Predictors of 90-day Readmissions in Adults with Bacterial Meningitis

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Abstract

Background

Bacterial meningitis is associated with high neurological morbidity, mortality, and cost. A large part of these outcomes can be associated with hospital readmission. However, little is known about the factors influencing readmissions following bacterial meningitis. The objective of this study is to examine rates of 90-day readmissions, factors associated with readmission, and the cost associated with bacterial meningitis.

Methods

In this retrospective cohort study, we examined adults hospitalized with a diagnosis of bacterial meningitis using the Nationwide Readmissions Database (NRD) during 2016 and 2017. We used a survey-weighted logistic regression models to determine the adjusted odds ratios (aOR) and 95% confidence intervals (95% CI) for risk factors associated with readmission within 90 days of index discharge.

Results

Among the 10,922 survivors of bacterial meningitis included in this study, 28.9% (n = 3158) were readmitted within 90 days. The majority of cases had an unknown etiology of their bacterial meningitis (54.5%, n = 5955), followed by *Streptococcus pneumoniae* (14.3%), streptococcal (12.4%), and staphylococcal (10.6%) meningitis. On multivariate analysis, patients with staphylococcal meningitis (aOR: 1.88; 95% CI: 1.45 – 2.44) and an unknown etiology (aOR: 1.30; 95% CI: 1.06 – 1.59) were significantly more likely to be readmitted in 90 days, as were patients with renal disease, metastatic cancer, and anemia.

Conclusion

Bacterial meningitis has high rates of readmission, with more than one in four patients being readmitted within 90 days of discharge. Further investigation into why patients with an unknown bacterial etiology of their meningitis is warranted.

Introduction

Meningitis is an inflammation of the meninges and cerebrospinal fluid (CSF)-filled subarachnoid space. Outcomes are associated with a high rate of morbidity and mortality placing a significant clinical and monetary burden for patients [1,2]. Bacterial meningitis is the most severe form of meningitis, and it can be acquired spontaneously in the community or in the healthcare setting.

Although other infectious diseases account for greater proportions of readmissions [3], readmission for meningitis is one of the most costly, second only to endocarditis in the average cost per readmission [4]. Despite this, relatively little is known about specific factors associated with readmissions for meningitis, specifically bacterial meningitis. The objective of this study is to examine rates of 90-day readmissions, factors associated with readmission, and the cost associated with bacterial meningitis.

Methods

Study population and cohort selection

This study utilized the 2016 to 2017 Nationwide Readmissions Database (NRD) [5]. The NRD is part of the Healthcare Cost and Utilization Project (HCUP), administered through the Agency for Healthcare Research and Quality (AHRQ), and is the only nationally representative readmissions database publicly available in the United States. The NRD captures roughly 50% of all hospitalizations in participating states and tracks patient readmissions across all hospitals, as long as it remains in the same state, via deidentified patient linkage variables. There were 27 and 28 states participating in the NRD project in 2016 and 2017, respectively. These cases can be used to calculate national estimates using a weighted conversion factor provided in the dataset [6].

We identified all hospital admissions of patients 18 years or older with an International Classification of Diseases, Tenth Revision, Clinical Modification (ICD-10) code indicating a diagnosis of bacterial meningitis amongst all listed diagnosis codes per each hospitalization (**Supplemental Table 1**). Patients with ICD-10 codes indicating multiple diagnoses of different bacterial meningitis etiologies were excluded from this study (**Supplemental Table 2**), as were patients with mycobacterial, fungal, parasitic, or spirochetal (e.g. Lyme, leptospirosis) meningitis. Because prior investigations have found high rates of culture negative pyogenic meningitis [7], patients with ICD-10 codes that indicated *bacterial* meningitis without specifying a pathogen (codes G00, G00.8, G00.9, and G01) were included and classified as "unknown". Patients admitted to out-of-state hospitals (i.e., a patient whose primary residence was not within the same state as the hospital) were excluded from our cohort because possible readmissions may not be included in the NRD. Only initial admissions from January to September of 2016 and 2017 were included in this study, allowing each patient to have at least 90 days of follow-up. Patients with missing data for any variables/predictors were also excluded (**Figure 1**). Patients who died during initial admission were

excluded from our readmission analysis but were included in our exploratory cost analysis. Otherwise, hospitalizations that meet these criteria were flagged as index events. Due to the descriptive nature of our outcome, we sought to only characterize the first readmission after index, if any occurred at all.

