Hospitalization Frequency and Charges for Neurocysticercosis, United States, 2003–2012

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Neurocysticercosis, brain infection with *Taenia solium* larval cysts, causes substantial neurologic illness around the world. To assess the effect of neurocysticercosis in the United States, we reviewed hospitalization discharge data in the Nationwide Inpatient Sample for 2003–2012 and found an estimated 18,584 hospitalizations for neurocysticercosis and associated hospital charges totaling >US $908 million. The risk for hospitalization was highest among Hispanics (2.5/100,000 population), a rate 35 times higher than that for the non-Hispanic white population. Nearly three-quarters of all hospitalized patients with neurocysticercosis were Hispanic. Male sex and age 20–44 years also incurred increased risk. In addition, hospitalizations and associated charges related to cysticercosis far exceeded those for malaria and were greater than for those for all other neglected tropical diseases combined. Neurocysticercosis is an increasing public health concern in the United States, especially among Hispanics, and costs the US health care system a substantial amount of money.

Neurocysticercosis is a leading cause of acquired epilepsy in the developing world (*1,2*). The disease occurs when larvae of the pork tapeworm, *Taenia solium*, encyst in the human brain; this process causes a broad range of neurologic signs and symptoms, including seizures, headache, obstructive hydrocephalus, encephalitis, stroke, and cognitive and other mental health disorders (*3,4*). Neurocysticercosis is endemic in poor rural communities in Latin America, sub-Saharan Africa, and Asia, where pigs can access and ingest human feces (Figure 1). However, the disease is also of increasing public health concern in the United States, especially in the immigrant population and among persons who have traveled to regions where cysticercosis is endemic (*5*).

The World Health Organization designates cysticercosis as a neglected tropical disease (NTD) and has called for international efforts to strengthen surveillance (*6–8*). The disease remains neglected partly because the scale of the problem has not been well defined (*2*). In most disease-endemic regions, population-level data are sparse because surveillance for neurocysticercosis is nonexistent and diagnostic neuroimaging is typically unavailable. In the United States, there is an opportunity to collect population-based data on neurocysticercosis because of the large immigrant population at risk for infection, the widespread availability of neuroimaging, and the well-established disease surveillance infrastructure. However, only Alaska, Arizona, California, New Mexico, Oregon, and Texas require reporting of neurocysticercosis.

Death rates due to neurocysticercosis in the United States have been reported previously (*9*), but national-level assessments of neurocysticercosis that use population–based data are lacking. The objective of our study was to evaluate the frequency and total associated charges for hospitalizations due to neurocysticercosis in the United States and to compare these against other tropical diseases of potential importance in the United States.

Methods

Data Source

We analyzed hospital discharge data contained in the Nationwide Inpatient Sample (NIS) for 2003–2012 (*10,11*). The NIS, a stratified weighted sample of short-term and nonfederal hospitals, is designed to approximate a 20% sample of all community hospitals in the United States. As of 2012, 47 states participated in reporting discharge data to the NIS (only Alabama, Delaware, Idaho, and the District of Columbia had not participated), creating a sample representing 95% of the national population. The NIS is the largest collection of longitudinal inpatient care data in the United States and holds information on ≈8 million hospitalizations from >1,000 hospitals each year (*10*). NIS data are de-identified and include information on demographics, diagnostic and procedural codes, length of stay, discharge status, total charges, and expected payees associated with each hospitalization.

Case Definitions

We based our case definitions for hospitalization on diagnostic and procedural codes from the International Classification
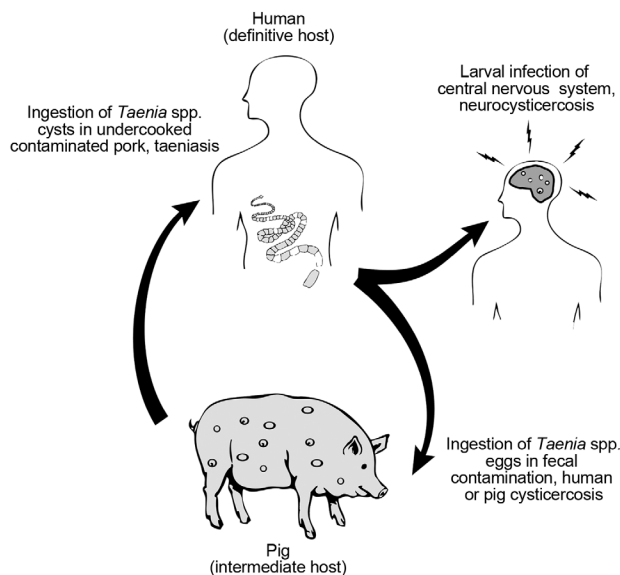
Figure 1. The lifecycle of the *Taenia solium* cestode parasite.

Table 1. Supporting diagnostic or procedural codes from ICD-9-CM used for conservative case definition for reporting hospitalizations associated with neurocysticercosis*

CCS code	Diagnosis or procedure
Diagnostic code	
76	Meningitis
77	Encephalitis
78	Other CNS infection and poliomyelitis
83	Epilepsy; convulsions
84	Headache; including migraine
85	Coma; stupor; and brain damage
90	Inflammation; infection of eye
95	Other nervous system disorders
109	Acute cerebrovascular disease
111	Other and ill-defined cerebrovascular disease
112	Transient cerebral ischemia
245	Syncope
650	Adjustment disorders
651	Anxiety disorders
652	Attention-deficit, conduct, and disruptive behavior disorders
653	Delirium, dementia, and amnestic and other cognitive disorders
656	Impulse control disorders, NEC
657	Mood disorders
658	Personality disorders
659	Schizophrenia and other psychotic disorders
662	Suicide and intentional self-inflicted injury
670	Miscellaneous mental disorders
Procedural codes	
1	Incision and excision of CNS
2	Insertion; replacement; or removal of extracranial ventricular shunt
177	Computerized axial tomography (CT) scan head
198	Magnetic resonance imaging
199	Electroencephalogram (EEG)

