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Economic impact of malaria-related hospitalizations in the United States, 2000–2014

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ABSTRACT

Background: Despite its elimination in the early 1950s, about 1700 cases of malaria are reported in the US every year. Few studies have quantified the direct and indirect costs of imported malaria in the US.
Methods: Disparities in the mean and total hospital days, hospital charges, and hospital costs for malaria-related hospitalizations in the US by demographic, clinical, species, financial, geographic, and institutional characteristics were examined using the 2000–2014 Nationwide Inpatient Sample (NIS). Trends and potential predictors for length of stay and hospital charges and costs were identified using negative binomial regression and linear regression, respectively.
Results: From 2000 to 2014, 22,029 malaria cases resulted in 95,948 hospital days for malaria-related hospitalizations, $176,391,466 in total hospital costs, and $555,435,849 in total charges. Mean charges increased significantly over the study period. Males, Blacks, and patients aged 25–44 years accounted for the highest direct and indirect costs. Older age and having severe malaria was associated with a longer length of stay. Older age, severe malaria, HIV infection, and longer lengths of stay were associated with higher charges and costs.
Conclusions: Malaria resulted in substantial direct and indirect costs in the US. Primary and secondary prevention measures should be prioritized among high-risk groups to reduce the economic burden.

Introduction

Malaria is the leading cause of death by parasitic disease in the world and remains one of the most important and intractable global public health problems. An estimated 216 million cases of malaria, and 445,000 deaths due to malaria occurred in 2016 [1]. Malaria is caused by infection with the protozoan agents of the genus *Plasmodium*. Several species of *Plasmodium* (*P. falciparum, P. vivax, P. ovale, P. malariae*, and *P. knowlesi*) are known to affect humans, with *P. falciparum* causing the most morbidity and the vast majority of the mortality [2].

The scale-up of interventions in the malaria endemic areas of the world has dramatically reduced global malaria incidence and mortality since 2000, although there is evidence that this progress is stalling [1]. In contrast, the number of malaria cases has steadily increased since the 1970s in the US [3] with increases in international travel [4,5]. An estimated 14% of international travelers develop a febrile illness, with malaria being the most common cause of febrile illness (19%) among international travelers [6–8]. About 1700 cases of malaria, including about 6 deaths, are reported each year in the US, mostly among returned travelers, and to a lesser extent among foreign visitors or immigrants from countries with endemic malaria [3]. Despite the abundance of available prevention [2] tools and its elimination since the early 1950s [9], malaria continues to impose a substantial disease burden in the US [10], with some subgroups particularly affected [11]. Few studies have quantified the costs of imported malaria in the US [12,13], and the domestic economic impact is largely unknown.

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Table 1
Economic burden of malaria compared to other travel-associated diseases in the US, NIS 2000–2014.

Disease	Discharges Total (95% CI)	Hospital days Total (95% CI)	Charges ($) Total (95% CI)	Costs ($) Total (95% CI)
Malaria	22,029 (20,304–23,754)	95,948 (88,754–103,143)	555,435,849 (512,512,251–598,359,447)	176,391,466 (160,715,853–192,067,079)
Filariasis	4,863 (3,989–5,737)	34,814 (25,838–43,790)	216,400,131 (178,592,681–254,207,581)	62,819,733 (54,106,011–71,533,454)
Dengue	3,888 (3,528–4,247)	16,468 (14,910–18,025)	120,372,142 (102,802,856–137,941,428)	33,723,776 (29,113,237–38,334,315)
Schistosomiasis	2,631 (2,320–2,942)	20,002 (17,082–22,921)	147,426,032 (123,783,761–171,068,304)	46,748,990 (38,925,631–54,572,349)
Trypanosomiasis	2,384 (1,968–2,800)	17,616 (13,261–21,971)	155,072,236 (118,911,478–191,232,995)	48,466,972 (37,249,980–59,683,965)
Leishmaniasis	1,469 (1,254–1,684)	12,259 (10,219–14,298)	76,947,850 (61,854,463–92,041,237)	24,849,517 (19,768,655–29,930,380)

Note: All numbers are national estimates based on weighted frequencies.
All charges and costs adjusted for inflation to 2015 US dollars. Cost data is for 2001–2014.

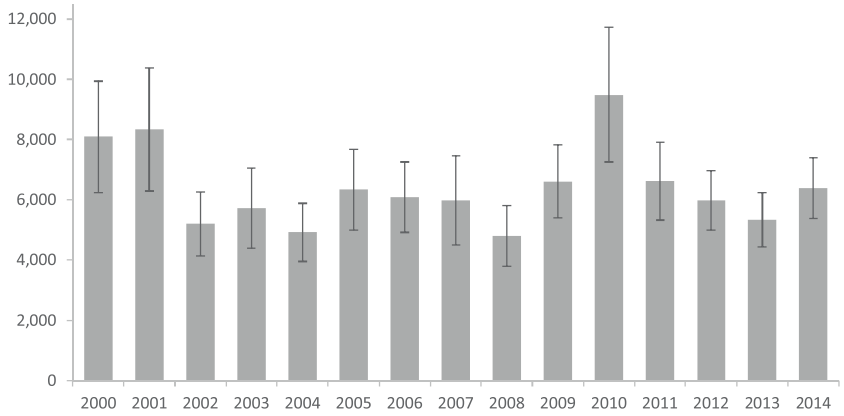

Fig. 1. Total hospital days for malaria-related hospitalizations in the US, NIS 2000–2014.
Note: All numbers are national estimates based on weighted frequencies and nonmissing data.

Study of the economic burden of malaria using hospital data in the US has rarely been explored, and can provide insight to the direct and indirect costs of imported malaria. This study aims to examine the malaria-associated direct costs by assessing hospital charges and costs, which represent health care resource utilization, and the indirect costs by assessing lengths of hospital stay, which represent lost productivity associated with malaria. A better understanding of these distributions and trends can help to inform improved targeted malaria prevention strategies in the US, especially for subgroups that incur high costs.

Methods

Hospital discharge records from the Nationwide Inpatient Sample (NIS) were used for analysis of malaria-related hospitalizations in the US during 2000–2014. The NIS is sampled from the State Inpatient Databases (SID), and is part of the Healthcare Cost and Utilization Project (HCUP) sponsored by the Agency for Healthcare Research and Quality (AHRQ). The NIS is the largest publicly available all-payer inpatient data source in the US, and each annual NIS dataset contains about 7–8 million hospital discharge records (about 20%) and over 100 clinical and non-clinical data elements, including sociodemographics, admission characteristics, diagnosis type, length of stay, co-diagnoses, procedures performed, institutional characteristics, and total charges. Details on the sampling scheme have been described elsewhere [14,15].