Exposures and covariates

Patients were categorized based on their bacterial etiology of meningitis during their index admission based on ICD-10 codes listed in **Supplemental Table 1**. Baseline demographics (age, sex, primary expected payor, median household income by zip code) were collected for each patient's index admission, as was their disposition when leaving the hospital.

Comorbidities present during index admission were identified using the Quan's adaption of Elixhauser comorbidity mapping algorithms [8]. Procedures during index admission were defined using the HCUP's Clinical Classifications Refined (CCSR) software [9] for ICD-10-PCS codes (**Supplemental Table 3**). CCSR categorizes multiple ICD-10 codes into a smaller number of clinically meaningful categories.

Outcomes

The primary outcome was all-cause readmission within 90 days from index discharge. A 90-day readmission window was chosen to capture cases after completion of most common antibiotic courses that would be prescribed at discharge from their index hospitalization. We also conducted an exploratory analysis investigating the reasons for readmission and cost associated with hospitalization. Reasons for readmission were categorized via the CCSR software [9] using the principal diagnosis for hospitalization for the first readmission in the 90-days following index discharge. Hospital associated costs were calculated using the cost-to-charge ratio file provided by the HCUP, which adjusts for intra-hospital variability in charges to estimate the cost of admission. These values were then temporally standardized and adjusted for inflation to the January 2022 US dollar using the monthly Consumer Price Index [10].

Statistical Analysis

Categorical variables are presented as weighted frequencies and percentages, and continuous variables are presented as weighted means and 95% confidence intervals, unless otherwise noted. To account for the lognormal distribution of costs, summary statistics for cost data are presented as weighted geometric means. Bivariate calculations were conducted with Student t-tests for continuous variables and chi-squared or Fisher's exact tests for categorical variables. Because the NRD uses a stratified sampling strategy, all analyses were conducted using weighted estimates and design-based standard errors to account for the complex design and produce nationally representative estimates.

A survey design logistic regression model was used to determine the adjusted odds ratios (aOR) for 90-day readmission. Comorbidities and procedures were included

in the multivariate analysis if they had a significance of p ≤ 0.10 on bivariate analysis (**Table 1**). Otherwise, a 2-sided value of P < 0.05 was set for statistical significance. All analysis was conducted using the R Statistical Software (version 4.2.0). No patient identifiable information is included in the NRD and thus does not require IRB approval.

Results

Among the 18,339 adults with bacterial meningitis, 10,922 were included in our analysis (**Figure 1**). Among patients with qualifying index admissions, 10.7% (n=1309) died during index admission. The average age of patients surviving index admission was 54.4 years of age (standard deviation [SD]: 17.3), and 49.9% (n=5447) of patients were female (**Table 1**). The majority of patients did not have a specific bacterial etiology that was identifiable using ICD codes (54.5%; n=5955), followed by *Streptococcus pneumoniae* (pneumococcal) (14.3%, n=1563), streptococcal sp. (12.4%, n=1353), and staphylococcal (10.6%, n=1157). The remaining etiologies (*Haemophilus influenzae*, *Neisseria meningitidis*, and *Listeria monocytogenes*) collectively accounted for less than 10% of the etiologies. Similar proportions of patients were either discharged home (33.4%; n=3647), sent home with home health (28.2%, n=3075), or transferred to a lower acuity medical facility (33.0%, n=3600) such as a skilled nursing facility.

Bivariate analysis

Among the 10,922 patients discharged from their index admission for bacterial meningitis, 3158 (28.9%) were readmitted within 90 days. On bivariate analysis, patients were significantly more likely to be readmitted if they were older, were insured by Medicare or Medicaid, had an unknown etiology or staphylococcal meningitis, and had either cardiovascular, hematologic, or oncologic comorbidities (**Table 1**). Patients who had invasive central nervous system (CNS) procedures, tracheostomies, gastrostomies, hemodialysis, and ventricular shunts placed were also more frequently readmitted. Patients who were discharged home or home with home health, however, were less likely to be readmitted.

