Published in final edited form as:

J Pediatr. 2014 July ; 165(1): 134–139. doi:10.1016/j.jpeds.2014.02.061.

Brain Magnetic Resonance Imaging of Infants with Bacterial Meningitis

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Abstract

Objectives—To describe the results of brain magnetic resonance imaging (MRI) of infants with bacterial meningitis and how the findings affected clinical management.

Study design—This retrospective study included all infants <12 months of age who were hospitalized at Children's Medical Center, Dallas and had culture-confirmed bacterial meningitis and a brain MRI from January 1, 2001 to December 1, 2011. Infants were identified by review of all positive bacterial cultures of cerebrospinal fluid (CSF) from the Children's Medical Center Microbiology Laboratory. Demographic, clinical, laboratory, and neuroimaging data were reviewed. Infants with ventriculoperitoneal shunt or whose CSF culture yielded skin commensals were excluded. A neuroradiologist blinded to clinical information reviewed all MRI studies.

Results—Of the 440 infants who had a positive CSF culture result, 111 (25%) had a pathogen isolated from CSF and were enrolled in the study. Of these, 68% (75/111) had a brain MRI performed during the hospitalization; abnormalities included leptomeningeal enhancement (57%), cerebral infarct (43%), subdural empyema (52%), cerebritis (26%), hydrocephalus (20%), and abscess (11%). By multiple logistic regression analysis, infants with late seizures and an abnormal neurologic examination were more likely to have an abnormal MRI ($P < .05$). MRI results led to neurosurgical intervention in 23% of infants; a positive bacterial culture of CSF obtained >48 hours after initiation of antibiotic therapy was associated with neurosurgical intervention ($P = .01$). Fourteen (19%) infants with bacterial meningitis had a normal brain MRI.

Conclusions—Brain MRIs were performed frequently and often were abnormal in infants with bacterial meningitis, leading to changes in clinical management.

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The authors declare no conflicts of interest.

Portions of the study were presented at ID Week, San Diego, CA, October 7–21, 2012 and at St Jude/Pediatric Infectious Diseases Society's Pediatric Infectious Diseases Research Conference, Memphis, TN, February 24–25, 2012.

Bacterial meningitis occurs in approximately 0.2 infants per 1000 live births.[1,2] Although mortality in neonates has decreased from 70% to 14%,[3] morbidity persists with as many as 47% of survivors experiencing intellectual and academic impairment.[4] Neuroimaging may detect central nervous system abnormalities that have been associated with worse neurodevelopmental outcomes, but the frequency and characteristics of such findings by magnetic resonance imaging (MRI) have not been well characterized. Studies have suggested obtaining neuroimaging if infants have persistent fever, positive cerebrospinal fluid (CSF) cultures despite treatment, focal neurologic signs, late seizures, or decreasing level of consciousness.[4,5] However, correlation of these clinical characteristics with MRI findings has not been performed, and whether the results of brain MRI leads to changes in clinical management has not been documented. Bacterial meningitis can be a diagnostic challenge when the lumbar puncture is traumatic or unsuccessful, and it is not known whether a normal brain MRI can exclude a diagnosis of bacterial meningitis.

The objectives of this study were to characterize the brain MRI findings of infants with bacterial meningitis and to identify clinical features and pathogens that are associated with brain MRI findings that lead to changes in clinical management, and specifically with neurosurgical intervention.

Methods

This retrospective study included all infants less than 12 months of age who had culture-confirmed bacterial meningitis and were hospitalized at Children's Medical Center (CMC), Dallas, Texas from January 1, 2001 to December 1, 2011. Infants were identified by review of all positive CSF cultures results performed by the Microbiology Laboratory at CMC. Infants were excluded if they had a ventriculoperitoneal shunt at the time of diagnosis. In addition, positive CSF culture that yielded coagulase-negative staphylococci or other skin commensals were assessed as contaminants and were excluded. The study was approved by the Institutional Review Board of the University of Texas Southwestern Medical Center.