*A complete list of ICD-9-CM codes used in this study is provided in the online Technical Appendix (http://wwwnc.cdc.gov/EID/article/21/6/14-1324-Techapp1.pdf). ICD-9-CM, International Classification of Diseases, 9th Revision, Clinical Modification; CCS, Clinical Classification Software groupings of ICD-9-CM codes (*12*); CNS, central nervous system; NEC, not elsewhere classified.

of Diseases, 9th Revision, Clinical Modification (ICD-9-CM). The ICD-9-CM code listed in the first diagnostic field is intended to capture the primary reason for hospitalization. However, there is no specific ICD-9-CM code for neurocysticercosis, so coding patterns may vary. For example, a hospitalization for neurocysticercosis might be coded with a first diagnostic field of 123.1 (cysticercosis) or with a neurologic code, such as 345.9 (epilepsy unspecified), in combination with 123.1 in a different diagnostic field.

We used 2 case definitions in this analysis. The first was a conservative case definition for reporting hospitalizations associated with neurocysticercosis. This definition required the ICD-9-CM code for cysticercosis (123.1) in any of the 15 available diagnostic fields and a supporting diagnostic or procedural code associated with a clinical manifestation of neurologic disease in any of the first 5 diagnostic or procedural fields (Table 1). We used individual ICD-9-CM codes and coding groups defined by Clinical Classification Software to define these additional diagnostic or procedural codes (*13*). This conservative case definition was designed to reduce the likelihood of including hospitalizations for persons carrying an existing diagnosis of neurocysticercosis who were hospitalized for an unrelated condition.

The second case definition was designed to facilitate comparison of hospitalizations for cysticercosis with those for the 16 other NTDs and malaria. The case definition for cysticercosis included all hospitalizations with an ICD-9-CM diagnostic code for cysticercosis (123.1) in any of the first 15 diagnosis fields, but it did not require an additional supportive diagnostic or procedural code. Similarly, the case definitions for the other tropical diseases in the comparative analysis relied on ICD-9-CM codes specific to the

disease without a requirement for an additional supportive diagnostic or procedural code. This approach ensured consistency of case definitions across the various diseases at the expense of greater specificity. We assumed that the likelihood of capturing unrelated hospitalizations was similar for the diseases we compared. We excluded Buruli ulcer from our comparison because there is no ICD-9-CM code specific for this disease. However, to our knowledge, Buruli ulcer has not been reported in the United States (*14*). We did not report hospitalizations for rabies, African trypanomiasis, or dracunculiasis because the numbers of hospitalizations were too low (<10/year) to provide accurate estimates. A list of ICD-9-CM codes used in all case definitions is provided in the online Technical Appendix (http://wwwnc.cdc.gov/EID/article/21/6/14-1324-Techapp1.pdf).

Statistical Methods

To account for the sampling design of the NIS, we analyzed all data by using the survey family of commands in

Stata 13 (StataCorp LP, College Station, TX, USA). We applied hospital discharge weights provided in the NIS to estimate total national hospitalizations on the basis of the stratified sample. All sampled hospitals, regardless of whether they had a patient who was hospitalized with neurocysticercosis, were included for calculation of SEs and CIs. We examined neurocysticercosis hospitalizations by patient age, sex, race, place of service, discharge status, and length of stay; US region; associated diagnostic and procedural codes; and hospitalization charges. State-level assessment was not possible because of the sampling and stratification strategy used in the NIS. Mean annual hospitalization rates were calculated as the weighted number of hospitalizations per 100,000 population on the basis of the US Census Bureau data for each year during the study period (15). Age- and sex-adjusted rates were calculated by using the direct standardization method and the 2005 US Census population as the reference population.

We used Gaussian family generalized linear models with logarithmic function link within the Stata survey framework to estimate the crude and adjusted mean length of stay and mean hospitalization charges. We first constructed univariate generalized linear models to evaluate demographic variables of interest, retaining those that were significant at the p<0.2 level (Wald test) in the final multivariate models. The independent categorical variables we evaluated were sex, age, race, hospital region, and year of hospitalization. Once we built the final models, we estimated the mean length of stay and mean hospitalization charges for diagnoses and procedures commonly seen with neurocysticercosis (i.e., seizures, obstructive hydrocephalus, headache, stroke, mental health disorder, encephalitis/meningitis, cerebral edema, syncope, neuroimaging, ventricular shunt management, and central nervous system surgery) by individually introducing dummy variables encoding these clinical variables into the models. Inflation-adjusted charges were used in all models.

Hospital Charges

We analyzed hospital charges that were billed to private insurance, Medicaid, Medicare, and other sources from the payer's perspective. Charges represent the amount that hospitals billed for services, not the actual cost of providing these services. Generally, total charges did not include professional fees, noncovered charges, or charges incurred in the emergency department unless the patient was admitted directly from the emergency department into the hospital. We adjusted all charges for inflation by using the Consumer Price Index, setting the base year to 2012.

Results

During 2003–2012, an estimated 23,266 hospitalizations (95% CI 21,741–24,792) in the United States were assigned an ICD-9-CM code of 123.1 in any of the first 15 diagnostic fields. Of these hospitalizations, 18,584 (95% CI 17,322–19,846), approximately 80% of the total, met our case definition of hospitalization due to neurocysticercosis. The number of hospitalizations due to neurocysticercosis per year ranged from a high of 2,247 in 2006 to a low of 1,495 in 2012. The largest proportion of hospitalizations due to neurocysticercosis occurred in the western region (n = 8,026, 42.9% [95% CI 39.2%–46.7%)], followed by the southern region (n = 5,860, 31.8% [95% CI 28.6%–35.1%]), the northeastern region (n = 2,902, 15.5% 95% CI [13.5%–17.6%]) and the midwestern region (n = 1,796, 9.8% [95% CI 8.2%–11.7%]).