Multivariate analysis

On multivariate analysis, females were 1.15 times more likely to be readmitted (95% CI 1.01-1.31); **Table 2**. Patients who were older were less likely to be readmitted, however this was not statistically significant (aOR: 0.96 per 10 years of age; 95% CI 0.91-1.01). Compared to those with pneumococcal meningitis, patients with staphylococcal meningitis were 1.88 times more likely to be readmitted (95% CI: 1.45-2.44). Patients with unknown etiologies of their meningitis were also more likely to be readmitted (aOR: 1.30; 95% CI: 1.06-1.59).

Despite the bivariate analysis showing numerous comorbidities and procedures that were associated with readmission, the adjusted analysis only revealed a handful of significant associations. Patients with deficiency anemias (aOR: 1.54), metastatic cancer (aOR: 1.46), and renal dysfunction (renal failure aOR: 1.37; hemodialysis aOR: 1.56)

had higher rates of readmission. The only comorbidity that had a significant protective effect was obesity (aOR: 0.82).

Compared to those discharged home, all other types of discharges were significantly more likely to be readmitted, with patients who were transferred to a short-term hospital (aOR: 2.61) and those who left against medical advice (aOR: 2.03) being at highest risk for readmission. Primary payor and household income were not significantly associated with rates of readmission.

Reasons for readmission and costs

Among the 3158 patients who were readmitted, the two most common reasons for readmission were sepsis (n=362; 11%) and meningitis (n=252; 8%), accounting for nearly one in five readmissions (**Table 3**). Other common reasons for readmissions were for disorders of the nervous system, complications from the index admission, and CNS abscess.

The log adjusted average of hospital associated cost per patient was $38,373 (95% CI: 36,964 – 39,837), including the costs of readmissions within 90 days (**Table 4**). Survivors of index admission who were not readmitted had lower average costs ($29,749; 95% CI: 28,559 – 30,988) compared to those who were readmitted ($66,867; 95% CI: 63,379 – 70,548). Among the etiologies of bacterial meningitis, staphylococcal sp. was on average the costliest ($63,336; 95% CI: 58,326 – 68,777) and *Haemophilus influenzae* the least costly ($26,842; 95% CI: 23,422 – 30,762).

Discussion

In this population-based retrospective cohort study, we found high rates of readmissions associated with bacterial meningitis (28.9% readmitted within 90 days). Our estimate of readmissions is substantially higher than an estimate by Ellis et al., who found that 11.4% of patients with meningitis were readmitted within 90 days [11]. We suspect this disparity is because this investigation was limited to bacterial meningitis, which is more severe than other types of meningitis, whereas Ellis et al. included meningitis due to any cause [11] (the majority of which were likely not bacterial [12]). In fact, our readmission rate is similar to readmission rates for other severe bacterial infections such as gram-negative bacteremia, *S. aureus* bacteremia, and endocarditis [13–15].

This study showed that the bacterial etiology was predictive of 90-day readmissions. Specifically, patients with staphylococcal meningitis were two times as likely to be readmitted and patients with unknown etiologies were 1.3 times more likely to be readmitted compared to pneumococcal meningitis. Although rates of readmission for staphylococcal meningitis have not been previously described, one in five patients with *S. aureus* bacteremia are readmitted within 30-days [14]. Meningitis due to the *staphylococcus* species is most commonly from nosocomial infections or seeding from elsewhere in the body (e.g., endocarditis), so it's unsurprising that survivors of staphylococcal meningitis have high rates of readmission.

More striking was the large number or patients with an unknown etiology of their bacterial meningitis and the high rate of readmissions among these patients. Although it's possible that some patients were labeled as "unknown" due to poor specificity in documentation, it's also likely that many of these patients did not have the bacterial etiology of their meningitis identified during their admission. Prior studies with access to microbiologic data have found over half of meningitis cases are from an unknown etiology [12], and one population-based study indicated that nearly half of pyogenic meningitis cases are culture negative [7]. The inability to identify a causative organism (potentially due sterilization of the CSF) could predispose these patients to readmission by inability of the treatment team to appropriately target antibiotics to culture and sensitivity data.