Cases of malaria in the NIS from 2000 to 2014 were identified from discharge records in the NIS by the primary and secondary diagnoses, which used the International Classification of Diseases, 9th revision (ICD-9) [16] codes of 084.0–084.9 (084.0:

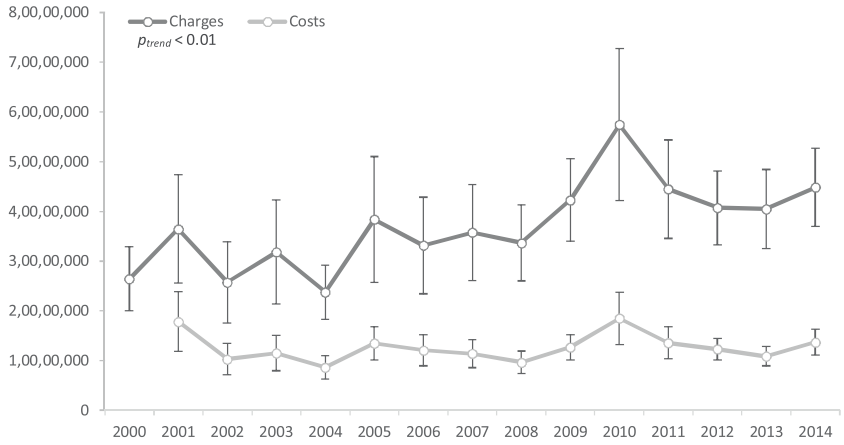

Fig. 2. Total charges and costs for malaria-related hospitalizations in the US, by year, NIS 2000–2014.
Note: All numbers are national estimates based on weighted frequencies and nonmissing data. All values adjusted for inflation to 2015 US dollars. Cost data available only for 2001–2014.

Table 2
Hospital days for malaria in the US, by characteristic, NIS 2000–2014.

Characteristics	Total discharges N (%)	Mean length of stay (95% CI)	Total hospital days (95% CI)	(95% CI)	Percent
Sex					
Male	13,244 (60.4)	4.12 (3.94–4.29)	54,512	(50,166–58,859)	56.8%
Female	8684 (39.6)	4.73 (4.48–4.99)	41,098	(37,285–44,911)	42.8%
Pregnant	1220 (5.5)	3.94 (3.54–4.34)	4,807	(3,950–5,664)	5.0%
Race					
White	4453 (24.0)	4.84 (4.52–5.16)	21,565	(19,428–23,702)	22.5%
Black	9735 (52.5)	4.21 (4.00–4.43)	41,011	(36,262–45,759)	42.7%
Hispanic	1169 (6.3)	4.65 (3.72–5.59)	5437	(4,117–6,757)	5.7%
Asian/Pacific Islander	1103 (6.0)	4.9 (4.17–5.62)	5403	(4367–6,440)	5.6%
Native American	174 (0.9)	5.29 (2.57–8.01)	921	(380–1,462)	1.0%
Other	1913 (10.3)	4.15 (3.77–4.52)	7932	(6878–8,986)	8.3%
Age (years)					
Under 5	863 (3.9)	3.9 (3.48–4.31)	3361	(2672–4,051)	3.5%
5–14	1725 (7.8)	3.55 (3.26–3.84)	6132	(5078–7,187)	6.4%
15–24	3560 (16.2)	3.8 (3.43–4.17)	13,533	(11,756–15,309)	14.1%
15–24	8148 (37.1)	3.75 (3.57–3.93)	30,545	(27,791–33,300)	31.8%
45–64	5819 (26.5)	4.98 (4.63–5.33)	28,984	(25,695–32,272)	30.2%
65–84	1708 (7.8)	6.86 (6.21–7.50)	11,712	(10,058–13,366)	12.2%
Over 85	166 (0.8)	9.58 (7.27–11.9)	1594	(1005–2,184)	1.7%
Malaria diagnosis					
Primary	18,297 (83.1)	3.84 (3.71–3.97)	70,295	(64,589–76,001)	73.3%
Secondary	3732 (16.9)	6.87 (6.31–7.44)	25,653	(22,751–28,556)	26.7%
Infecting Species					
Falciparum	8495 (38.6)	4.56 (4.33–4.79)	38,726	(34,936–42,517)	40.4%
Vivax	2,612 (11.9)	3.61 (3.36–3.86)	9434	(8,379–10,488)	9.8%
Ovale	358 (1.6)	3.88 (3.43–4.32)	1283	(963–1,603)	1.3%
Malariae	331 (1.5)	3.41 (3.00–3.82)	1221	(942–1,500)	1.3%
Clinical classification					
Uncomplicated malaria	17,206 (78.1)	3.38 (3.29–3.47)	58,185	(53,881–62,490)	60.6%
Severe malaria	4823 (21.9)	7.83 (7.27–8.39)	37,763	(33,636–41,891)	39.4%
Cerebral malaria	956 (4.3)	10.22 (8.43–12.01)	9,770	(7,544–11,995)	10.2%
Severe anemia	1587 (7.2)	8.45 (7.49–9.41)	13,415	(11,348–15,482)	14.0%
Renal failure	2113 (9.6)	8.35 (7.55–9.16)	17,656	(15,333–19,978)	18.4%
ARDS	900 (4.1)	15.95 (13.81–18.09)	14,357	(11,446–17,269)	15.0%
Jaundice	808 (3.7)	4.62 (3.99–5.24)	3730	(3014–4446)	3.9%
Pre-existing conditions					
HIV infection	399 (1.5)	6.55 (4.88–8.23)	2219	(1524–2,913)	2.3%
Diabetes mellitus (type II)	1664 (7.6)	5.49 (4.89–6.09)	9128	(7714–10,542)	9.5%
Essential hypertension	3119 (14.2)	5.23 (4.83–5.63)	16,314	(14,367–18,262)	17.0%
Procedures performed					
0	14,746 (66.9)	3.08 (3.01–3.15)	45,424	(42,372–48,475)	47.3%
1	3834 (17.4)	4.27 (4.10–4.45)	16,379	(14,782–17,975)	17.1%
2 or more	3448 (15.7)	9.9 (9.05–10.76)	34,146	(29,786–38,507)	35.6%
Admission source[a]					
Emergency department	9036 (69.8)	4.38 (4.12–4.63)	39,539	(35,153–43,926)	68.7%
Another hospital	512 (4.0)	6.12 (5.18–7.06)	3134	(2,410–3,857)	5.4%
Another facility	97 (0.8)	7.35 (4.67–10.02)	715	(347–1,082)	1.2%
Routine/birth/other	3304 (25.5)	4.29 (3.86–4.71)	14,163	(11,902–16,425)	24.6%
In-hospital death					
Did not die	21,828 (99.2)	4.29 (4.14–4.44)	93,613	(86,606–100,620)	97.6%
Died	182 (0.8)	11.82 (7.9–15.74)	2153	(1236–3,071)	2.2%
Median income for zip code					
High	11,955 (57.8)	4.22 (4.02–4.42)	50,435	(45,489–55,381)	52.6%
Low	8742 (42.2)	4.54 (4.30–4.78)	39,674	(35,832–43,516)	41.3%
Primary payer					
Medicare	1516 (6.9)	7.7 (6.92–8.49)	11,680	(9866–13,493)	12.2%
Medicaid	4260 (19.4)	4.83 (4.34–5.31)	20,569	(17,697–23,441)	21.4%
Private insurance	9936 (45.2)	3.99 (3.81–4.18)	39,671	(36,145–43,198)	41.3%
Self-pay	4,762 (21.7)	3.56 (3.41–3.72)	16,970	(14,815–19,126)	17.7%
No charge	451 (2.1)	4.43 (3.69–5.18)	1997	(1214–2,780)	2.1%
Other	1,043 (4.8)	4.51 (4.05–4.98)	4,710	(3,868–5,553)	4.9%
Hospital Region					
Northeast	7523 (34.2)	4.37 (4.10–4.64)	32,870	(28,746–36,994)	34.3%
Midwest	3131 (14.2)	3.92 (3.61–4.22)	12,261	(10,346–14,176)	12.8%
South	8164 (37.1)	4.55 (4.28–4.81)	37,111	(31,794–42,428)	38.7%
West	3211 (14.6)	4.27 (3.88–4.66)	13,707	(12,019–15,395)	14.3%
Hospital Location					
Rural	811 (3.7)	3.37 (2.96–3.77)	2,730	(2,200–3,261)	2.8%
Urban	21,180 (96.3)	4.39 (4.24–4.55)	93,081	(85,903–100,258)	97.0%
Hospital ownership[a]					
Gov., nonfederal, public	1962 (18.8)	4.44 (3.88–5.01)	8720	(6503–10,936)	19.3%
Private, non-profit, voluntary	7635 (73.1)	4.24 (4.04–4.44)	32,378	(29,279–35,476)	71.8%
Private, investor owned	853 (8.2)	4.71 (4.11–5.31)	4015	(3158–4,873)	8.9%

