Academic Emergency Medicine
Official Journal of the Society for Academic Emergency Medicine

BRIEF REPORT

The Effect of Traumatic Lumbar Puncture on Hospitalization Rate for Febrile Infants 28 to 60 Days of Age

Elizabeth W. Pingree, MD, Amir A. Kimia, MD, and Lise E. Nigrovic, MD, MPH

Abstract

Objectives: The authors measured the effect of a traumatic or unsuccessful lumbar puncture (LP) on the management of febrile infants.

Methods: This was a 10-year retrospective cross-sectional study of low-risk infants by the "Boston" criteria 28 to 60 days of age presenting to the emergency department for evaluation of fever. "Normal LP" infants had cerebrospinal fluid (CSF) WBC $< 10 \times 10^6$ cells/L. "Traumatic" or "unsuccessful LP" infants had CSF red blood cell count $\geq 10 \times 10^9$ cells/L or no CSF cell counts obtained, respectively. A serious bacterial infection (SBI) was defined as growth of a bacterial pathogen from culture. The hospitalization and SBI rates were compared between infants with normal versus traumatic or unsuccessful LPs.

Results: Of the 929 study infants, 756 (81.4%) had normal LPs, and 173 (18.6%) had traumatic or unsuccessful LPs. Infants with traumatic or unsuccessful LPs had a higher hospitalization rate (72.3% traumatic or unsuccessful LP vs. 18.1% normal LP; difference = 54.1%; 95% confidence interval [CI] = 46.4% to 60.8%), but a similar SBI rate (2.9% vs. 4.1%; difference = 1.2%; 95% CI = –2.7% to 3.6%). No infant had proven bacterial meningitis (0% risk, 95% CI = 0 to 0.3%).

Conclusions: Low-risk infants aged 28 to 60 days with traumatic or unsuccessful LPs are more frequently hospitalized, although SBI rates were similar to those of infants with normal LPs.

ACADEMIC EMERGENCY MEDICINE 2015;22:240–243 © 2015 by the Society for Academic Emergency Medicine

Febrile infants presenting to the emergency department (ED) typically undergo a standardized laboratory evaluation for serious bacterial infection (SBI). Well-appearing infants aged 28 to 60 days of age who meet low-risk criteria (including normal cerebrospinal fluid [CSF] analysis) can be managed as outpatients.[1] However, a substantial minority of lumbar punctures (LPs) in young infants are either traumatic or unsuccessful, potentially leading to diagnostic ambiguity and hospitalization.[2]

To this end, we designed a 10-year cross-sectional study of febrile infants aged 28 to 60 days of age evaluated in the ED. Our goal was to determine the effect of a traumatic or unsuccessful LP on patient management. In particular, we measured the effect of a traumatic or unsuccessful LP on the rate of hospitalization and determined the incidence of SBI in these infants.

METHODS

Study Design

We performed a retrospective cross-sectional study of infants. The institutional review board approved the study protocol with a waiver of informed consent.

Study Setting and Population

Using an electronic medical records query, we identified all infants presenting to the Boston Children's Hospital

From the Department of Medicine (EWP), the Division of Emergency Medicine (AAK, LEN), and the Division of General Pediatrics (EWP), Boston Children's Hospital, Boston, MA.

Received June 6, 2014; revision received August 13, 2014; accepted September 9, 2014.

Presented at the Pediatric Academic Societies Meeting, Vancouver, BC, Canada, May 2014; and Eastern Society of Pediatric Research Annual Meeting, Philadelphia, PA, March 2014.

Supported by the Fred Lovejoy Resident Research Award, Boston Children's Hospital.

The authors have no relevant financial information or potential conflicts to disclose.

Supervising Editor: Elizabeth Alpern, MD, MSCE.

Address for correspondence and reprints: Lise E. Nigrovic, MD, MPH; e-mail: lise.nigrovic@childrens.harvard.edu.