Pertinent demographic, clinical, laboratory, and neuroimaging data from all infants were reviewed. When multiple test results were available, the most abnormal one was used. Prematurity was defined as a gestational age <37 weeks, and low birth weight was <2500 g. Persistent fever was defined as a temperature >38.0°C for ≥4 days after initiation of intravenous antibiotic therapy, and secondary fever was new onset of fever after initial defervescence for ≥24 hours. Late seizure activity was epileptic activity ≥4 days after initiation of antibiotic therapy. Abnormal neurologic examination was defined as the presence of any of the following chart notations: persistent meningismus ≥2 days after initiation of therapy, or altered level of consciousness in the absence of sedation, unequal pupils, clonus, hypertonia, hyperreflexia, paralysis, increased frontal-occipital-circumference, or cranial nerve palsy any time during hospitalization. Leukopenia was defined as a white blood cell count of ≤5000 mm^3. CSF that had a red blood cell count of >100 000/mm^3 was excluded from analysis; otherwise, the CSF white blood cell count was adjusted for blood contamination by dividing the red blood cell count by 500 and subtracting this value from the white blood cell count.[6] Infants were assessed as having hearing impairment if they did not pass automated auditory brainstem response or evoked

otoacoustic emissions tests (with confirmation by a diagnostic auditory brainstem response test) that were performed during the hospitalization for meningitis. Neurosurgical interventions consisted of ventriculoperitoneal shunt placement, performance of burr hole surgery, drainage of subdural empyema or abscess, or ventricular tap through the anterior fontanel.

A board-certified pediatric neuroradiologist (M.M.) who was blinded to the clinical data and had not been involved in the original reading of the MRIs reviewed all brain MRIs for this study using a template of a priori findings that he had generated. If multiple MRI studies were performed during the same hospitalization, the initial study at the time of diagnosis of meningitis was assessed, and subsequent studies were reviewed for the development of progressive or new complications. MRI studies were performed on 1.5 and 3.0 Tesla MR units (Philips Healthcare System, Best, The Netherlands) and included T1-weighted sagittal and axial images, T2-weighted axial and coronal images, diffusion-weighted axial imaging, and postintravenous contrast T1-weighted imaging in the axial and sagittal planes and postcontrast fluid-attenuated inversion recovery axial imaging. In 71 (95%) of the studies, intravenous gadolinium enhanced images were available. MRI studies were evaluated for leptomeningeal enhancement, cerebritis, choroid plexitis, ventriculitis, hydrocephalus, empyema, abscess, infarct, venous thrombosis, and hemorrhage. Leptomeningeal enhancement, ventriculitis, cerebritis, and choroid plexitis were diagnosed based on abnormal enhancement of the meninges, ventricular ependymal margins, subcortical parenchyma, and choroid plexus, respectively. Hydrocephalus was diagnosed if ventricles were enlarged outside the normal limits for age (ie, the third ventricle having a width greater than 0.3 cm in a neonate). Edema was defined as abnormally increased T2 signal in the parenchyma. Abscess was noted if there was a fluid collection with enhancing margins, and cortical infarction was diagnosed if there was cortical diffusion restriction and edema.

Statistical Analyses

Data analysis was performed using Statistical Analysis System (SAS-PC; SAS Institute Inc, Cary, North Carolina) with results reported as the mean ± SD, median with IQR, or as the number and percentage. Student *t* test (2-sided), χ^2 or Fisher exact tests, and Mann-Whitney U tests were used where appropriate. A *P* value of <.05 was considered to be statistically significant.

A multiple logistic regression model was used to ascertain variables that were predictive of an infant having an abnormal brain MRI or required neurosurgical intervention. All of the variables that had a *P* value of <.1 in the simple logistic regression were included in the multiple logistic model. A stepwise method was used to select the final group of predictors, and adjusted *P* values were obtained. The variables included were age at presentation, gestational age, birth weight, temperature, heart rate, blood pressure, and respiratory rate at presentation. Also included were duration of illness prior to hospitalization, bulging fontanel, total days of antibiotics, days in the intensive care unit, days in hospital, white blood cell count, hemoglobin, platelets, urinalysis, CSF, liver enzyme tests, serum creatinine concentration, clinical signs at presentation (tachypnea, grunting, apnea, lethargy, diarrhea,

emesis, seizures, and irritability), vasopressor therapy, endotracheal intubation, and coexisting bacteremia, urinary tract infection, or pneumonia.

Results

Of the 440 infants who had a positive CSF culture, 111 (25%) had a pathogen isolated from CSF and were enrolled in the study. Excluded infants were 237 (54%) whose positive CSF culture was assessed as a contaminant, and 92 (21%) who had a ventriculoperitoneal shunt at the time that meningitis was diagnosed. The 111 enrolled infants had a median age of 78 ± 79 days, 57% (n = 63) were male, and 77% (n = 86) were full term (Table I). None had a cochlear implant before developing meningitis.

