

BRIEF REPORT

Following the (Clinical Decision) Rules: Opportunities for Improving Safety and Resource Utilization With the Bacterial Meningitis Score

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ABSTRACT

BACKGROUND: The Bacterial Meningitis Score accurately classifies children with cerebrospinal fluid (CSF) pleocytosis at very low risk (VLR) versus not very low risk (non-VLR) for bacterial meningitis. Most children with CSF pleocytosis detected during emergency department evaluation are hospitalized despite the high accuracy of this prediction rule and the decreasing incidence of bacterial meningitis. The lack of widespread use of this rule may contribute to unnecessary risk exposure and costs.

METHODS: This cross-sectional study included 1049 patients who, between January 2010 and May 2013, had suspicion for meningitis and underwent both a complete blood cell count and CSF studies during their emergency department evaluation. We then examined their hospitalizations to characterize exposure to drugs, radiologic studies, and the costs associated with their care to determine the safety and value repercussions of these VLR admissions. Primary outcomes include duration of antibiotics, exposure to drugs and radiology studies, safety events, and costs incurred during these VLR admissions.

RESULTS: Twenty patients classified as VLR were admitted to the hospital. On average they received 35 hours of antibiotic therapy. There was 1 adverse drug event and 1 safety event.

CONCLUSIONS: The VLR patients admitted to the hospital were exposed to risk and costs despite their low risk stratification. Systematic application of the Bacterial Meningitis Score could prevent these exposures and costs.

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The Bacterial Meningitis Score (BMS) is a clinical prediction rule used to identify children at very low risk (VLR) for bacterial meningitis.^{1,2} The rule performed well in a multicenter validation, maintained a high negative predictive value in subsequent studies, and has performed better than other bacterial meningitis prediction rules.^{3–7} Despite the decreasing incidence of bacterial meningitis in the era of multivalent conjugate pneumococcal and meningococcal vaccines, most children identified in the emergency department (ED) with cerebrospinal fluid (CSF) pleocytosis are still admitted to the hospital, leading to unnecessary costs and drug exposures.^{8–10}

The “Choosing Wisely” initiative represents the growing momentum in health care for eliminating cost and risk exposure due to overuse and proper resource stewardship by patients and physicians.¹¹ Furthermore, the growing ubiquity of electronic health records (EHRs) capable of providing point-of-care decision support by using existing data to implement clinical decision rules provides opportunities to empower practitioners to use health care resources wisely.¹²

Our overarching hypothesis was that nonadherence to, or heterogeneous application of, the BMS clinical prediction rule leads to both overutilization of health care resources and preventable safety events. We suspect that these problems occur in both VLR children who are admitted and in not very low risk (non-VLR) children who are discharged. We retrospectively applied the BMS to EHR data to study the following specific hypotheses: First, VLR patients are admitted to the hospital, subjecting them to needless resource utilization and risk (ie, safety events). Second, inappropriately discharged non-VLR patients will seek care again, leading to increased resource utilization. Finally, certain components of the BMS are commonly violated in clinical practice, leading to improper disposition.

METHODS

Setting

Cincinnati Children’s Hospital Medical Center (CCHMC) is a 578-bed quaternary

care facility affiliated with the University of Cincinnati. There are ~120 000 annual ED visits.¹³ The current EHR (Epic Systems, Verona, WI) was implemented in the ED in November 2009, and the inpatient module was implemented in January 2010.

Retrospective Cohort Identification

This study was approved by the institutional review board at CCHMC with a waiver of informed consent. To identify children who were admitted to the hospital despite being VLR for bacterial meningitis, we conducted a query of ED visits starting with the implementation of our EHR on January 10, 2010 through March 31, 2013. Our query identified 1049 patients who were seen in the ED and underwent a complete blood cell count (CBC) and lumbar puncture (LP). Of these patients, 248 had CSF pleocytosis, defined as ≥ 10 white blood cells/mm³. In accordance with best practice, we did not correct for CSF RBC count in determining pleocytosis. The records of these patients were reviewed to classify them as either VLR or non-VLR according to the BMS. VLR patients met the following criteria: no bacteria on CSF Gram stain, CSF pleocytosis, CSF protein < 80 mg/dL, peripheral absolute neutrophil count (ANC) $< 10\,000$ /mm³, and no seizure at time of presentation. Additionally, any patient < 60 days of age was not included in the VLR group because of previously published concerns about validity of the BMS in this age group.