ISSN 1069-6563
PII ISSN 1069-6563583

doi: 10.1111/acem.12582

ED during the 10 years from June 1, 2003, to May 30, 2013, who were 28 to 60 days of age and who had blood cultures sent from the ED. We then reviewed the medical record to determine study eligibility. We included infants with documented fevers (temperature ≥ 38°C obtained at home, by the referring provider, or in the ED), complete blood counts, urine dipsticks or urinalysis, and urine cultures obtained. As we were interested in the effect of a traumatic or unobtainable LP on patient management, we limited our study to those infants who had LPs attempted by the ED clinicians, regardless of whether any CSF was obtained.

We excluded infants who met *any* of the following criteria that affect ED management: prematurity (under 37 weeks gestational age), major congenital malformation, immunodeficiency, indwelling hardware (ventricular shunt or central venous line), respiratory distress, dehydration requiring intravenous fluid hydration, focal bacterial infection, apparent life-threatening event, and a positive blood culture known at the time of ED evaluation. We also excluded infants who had received any antibiotic treatment within the previous 72 hours of index ED visit, as pretreatment may render cultures falsely negative.[3] For infants who had more than one eligible ED visit, we only included the first visit.

Study Protocol

For eligible infants, we abstracted the following by manual electronic medical record review into an electronic study database: demographics, clinical history, diagnostic testing, and patient management. Additionally, we reviewed medical records to determine if study infants were diagnosed with SBIs in the 30 days following the initial ED encounter. Hospital charges that included ED charges for the encounter were abstracted from hospital billing records and converted to 2013 dollars using standardized health care inflation indexes.[4]

At the study institution, ED clinicians used a clinical practice guideline for the management of febrile infants based on the "Boston Criteria" to identify infants at low risk for SBI:[5] infants 28 to 60 days of age with peripheral white blood cell (WBC) count $< 20 \times 10^9$ cells/L, urine WBC < 10 cells/high-power field (hpf), and no infiltrate on chest radiograph (if performed). These infants were categorized as "normal LP" if CSF WBC $< 10 \times 10^6$ cells/L; "traumatic LP" as CSF red blood cell count $\geq 10 \times 10^9$ cells/L, and "unsuccessful LP" as one in which no CSF was available for cell counts.[2]

Outcome Measures

Our primary outcome was hospitalization rate. Our secondary outcome was presence of SBI, defined as growth of pathogenic bacteria from culture of blood, CSF, or urine.[6] We defined a urinary tract infection (UTI) by growth of ≥50,000 colony-forming units (CFUs) of a uropathogen from a catheterized specimen or ≥10,000 CFUs with a positive urinalysis (WBCs ≥ 5 cells/hpf.[6] Infants with no CSF culture obtained but negative blood cultures were assumed not to have bacterial meningitis, as most infants with bacterial meningitis will have the pathogen isolated from blood as well as CSF culture.[7]

Data Analysis

We performed bivariable analysis to compare the normal LP infants to infants with traumatic or unsuccessful LPs. We compared categorical variables using risk difference for proportions. We compared continuous variables using the Hodges-Lehmann test for medians. We used SPSS for all analyses (Version 21.0).

RESULTS

We identified 1,858 febrile infants aged 28 to 60 days who had blood cultures sent from the ED, of whom 1,199 (64.5%) met study criteria. Of these, 270 were classified in the ED as not low risk by institutional guidelines and were excluded. Of the remaining 929