The results of the CSF cultures by age of diagnosis are provided in Table II. The majority of infants (68%; 76/111) had Gram-positive bacteria isolated from CSF. Among infants ≤59 days of age, the most common bacterial isolates were *Streptococcus agalactiae* (46%; 30/65) and *Escherichia coli* (20%; 13/65). Among infants of 60–179 days of age, *Streptococcus pneumoniae* (45%; 13/29) was the most common, but *S agalactiae* (24%; 7/29) and *E coli* (14%; 4/29) also were seen. After 6 months of age, *S pneumoniae* (71%; 12/17) was the predominant pathogen. *Neisseria meningitidis* accounted for only 1 case in an infant 9 months of age. There was no case of meningitis because of *Haemophilus influenzae type b*, and 4 infants who were older than 2 months of age had nontypeable *H influenzae* isolated from CSF. Overall, only 50% of infants with culture-confirmed meningitis had a positive blood culture at the time of diagnosis.

Seventy-five (68%) of the 111 infants had a brain MRI performed during the hospitalization (Table I); the median time from diagnosis of meningitis to performance of the brain MRI was 4 days (IQR range, 2–11 days). Compared with infants without an MRI, infants who had an MRI performed were significantly more likely to have apnea, lethargy, diarrhea, seizures, or irritability at hospitalization; to have co-existing bacteremia; and to require mechanical ventilation (Table I). They also were more likely to have comparatively higher CSF white blood cell count, higher protein content, longer median hospital stay, and lower glucose concentration. They did not differ in median days in the intensive care unit or mortality. Hearing impairment occurred in 17% (19/111) of infants, with 88% (17/19) being unilateral. Of the 19 infants, 9 (47%) had meningitis because of *S pneumoniae*, 7 (37%) because of group *B streptococci*, and 1 (5%) each with *S aureus, H influenzae*, and *Salmonella* spp. Of the 26 infants with pneumococcal meningitis, 9 (35%) developed hearing loss, compared with 7 (18%) of 38 infants with group B streptococcal meningitis ($P = .14$) and none of the 18 infants with meningitis because of *E coli*.

Brain MRIs were abnormal in 61 (81%) of 75 infants studied (Table III). There were no discrepancies found between the blinded neuroradiologist's interpretation of the brain MRI and the original "real-time" reported interpretation. Leptomeningeal enhancement was the most common finding, which occurred in 57% of patients. Infarcts (43%) and subdural empyema (52%) also were common. Of the 39 infants with subdural empyemas, 17/39 (44%) were associated with meningitis because of group B streptococci, 10/39 (26%) by *S pneumoniae*, 7/39 (18%) by *E coli*, and 1/39 (3%) each by *H influenzae* and *Enterobacter*

spp. Eight (11%) infants had a cerebral abscess associated with the bacterial meningitis; these were because of *E coli* (2/8), *S aureus* (2/8), *Citrobacter* spp. (1/8), *Enterobacter* spp. (1/8), group B streptococci (1/8), and *Salmonella* spp (1/8). Of the 14 infants with normal brain MRI, 5 (36%) had the study performed in the first week of hospitalization, 4 (29%) in the second week, and the remaining ones thereafter. Five (36%) of the 14 infants with normal brain MRI were ≤7 days old, 6 (43%) were 8–59 days old, and 3 (21%) were ≥60 days old at the time of diagnosis. Neonates ≤7 days of age who had a brain MRI were statistically more likely to have a normal MRI compared with infants >6 months of age ($P < .001$; Table III). Of the neonates who had normal MRI's and were <7 days old at the time of diagnosis, the median day at which the MRI was performed was 8 and the range was 2–21 days.

After performance of the brain MRI, 45% (34/75) of infants had at least 1 change in their clinical management, with prolongation of antibiotic therapy in 30% (23/75) and neurosurgical intervention in 23% (17/75) of infants. The neurosurgical interventions included 5 ventriculoperitoneal shunts, 1 burr hole, 5 anterior fontanel taps, and 7 drainage procedures for a subdural empyema or abscess. Specifically, of the 39 infants with subdural empyemas, 13 (33%) underwent neurosurgical intervention and 25% (2/8) of those with cerebral abscesses received surgical drainage.