These identified encounters were then manually reviewed for any exclusion criteria such as indwelling shunts, seizure at time of presentation, severely altered mental status, pretreatment of LP with antibiotics in the preceding 72 hours, or other clinical factors that would have exempted application of the BMS. These factors included other conditions necessitating admission and automatically placed a child in the non-VLR category.

Once the cohort was risk stratified according to the BMS, the patient’s disposition was determined via chart review. VLR patients who were admitted were identified, and their admission records were examined to identify unnecessary exposure or risks these children experienced as a result of their admission.

Non-VLR patients who were discharged were identified, and their charts were reviewed for return visits within our system.

Outcome Measures

The primary outcome examined was the presence or absence of bacterial meningitis. VLR cases admitted to the hospital were scrutinized for resources used in excess of other VLR cases discharged from the hospital. Non-VLR cases discharged were examined for evidence of greater utilization after their discharge. These measures included revisits to the ED, readmission, time spent in the ED, hospital charges, repeat tests, false positive results, and duration of antibiotics administered during the admission.

We examined the charts of VLR patients admitted to the hospital for exposure to medications and specifically antibiotics, additional radiology procedures (after those performed in the ED), and any adverse events associated with the hospitalization including intravenous catheter-associated complications, adverse drug events, and safety events as defined by the Institute for Healthcare Improvement.¹⁴

Considering the high seasonal burden of enterovirus meningitis, we also examined the patterns of cases presenting to the ED for CBC and LP in relation to the typical enterovirus season here at CCHMC (April–October of each year).

RESULTS

Of 1049 eligible patients identified with ED encounters, 248 demonstrated pleocytosis on their CSF studies (Table 1). Of these patients, 222 were classified as non-VLR because their BMS was not equal to 0 or because of exclusion criteria identified during medical record review; 219 of these patients were admitted to the hospital. Twenty-six patients were identified as VLR, with BMS equal to 0 and no exclusion criteria; 20 (69%) were hospitalized, and the remaining 6 were discharged from the hospital (Fig 1). Chart review of these VLR patients identified no alternative diagnosis to explain presentation or otherwise require inpatient admission such as pain control. Final diagnosis in 7 of these 20 admissions was viral meningitis, with the remainder

TABLE 1 Demographics and Clinical Characteristics

	All Evaluated Patients (<i>n</i> = 248)	Non-VLR Admissions (<i>n</i> = 219)	VLR Admissions (<i>n</i> = 20)	VLR Discharges (<i>n</i> = 6)	Non-VLR Discharges (<i>n</i> = 3)	<i>P</i>
Age in mo, median (IQR)	2 (1, 29)	2 (1, 17)	54 (5, 118)	95 (71, 193)	2 (1, 2)	<.01
Female, <i>n</i> (%)	100 (40)	87 (40)	12 (60)	1 (17)	0	.09
ED LOS in hr, median (IQR)	6.2 (5.2, 7.4)	6.1 (5.1, 7.3)	7.5 (6.1, 8.9)	5.9 (5.2, 6.6)	6.5 (6.2, 6.5)	.03
Bacterial meningitis, <i>n</i> (%)	8 (3)	8 (4)	0	0	0	.99
Enterovirus meningitis, <i>n</i> (%)	28 (11)	22 (10)	5 (25)	1 (17)	0	.17
Enterovirus season, ^a <i>n</i> (%)	119 (48)	97 (44)	15 (75)	5 (83)	2 (67)	.01
Peripheral WBC (K/ μ L), geometric mean (SD)	11.6 (1.6)	11.9 (1.6)	9.6 (1.5)	8.6 (1.5)	9.0 (1.8)	.07
Peripheral ANC (K/ μ L), geometric mean (SD)	4.4 (2.4)	4.4 (2.4)	4.9 (2.0)	5.2 (1.4)	1.4 (2.1)	.18
CSF WBC (mm ³), geometric mean (SD)	71 (5)	70 (5)	93 (5)	79 (3)	24 (3)	.44
CSF ANC (K/ μ L), geometric mean (SD)	7 (22)	7.2 (23)	7.6 (25)	15.9 (4.3)	4.0 (4)	.82
CSF protein (mg/dL), geometric mean (SD)	89 (3) [<i>n</i> = 243]	97 (3) [<i>n</i> = 214]	42 (2)	53 (1)	148 (5)	<.01
CSF glucose (mg/dL), mean (SD)	48 (15) [<i>n</i> = 244]	48 (16) [<i>n</i> = 215]	52 (9)	54 (3)	51 (13)	.20

IQR, interquartile range; LOS, length of stay; WBC, white blood cell count.