Table 1
Comparison of Normal LP and Traumatic or Unsuccessful LP Groups

Variable	Normal LP (n = 756)	Traumatic or Unsuccessful LP (n = 173)	Difference, % (95% CI)
Age (days), median (IQR)	47.1 (39–55)	42.6 (37.6–51.5)	3.4 (1.8 to 5.0)
Sex (% male)	420 (55.5)	99 (57.2)	1.7 (–6.5 to 9.7)
Season			
Spring	201 (26.6)	41 (23.7)	2.9 (–4.6 to 9.5)
Summer	155 (20.5)	42 (24.3)	3.8 (–2.8 to 11.2)
Fall	181 (23.9)	35 (20.2)	3.7 (–3.5 to 9.9)
Winter	219 (29.0)	55 (31.8)	2.8 (–4.5 to 10.7)
Patient management			
Admission	137 (18.1)	125 (72.3)	54.1 (46.4 to 60.8)
Length of stay (days)	1.9	1.8	0.1 (0 to 0.3)
Parenteral antibiotics	752 (99.5)	149 (86.1)	13.3 (8.9 to 19.2)
Outcomes			
Any SBI	31 (4.1)	5 (2.9)	1.2 (–2.7 to 3.6)
Urinary tract infection	21 (2.8)	3 (1.7)	1.0 (–2.3 to 2.9)
Bacteremia	10 (1.3)	2 (1.2)	0.2 (–2.2 to 1.6)
Bacterial meningitis*	0 (0)	0 (0)	0 (–0.5 to 2.8)

Data are reported as n (%) unless otherwise noted
CSF = cerebrospinal fluid; LP = lumbar puncture; SBI = serious bacterial infection.
*Forty infants in the traumatic LP group did not have CSF cultures obtained.

infants, 756 infants (81.4%) had normal LPs and 173 (18.6%) had either traumatic or unsuccessful LPs.

Traumatic or unsuccessful LP infants were slightly younger and more likely to be hospitalized than normal LP infants (Table 1). The length of hospital stay for infants in both groups was similar.

Overall, the SBI rate did not differ between the normal LP and the traumatic or unsuccessful LP infants. UTIs were the most common SBI identified, of which 72% were caused by *Escherichia coli*. The two most common bacteremia pathogens were *Streptococcus agalactiae* (50.0%) and *Staphylococcus aureus* (16.7%). No children in either study group had bacterial meningitis. Of the infants with traumatic or unsuccessful LPs, 40 (4% of study infants) did not have CSF cultures obtained.

Median hospital charges were higher for those infants with traumatic or unsuccessful LPs than for those with normal LPs ($5,117 vs. $2,083; median difference = $2,368; 95% confidence interval [CI] = $1,835 to $2,842), although median ED charges were relatively similar ($1,550 vs. $1,454; median difference = $131; 95% CI = $24 to $221).

DISCUSSION

Approximately one-quarter of LPs attempted in infants are either traumatic or unsuccessful.[2,8] To the best of our knowledge our study is the first to investigate the effect of traumatic LPs on the management of febrile infants age 28 to 60 days of age. We demonstrated that otherwise low-risk infants with traumatic LPs had both substantially higher hospitalization rates and patient charges, but a similar SBI rate when compared to low-risk infants with normal LPs. None of the study infants was found to have bacterial meningitis.

Clinicians may hospitalize an infant with a traumatic or unsuccessful LP due to uninterpretable CSF results. Correction formulas based on either the peripheral blood red blood cell count to WBC ratio or a standardized 500:1 ratio can be applied, but may not reliably exclude bacterial meningitis.[9] Bacterial meningitis incidence has fallen dramatically over the past several decades and has become an uncommon pediatric infection.[10] Future investigations should determine the most accurate method of traumatic spinal fluid interpretation to help clinicians identify low-risk infants who can be safely managed as outpatients while awaiting bacterial culture results.

Previous investigations have identified factors associated with LP success. Procedural factors such as local anesthetic use and advancement of the spinal needle with stylet removed (e.g., Cincinnati technique) improve LP success and should be used.[2,8] Given the demonstrated effect of a traumatic or unsuccessful LP on febrile infant management, efforts should be focused on effective education for pediatric providers in training. In the current training environment, residents have decreased opportunities for procedural experience. A substantial proportion of pediatric interns have never performed an infant LP at the beginning of residency.[11] "Just-in-time" LP training has been shown to increase rates of successful infant LP for pediatric interns at one center by using a simulation model to provide both targeted education and procedural practice just prior to performing the procedure.[12] Although these findings were not replicated in a larger multicenter study,[13] simulation training provides a promising approach for procedural education for inexperienced providers.