Infants with late seizures and abnormal neurologic examination were significantly more likely to have an abnormal MRI than those without these findings (97% and 89%, respectively; $P < .05$; Table IV). Infants who had a positive repeat culture of CSF performed >48 hours after initiation of antibiotic therapy were significantly more likely to receive neurosurgical intervention (Table IV). Logistic regression analysis demonstrated that a persistently positive CSF culture was the only factor that was associated significantly with neurosurgical intervention (OR 6.2, 95% CI, 1.67–23.25; $P < .05$; Table IV). Persistently positive CSF cultures were most often because of group B streptococci (8/18; 44%) or *E coli* (6/18; 33%). In addition, 87% (47/53) of infants who had meningitis because of Gram-positive bacteria had an abnormal MRI compared with 64% (14/22) of infants who had Gram-negative bacterial meningitis ($P = .01$). Of infants with group B streptococcal and *E coli* meningitis, 90% (28/31) and 69% (9/13), respectively, had abnormal MRI findings.

Discussion

In this 11-year, single institution study of infants with bacterial meningitis who had brain MRIs performed as part of clinical care, 81% (61/75) of MRIs were abnormal, and in 45% (34/75) of infants, the findings resulted in a change in clinical management. Compared with those who did not have a MRI performed, infants who had MRIs were more likely to have presented with leukopenia, seizures, and required intubation. The number of intensive care unit admissions, duration of intensive care unit stay and hospitalization, as well as mortality did not differ.

The abnormalities seen on brain MRI reflected the pathophysiology of meningitis. Bacterial meningitis involves inflammation of the meninges and ventricles, and is demonstrated radiologically as contrast enhancement of the leptomeninges and the ependyma of the

ventricles. The inflammation can extend to the cerebral vessels and promote vasculitis and vasospasm resulting in cerebral infarction. Perivascular inflammation can also extend to the parenchyma of the brain and induce cerebritis, which leads to development of a subdural empyema or brain abscess.[7] Consistent with previously published data,[8] leptomeningeal enhancement was the most common finding seen in 57% of our cases of bacterial meningitis. Leptomeningeal enhancement is not specific to bacterial meningitis because this can occur in a variety of noninfectious disorders such as leptomeningeal carcinomatosis, granulomatous diseases, and primary central nervous system vasculitis. Although our data are insufficient to determine the specificity or sensitivity of MRI in diagnosing meningitis, they demonstrate that MRI alone is not sufficiently sensitive to exclude meningitis based on 14 (19%) infants who had a normal brain MRI in the setting of culture-proven bacterial meningitis.

The abnormalities seen on brain MRI may reflect changes caused by specific bacteria. Gram-negative bacilli such as *Citrobacter koseri* and *Cronobacter sakazakii* have been associated with cerebral abscess formation, even in infants who have a relatively benign clinical course, and hence the recommendation for routine neuroimaging.[9,10] In the study by Graham and Band,[10] 41 of 53 (77%) neonates with *Citrobacter diversus* developed a brain abscess. In our study, there were 4 cases of meningitis because of *Citrobacter* spp *or Enterobacter* spp, and despite 50% of them having cerebral abscesses on MRI, all received prolonged antimicrobial therapy without neurosurgical intervention. Meningitis because of *E coli* is associated with high morbidity and mortality,[11] and as a consequence, a brain MRI often may be obtained empirically. Among the 18 infants with *E coli* meningitis in our study, 13 (72%) had a brain MRI performed, and 4 (22%) eventually received neurosurgical intervention.

Meningitis because of *S pneumoniae* and *H influenzae* type b has been associated with subdural empyema.[12] However, among our 39 infants with subdural empyema, 31% (12/39) had group B streptococcal meningitis compared with 18% (7/39) with pneumococcal meningitis.

Seizure as the presenting sign of bacterial meningitis occurs in about 20% to 50% of cases,[13,14] and studies suggest that seizures are more frequent with Gram-negative than Gram-positive bacterial meningitis. We found that 47% (52/111) of infants with culture-confirmed bacterial meningitis had seizures at the time of hospitalization, and seizures occurred in 58% (44/75) of those who had a brain MRI preformed vs 11% (4/36) who did not. However, 87% (33/38) of these infants who presented with seizures had meningitis because of Gram-positive rather than Gram-negative bacteria.

Hearing impairment is a frequent sequela of bacterial meningitis, which often is attributed to infection with *S pneumoniae*.[15,16] Our data, though limited to hearing evaluation performed during the acute illness, supports this association, in that 44% (9/19) of infants with hearing impairment had pneumococcal meningitis.

Despite the ability to identify frequently some abnormality on brain MRI in infants with bacterial meningitis, the question remains whether these findings affect clinical

management. Our study supports that findings of the study do affect management. Overall, 45% (34/75) of infants with an abnormal MRI had a change in management, including prolongation of antimicrobial therapy (23/75; 30%) to neurosurgical intervention (17/75; 23%). This results in a “number needed to image” of 2.2 for detecting an abnormality associated with a change in management of clinical importance.