Beyond bacterial etiology, we also found the presence of metastatic cancer, renal failure, and anemia to confer an increased risk of readmission. These factors could be related to underlying patient immunosuppression, although rheumatologic disease, non-metastatic solid-malignancy, diabetes with complications, and older age were not significantly associated with increased risk for readmission. Alternately, end stage renal disease, cytopenias, and advanced cancers increase the risk for antibiotic associated toxicity and could predispose patients for readmission. Surprisingly, placement of a ventricular drain was not associated with readmission for meningitis. Estimates of the incidence of nosocomial meningitis from ventricular catheters range from 4-17%, most frequently developing within the first month after surgery, which would have been captured during the time frame of this study [16].

We found bacterial meningitis to carry a substantial financial burden, especially for patients who were readmitted. In fact, patients who were readmitted within 90 days from discharge had twice the average cost ($66,867) compared to those who survived index admission and were not readmitted ($29,749). Our pathogen-specific cost analysis found staphylococcal meningitis to be the most costly ($63,336), similar to previous investigations [2]. These cost estimates should be interpreted with caution, as these values only represent hospital associated costs, which is only a fraction of the total healthcare and socioeconomic costs of any disease. Thus, the estimates presented here likely underestimate the true burden of bacterial meningitis, as we were unable to include the costs associated with provider billing, rehabilitation, and outpatient care. A detailed cost analysis is beyond the scope of this study, but this further highlights the importance of reducing bacterial meningitis-associated readmissions.

Although this study uses nationally representative data, it is not without limitations. First, because the NRD lacks microbiologic data, the etiology of bacterial meningitis was established using ICD-10 codes. As discussed above, it's possible that some of our cases identified as unknown etiology were misclassified due to inadequate documentation. Similarly, 12.3% of cases were classified as streptococcal meningitis. The most common cause of streptococcal meningitis is *S. pneumoniae* (i.e. pneumococcal

meningitis), which represents over half of total cases in the United States [17]. However, in one US surveillance study, 7.4% of bacterial meningitis cases in adults were caused by group B streptococcus [18]. While the relatively low proportion of pneumococcal meningitis (and disproportionately high number of streptococcal meningitis) observed in our study likely represents misclassification of pneumococcal meningitis as streptococcal meningitis, it remains impossible to identify which cases of streptococcal meningitis were misclassified in the absence of microbiologic data. Second, we only characterized risk factors for each patient's first qualifying index admission per calendar year. Although this was done for analytic reasons (to preserve the assumption of independent observations), this limits the ability to analyze those with multiple readmissions and/or patients who had meningitis more than once in a year. Third, the NRD does not provide data about laboratory values or medications administered (e.g., antimicrobials, steroids), which could result in residual confounding. Finally, as with all studies using secondary data sources, the quality of the results depends on the quality of the initial recording of data.

In summary, our analysis found that bacterial meningitis, particularly staphylococcal sp. and bacterial meningitis of unknown microbiologic etiology, has a high rate of readmission and is associated with a substantial financial burden to the healthcare system. Further investigation into interventions to decrease the rates of readmission following hospitalization for bacterial meningitis are warranted.

Authors' Contributions

All authors had full access to the data, including statistical reports and tables.

CRediT taxonomy: Conceptualization (HR, RH); methodology & design (HR & MH); formal analysis (HR); interpretation & writing of the full draft (HR, MH, RH)

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Tables

Table 1

Caption: Demographics and clinical characteristics of hospitalized bacterial meningitis patients. The second column lists the nationally weighted estimates of the overall cohort, and columns 3-5 demonstrate the bivariate analysis, stratified by 90-day readmission.