LIMITATIONS

First, our study was retrospective. However, we collected only objective data elements that we would expect to be accurately recorded in the medical record. Second, our study was conducted at a single center, which limits the generalizability to other practice settings. In particular, febrile infant management guidelines vary across institutions, and the effect of a traumatic LP may differ in another setting. Third, we could not reliably exclude bacterial meningitis in the 40 infants who had no CSF obtained for culture. Although we were unable to review care obtained at other institutions, none of these infants had either positive blood cultures or return visits within 30 days with SBI, making a missed case of bacterial meningitis unlikely. Last, we were underpowered to compare bacterial meningitis rates between the normal LP and traumatic or unsuccessful LP groups. As bacterial meningitis incidence has declined even among young infants, a large, likely multicentered, study would be required.

CONCLUSIONS

In our cohort of febrile infants aged 28 to 60 days of age, otherwise low-risk infants with traumatic or unsuccessful lumbar punctures compared to the low-risk infants with normal lumbar punctures were hospitalized at a higher rate, although serious bacterial infection rates were similar. In the era of widespread conjugate vaccinations and routine antibiotic prophylaxis, the safest approach to the evaluation of a well-appearing febrile infant will need to balance the risk of bacterial infection with the unintended consequences of our diagnostic evaluation, which includes a traumatic or unsuccessful lumbar puncture.

References

1. Baker MD, Bell LM, Avner JR. The efficacy of routine outpatient management without antibiotics of fever in selected infants. Pediatrics 1999;103:627–31.
2. Nigrovic LE, Kuppermann N, Neuman MI. Risk factors for traumatic or unsuccessful lumbar punctures in children. Ann Emerg Med 2007;49:762–71.
3. Kanegaye JT, Soliemanzadeh P, Bradley JS. Lumbar puncture in pediatric bacterial meningitis: defining the time interval for recovery of cerebrospinal fluid pathogens after parenteral antibiotic pretreatment. Pediatrics 2001;108:1169–74.
4. United States Department of Labor, Bureau of Labor Statistics. Consumer Price Index. Available at: http://www.bls.gov/cpi/. Accessed Nov 8, 2014.

5. Baskin MN, O'Rourke EJ, Fleisher GR. Outpatient treatment of febrile infants 28 to 89 days of age with intramuscular administration of ceftriaxone. J Pediatr 1992;120:22–7.
6. Schnadower D, Kuppermann N, Macias CG, et al. Febrile infants with urinary tract infections at very low risk for adverse events and bacteremia. Pediatrics 2010;126:1074–83.
7. Nigrovic LE, Kuppermann N, Malley R. Children with bacterial meningitis presenting to the emergency department during the pneumococcal conjugate vaccine era. Acad Emerg Med 2008;15:522–8.
8. Baxter AL, Fisher RG, Burke BL, Goldblatt SS, Isaacman DJ, Lawson ML. Local anesthetic and stylet styles: factors associated with resident lumbar puncture success. Pediatrics 2006;117:876–81.
9. Mazor SS, McNulty JE, Roosevelt GE. Interpretation of traumatic lumbar punctures: who can go home? Pediatrics 2003;111:525–8.
10. Thigpen MC, Whitney CG, Messonnier NE, et al. Bacterial meningitis in the United States, 1998-2007. N Engl J Med 2011;364:2016–25.
11. Auerbach M, Chang TP, Reid J, et al. Are pediatric interns prepared to perform infant lumbar punctures? A multi-institutional descriptive study. Pediatr Emerg Care 2013;29:453–7.
12. Kessler DO, Auerbach M, Pusic M, Tunik MG, Foltin JC. A randomized trial of simulation-based deliberate practice for infant lumbar puncture skills. Simul Health Care 2011;6:197–203.
13. Kessler DO, Arteaga G, Ching K, et al. Interns' success with clinical procedures in infants after simulation training. Pediatrics 2013;131:e811–20.