Based on our findings and absent prospective data, we consider that brain MRI should be utilized as a selective imaging tool in infants with bacterial meningitis who have persistently positive cultures of CSF despite antibiotic therapy, late seizures, or abnormal findings on neurologic examination. Performance of brain MRI for all infants with bacterial meningitis is unlikely to result in changes in surgical management to warrant its routine use for this purpose.

This study is subject to several limitations. Because of its retrospective nature and small sample size, the results likely are confounded by selection bias. Although infants with more severe meningitis may be more likely to have a brain MRI performed, 68% of our study infants had MRI performed, and we did not detect significant differences in either provision or duration of intensive care, or length of hospitalization. In addition, only those infants with culture-confirmed bacterial meningitis were enrolled, thus excluding some infants in which the CSF was unable to be obtained or was abnormal and consistent with bacterial meningitis but the culture was sterile secondary to previous antimicrobial therapy. Our inclusion criteria, however, is the most supportive of the condition studied. The appropriateness of the antimicrobial therapy and the impact of antimicrobial resistance were not investigated, and these could have played a role in findings of abnormal neuroimaging. Receipt of adjunctive corticosteroid therapy was not studied. In addition, criteria used for certain neurosurgical interventions were not assessable. Finally, there was no long-term follow-up of these infants to know the predictive ability of the brain MRI.

Acknowledgments

We thank Shari Young for providing the list of positive CSF culture results performed in the Microbiology Laboratory at CMC; Rong Huang, MS (biostatistician at CMC), for performing part of the statistical analyses; and Nancy K. Rollins, MD (Chief of Radiology, CMC) for support of the study.

Glossary

CMC	Children’s Medical Center
CSF	Cerebrospinal fluid
MRI	Magnetic resonance imaging

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Table I.

Characteristics of the 111 infants with bacterial meningitis

	Bacterial meningitis			
	Brain MRI			
	Yes	No	Total	
	n (%)	n (%)	n (%)	*P* value
No. of infants	75 (68)	36 (32)	111	-
Age, median, in d (range)	76 ± 77	85 ± 86	78 ± 79	.55
Male	40 (54)	23 (64)	63 (57)	.29
Birth weight <2500 g	13 (17)	6 (16)	19 (17)	.93
Gestational age >37 wk	60 (80)	26 (72)	86 (77)	.36
Clinical features at presentation				
Duration of signs/symptoms in days; mean ± SD	3 ± 5	2 ± 2	3 ± 4	.07
Apnea	34 (46)	3 (8)	37 (33)	<.05
Lethargy	59 (79)	22 (61)	81 (73)	<.05
Diarrhea	20 (26)	3 (8)	23 (21)	<.05
Emesis	22 (29)	10 (28)	32 (28)	.86
Seizures	44 (58)	4 (11)	48 (43)	<.05
Irritability	71 (94)	27 (75)	98 (88)	<.05
URI symptoms	27 (36)	11 (31)	38 (34)	.57
Bulging fontanel	26 (35)	7 (19)	33 (30)	.1
Intubation	38 (51)	7 (19)	45 (40)	<.05
Vasopressor therapy	18 (24)	4 (11)	22 (20)	.11
ICU stay in d; median (range)	2 (0–68)	0 (0–109)	1 (0–109)	.07
Hospital stay in d; median (range)	21 (3–68)	14 (6–119)	21 (3–119)	<.01
Leukopenia	24 (32)	5 (14)	29 (26)	<.05
Urinary tract infection	9 (12)	5 (14)	14 (13)	.78
Pneumonia	10 (13)	3 (8)	13 (12)	.44
Positive blood culture	49 (65)	7 (18)	56 (50)	<.05
Outcome				
Hearing impairment	15 (20)	4 (11)	19 (17)	.24

	Bacterial meningitis			
	Brain MRI			
	Yes n (%)	No n (%)	Total n (%)	*P* value
Mortality	4 (3)	1 (3)	5 (5)	.97
Gram-negative bacilli	22 (29)	13 (36)	35 (32)	.47
CSF*				
WBC count in cells/mm^3†; mean ± SD	2725 ± 3834	1226 ± 3467	2191 ± 3776	<.05
Protein in mg/dL; mean ± SD	380 ± 419	231 ± 219	279 ± 258	<.05
Glucose in mg/dL; mean ± SD	21 ± 20	46 ± 20	36 ± 20	<.05

ICU, intensive care unit; *URI*, upper respiratory infection; *WBC*, white blood cell.