Table 2 (*Continued*)

Characteristics	Total discharges N (%)	Mean length of stay (95% CI)	Total hospital days (95% CI)	(95% CI)	Percent
Hospital bed size					
Small	2361 (10.7)	4.10 (3.76–4.44)	9682	(8290–11,075)	10.1%
Medium	6238 (28.4)	4.44 (4.10–4.77)	27,677	(23,391–31,963)	28.8%
Large	13,392 (60.9)	4.36 (4.18–4.55)	58,452	(52,841–64,063)	60.9%
Total	22,029 (100.0)	4.36 (4.20–4.51)	95,948	(88,754–103,143)	100.0%

Note: All numbers are national estimates based on weighted frequencies and nonmissing data.
Numbers and proportions may not sum to total or 100% due to missing values.
Length of stay in days.

[a] Admission source for 2000–2011. Hospital ownership for 2008–2012.

falciparum malaria, malignant tertian; 084.1: vivax malaria, benign tertian; 084.2: malariae, quartan; 084.3: ovale malaria; 084.4: other malaria; 084.5: mixed malaria; 084.6: malaria, unspecified; 084.7: induced malaria; 084.8: Blackwater fever; 084.9: other pernicious complications of malaria) and of 647.4 (malaria complicating pregnancy, childbirth, or puerperium).

In this study, the definition of severe malaria was modified from that used by the CDC [3]. Since no specific drugs used or laboratory results are available in the NIS, we were unable to use parasitemia ≥5% or treatment for severe malaria (i.e. artesunate or quinidine) as specified in the CDC definition. Malaria complications were identified using ICD-9 codes and Clinical Classification Software (CCS) [17] categories, which are clinically meaningful categories of ICD-9 codes. Discharge records listing a malaria diagnosis along with one or more of the following criteria were considered as severe malaria cases: 1. Neurologic symptoms (cerebral malaria)– CCS codes 82, 83, 85, or 95 (paralysis, epilepsy, convulsions, alteration of consciousness, coma, stupor, brain damage, other nervous system disorders); 2. Renal failure – CCS code 157; 3. Severe anemia – CCS code 59 (deficiency anemia) with procedural CCS code 222 (blood transfusion); 4. Acute respiratory distress syndrome (ARDS) – CCS code 131; 5. Jaundice – ICD-9 code 782.4; or 6. Exchange transfusion – ICD-9 code 99.01. Malaria-related hospitalizations with an in-hospital death were also considered as severe malaria cases.

Hospital charges represent the amount that hospitals bill for services, and are generally more than the total costs or the amount paid by the payers [18]. Hospital costs, which reflect the amount hospital services actually cost according to the required detailed reports by hospitals to the Centers for Medicare and Medicaid Services, were calculated by multiplying the charges by the hospital-level charge-to-cost ratios provided by HCUP available for 2001 and after. All charge and cost data were adjusted for inflation to 2015 US dollars using the general Consumer Price Index [19].

Data analyses were performed using SAS 9.4 (SAS Institute, Cary, North Carolina, USA) with survey procedures that accounted for the complex sampling design. National estimates of the mean and sum of length of stay (LOS), hospital charges, and hospital costs for malaria-related hospitalizations by different characteristics were produced using NIS discharge-level sample weights, which were provided by HCUP. Direct costs (assessed using hospital charges and costs) and indirect costs (assessed using LOS) for malaria-related hospitalizations were compared to that for other select travel-associated diseases.

For total charges and costs, trends were assessed using simple linear regression, and potential predictors were assessed using multiple linear regression. For LOS, trends were assessed using simple negative binomial regression, and potential predictors were assessed using multiple negative binomial regression. Potential predictors simultaneously tested included demographic, clinical, financial, and institutional variables. Directed acyclic graphs were used to examine the possible relationships between variables involved with LOS or total hospital charges [20,21]. Imputation of missing variables was not feasible due to the large size of the NIS and limited computing power.