We found distinct differences in the mean annual incidence rates of hospitalization stratified by age, sex, and race (Table 2). The mean annual incidence of hospitalization was highest in 20- to 44-year-old age group (1.04 hospitalizations/100,000 population). Hospitalization rates were 33% higher among male patients than female patients. The age- and sex-adjusted mean annual incidence of hospitalizations was highest among Hispanics (2.50 hospitalizations/100,000

Table 2. Number and rate of hospitalizations for neurocysticercosis in the United States, by demographic group, 2003–2012*

Characteristic†	No. hospitalizations (SE)	% All hospitalizations (95% CI)	Rate (95% CI)‡
Age, y			
<20	1,493 (103)	8.0 (7.1–9.1)	0.18 (0.16–0.21)
20–44	10,827 (394)	58.3 (56.5–60.1)	1.04 (0.97–1.12)
45–64	4,357 (232)	23.5 (22.0–25.0)	0.56 (0.51–0.62)
≥65	1,889 (136)	10.2 (9.0–11.5)	0.49 (0.42–0.56)
Sex			
M	10,377 (373)	56.3 (54.5–58.2)	0.70 (0.65–0.75)
F	8,043 (349)	43.7 (41.8–45.5)	0.52 (0.48–0.57)
Race/ethnicity			
Hispanic	12,030 (551)	74.0 (71.5–76.3)	2.50 (2.27–2.73)
White	1,530 (104)	9.4 (8.2–10.7)	0.07 (0.06–0.08)
Black	900 (95)	5.5 (4.5–6.8)	0.25 (0.21–0.30)
Asian/Pacific Islander	377 (61)	2.3 (1.7–3.2)	0.31 (0.23–0.39)
Overall	18,584 (644)		0.61 (0.57–0.66)

*National estimates were based on the Nationwide Inpatient Sample, by using diagnosis code 123.1 from the International Classification of Diseases, 9th Revision, Clinical Modification.
†Missing data not presented
‡Rate for age and sex are unadjusted. Rate for race/ethnicity is adjusted for age and sex by direct standardization method by using 2005 US Census data. Rates expressed as mean annual incidence per 100,000 population.

Table 3. Source of admission, disposition, and expected payer for hospitalizations due to neurocysticercosis, United States, 2003–2012*

Characteristic	No. hospitalizations (SE)	% All hospitalizations (95% CI)
Source of admission		
Emergency department	9,436 (484)	74.7 (72.3–76.9)
Routine	2,210 (145)	17.5 (15.6–19.6)
Transfer	947 (80)	7.5 (6.4–8.7)
Disposition		
Routine	15,693 (562)	84.5 (83.1–85.8)
Transfer	1,617 (107)	8.7 (7.7–9.8)
Home health	834 (81)	4.5 (3.8–5.4)
Against medical advice	205 (33)	1.1 (0.8–1.5)
Died	218 (32)	1.2 (0.9–1.6)
Expected primary payer		
Medicare	2,025 (139)	10.9 (9.7–12.3)
Medicaid	5,543 (316)	29.9 (27.8–32.1)
Private insurance	4,335 (206)	23.4 (21.4–25.4)
Self-pay	4,753 (224)	25.6 (23.8–27.5)
Other payer	1,883 (160)	10.2 (8.9–11.6)

*National estimates were determined on the basis of the Nationwide Inpatient Sample, by using diagnosis code 123.1 from the International Classification of Diseases, 9th Revision, Clinical Modification.

population); the rate was 35 times higher than that for non-Hispanic whites, 10 times higher than that for blacks, and 8 times higher than that for Asian/Pacific Islanders. Unadjusted rates by race were similar: Hispanic, 2.57/100,000; white, 0.06/100,000; black, 0.23/100,000; and Asian/Pacific Islander, 0.26/ 100,000.

Length of Stay, Total Charges, and Payees

The mean length of hospitalization was 6.0 (95% CI 5.7–6.4) days and did not show a significant trend over the study period (p = 1.0). Total inflation-adjusted hospitalization charges over the 10-year study period were US $908,238,000 (95% CI US $814,483,000–$1,001,992,000), increasing 27% from US $72,560,000 in 2003 to US $91,959,000 in 2012. The mean charge per hospitalization was US $50,976 (95% CI US $47,492–$54,716), increasing 50% over the 10-year study period from US $41,874 in 2003 to US $62,986 in 2012. After we adjusted for demographic variables, mean length of stay and mean hospitalization charges were substantially higher for male patients, middle-aged adult patients, and patients from the western region (online Technical Appendix). Publically funded insurance (Medicaid or Medicare) was the primary payer in 40% of the hospitalizations (Table 3).

Associated Diagnoses and Procedures

The most common diagnosis group associated with hospitalization for neurocysticercosis was epilepsy/convulsions, which occurred in 57.3% of hospitalizations, followed by obstructive hydrocephalus (17.7%) and headache (12.4%) (Table 4). After we controlled for year and patient demographics, the diagnoses associated with the longest mean length of stay and the highest mean charges were encephalitis/meningitis (12.2 days and US $78,984) and hydrocephalus (11.4 days and US $79,084). Diagnostic codes for syncope and headache were associated with the shortest

Table 4. Diagnostic and procedure codes for hospitalizations due to neurocysticercosis, United States, 2003–2012*