	Total (n=10,922)	**Not readmitted** (n=7763; 71.1%)	**Readmitted** (n=3158; 28.9%)	**p**
Mean age ± SD, in years	54.37 ± 17.33	54.00 ± 17.53	55.28 ± 16.81	0.024
Sex: Female (%)	5447 (49.9%)	3822 (49.2%)	1626 (51.5%)	0.144
Household income quartile (%)				0.414
1st (lowest income)	3338 (30.6%)	2324 (29.9%)	1014 (32.1%)	
2nd	2995 (27.4%)	2150 (27.7%)	845 (26.8%)	
3rd	2592 (23.7%)	1843 (23.7%)	749 (23.7%)	
4th (highest income)	1997 (18.3%)	1446 (18.6%)	550 (17.4%)	
Payor (%)				0.001
Medicare	4135 (37.9%)	2825 (36.4%)	1310 (41.5%)	
Private insurance	3798 (34.8%)	2762 (35.6%)	1036 (32.8%)	
Medicaid	2068 (18.9%)	1464 (18.9%)	604 (19.1%)	
Self-pay	515 (4.7%)	414 (5.3%)	100 (3.2%)	
Other	407 (3.7%)	298 (3.8%)	108 (3.4%)	
Index Disposition (%)				<0.001
Against medical advice	178 (1.6%)	115 (1.5%)	63 (2.0%)	
Home health care	3075 (28.2%)	2212 (28.5%)	863 (27.3%)	
Routine to home	3647 (33.4%)	2860 (36.8%)	787 (24.9%)	
Transfer other (SNF, ICF, etc)	3600 (33.0%)	2336 (30.1%)	1265 (40.0%)	
Transfer to short-term hospital	421 (3.9%)	241 (3.1%)	180 (5.7%)	
Infectious Etiology (%)				<0.001
Neisseria meningitidis	263 (2.4%)	218 (2.8%)	45 (1.4%)	

Haemophilus influenzae	352 (3.2%)	280 (3.6%)	72 (2.3%)	
Listeria monocytogenes	278 (2.5%)	202 (2.6%)	76 (2.4%)	
Streptococcus pneumoniae	1563 (14.3%)	1181 (15.2%)	382 (12.1%)	
Staphylococcal species	1157 (10.6%)	693 (8.9%)	464 (14.7%)	
Streptococcal species	1353 (12.4%)	997 (12.8%)	356 (11.3%)	
Unknown	5955 (54.5%)	4191 (54.0%)	1764 (55.9%)	
Comorbidities				
Congestive heart failure (%)	1124 (10.3%)	741 (9.5%)	383 (12.1%)	0.005
Cardiac arrhythmias (%)	2222 (20.3%)	1482 (19.1%)	740 (23.4%)	0.001
Valvular disease (%)	648 (5.9%)	427 (5.5%)	220 (7.0%)	0.042
Pulmonary hypertension (%)	446 (4.1%)	286 (3.7%)	159 (5.0%)	0.021
Peripheral vascular disorders (%)	435 (4.0%)	278 (3.6%)	157 (5.0%)	0.022
Hypertension (%)	5900 (54%)	4148 (53.4%)	1752 (55.5%)	0.185
Paralysis (%)	882 (8.1%)	565 (7.3%)	317 (10.0%)	0.003
Other neurological disorders (%)	5083 (46.5%)	3549 (45.7%)	1534 (48.6%)	0.072
Chronic pulmonary disease (%)	1763 (16.1%)	1221 (15.7%)	542 (17.2%)	0.272
Diabetes w/o complications (%)	1166 (10.7%)	858 (11.1%)	308 (9.8%)	0.159
Diabetes with complications (%)	1442 (13.2%)	979 (12.6%)	463 (14.6%)	0.064
Hypothyroidism (%)	1240 (11.4%)	866 (11.1%)	374 (11.9%)	0.500
Renal failure (%)	1186 (10.9%)	731 (9.4%)	456 (14.4%)	<0.001
Liver disease (%)	722 (6.6%)	486 (6.3%)	235 (7.5%)	0.135
Peptic ulcer disease (%)	56 (0.5%)	36 (0.5%)	21 (0.7%)	0.424
HIV (%)	176 (1.6%)	123 (1.6%)	54 (1.7%)	0.737
Lymphoma (%)	227 (2.1%)	148 (1.9%)	79 (2.5%)	0.172
Metastatic cancer (%)	301 (2.8%)	186 (2.4%)	115 (3.7%)	0.008
Solid tumor w/o metastasis (%)	385 (3.5%)	240 (3.1%)	146 (4.6%)	0.007
Rheumatic disease (%)	510 (4.7%)	331 (4.3%)	179 (5.7%)	0.063
Coagulopathy (%)	1575 (14.4%)	1035 (13.3%)	540 (17.1%)	0.001
Obesity (%)	1764 (16.1%)	1305 (16.8%)	459 (14.5%)	0.047
Weight loss (%)	1399 (12.8%)	900 (11.6%)	499 (15.8%)	<0.001
Fluid & electrolyte disorders (%)	6341 (58.1%)	4424 (57%)	1917 (60.7%)	0.029
Blood loss anemia (%)	76 (0.7%)	49 (0.6%)	27 (0.8%)	0.433
Deficiency anemias (%)	521 (4.8%)	320 (4.1%)	201 (6.4%)	0.001