Results

From 2000 to 2014, malaria-related hospitalizations accounted for 95,948 (95% confidence interval [CI]: 88,754–103,143) hospital days, and $555,435,849 (95% CI: in $512,512,251–$598,359,447) in total charges. From 2001-2014, malaria-related hospitalizations accounted for $176,391,466 (95% CI: $160,715,853–$192,067,079) in total hospital costs. The economic burden of malaria-related hospitalizations far exceeded those of other travel-associated diseases, including filariasis, dengue, schistosomiasis, trypanosomiasis, and leishmaniasis (Table 1). The annual total LOS and cost for malaria-related hospitalizations remained relatively constant (Fig. 1, 2), while the annual total charges increased significantly ($p_{trend} < 0.01$) from 2000 to 2014 (Fig. 2).

Demographics

In this study, patients of working age (25–64 years) comprised the majority of malaria hospitalizations and hospital days. Mean hospital days, charges, and costs increased with age for those older than 45 years (Tables 2–4). Controlling for all other covariates, older age was associated with longer lengths of stay and higher costs (Tables 5, 6). Controlling for all other covariates, Blacks had shorter LOS compared to Whites (Table 5).

Species

P. falciparum accounted for the majority of hospital days, hospital charges, and hospital costs among malaria-related hospitalizations with known species information (52.9%), followed by *P. vivax*, *P. ovale*, and *P. malariae* (Tables 2–4).

Clinical

The majority (69.8%) of cases with known admission source were admitted from the emergency room, and accounted for 71.9% of the total charges and 69.7% of the total costs. Discharge records listing malaria as a secondary diagnosis had longer mean LOS, and accounted for a greater proportion of the total charges and costs than those with a primary malaria diagnosis. Severe malaria cases comprised 21.9% of all malaria-related hospitalizations, but accounted for 39.4% of the total hospital days, 49.8% of the total charges, and 46.0% of the total costs (Tables 2–4). A diagnosis of ARDS was the strongest predictor of increased mean LOS, charge, and cost of malaria-related hospitalization, followed by severe anemia (Tables 5, 6). Malaria cases with ARDS (4.1%) had especially prolonged mean LOS (16.0 days), high mean charges ($155,873), and high mean costs ($48,774), which disproportionately accounted for 15.0% of total hospital days, 25.0% of total charges, and 22.6% of total costs (Tables 2–4). Having jaundice did not affect the LOS, charges, or costs. Co-occurring HIV infection was associated with higher mean LOS, charges, and costs, and co-occurring type II diabetes mellitus was associated with higher

Table 3
Hospital charges for malaria-related hospitalizations in the US, by characteristic, NIS 2000–2014.