Associated diagnoses and procedures	No. hospitalizations (SE)	% All hospitalizations (95% CI)	Mean length of stay, d†	Mean charges, US$†
Diagnoses				
Epilepsy; convulsions	10,652 (360)	57.3 (55.3–59.3)	5.4 (4.2–6.9)	33,058 (21,846–50,023)
Obstructive hydrocephalus	3,292 (208)	17.7 (16.2–19.3)	11.4 (8.1–16.2)	79,084 (46,139–135,552)
Headache, including migraine	2,308 (126)	12.4 (11.3–13.6)	3.8 (2..9–4.9)	19,893 (12,422–31,857)
Cerebrovascular disease	1,650 (121)	8.9 (7.9–10.0)	7.5 (5.3–10.6)	45,183 (26,027–78,436)
Mental health disorder	1,843 (132)	9.9 (8.8–11.2)	6.4 (4.7–8.8)	24,436 (13,578–43,979)
Encephalitis/meningitis	1,033 (81)	5.6 (4.8–6.4)	12.2 (8.1–18.6)	78,983 (46,851–133,151)
Cerebral edema	931 (79)	5.0 (4.3–5.9)	7.5 (5.6–10.0)	40,639 (23,449–70,429)
Syncope	573 (56)	3.1 (2.6–3.7)	3.4 (2.6–4.6)	20,017 (11,934–33,577)
Procedures				
Neuroimaging, CT of head or MRI	3,087 (330)	16.6 (13.9–19.8)	6.1 (4.8–7.7)	34,905 (22,177–54,937)
Ventricular shunt, insert, remove, or repair	1,661 (137)	8.9 (7.9–10.2)	16.3 (10.6–25.1)	86,272 (48,313–154,054)
CNS incision or excision	1,499 (111)	8.1 (7.1–9.2)	10.3 (7.9–13.5)	89,893 (56,625–142,709)

*National estimates were based on the Nationwide Inpatient Sample, by using diagnosis code 123.1 from the International Classification of Diseases, 9th Revision, Clinical Modification. CNS, central nervous system; CT, computed tomography; MRI, magnetic resonance imaging.
†Mean length of stay and mean inflation-adjusted hospitalization charges for diagnostic and procedure codes after adjusting for year, patient age, sex, race, and hospital region. Diagnostic and procedure codes were evaluated individually as independent variables in the final generalized linear models built for length of stay and charges.

stays and lowest charges (3.4 days and US $20,017 and 3.8 days and US $19,893, respectively). Procedure codes for shunt management (insertion, removal, or repair) were associated with a mean length of stay of 16.3 days and mean hospitalization charges of US $86,272; codes for brain surgery (central nervous system incision or excision) were associated with a mean length of stay of 10.3 days and mean hospitalization charges of US $89,893. Only 17% of hospitalizations included a procedural code for either computed tomography scans or magnetic resonance imaging of the head.

Comparison of NIS Data for Cysticercosis with that for NTDs and Malaria

The frequency of and total charges for hospitalizations due to cysticercosis exceeded those for all other NTDs combined (Figure 2). During 2003–2012, an estimated 23,266 (95% CI 21,741–24,792) hospitalizations were associated with a diagnosis code for cysticercosis, resulting in US $1,149,044,000 in total hospital charges (95% CI US $1,038,730,000–$1,259,357,000). In contrast, there were 20,029 hospitalizations and US $1,043,109,000 in total charges for all of the other NTDs combined (Table 5).

Discussion

The study findings demonstrate that neurocysticercosis poses considerable health and economic problems in the United States, especially among the Hispanic population. Over the 10-year study period, >18,500 hospitalizations for neurocysticercosis occurred, totaling hospital charges of >US $908 million, of which 40% was billed to publicly funded insurance programs. Hospitalization stays were prolonged and expensive, reflecting the complicated nature of acute disease management. Hospitalizations and associated charges for cysticercosis exceeded the totals for malaria and for all of the other NTDs combined.

The hospitalization rates we report in this nationwide study are comparable to those reported in previous state- or county-level studies, providing support for the case definition we used (12, 15–20). Because there is no ICD-9-CM diagnostic code specific for neurocysticercosis, the case definitions varied slightly among these studies. The estimated overall hospitalization rate of 0.65/100,000 population that we report falls between the rates previously observed in California (0.8–1.1 hospitalization/100,000 population) and Oregon (0.2–0.5 hospitalizations/100,000 population) (12, 16–18). Risk for hospitalization was highest among Hispanic, male, and young to middle-aged adult patients in all studies.

Nearly three quarters of all patients hospitalized for neurocysticercosis in the United States were Hispanic. The Hispanic population is the largest minority group in the United States and among the fastest growing US
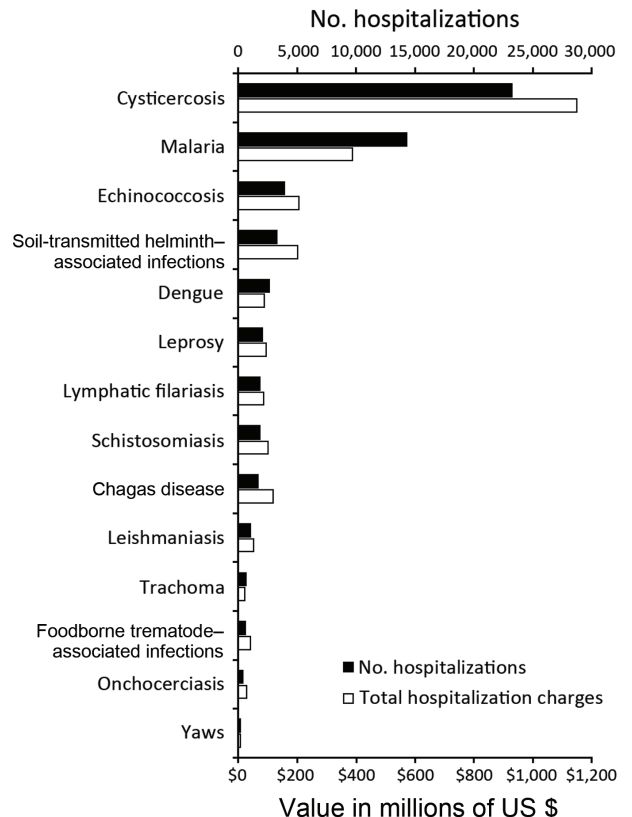