Alcohol abuse (%)	801 (7.3%)	560 (7.2%)	241 (7.6%)	0.623
Drugs abuse (%)	1008 (9.2%)	705 (9.1%)	303 (9.6%)	0.541
Psychoses (%)	216 (2.0%)	157 (2.0%)	59 (1.9%)	0.721
Depression (%)	1580 (14.5%)	1095 (14.1%)	485 (15.4%)	0.265
Procedures				
Ventricular shunt (%)	466 (4.3%)	290 (3.7%)	176 (5.6%)	0.006
Invasive CNS procedure (%)	1354 (12.4%)	879 (11.3%)	475 (15.0%)	<0.001
Tracheostomy (%)	515 (4.7%)	316 (4.1%)	198 (6.3%)	0.001
Gastrostomy (%)	743 (6.8%)	449 (5.8%)	294 (9.3%)	<0.001
EEG (%)	454 (4.2%)	310 (4.0%)	145 (4.6%)	0.327
Mechanical ventilation (%)	2781 (25.5%)	1945 (25.1%)	836 (26.5%)	0.340
Hemodialysis (%)	224 (2.1%)	120 (1.5%)	104 (3.3%)	<0.001

Abbreviations: SD=Standard deviation, SNF=skilled nursing facility, ICF= intermediate care facility, w/o=without, CNS=Central nervous system, EEG= Electroencephalogram

Table 2

Caption: Multivariate analysis of readmissions

	aOR	95% CI	p-value
Age, per 10 years of age	0.96	[0.91, 1.01]	0.150
Sex:			
Male	Reference	—	—
Female	**1.15**	**[1.01, 1.31]**	**0.030**
Household income quartile			
1st (lowest income)	Reference	—	—
2nd	0.91	[0.77, 1.07]	0.240
3rd	0.94	[0.79, 1.11]	0.463
4th (highest income)	0.87	[0.73, 1.04]	0.125
Payor			
Private insurance	Reference	—	—
Medicare	1.04	[0.86, 1.26]	0.653
Medicaid	0.98	[0.81, 1.18]	0.804
Self-pay	0.71	[0.50, 1.01]	0.060
Other	0.94	[0.68, 1.29]	0.695
Index Disposition			
Routine to home	Reference	—	—
Against medical advice	**2.03**	**[1.25, 3.31]**	**0.004**
Home health care	**1.36**	**[1.14, 1.62]**	**<0.001**
Transfer other (SNF, ICF, etc)	**1.67**	**[1.39, 2.00]**	**<0.001**
Transfer to short-term hospital	**2.61**	**[1.88, 3.63]**	**<0.001**
Infectious Etiology			
Streptococcus pneumoniae	Reference	—	—
Haemophilus influenzae	0.85	[0.56, 1.31]	0.472
Listeria monocytogenes	0.99	[0.63, 1.56]	0.967
Neisseria meningitidis	0.68	[0.41, 1.14]	0.142
Staphylococcal species	**1.88**	**[1.45, 2.44]**	**<0.001**
Streptococcal species	1.10	[0.83, 1.45]	0.524
Unknown	**1.30**	**[1.06, 1.59]**	**0.013**
Comorbidities			
Congestive heart failure	1.10	[0.90, 1.34]	0.339
Cardiac arrhythmias	1.15	[0.97, 1.35]	0.101
Valvular disease	1.08	[0.83, 1.41]	0.553
Pulmonary hypertension	1.13	[0.84, 1.52]	0.406
Peripheral vascular disorders	1.22	[0.91, 1.64]	0.185
Hypertension	1.11	[0.87, 1.41]	0.397
Other neurological disorders	0.95	[0.83, 1.08]	0.424
Diabetes with complications	1.05	[0.87, 1.28]	0.593
Renal failure	**1.37**	**[1.12, 1.69]**	**0.002**
Metastatic cancer	**1.46**	**[1.04, 2.05]**	**0.029**
Solid tumor w/o metastasis	1.36	[0.98, 1.87]	0.064