Characteristics	Total discharges N (%)	Mean charges 95% CI	Total charges Total 95% CI	Percent
Sex				
Male	13,244 (60.4)	24,376 (22,650–26,103)	316,012,572 (287,520,381–344,504,764)	56.9%
Female	8684 (39.6)	27,995 (25,704–30,286)	237,834,644 (213,436,166–262,233,122)	42.8%
Pregnant	1220 (5.5)	18,988 (16,009–21,968)	22,449,863 (18,042,772–26,856,954)	4.0%
Race				
White	4453 (24.0)	30,321 (27,150–33,491)	132,454,999 (115,931,222–148,978,775)	23.8%
Black	9735 (52.5)	24,513 (22,316–26,709)	234,145,862 (205,990,578–262,301,147)	42.2%
Hispanic	1169 (6.3)	23,580 (19,084–28,075)	26,671,531 (20,619,839–32,723,224)	4.8%
Asian/Pacific Islander	1103 (6.0)	38,695 (31,136–46,254)	39,669,573 (30,555,817–48,783,328)	7.1%
Native American	174 (0.9)	26,511 (15,008–38,013)	4,617,666 (2,170,767–7,064,565)	0.8%
Other	1913 (10.3)	25,023 (21,341–28,705)	46,337,462 (38,200,479–54,474,445)	8.3%
Age (years)				
Under 5	863 (3.9)	19,963 (16,465–23,461)	17,228,190 (13,165,562–21,290,818)	3.1%
5–14	1725 (7.8)	21,412 (17,023–25,800)	35,993,936 (26,222,118–45,765,754)	6.5%
15–24	3560 (16.2)	19,943 (17,231–22,654)	69,522,798 (58,797,544–80,248,053)	12.5%
25–44	8148 (37.1)	20,912 (19,201–22,623)	166,174,324 (148,882,109–183,466,539)	29.9%
45–64	5819 (26.5)	31,631 (28,538–34,725)	179,761,649 (158,097,698–201,425,600)	32.4%
65–84	1708 (7.8)	46,397 (40,684–52,109)	78,202,914 (65,434,141–90,971,688)	14.1%
Over 85	166 (0.8)	49,216 (35,071–63,360)	7,961,404 (4,768,679–11,154,130)	1.4%
Malaria diagnosis				
Primary	18,297 (83.1)	43,738 (39,074–48,402)	159,155,469 (139,391,734–178,919,204)	28.7%
Secondary	3732 (16.9)	22,140 (20,783–23,498)	396,280,380 (361,969,018–430,591,742)	71.3%
Infecting Species				
Falciparum	8495 (38.6)	27,980 (25,387–30,572)	233,124,401 (206,627,322–259,621,479)	42.0%
Vivax	2612 (11.9)	20,192 (17,493–22,892)	50,466,833 (42,558,334–58,375,332)	9.1%
Ovale	358 (1.6)	21,233 (14,903–27,564)	6669,245 (4,209,475–9,129,015)	1.2%
Malariae	331 (1.5)	18,333 (12,784–23,883)	6374,267 (4,099,056–8,649,479)	1.1%
Clinical classification				
Uncomplicated malaria	17,206 (78.1)	16,586 (15,770–17,402)	278,778,169 (257,738,684–299,817,654)	50.2%
Severe malaria	4823 (21.9)	58,500 (53,308–63,692)	276,657,680 (245,558,286–307,757,075)	49.8%
Cerebral malaria	956 (4.3)	79,130 (66,928–91,333)	74,235,134 (58,743,951–89,726,318)	13.4%
Severe anemia	1587 (7.2)	62,074 (54,402–69,745)	95,247,325 (80,101,123–110,393,526)	17.1%
Renal failure	2113 (9.6)	66,869 (58,703–75,035)	140,121,849 (118,805,762–161,437,936)	25.2%
ARDS	900 (4.1)	155,873 (134,909–176,838)	139,087,241 (113,051,600–165,122,883)	25.0%
Jaundice	808 (3.7)	32,087 (25,748–38,425)	25,571,367 (19,538,261–31,604,474)	4.6%
Pre-existing conditions				
HIV infection	399 (1.5)	48,171 (30,740–65,602)	16,099,297 (9,682,288–22,516,307)	2.9%
Diabetes mellitus (type II)	1664 (7.6)	37,469 (31,330–43,608)	60,596,173 (48,952,392–72,239,955)	10.9%
Essential hypertension	3119 (14.2)	33,711 (29,696–37,727)	102,558,490 (86,857,369–118,259,612)	18.5%
Procedures performed				
0	14,746 (66.9)	14,550 (13,901–15,200)	210,284,510 (195,776,336–224,792,683)	37.9%
0	3834 (17.4)	23,722 (22,178–25,267)	87,901,832 (79,523,938–96,279,726)	15.8%
2 or more	3448 (15.7)	76,113 (68,294–83,932)	257,249,508 (225,215,265–289,283,750)	46.3%
Admission source[a]				
Emergency department	9036 (69.8)	24,167 (21,970–26,364)	210,415,486 (184,542,542–236,288,430)	71.9%
Another hospital	512 (4.0)	37,291 (22,373–52,208)	18,744,077 (10,658,240–26,829,913)	6.4%
Another facility	97 (0.8)	23,565 (14,390–32,741)	2,291,932 (1,065,803–3,518,060)	0.8%
Routine/birth/other	3304 (25.5)	19,260 (15,517–23,002)	61,265,553 (48,444,629–74,086,478)	20.9%
In-hospital death				
Did not die	21,828 (99.2)	25,082 (23,680–26,484)	535,289,928 (494,661,979–575,917,877)	96.4%
Died	182 (0.8)	108,825 (78,810–138,839)	19,285,623 (11,452,751–27,118,496)	3.5%
Length of stay (days)				
0–1	3300 (15.0)	6811 (6380–7,243)	21,840,336 (19,640,733–240,399,38)	3.9%
2–3	9385 (42.6)	12,575 (12,020–13,131)	114,786,104 (106,389,393–123,182,815)	20.7%
4–6	6464 (29.3)	25,165 (24,052–26,278)	160,402,003 (148,097,389–172,706,617)	28.9%
7+	2880 (13.1)	91,330 (83,394–99,266)	258,407,404 (226,277,423–290,537,391)	46.5%
Median income for zip code				
High	11,955 (57.8)	25,149 (23,249–27,048)	292,753,192 (265,792,964–319,713,421)	52.7%
Low	8742 (42.2)	26,740 (24,503–28,977)	231,416,928 (205,506,550–257,327,305)	41.7%
Primary payer				
Medicare	1516 (6.9)	49,513 (42,333–56,694)	73,464,426 (59,686,558–87,242,295)	13.2%
Medicaid	4260 (19.4)	25,591 (22,730–28,451)	108,397,486 (93,435,946–123,359,026)	19.5%
Private insurance	9936 (45.2)	24,749 (22,591–26,906)	237,098,649 (212,182,627–262,014,671)	42.7%
Self-pay	4762 (21.7)	20,944 (18,759–23,129)	98,352,869 (85,459,098–111,246,640)	17.7%
No charge	451 (2.1)	21,059 (16,586–25,533)	9,390,633 (5,458,896–13,322,371)	1.7%
Other	1043 (4.8)	26,182 (22,292–30,072)	27,074,210 (21,610,973–32,537,448)	4.9%
Hospital Region				
Northeast	7523 (34.2)	25,787 (23,425–28,150)	194,002,292 (169,657,026–218,347,559)	34.9%
Midwest	3131 (14.2)	20,792 (17,713–23,871)	64,887,142 (52,544,614–77,229,670)	11.7%
South	8164 (37.1)	23,374 (21,078–25,671)	188,335,776 (160,066,769–216,604,783)	33.9%
West	3211 (14.6)	38,157 (32,817–43,497)	108,210,639 (90,912,785–125,508,493)	19.5%
Hospital Location				
Rural	811 (3.7)	11,467 (9,975–12,959)	9,247,746 (7,456,392–11,039,100)	1.7%
Urban	21,180 (96.3)	26,357 (24,820–27,893)	545,400,389 (502,503,230–588,297,549)	98.2%

Table 3 (*Continued*)

Characteristics	Total discharges N (%)	Mean charges 95% CI	Total charges Total 95% CI	Percent
Hospital ownership[a]				
Gov., nonfederal, public	1962 (18.8)	28,633 (23,047–34,219)	56,179,032 (40,007,301–72,350,764)	10.1%
Private, non-profit, voluntary	7635 (73.1)	27,908 (25,879–29,937)	209,360,921 (188,907,169–229,814,672)	37.7%
Private, investor owned	853 (8.2)	44,169 (37,642–50,695)	37,654,515 (29,080,168–46,228,862)	6.8%
Hospital bed size				
Small	2361 (10.7)	23,296 (20,483–26,109)	52,929,371 (43,980,598–61,878,144)	9.5%
Medium	6238 (28.4)	25,332 (22,560–28,104)	154,337,786 (131,378,944–177,296,628)	27.8%
Large	13,392 (60.9)	26,447 (24,450–28,445)	347,380,979 (312,221,538–382,540,419)	62.5%
Total	22,029 (100.0)	25,789 (24,318–27,261)	555,435,849(512,512,251–598,359,447)	100.0%

Note: All numbers are national estimates based on weighted frequencies and nonmissing data.
Numbers and proportions may not sum to total or 100% due to missing values.
Charges adjusted for inflation to 2015 US dollars.
[a] Admission source data for 2000–2011. Hospital ownership data for 2008–2012.

charges (Tables 5, 6). LOS was the most important predictor of mean charges and costs (Tables 5, 6).

Financial

The most common primary payer for patients with a malaria-related hospitalization was private insurance (45.2%), accounting for 41.3% of hospital days, 42.7% of hospital charges, and 38.3% of hospital costs. Controlling for all other covariates, patients with Medicare as their primary payer had longer mean LOS compared to those with other payers (Tables 2, 6). Controlling for all other covariates, self-paying patients (uninsured) had lower mean charges and costs compared to those with Medicare (Table 6).