P values based on Kruskal–Wallis test for continuous variables and Fisher's exact test for categorical variables.

Peripheral WBC, peripheral ANC, CSF WBC, CSF ANC, and CSF protein were natural logarithm transformed to obtain normal distributions.

^a Enterovirus season is June–October.

including broader or nonspecific diagnoses such as headache and meningitis.

All non-VLR patients who were discharged from the hospital were classified as non-VLR based on age >29 days and <60 days; in addition, 1 patient had a grossly bloody LP with elevated CSF protein and resulting nonzero BMS. Chart review revealed that all 3 children did well after discharge, with none developing bacterial meningitis or other significant clinical conditions in this very small cohort.

The resource utilization metrics demonstrated that the admitted VLR patients spent longer in the ED than either of the other groups and had 2 revisits to the ED within 3 days of discharge but no readmissions (Table 1). One patient was admitted to the ICU, and, on average, the VLR patients admitted received 35 hours of antibiotic therapy, with average hospital charges of \$17 548.73. In these 20 VLR patients, there was 1 false-positive initial blood culture and 2 follow-up blood cultures obtained.

We examined these admission for clinical and safety outcomes. As a cohort, VLR patients admitted to the hospital received 82 doses of antibiotics and 188 total doses of all medications (including antibiotics), underwent 6 imaging procedures (including 4 brain or neck magnetic resonance

imaging tests, 1 computed tomography scan, and 1 chest radiograph), and suffered 8 intravenous catheter–related complications, 1 adverse drug reaction (red man syndrome attributable to vancomycin) and 1 overdose to acetaminophen.

Finally, given that enterovirus is highly seasonal and to evaluate its effects on the BMS, we examined each presentation in relation to the typical enterovirus season at CCHMC (Table 1, Fig 2). Seventy-five percent of the VLR admissions occurred during enterovirus season.

DISCUSSION

The purpose of this study was to examine safety and resource utilization implications of heterogeneously applying a well-validated clinical decision rule. In other words, what does the safety and cost gap between ideal application of the BMS and real-world practice look like? Our study shows that children who qualified as VLR and were admitted, rather than discharged in accordance with BMS recommendations, were subjected to exposure and risks inherent to empirical treatment of bacterial meningitis. Strikingly, medical record documentation for every child in this group indicated strong clinical suspicion for viral meningitis, demonstrating that clinical diagnostic reasoning aligned with the BMS. Therapeutic reasoning did not follow suit,

however, with therapeutic decisions anchored in the ED carried over and continued despite evidence and even discussion to the contrary. This treatment plan inertia resulted in exposure to medications, additional imaging and laboratory diagnostics, and medical errors usually absent from the supportive treatment indicated for aseptic meningitis.¹⁵ Although this was a small group of patients, they were exposed to unnecessary antibiotics and drugs (82 and 188 doses, respectively), and even considering the small numbers, there was 1 adverse drug reaction and 1 acetaminophen overdose. These children were also exposed to 8 peripheral intravenous catheter complications, with 7 documented failed attempts among the group and 1 identified peripheral intravenous catheter infiltrate. Despite their VLR stratification, these children also received radiology testing after their ED treatment, which is not part of routine evaluation of aseptic meningitis.

These additional therapies and treatments lead not only to increased exposure and risk for these patients but also significant additional cost. The VLR patients who were admitted to the hospital were charged, on average, \$17 548.73 for their hospital care.

