 100.9)	99.7 (98.7, 100.8)
CBC WBC Count (cells/mm ³) ^a	10.4 (7.8, 13.5)	10.7 (7.9–13.6)
Admitted, n/N (%)	15482/17232 (89.8)	2682/2847 (94.2)
Admitted to ICU, n/N (%)	2529/15482 (16.3)	394/2682 (14.7)
Length of stay for admitted (days) ^a	2.2 (1.7, 3.0)	2.2 (1.8, 3.0)
Microbiology results By Age Category^b		
Urinary tract infection, n/N Tested (%)		
0–29 days	548/7911 (6.9)	90/1519 (5.9)
29–60 days	702/8000 (8.8)	84/1108 (7.6)
Bacteremia, n/N Tested (%)		
0–29 days	210/8214 (2.6)	32/1566 (2.0)
29–60 days	198/8318 (2.4)	30/1144 (2.6)
Bacterial meningitis, n/N (%)		
0–29 days	84/8628 (1.0)	26/1665 (1.6)
29–60 days	78/8811 (0.9)	7/1215 (0.6)
HSV Meningoencephalitis, n/N Tested (%)		
0–29 days	29/3532 (0.8)	3/766 (0.4)
29–60 days	4/1700 (0.2)	1/306 (0.3)
Enteroviral meningitis, n/N Tested (%)		
0–29 days	382/1614 (23.7)	33/293 (11.3)
29–60 days	440/1641 (26.8)	35/209 (16.8)

^aMedian (interquartile range)^bNumbers do not sum as microbiologic testing not available for all patients

TABLE 2
Comparison of approaches for the detection of bacterial meningitis in all infants 60 days with a traumatic LP

Strategy	Sensitivity % (95%CI)	Specificity % (95%CI)	NPV % (95%CI)	AUC (95%CI)	CSF Pleocytosis N (%)	Misclassified infants with bacterial meningitis but no CSF pleocytosis N (% All Infants with Traumatic LP)
Traumatic LPs (N=2,880, 33 bacterial meningitis)						
1. Uncorrected CSF WBC Count	87.9 (71.8–96.6)	21.8 (20.3–23.4)	99.4 (98.4–99.8)	0.71 (0.61–0.81)	2255 (78)	4 (0.1)
2. Derived 877:1 Correction	66.7 (48.2–82.0) *	67.4 (65.7–69.1) *	99.4 (99.0–99.7)	0.74 (0.63–0.84)	950 (33) *	11 (0.4)
3. 1000:1 Correction	66.7 (48.2–82.0) *	63.4 (61.6–65.2) *	99.4 (98.9–99.7)	0.73 (0.63–0.84)	1063 (37) *	11 (0.4)
4. 500:1 Correction	60.6 (42.1–77.1) *	81.5 (80.0–82.9) *	99.4 (99.1–99.7)	0.75 (0.66–0.85)	547 (19)	13 (0.5) *
5. Peripheral Ratio RBC:WBC¹	44.0 (24.4–65.1) *	86.8 (85.4–88.2) *	99.3 (99.0–99.6)	0.70 (0.59–0.81)	318 (13) *	14 (0.6) *
Non-Traumatic LPs (N = 17,439, 162 bacterial meningitis)						
Uncorrected CSF WBC Count	58.6 (50.7–66.3)	85.2 (84.6–85.7)	99.6 (99.4–99.7)	0.77 (0.72–0.81)	2658 (15)	67 (0.4)

¹Numbers for peripheral ratio based on total number of LPs with peripheral cell counts available, N = 2364

* Statistically different than uncorrected CSF WBC at p < 0.05

TABLE 3

Comparison of approaches for the detection of bacterial meningitis in all infants 29–60 days with a traumatic LP

Strategy	Sensitivity % (95%CI)	Specificity % (95%CI)	NPV % (95%CI)	AUC (95%CI)	CSF Pleocytosis N (%)	Misclassified infants with bacterial meningitis but no CSF pleocytosis N (% Total)
Traumatic LPs (N=1,221, 7 bacterial meningitis)						
1. Uncorrected CSF WBC Count	100 (59.0–100)	15.2 (13.2–17.3)	100 (98.0–100)	0.79 (0.58–1.00)	1032 (85)	0 (0)
2. Derived 877:1 Correction	85.7 (42.1–99.6)	63.9 (61.3–66.6)*	99.9 (99.3–100)	0.84 (0.65–1.00)*	442 (36)*	1 (0.1)
3. 1000:1 Correction	85.7 (42.1–99.6)	59.2 (56.4–62.0)*	99.9 (99.2–100)	0.87 (0.74–1.00)*	499 (41)*	1 (0.1)
4. 500:1 Correction	85.7 (42.1–99.6)	78.7 (76.3–81.0)*	99.9 (99.4–100)*	0.86 (0.70–1.00)*	263 (22)*	1 (0.1)
5. Peripheral Ratio RBC:WBC¹	60.0 (14.7–94.7)	85.7 (83.4–87.8)*	99.8 (99.2–100)	0.75 (0.48–1.00)	148 (15)*	2 (0.2)
Non-Traumatic LPs (N=8811, bacterial meningitis 78)						
Uncorrected CSF WBC Count	57.7 (46.0–68.8)	82.2 (81.4–83.0)	99.5 (99.4–99.7)	0.74 (0.68–0.81)	1598 (18)	33 (0.4%)

¹Numbers for peripheral ratio based on total number of LPs with peripheral cell counts available, N = 1023

* Statistically different than uncorrected CSF WBC at $p < 0.05$

TABLE 4
Cases of bacterial meningitis misclassified as not having CSF pleocytosis by either the 877:1 or 1000:1 correction factor

ID	Age (Days)	Sex	Peripheral WBC Count (X10 ³ /μL)	CSF RBC Count (/mm ³)	Uncorrected CSF WBC Count (/mm ³)	877:1 Corrected CSF WBC Count (/mm ³)	1000:1 Corrected CSF WBC Count (/mm ³)	CSF Gram Stain	Bacteremia	CSF Organism
1	6	Female	8.0	38000	8	0	0	Negative	No	<i>E. coli</i>
2	6	Male	18.1	17360	36	16	19	Negative	No	<i>S. aureus</i>
3	15	Female	5.9	110000	76	0	0	Unknown	No	<i>Enterococcus</i>
4	15	Male	12.0	53805	53	0	0	Negative	Yes	<i>S. aureus</i>
5	16	Male	18.7	36000	22	0	0	Negative	No	<i>S. aureus</i>
6	19	Male	10.2	243500	50	0	0	Negative	No	<i>E. coli</i>
7	23	Male	12.0	77500	53	0	0	Negative	No	<i>M. catarrhalis</i>
8	24	Male	9.1	12150	17	3	5	Negative	No	<i>E. coli</i>
9	24	Male	4.9	16200	16	0	0	Positive	No	<i>S. aureus</i>
10	25	Female	8.4	20125	14	0	0	Negative	No	<i>Proteus</i>
11	45	Female	11.8	12900	13	0	0	Negative	No	<i>S. aureus</i>