Institutional

Mean LOS for malaria-related hospitalizations did not vary by region (Tables 2, 5). However, the mean charges and costs were higher in the Western region compared to all other regions (Tables 3, 4), even after controlling for all other covariates (Table 6). Malaria patients who stayed at rural hospitals had lower mean LOS and charges mean compared to those at urban hospitals (Tables 2, 3), even after controlling for other covariates (Tables 5, 6). Mean LOS did not vary by hospital control/ownership (Tables 2, 5). However, the mean charge was higher for patients who stayed at private, investor-owned hospitals compared to government, nonfederal hospitals, while the mean cost was lower for even after controlling for other covariates (Table 6). Compared to patients who stayed at hospitals with large bed size, those who were hospitalized in hospitals with small bed size had higher mean costs (Table 6).

Discussion

Malaria imposes a great disease and economic burden with substantial direct and indirect costs in the US. Malaria-related hospitalizations resulted in an estimated total of over half a billion dollars in hospital charges and over 176 million in hospital costs for nearly 96,000 hospital days in the US from 2000 to 2014. Although the mean LOS, charge, and cost per hospitalization for malaria were lower than that for other travel-associated diseases, including filariasis, dengue, schistosomiasis, trypanosomiasis, and leishmaniasis, malaria accounted for a much larger total bill and hospital days due to the excess number of cases. Furthermore, malaria-related hospital charges demonstrated an increasing trend over the study period, suggesting a growing economic burden due to malaria in the US.

The heavy economic burden of malaria, much of which is attributable to the use of high-cost services as indicated by the large proportion of cases admitted from the emergency room and the large proportion of cases with severe malaria complications, underscores the need for education and prevention efforts among prospective travelers, especially during peak travel seasons. Pre-travel consultations give health care providers an important opportunity to explain the destination-specific malaria risk, counsel on mosquito avoidance techniques, prescribe and encourage compliance with chemoprophylaxis, and educate on malaria and its warning signs. Pre-travel consultations are recommended by the CDC [22] for international travelers for its effectiveness in reducing the risk of insect bites, malaria acquisition [23], and delayed presentation to medical attention when symptoms occur. However, few prospective travelers visit health care providers for pre-travel health consultations due to barriers such as cost [24–26] and other factors, despite studies showing that pre-travel consultation with adherence to chemoprophylaxis results in net savings for both the traveler and the payer, especially as travel duration and malaria risk increases [27].

Several populations known to be at particularly high risk include prospective travelers with travel destinations in Sub-Saharan Africa and parts of the Caribbean, where the relatively more virulent malaria infecting species, *P. falciparum*, is endemic and where the majority of the global malaria burden occurs [1,3,28]. Among imported cases in the US, *P. falciparum* is similarly the predominant infecting species, as this study showed that *P. falciparum* disproportionately accounted for over three quarters of all hospital days, charges, and costs among malaria-related hospitalizations with known species information.

Those who return to their countries of origin to visit friends and relatives (VFR) [22,29], and Blacks are two, possibly partially overlapping populations at high risk of contracting malaria. VFR travelers to malaria-endemic countries tend to have increased exposure to malaria vectors and lower malaria risk perception (e.g. belief in immunity) [22]. In this study, Blacks were by far the largest race group among malaria-related hospitalizations accounting for about half of all hospital days, charges, and costs, and were associated with having a shorter LOS compared to Whites, which is consistent with patterns of immigration, and travel for VFR in malaria-endemic countries. Some VFR travelers may also have protective factors of malaria and severe malaria, such as malaria protective genetic variations (e.g. sickle cell trait) [30] and acquired partial immunity [31], which may partially explain the association between Black race and shorter LOS in this study. This advantage of acquired immunity to malaria, however, wanes without sustained exposure, and all prospective travelers who are VFR should be encouraged to take full preventive precautions, including vector avoidance and chemoprophylaxis, similarly to malaria-naive patients. Another possible explanation for the observed association between shorter LOS and Blacks compared to Whites may be institutionalized racism [32].

Those who are immunocompromised, including those of older age, with HIV [33], with type II diabetes [34], who are pregnant

Table 4
Hospital costs for malaria-related hospitalizations in the US, by characteristic, NIS 2001–2014.