Rheumatic disease	1.24	[0.90, 1.72]	0.194
Coagulopathy	1.18	[0.99, 1.42]	0.071
Obesity	**0.82**	**[0.68, 0.99]**	**0.037**
Weight loss	1.11	[0.92, 1.34]	0.274
Fluid & electrolyte disorders	0.99	[0.86, 1.14]	0.864
Deficiency anemias	**1.54**	**[1.19, 2.01]**	**0.001**
Procedures			
Ventricular shunt	1.15	[0.82, 1.60]	0.413
Invasive CNS procedure	1.10	[0.88, 1.37]	0.397
Tracheostomy	1.02	[0.72, 1.45]	0.916
Gastrostomy	1.21	[0.90, 1.63]	0.216
Hemodialysis	**1.56**	**[1.02, 2.37]**	**0.03**

Abbreviations: aOR=Adjusted odds ratio, CI=Confidence interval, SNF=skilled nursing facility, ICF= intermediate care facility, w/o=without, CNS=Central nervous system

Table 3

Caption: Top 10 reasons for readmission

	Reason for readmission	Number of readmissions (%)
1	Septicemia	362 (11.5%)
2	Meningitis	252 (8.0%)
3	Other specified nervous system disorders	226 (7.2%)
4	Complication of other surgical or medical care, injury, initial encounter	168 (5.3%)
5	Postprocedural or postoperative nervous system complication	89 (2.8%)
6	CNS abscess	78 (2.5%)
7	Epilepsy; convulsions	74 (2.3%)
8	Acute and unspecified renal failure	71 (2.2%)
9	Pneumonia (except that caused by tuberculosis)	59 (1.9%)
10	Heart failure	58 (1.8%)
—	All other causes (200 additional causes)	1721 (54.5%)

Table 4

Caption: Geometric mean costs of index hospitalization plus any readmissions within 90 days from index discharge