Figure 2. Frequency and total charges of hospitalizations in the United States during 2003–2012 for 13 of the World Health Organization (WHO)–designated neglected tropical diseases (NTDs) and malaria. Estimates were determined by using the Nationwide Inpatient Sample, which codes diagnoses according to the International Classification of Diseases, 9th Revision, Clinical Modification. Frequency of and total charges for hospitalizations for the other NTDs (i.e., Buruli ulcer, rabies, African trypanomiasis, and dracunculiasis) are not shown because there were too few hospitalizations for these diseases for accurate estimation. Frequency and total charges of hospitalizations for malaria, although it is not one of the WHO–designated NTDs, are shown for comparison.

population groups. Because the hospitalization rate for the Hispanic population is 36 times greater than that of the non-Hispanic white population, the effect of neurocysticercosis on the US economy is likely to increase substantially in the coming years. The US Census Bureau projects that the Hispanic population will grow from 53 million in 2012 to >78 million by 2030 (21). Without changes in the rate of hospitalization or the increase in mean hospitalization charges, there could be >1,900 hospitalizations and US $250 million total charges related to neurocysticercosis among Hispanics alone in the year 2030. Changing immigration patterns may also bring an influx of cases in persons from other regions of the world where neurocysticercosis is endemic, particularly Asia and sub-Saharan Africa.

Table 5. Hospitalizations and total charges for neglected tropical diseases and malaria, United States, 2003–2012*

Disease	Hospitalizations		Total charges	
	No. (SE)	95% CI	US$, millions (SE)	95% CI
Cysticercosis	23,266 (778)	21,741–24,792	1,149 (56)	1,039–1,259
Malaria	14,319 (434)	13,469–15,169	387 (18)	351–423
Echinococcosis	3,919 (170)	3,586–4,252	206 (16)	174–237
Soil-transmitted helminth–associated infections	3,256 (151)	2,959–3,552	201 (19)	162–239
Dengue	2,644 (135)	2,379–2,909	89 (9)	70–107
Leprosy	2,055 (135)	1,791–2,319	94 (9)	76–111
Lymphatic filariasis	1,836 (106)	1,629–2,044	86 (9)	68–103
Schistosomiasis	1,811 (120)	1,576–2,046	101 (12)	78–125
Chagas disease	1,686 (151)	1,389–1,982	118 (17)	84–152
Leishmaniasis	1,022 (92)	841–1,203	52 (7)	38–66
Trachoma	649 (69)	514–784	20 (4)	13–28
Foodborne trematode–associated infections	610 (60)	492–729	41 (7)	28–54
Onchocerciasis	380 (47)	287–473	29 (12)	5–53
Yaws	161 (28)	106–216	7 (2)	3–11

*National estimates were determined on the Nationwide Inpatient Sample by using diagnostic codes from the International Classification of Diseases, 9th Revision, Clinical Modification. A complete list of ICD-9-CM codes used in this study is provided in the online Technical Appendix (http://wwwnc.cdc.gov/EID/article/21/6/14-1324-Techapp1.pdf).

Several hospital-based studies have shown that seizures are the most frequent reason for hospitalization for neurocysticercosis (3,4,22). In this study, epilepsy was the most frequent diagnosis associated with hospitalization for neurocysticercosis; it was coded in more than half of all hospitalizations for the disease. Seizures in neurocysticercosis are typically amenable to therapy with antiepileptic and anti-inflammatory drugs, resulting in relatively uncomplicated and short hospital stays. In contrast, more severe disease may require intensive interventions and longer hospitalizations, resulting in higher charges (23–25). While diagnoses of obstructive hydrocephalus or encephalitis/meningitis occurred in ≈20% of persons hospitalized for neurocysticercosis, these more severe presentations accounted for 40% of the total charges incurred.

We report hospitalization diagnostic codes that may not represent the distribution of disease manifestations experienced by individual patients. For example, although a diagnostic code for headache was listed for 11% of hospitalized patients, only patients with headaches associated with underlying pathology requiring acute intervention, such as obstructive hydrocephalus, are likely to be admitted and therefore represented in this study. Even then, the diagnosis of headache may be underrepresented. There were twice as many hospitalizations with diagnostic codes for hydrocephalus and encephalitis than for headache, although both of these manifestations would be expected to be associated with headache (22). Similar caution is suggested in interpreting the frequency of other diagnoses presented here. It may seem contradictory that only 17% of hospitalizations had a procedural code for neuroimaging. However, because most imaging for neurocysticercosis would be expected to occur in the emergency department before admission, the infrequent coding for neuroimaging may reflect exclusion of these procedural codes from the hospital discharge summary.

This study documents the substantial costs of hospitalizations due to neurocysticercosis in the United States, but the true effect of neurocysticercosis on the US health care system is likely much greater. Only those emergency department visits that result directly in inpatient admission are captured in the hospital discharge databases in the NIS. In Oregon (15), over 40% (31/72) of all patients with neurocysticercosis were seen only in the emergency department and were not admitted to the hospital. While nonadmissions likely represent cases of less clinical severity, substantial charges are still incurred in the emergency department and in outpatient follow-up. Neurocysticercosis is also likely to be substantially underdiagnosed and misdiagnosed because of the lack of a definitive diagnostic test and limited provider awareness of the disease.

Neurocysticercosis also often results in chronic disease that requires outpatient follow-up with infectious disease or neurology specialists, none of which is captured in this study. Management of neurocysticercosis may involve long-term antiepileptic therapy, prolonged regimens of antiparasitic drugs and high-dose corticosteroids, monitoring and repair of ventriculoperitoneal shunts, and treatment of frequent complications resulting from these interventions (26,27). A chart review at the outpatient neurology clinic in a Houston hospital showed that 2% of all patients were seen for management of neurocysticercosis (28). A few states are now collecting comprehensive claims data covering health care provided in inpatient, outpatient, and long-term care settings. Data from these programs could provide more complete information about health care and associated costs related to management of neurocysticercosis in all settings. The high neurocysticercosis hospitalization rate we noted in young adults and men suggests substantial indirect costs to the US domestic workforce. Loss of worker productivity should also be considered in the overall costs of neurocysticercosis.