*Of the 111 CSF samples, 10 (9%) were excluded because of RBC count >100 000 mm^3.

†WBC count of 37 (33%) of the 111 CSF samples was adjusted to account for red blood cell count >500/mm^3.

Table II.

Etiologic agents of bacterial meningitis and age of presentation among 111 infants

	Age at presentation				
	0–7 d	**8–59 d**	**60–179 d**	**6–12 mo**	**Total**
No. of infants	8 (7)	57 (51)	29 (26)	17 (15)	111
Organism					
Streptococcus agalactiae	3 (38)	27 (47)	7 (24)	1 (6)	38 (34)
Streptococcous pneumoniae		1 (2)	13 (45)	12 (71)	26 (23)
Escherichia coli	2 (25)	11 (19)	4 (14)	1 (6)	18 (16)
Haemophilus influenzae (non-type b)		1 (2)	2 (7)	2 (12)	5 (5)
Enterococcus spp.		3 (5)	1 (3)		4 (4)
Streptococcus bovis	1 (13)	3 (5)			4 (4)
Citrobacter spp.	1 (13)	2 (4)			3 (3)
Klebsiella pneumoniae	1 (13)	1 (2)			2 (2)
Listeria monocytogenes		2 (4)			2 (2)
Salmonella spp.		2 (4)			2 (2)
Staphylococcus aureus		1 (2)	1/29 (3)		2 (2)
Acinetobacter spp.			1 (3)		1 (1)
Enterobacter spp.		1 (2)			1 (1)
Flavobacterium spp.		1 (2)			1 (1)
Neisseria meningitidis				1 (6)	1 (1)
Proteus mirabilis		1 (2)			1 (1)

Numbers in parentheses, percent.

Table III.

Results of brain MRI by age of presentation in 75 infants with bacterial meningitis

	Age at presentation				
	0–7 d	**8–59 d**	**60–179 d**	**6–12 mo**	**Total**
No. of infants	7 (9)	36 (48)	21 (28)	11 (15)	75
Brain MRI findings					
Normal	5 (71)	6 (16)	3 (14)		14 (19)
Choroid plexitis	1 (14)	1 (3)			2 (3)
Hemorrhage		3 (8)	2 (10)		5 (7)
Venous thrombosis		5 (14)	2 (9)		7 (9)
Ventriculitis	1 (14)	3 (8)	3 (14)		7 (9)
Brain abscess	1 (14)	3 (8)	3 (14)	1 (9)	8 (11)
Hydrocephalus	1 (14)	6 (17)	6 (29)	2 (18)	15 (20)
Cerebritis		12 (33)	5 (24)	3 (27)	20 (26)
Subdural empyema	1 (14)	17 (47)	12 (57)	9 (82)	39 (52)
Brain parenchymal ischemia/infarction	1 (14)	15 (42)	10 (48)	6 (55)	32 (43)
Leptomeningeal enhancement	1 (14)	19 (53)	12 (57)	11 (100)	43 (57)

Numbers in parentheses, percent.

Table IV.

Results of multiple regression analysis of factors associated with an abnormal brain MRI and neurosurgical intervention in the 75 infants with bacterial meningitis who had MRI performed

	Brain MRI				Neurosurgical intervention after MRI			
	Abnormal MRI	Normal MRI	*P* value	OR (95% CI)	Neurosurgery after MRI	No neurosurgery after MRI	*P* value	OR (95% CI)
No. of infants (n = 75)	61	14	-	-	17	58	-	-
Late seizures (n = 38)	37 (97%)	1 (3%)	.0001	20 (2.4–163)	11 (29%)	27 (71%)	.18	2.1 (0.68–6.5)
New onset of fever (n = 10)	8 (80%)	2 (20%)	1	0.8 (0.1620134.5)	3 (30%)	7 (70%)	.55	1.5 (0.35–6.8)
Fever for ≥4 d (n = 18)	15 (83%)	3 (17%)	.68	1.1 (0.2–4.86)	6 (33%)	12 (67%)	.21	2.0 (0.64–6.8)
Abnormal neurologic examination (n = 25)	24 (96%)	1 (4%)	.01	8.4 (1.0–68.7)	8 (32%)	17 (68%)	.17	2.1 (0.7–6.49)
Positive CSF culture >48 h (n = 18)	16 (89%)	2 (11%)	.16	2.1 (0.4–10.5)	8 (44%)	10 (56%)	.01	4.2 (1.3–13.7)