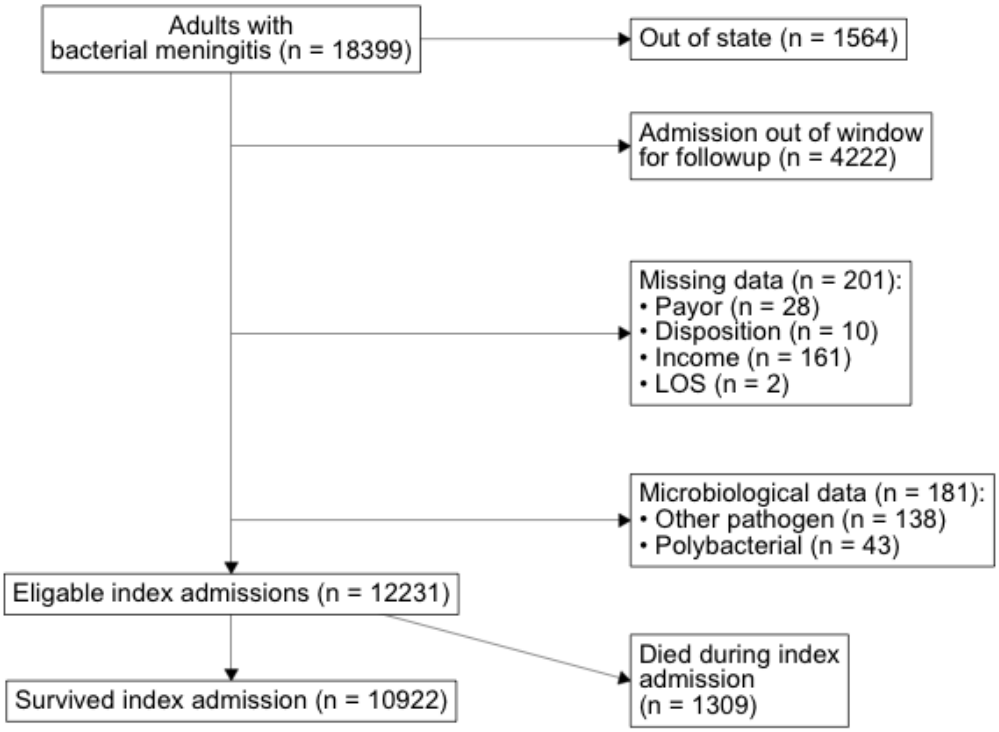
Variable	Average Cost	95% CI
Overall	$38,373	$36,964 – $39,837
Etiology		
Haemophilus influenzae	$26,842	$23,422 – $30,762
Listeria monocytogenes	$43,817	$38,146 – $50,331
Neisseria meningitidis	$31,874	$27,331 – $37,172
Streptococcus pneumoniae	$37,224	$34,947 – $39,649
Staphylococcal species	$63,336	$58,326 – $68,777
Streptococcal species	$37,697	$35,028 – $40,569
Unknown	$35,906	$34,244 – $37,648
Outcome		
Died during index admission	$45,831	$42,342 – $49,608
Not readmitted	$29,749	$28,559 – $30,988
Readmitted	$66,867	$63,379 – $70,548

Abbreviations: CI=Confidence interval

Figure captions

Figure 1

Figure 1 caption: Study flow diagram



Supplementary Information

Supplemental Table 1

ICD-10 codes used for classification of bacterial meningitis

Meningitis etiology	ICD-10 code / description
Listeria monocytogenes	[A32.1] Listerial meningitis and meningoencephalitis [A32.11] Listerial meningitis [A32.12] Listerial meningoencephalitis
Neisseria meningitidis	[A39.0] Meningococcal meningitis
Haemophilus influenzae	[G00.0] Hemophilus meningitis
Streptococcus pneumoniae	[G00.1] Pneumococcal meningitis
Streptococcal species	[G00.2] Streptococcal meningitis
Staphylococcal species	[G00.3] Staphylococcal meningitis
Unknown	[G00] Bacterial meningitis, not elsewhere classified [G00.8] Other bacterial meningitis [G00.9] Bacterial meningitis, unspecified [G01] Meningitis in bacterial diseases classified elsewhere

Supplemental Table 2

ICD-10 codes used for identification of non-bacterial meningitis

ICD code	Description
A17.0	Tuberculous meningitis
A27.81	Aseptic meningitis in leptospirosis
A69.21	Meningitis due to Lyme disease
B37.5	Candidal meningitis
B38.4	Coccidioidomycosis meningitis
B42.81	Cerebral sporotrichosis
B45.1	Cerebral cryptococcosis
B57.41	Meningitis in Chagas' disease
B57.42	Meningoencephalitis in Chagas' disease
B58.2	Toxoplasma meningoencephalitis
G02	Meningitis in other infectious and parasitic diseases classified elsewhere

Supplemental Table 3

Clinical Classifications Software Refined (CCSR) categories to be used to identify procedures

CCSR categories	Category description
ESA003	Mechanical ventilation
RES010	Tracheostomy
GIS017	Gastrostomy
MAM011	Electroencephalogram (EEG)
ESA001	Hemodialysis
CNS010	Ventricular shunt
CNS004, CNS005, CNS006, CNS007	Invasive procedure of the central nervous system (CNS)