Although this study was not designed to validate the BMS, the high negative

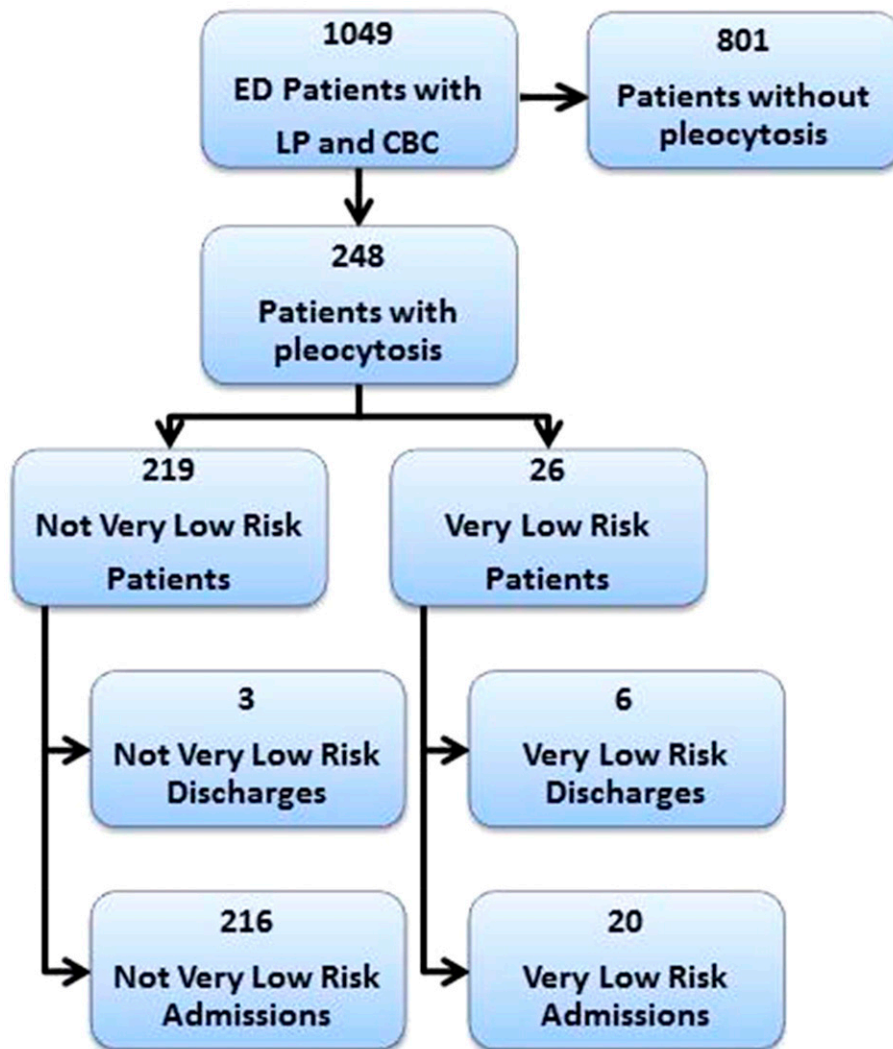


FIGURE 1 Flow diagram of patients presenting to CCHMC ED who underwent both a CBC and LP as part of their workup.

predictive value of the BMS was preserved in our cohort. This finding reinforces the fact that, despite robust validation work, heterogeneous application of a valuable clinical decision rule persists. In our

cohort more than two thirds of the children identified as VLR were admitted to the hospital, and most of these admissions occurred during enterovirus season.

Although we recognize that clinical prediction rules do not provide certainty and each case should be evaluated individually, we think that systematic implementation of the BMS, perhaps harnessing clinical decision support

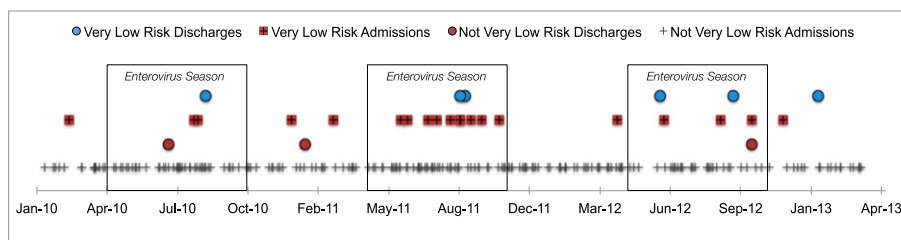


FIGURE 2 Time line of patient cohort presentations to the ED sorted by risk and disposition. Overlying shaded boxes designate the window of June–October enterovirus season. VLR admissions and non-VLR discharges had clinical dispositions that did not conform with the BMS.

architecture in contemporary EHRs, could provide a tool to help prevent unnecessary exposure to risk and cost due to hospitalization.

The limitations of this study include the retrospective nature of our review and our strict application of the BMS, which omits any clinical factors that may have influenced caregivers during an encounter.

Furthermore, we did not examine the disposition of patients without CSF pleocytosis. Additional study of this cohort could uncover exposure to risk and costs as a result of conservative clinical practice. Additionally, this is a single-site study, and therefore our sample sizes are small. Collection of data from multiple sites would increase the external validity of this work.

CONCLUSIONS

We conclude that consistent application of a well-supported clinical prediction rule such as the BMS has the potential to help both physicians and families make well-informed decisions in cases of suspected meningitis, which may reduce needless costs and exposure to risk.

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