	Total discharges N %	Mean Mean 95% CI	Costs Total 95% CI	Percent
Sex				
Male	13,244 (60.4)	8541 (7957–9125)	94,831,772 (84,949,669–104,713,874)	53.8%
Female	8684 (39.6)	9491 (8814–10,167)	70,585,273 (63,282,341–77,888,206)	40.0%
Pregnant	1220 (5.5)	7470 (5955–8986)	7,503,904 (5,683,379–9,324,429)	4.3%
Race				
White	4453 (24.0)	10,048 (9014–11,081)	37,139,733 (32,525,357–41,754,109)	21.1%
Black	9735 (52.5)	8520 (7902–9,138)	71,738,707 (61,989,587–81,487,826)	40.7%
Hispanic	1169 (6.3)	9547 (6491–12,602)	8,145,292 (5,321,440–10,969,143)	4.6%
Asian/Pacific Islander	1103 (6.0)	11,236 (9153–13,318)	10,362,446 (8,034,883–12,690,010)	5.9%
Native American	174 (0.9)	9605 (2572–16,638)	1,483,735 (306,743–2,660,726)	0.8%
Other	1913 (10.3)	8557 (7385–9729)	13,387,851 (11,030,111–15,745,591)	7.6%
Age (years)				
Under 5	863 (3.9)	10,048 (9014–11,081)	37,139,733 (32,525,357–41,754,109)	21.1%
5–14	1725 (7.8)	8520 (7902–9138)	71,738,707 (61,989,587–81,487,826)	40.7%
15–24	3560 (16.2)	9547 (6491–12,602)	8,145,292 (5,321,440–10,969,143)	4.6%
25–44	8148 (37.1)	11,236 (9153–13,318)	10,362,446 (8,034,883–12,690,010)	5.9%
45–64	5819 (26.5)	9605 (2,72–16,638)	1,483,735 (306,743–2,660,726)	0.8%
65–84	1708 (7.8)	8557 (7385–9729)	13,387,851 (11,030,111–15,745,591)	7.6%
Over 85	166 (0.8)	10,048 (9014–11,081)	37,139,733 (32,525,357–41,754,109)	21.1%
Malaria diagnosis				
Primary	18,297 (83.1)	14,623 (13,188–16,058)	46,766,629 (40,975,520–52,557,738)	26.5%
Secondary	3732 (16.9)	7726 (7296–8155)	119,063,479 (107,416,013–130,710,945)	67.5%
Infecting Species				
Falciparum	8495 (38.6)	9723 (8930–10,517)	70,892,801 (62,357,667–79,427,935)	40.2%
Vivax	2612 (11.9)	6980 (6173–7787)	14,519,035 (12,356,879–16,681,190)	8.2%
Ovale	358 (1.6)	8591 (5760–11,422)	2,411,007 (1,430,140–3,391,874)	1.4%
Malariae	331 (1.5)	6208 (4608–7807)	1,650,004 (1,096,226–2,203,781)	0.9%
Clinical classification				
Uncomplicated malaria	17,206 (78.1)	5,924 (5659–6189)	84,699,433 (76,765,043–92,633,823)	48.0%
Severe malaria	4823 (21.9)	18,819 (17,224–20,414)	81,130,675 (71,483,837–90,777,512)	46.0%
Cerebral malaria	956 (4.3)	26,267 (21,806–30,727)	23,194,938 (18,065,204–28,324,672)	13.1%
Severe anemia	1587 (7.2)	21,843 (19,311–24,374)	29,766,121 (24,989,460–34,542,782)	16.9%
Renal failure	2113 (9.6)	20,519 (17,934–23,104)	39,642,620 (33,342,591–45,942,648)	22.5%
ARDS	900 (4.1)	48,774 (42,230–55,319)	39,860,827 (31,968,004–47,753,649)	22.6%
Jaundice	808 (3.7)	10,775 (8522–13,027)	8,138,000 (6,092,644–10,183,356)	4.6%
Pre-existing conditions				
HIV infection	399 (1.5)	16,181 (10,612–21,749)	4,805,411 (2,900,157–6,710,665)	2.7%
Diabetes mellitus (type II)	1664 (7.6)	11,864 (10,123–13,605)	17,345,129 (14,027,284–20,662,973)	9.8%
Essential hypertension	3119 (14.2)	11,091 (9842–12,340)	29,894,586 (25,134,778–34,654,394)	16.9%
Procedures performed				
0	14,746 (66.9)	5007 (4845–5169)	61,576,537 (56,966,395–66,186,679)	34.9%
1	3834 (17.4)	8375 (7957–8792)	27,460,704 (24,218,974–30,702,435)	15.6%
2 or more	3448 (15.7)	25,332 (22,902–27,761)	76,792,866 (66,521,034–87,064,698)	43.5%
Admission source[a]				
Emergency department	9036 (69.8)	9150 (8359–9942)	63,632,893 (55,026,712–72,239,074)	69.7%
Another hospital	512 (4.0)	15,130 (10,065–20,196)	6,081,537 (3,706,971–8,456,103)	6.7%
Another facility	97 (0.8)	11,037 (6792–15,281)	807,353 (347,889–1,266,816)	0.9%
Routine/birth/other	3304 (25.5)	8475 (6808–10,142)	20,801,772 (15,727,155–25,876,389)	22.8%
In-hospital death				
Did not die	21,828 (99.2)	8,696 (8268–9123)	160,362,468 (146,404,116–174,320,821)	90.9%
Died	182 (0.8)	35,253 (25,261–45,244)	5,394,958 (3,181,410–7,608,507)	3.1%
Length of stay (days)				
0–1	3300 (15.0)	2509 (2378–2640)	7,360,695 (6,591,081–8,130,309)	4.2%
2–3	9385 (42.6)	4466 (4,303–4,628)	37,318,006 (34,010,960–40,625,052)	21.2%
4–6	6464 (29.3)	8708 (8,370–9,047)	51,445,525 (46,954,559–55,936,492)	29.2%
7+	2880 (13.1)	30,974 (28,350–33,599)	80,267,240 (69,243,005–91,291,475)	45.5%
Median income for zip code				
High	11,955 (57.8)	8676 (8095–9258)	85,707,709 (76,925,944–94,489,474)	48.6%
Low	8742 (42.2)	9106 (8378–9834)	69,162,408 (60,579,192–77,745,623)	39.2%
Primary payer				
Medicare	1516 (6.9)	15,377 (13,125–17,630)	19,783,152 (15,952,748–23,613,555)	11.2%
Medicaid	4260 (19.4)	9679 (8563–10,794)	35,789,162 (30,023,942–41,554,382)	20.3%
Private insurance	9936 (45.2)	8275 (7581–8969)	67,619,894 (60,321,254–74,918,533)	38.3%
Self-pay	4762 (21.7)	7537 (6932–8141)	30,700,491 (25,628,544–35,772,438)	17.4%
No charge	451 (2.1)	7183 (5849–8517)	3,038,407 (1,676,385–4,400,428)	1.7%
Other	1,043 (4.8)	9,195 (7,809–10,580)	8,356,363 (6,559,685–10,153,040)	4.7%
Hospital Region				
Northeast	7523 (34.2)	9041 (8413–9669)	59,441,394 (50,642,238–68,240,550)	33.7%
Midwest	3131 (14.2)	8107 (6968–9246)	22,870,807 (18,053,219–27,688,395)	13.0%
South	8164 (37.1)	8126 (7346–8906)	54,333,394 (44,824,538–63,842,251)	30.8%
West	3211 (14.6)	11,549 (10,024–13,074)	29,184,512 (24,538,871–33,830,153)	16.5%
Hospital Location				
Rural	811 (3.7)	6126 (5278–6975)	4,087,951 (3,225,231–4,950,671)	2.3%
Urban	21,180 (96.3)	9020 (8561–9480)	161,504,559 (146,947,291–176,061,827)	91.6%

Table 4 (*Continued*)

	Total discharges N %	Mean Mean 95% CI	Costs Total 95% CI	Percent
Hospital ownership[a]				
Gov., nonfederal, public	1962 (18.8)	9779 (7983–11,574)	19,186,183 (13,661,502–24,710,864)	21.7%
Private, non-profit, voluntary	7635 (73.1)	8609 (8101–9116)	62,450,438 (56,002,043–68,898,833)	70.5%
Private, investor owned	853 (8.2)	8452 (6998–9905)	6,927,984 (5,251,166–8,604,802)	7.8%
Hospital bed size				
Small	2361 (10.7)	8172 (7390–8954)	16,162,908 (13,549,024–18,776,791)	9.2%
Medium	6238 (28.4)	9141 (8262–10,020)	47,122,815 (39,421,460–54,824,170)	26.7%
Large	13,392 (60.9)	8944 (8358–9530)	102,306,787 (90,202,445–114,411,129)	58.0%
Total	22,029 (100.0)	8914 (8458–9369)	176,391,466 (160,715,853–192,067,079)	100%

Note: All numbers are national estimates based on weighted frequencies and nonmissing data. Numbers and proportions may not sum to total or 100% due to missing values. All costs adjusted for inflation to 2015 US dollars.