The use of administrative databases, such as the NIS, to obtain data for this study does have drawbacks, including several limitations we already described. An additional drawback to using the NIS was the inability to identify multiple hospitalizations for a single person, which precludes the ability to estimate the prevalence or incidence of disease. Although the number of states participating in NIS has grown over the years, several states still do not participate in reporting hospital discharge data. In addition, the regional sampling structure of the NIS does not allow for accurate state-level estimates, limiting the ability to identify specific states whose populations are at increased risk for neurocysticercosis. Furthermore, the lack of in-depth demographic and clinical information in the NIS limits the type of questions that can be addressed. For example, knowing the country of birth or travel history of patients with neurocysticercosis could help understand their source of exposure.

Although the primary purpose of this study was to evaluate hospitalizations for neurocysticercosis, we also compared hospitalizations for cysticercosis with those for other NTDs and malaria. Our findings showed that the number of hospitalizations for cysticercosis was nearly 2 times the number for malaria, and the associated hospital charges were nearly 3 times higher. In addition, hospitalizations and charges for cysticercosis were higher than those for all other NTDs we evaluated combined. This comparative analysis was not meant to be exhaustive; we recognize that many factors other than hospitalization contribute to the public health effect of any particular disease. However, the markedly higher number of hospitalizations and associated charges related to cysticercosis, compared with those for other NTDs and malaria in the United States, merits attention and further exploration.

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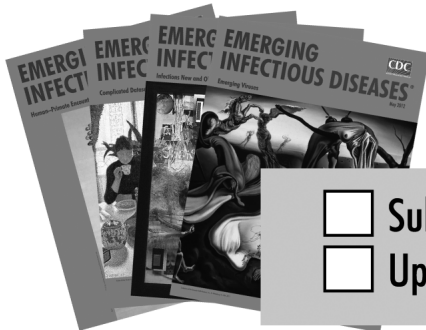
Hospitalization Frequency and Charges for Neurocysticercosis, United States, 2003–2012

Technical Appendix

The Agency for Healthcare Research and Quality (AHRQ) developed the Clinical Classification Software (CCS) tool that groups International Classification of Diseases, 9th revision, Clinical Modification, (ICD-9-CM) diagnostic and procedural codes into clinically meaningful categories. Single-level CCS grouping codes were used in this study to identify hospitalizations for neurocysticercosis. The study case definition required an ICD-9-CM diagnostic code for cysticercosis (1231) *and* at least one other single-level CCS diagnostic or procedural code for a neurologic manifestation associated with neurocysticercosis.

CCS Diagnostic Codes

76 Meningitis (except that caused by tuberculosis or sexually transmitted disease)

00321 0360 0470 0471 0478 0479 0490 0491 0530 05472 0721 10081 11283 1142 11501 11511 11591 3200 3201 3202 3203 3207 3208 32081 32082 32089 3209 3210 3211 3212 3213 3214 3218 3220 3221 3222 3229

77 Encephalitis (except that caused by tuberculosis or sexually transmitted disease)

0361 0462 0498 0499 0520 0543 0550 05601 05821 05829 0620 0621 0622 0623 0624 0625 0628 0629 0630 0631 0632 0638 0639 064 0662 0722 1300 1390 3230 32301 32302 3231 3232 3234 32341 32342 3235 32351 32352 3236 32361 32362 32363 3237 32371 32372 3238 32381 32382 3239 34120 34121 34122

78 Other CNS infection and poliomyelitis

04500 04501 04502 04503 04510 04511 04512 04513 04520 04521 04522 04523 04590 04591 04592 04593 0460 0461 04611 04619 0463 04671 04672 04679 0468 0469 048 138 3240 3241 3249 326 V1202

83 Epilepsy; convulsions

3450 34500 34501 3451 34510 34511 3452 3453 3454 34540 34541 3455 34550 34551 3456 34560 34561 3457 34570 34571 3458 34580 34581 3459 34590 34591 7803 78031 78032 78033 78039

84 Headache; including migraine

33900 33901 33902 33903 33904 33905 33909 33910 33911 33912 33920 33921 33922 3393 33941 33942 33943 33944 33981 33982 33983 33984 33985 33989 3460 34600 34601 34602 34603 3461 34610 34611 34612 34613 3462 34620 34621 34622 34623 34630 34631 34632 34633 34640 34641 34642 34643 34650 34651 34652 34653 34670 34671 34672 34673 3468 34680 34681 34682 34683 3469 34690 34691 34692 34693 7840

85 Coma; stupor; and brain damage

3481 7800 78001 78003 78009

90 Inflammation; infection of eye (except that caused by tuberculosis or sexually transmitted disease)

0213 03281 05320 05321 05322 05329 05440 05441 05442 05443 05444 05449 05571 0760 0761 0769 0770 0771 0772 0773 0774 0778 0779 07798 07799 11502 11512 11592 1301 1302 1391 36000 36001 36002 36003 36004 36011 36012 36013 36014 36019 36300 36301 36303 36304 36305 36306 36307 36308 36310 36311 36312 36313 36314 36315 36320 36321 36322 36400 36401 36402 36403 36404 36405 36410 36411 36421 36422 36423 36424 3643 37020 37021 37022 37023 37024 37031 37032 37033 37034 37035 37040 37044 37049 37050 37052 37054 37055 37059 3708 3709 37200 37201 37202 37203 37204 37205 37206 37210 37211 37212 37213 37214 37215 37220 37221 37222 37230 37231 37233 37239 37300 37301 37302 37311 37312 37313 37331 37332 37333 37334 3734 3735 3736 3738 3739 37500 37501 37502 37503 37530 37531 37532 37533 37541 37542 37543 37600 37601 37602 37603 37604 37610 37611 37612 37613 37730 37731 37732 37733 37734 37739 37900 37901 37902 37903 37904 37905 37906 37907 37909 37960 37961 37962 37963

95 Other nervous system disorders

325 32702 32715 32730 32731 32732 32733 32734 32735 32736 32737 32739 32753 33183 3321 33720 33721 33722 33729 3380 33811 33812 33818 33819 33821 33822 33828 33829 3383 3384 3410 3411 3418 3419 34461 347 34700 34701 34710 34711 3480 3482 3483

34830 34831 34839 3484 3485 3488 34881 34882 34889 3489 3492 34981 34982 34989 3499 3501 3502 3508 3509 3510 3511 3518 3519 3520 3521 3522 3523 3524 3525 3526 3529 3530 3531 3532 3533 3534 3535 3536 3538 3539 3540 3541 3542 3543 3544 3545 3548 3549 3550 3551 3552 3553 3554 3555 3556 3557 35571 35579 3558 3559 3560 3561 3562 3563 3564 3568 3569 3570 3571 3572 3573 3574 3576 3577 3578 35781 35782 35789 3579 3580 35800 35801 3581 3582 35830 35831 35839 3588 3589 3590 3591 3592 35921 35922 35923 35924 35929 3593 3594 3595 3596 35971 35979 3598 35981 35989 3599 7810 7811 7812 7813 7817 7818 7820 7843 7845 78451 78452 78459 78460 78461 78469 7920 7930 79400 79401 79402 79409 79410 79411 79412 79413 79414 79415 79416 79417 79419 7961 79951 79952 79953 79954 79955 79959 V124 V1240 V1241 V1242 V1249 V415 V452 V484 V485 V493 V530 V5301 V5302 V5309

109 Acute cerebrovascular disease

34660 34661 34662 34663 430 431 4320 4321 4329 43301 43311 43321 43331 43381 43391 4340 43400 43401 4341 43410 43411 4349 43490 43491 436

111 Other and ill-defined cerebrovascular disease

4370 4371 4373 4374 4375 4376 4377 4378 4379

112 Transient cerebral ischemia

4350 4351 4352 4353 4358 4359

245 Syncope

7802

650 Adjustment disorders

3090 3091 30922 30923 30924 30928 30929 3093 3094 30982 30983 30989 3099

651 Anxiety disorders

29384 30000 30001 30002 30009 30010 30020 30021 30022 30023 30029 3003 3005 30089 3009 3080 3081 3082 3083 3084 3089 30981 3130 3131 31321 31322 3133 31382 31383

652 Attention-deficit, conduct, and disruptive behavior disorders

31200 31201 31202 31203 31210 31211 31212 31213 31220 31221 31222 31223 3124 3128 31281 31282 31289 3129 31381 31400 31401 3141 3142 3148 3149

653 Delirium, dementia, and amnestic and other cognitive disorders

2900 29010 29011 29012 29013 29020 29021 2903 29040 29041 29042 29043 2908 2909 2930 2931 2940 2941 29410 29411 29420 29421 2948 2949 3100 3102 3108 31081 31089 3109 3310 3311 33111 33119 3312 33182 797

656 Impulse control disorders, NEC

31230 31231 31232 31233 31234 31235 31239

657 Mood disorders

29383 29600 29601 29602 29603 29604 29605 29606 29610 29611 29612 29613 29614 29615 29616 29620 29621 29622 29623 29624 29625 29626 29630 29631 29632 29633 29634 29635 29636 29640 29641 29642 29643 29644 29645 29646 29650 29651 29652 29653 29654 29655 29656 29660 29661 29662 29663 29664 29665 29666 2967 29680 29681 29682 29689 29690 29699 3004 311

658 Personality disorders

3010 30110 30111 30112 30113 30120 30121 30122 3013 3014 30150 30151 30159 3016 3017 30181 30182 30183 30184 30189 3019

659 Schizophrenia and other psychotic disorders

29381 29382 29500 29501 29502 29503 29504 29505 29510 29511 29512 29513 29514 29515 29520 29521 29522 29523 29524 29525 29530 29531 29532 29533 29534 29535 29540 29541 29542 29543 29544 29545 29550 29551 29552 29553 29554 29555 29560 29561 29562 29563 29564 29565 29570 29571 29572 29573 29574 29575 29580 29581 29582 29583 29584 29585 29590 29591 29592 29593 29594 29595 2970 2971 2972 2973 2978 2979 2980 2981 2982 2983 2984 2988 2989

662 Suicide and intentional self-inflicted injury

E9500 E9501 E9502 E9503 E9504 E9505 E9506 E9507 E9508 E9509 E9510 E9511 E9518 E9520 E9521 E9528 E9529 E9530 E9531 E9538 E9539 E954 E9550 E9551 E9552 E9553 E9554 E9555 E9556 E9557 E9559 E956 E9570 E9571 E9572 E9579 E9580 E9581 E9582 E9583 E9584 E9585 E9586 E9587 E9588 E9589 E959 V6284

670 Miscellaneous mental disorders

29389 2939 30011 30012 30013 30014 30015 30016 30019 3006 3007 30081 30082 3021 3022 3023 3024 30250 30251 30252 30253 3026 30270 30271 30272 30273 30274 30275

30276 30279 30281 30282 30283 30284 30285 30289 3029 3060 3061 3062 3063 3064 30650 30651 30652 30653 30659 3066 3067 3068 3069 3071 30740 30741 30742 30743 30744 30745 30746 30747 30748 30749 30750 30751 30752 30753 30754 30759 30780 30781 30789 3101 316 64840 64841 64842 64843 64844 V402 V403 V4031 V4039 V409 V673

CCS Procedural Codes

One incision and excision of CNS

0101 0109 0121 0122 0123 0124 0125 0126 0127 0128 0131 0132 0139 0141 0142 0151 0152 0153 0159

Two insertion; replacement; or removal of extracranial ventricular shunt

0231 0232 0233 0234 0235 0239 0242 0243

177 Computerized axial tomography (CT) scan head

8703

198 Magnetic resonance imaging

0032 8891 8892 8893 8894 8895 8896 8897 8899

199 Electroencephalogram (EEG)

8914

Diagnostic Codes

(ICD-9-CM was used in this study to identify diagnostic codes for the neglected tropical diseases and malaria. The following diagnostic codes were used to evaluate the number of hospitalizations and total charges associated with the following diseases:

Buruli ulcer: (none)

Chagas: 0860 0861 0862 0869

Dengue: 061

Dracunculiasis: 1257

Echinococcus: 1220 1221 1222 1223 1224 1225 1226 1227 1228 1229

Foodborne trematodes: 1210 1211 1212 1213 1114 1215 1216 1218 1219

Human African trypanosomiasis: 0863 0864 0865 0869 3213

Leishmaniasis: 0850 0851 0852 0853 0854 0855 0859

Leprosy: 0300 0301 0302 0303 0308 0309

Lymphatic filariasis: 1250 1251 1256 1259

Malaria: 0840 0841 0842 0843 0844 0845 0846 0847 0848 0849

64740 64741 64742 64743 64744

Onchocerciasis: 1253

Rabies: 071

Schistosomiasis: 1200 1201 1202 1203 1208 1209

Soil transmitted helminthes: 1260 1261 1269 1270 1273

Taeniasis–cysticercosis: 1230 1231

Trachoma: 0760 0761 0769 1391

Yaws: 1020 1021 1022 1023 1024 1025 1026 1027 1028 1029

Technical Appendix Table 1. Region groups for states included in the Nationwide Inpatient Sample during years 2003–2012*

Region	States
Northeast	Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont
Midwest	Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota, Wisconsin
South	Arkansas, Florida, Georgia, Kentucky, Louisiana, Maryland, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, Virginia, West Virginia
West	Alaska, Arizona, California, Colorado, Hawaii, Montana, Nevada, New Mexico, Oregon, Utah, Washington, Wyoming

*Not represented: Alabama, Delaware, District of Columbia, Idaho.

Technical Appendix Table 2. Regression output for univariate and multivariate generalized linear models with log link estimating mean hospitalization charges while controlling for year and demographic variables. Inflation-adjusted hospitalization charges are represented.*

Variable		Univariate			Multivariate		
		exp(b)	p >|t|	p >|F|†	exp(b)	p	95% CI
Year				<0.01			
	2003	Ref.	–		Ref.	–	–
	2004	0.95	0.7		0.99	1.0	0.76–1.29
	2005	0.96	0.8		1.06	0.7	0.82–1.37
	2006	1.17	0.3		1.19	0.3	0.88–1.62
	2007	1.30	0.1		1.27	0.2	0.87–1.87
	2008	1.38	0.1		1.62	0.1	0.94–2.81
	2009	1.10	0.5		1.04	0.8	0.79–1.35
	2010	1.32	0.04		1.35	0.1	0.98–1.86
	2011	1.56	<0.01		1.60	0.01	1.10–2.31
	2012	1.50	0.01		1.54	0.02	1.07–2.22

Variable	Univariate			Multivariate		
	exp(b)	p >|t|	p >|F|†	exp(b)	p	95% CI
Sex			<0.01			
M	Ref.	–		Ref.	–	–
F	0.85	<0.01		0.76	<0.01	0.64–0.91
Age			<0.01			
0–19	Ref.	–		Ref.	–	–
20–44	1.4	<0.01		1.23	0.3	0.84–1.79
45–64	1.8	<0.01		1.44	0.02	1.05–1.96
≥65	1.6	<0.01		1.14	0.5	0.74–1.77
Race			<0.01			
White	Ref.	–		Ref.	–	–
Black	0.93	0.7		1.42	0.4	0.68–3.00
Hispanic	1.05	0.6		1.08	0.6	0.81–1.43
Asian/Pacific Islander	0.74	0.1		0.99	1.0	0.64–1.52
Other	0.74	0.01		0.91	0.6	0.66–1.25
Region			<0.01			
Northeast	Ref.	–		Ref.	–	–
Midwest	0.70	<0.01		0.70	0.02	0.51–0.95
South	0.79	<0.01		0.82	0.02	0.69–0.97
West	1.44	<0.01		1.61	<0.01	1.18–2.19

*Ref., reference. †Adjusted Wald test.

Technical Appendix Table 3. Regression output for univariate and multivariate generalized linear models with log link estimating mean length of hospital stay while controlling for year and demographic variables.*

Variable	Univariate			Multivariate		
	exp(b)	p > |t|	p > |F|*	exp(b)	p	95% CI
Year			1.0			
2003	Ref.	–				
2004	1.04	0.7				
2005	1.00	1.0				
2006	1.08	0.5				
2007	1.08	0.5				
2008	1.08	0.5				
2009	1.04	0.8				
2010	1.08	0.6				
2011	1.13	0.3				
2012	1.07	0.6				
Sex			<0.01			
M	Ref.	–		Ref.	–	–
F	0.83	<0.01		0.82	<0.01	0.73–0.91
Age			<0.01			
0–19	Ref.	–		Ref.	–	–
20–44	1.31	<0.01		1.31	<0.01	1.12–1.53
45–64	1.46	<0.01		1.45	<0.01	1.20–1.74
≥65	1.34	<0.01		1.33	<0.01	1.10–1.62
Race			0.03			
White	Ref.	–		Ref.	–	–
Black	1.17	0.2		1.21	0.2	0.91–1.60
Hispanic	1.00	1.0		0.98	0.8	0.82–1.16
Asian/Pacific Island	0.79	0.1		0.80	0.1	0.62–1.04
Other	0.88	0.2		0.85	0.1	0.6–1.04
Region			<0.01			
Northeast	Ref.	–		Ref.	–	–
Midwest	0.73	<0.01		0.67	<0.01	0.56–0.79
South	0.88	0.06		0.87	0.06	0.76–1.01
West	0.96	0.5		0.97	0.7	0.83–1.12

*Ref., reference. †Adjusted Wald test.