[a] Admission source data for 2001–2011. Hospital ownership data for 2008–2012.

Table 5
Negative binomial regression of length of stay, US, NIS 2008–2014.

Characteristics	Estimate (95% CL)
Age (continuous)	**0.00 (0.00, 0.01)**
Sex (referent: male)	
Female	0.03 (−0.05, 0.11)
Race/ethnicity (referent: White)	
Black	**−0.17 (−0.27, −0.06)**
Hispanic	−0.12 (−0.37, 0.14)
API	−0.01 (−0.19, 0.16)
Other race	−0.09 (−0.23, −0.05)
Severe malaria complications (referent: no)	
Cerebral malaria	**0.43 (0.22, 0.64)**
Malaria with severe anemia	**0.48 (0.34, 0.61)**
Malaria with renal failure	**0.29 (0.16, 0.42)**
Malaria with ARDS	**0.79 (0.63, 0.95)**
Malaria with jaundice	0.04 (−0.10, 0.19)
Pre−existing conditions (referent: no)	
HIV infection	**0.19 (0.02, 0.36)**
Diabetes mellitus (type II)	0.10 (−0.07, 0.26)
Essential hypertension	0.03 (−0.11, 0.16)
Income by zip code (referent: high)	
Low	0.01 (−0.07, 0.09)
Primary payer (referent: Medicare)	
Medicaid	−0.19 (−0.44, 0.07)
Private insurance	**−0.39 (−0.58, −0.20)**
Self−pay	**−0.48 (−0.67, −0.28)**
No charge	**−0.29 (−0.54, −0.05)**
Other payer	−0.26 (−0.53, 0.01)
Hospital region (referent: West)	
Northeast	−0.02 (−0.27, 0.23)
Midwest	−0.06 (−0.31, 0.19)
South	0.01 (−0.16, 0.18)
Hospital Location (referent: urban)	
Rural	−0.26 (−0.57, −0.4)
Hospital Control (referent: gov., public)	
Private, non−profit	−0.11 (−0.22, 0.01)
Private, investor owned	−0.11 (−0.26, 0.05)
Hospital bed size (referent: large)	
Small	−0.03 (−0.14, 0.20)
Medium	0.02 (−0.51, −0.10)

Bold text represents estimates significant at the $p < 0.05$ level.

[35], or taking immunosuppressant medication [22], may be more susceptible to malaria and its severe manifestations. This study supports that older age and comorbid HIV infection are associated with longer LOS among malaria patients. It is important that health care providers have a high index of suspicion for malaria in patients presenting with unexplained febrile illness and elicit appropriate travel history [36] to enable prompt appropriate diagnosis [37] and treatment [38], particularly if they are in one of the high-risk groups.

In addition to demographic factors, we also found associations between institutional factors and direct and indirect costs for malaria-related hospitalizations, which were largely consistent with the overall patterns observed for all discharges in the NIS [39]. Confounding of the association between payer and LOS is also possible, in which patients with private insurance or no insurance may have been wealthier or had better baseline health before malaria, and thus were able to recover from malaria faster and with fewer complications. Malaria patients hospitalized in the western region had much higher charges and costs compared to all other regions, consistent with the higher charges and costs for all discharges in the NIS in the western region. LOS and hospital charges for patients hospitalized in rural locations were lower, which may be because more complicated, resource demanding cases are referred to hospitals in more urban locations that tend to offer higher level services. The higher hospital charges and lower hospital costs for patients hospitalized at private, investor-owned hospitals compared to public, government, nonfederal hospitals, may be due to differences in the business missions and in the number of patients served that require financial assistance and cost-shifting. The higher hospital costs for malaria patients hospitalized in hospitals with small bed size compared to large bed size is not consistent with that of overall discharges in the NIS, and may possibly be related to the relatively smaller bargaining power for acquiring malaria-related supplies compared to larger hospitals.

The NIS provides valuable information on direct and indirect costs, but some limitations should be considered. The economic burden of malaria cannot be fully captured by malaria-related hospitalizations alone. The number of days spent in the hospital has implications for, but does not quantify the costs of foregone income, opportunity costs of lost productivity in wage and household work, or the overall duration of impaired quality of life, which all extend to further costs during time spent as an outpatient in recovery [27]. Although hospital charges overestimate the direct costs of malaria-related hospitalizations since a markup is included, it does not account for professional fees, certain serology diagnostics, certain procedures used for diagnosis and treatment, the costs of treatment or management before and after hospitalization, the costs of outpatient services, and the cost of some emergency department services. Other the direct and indirect costs for fatal cases are also not included. Furthermore, the public expenditures on prevention, surveillance, and treatment (e.g. vector control, health facilities, education, research), and the cost of transportation to medical facilities and necessary support [40] are not accounted for in the total charges or costs, and the true total costs are likely to be more than what we report from this study. Error in the identification of the malaria-related hospitalizations, and its corresponding direct and indirect costs, is possible due to misdiagnoses, since malaria is a relatively rare disease with some non-specific clinical manifestations that can be difficult to diagnose [37]. The random and intentional (state-level suppression) missing values, especially for race, result in underestimation of the total and subgroup estimates since cases with missing values are excluded from the calculations of mean and sums. The final hospital bill for patients and other payers, and the accuracy of the patient discharge records cannot be verified by follow-up since identifying information have been stripped to pre-

Table 6
Multiple linear regression of log(charges) and log(costs), US, NIS 2008–2014.

Characteristics	Outcome	
	Log(charges) Estimate (95% CL)	Log(costs) Estimate (95% CL)
Age (continuous)	0.00 (0.00, 0.00)	**0.00 (0.00, 0.00)**
Sex (referent: male)		
Female	−0.04 (−0.10, 0.02)	−0.03 (−0.08, 0.02)
Race/ethnicity (referent: White)		
Black	−0.05 (−0.13, 0.03)	0.01 (−0.06, 0.08)
Hispanic	0.08 (−0.08, 0.24)	0.09 (−0.05, 0.23)
API	0.12 (0.00, 0.24)	0.06 (−0.04, 0.15)
Other race	0.04 (−0.06, 0.14)	0.06 (−0.03, 0.14)
Severe malaria complications (referent: no)		
Cerebral malaria	**0.17 (0.04, 0.30)**	**0.22 (0.12, 0.33)**
Malaria with severe anemia	**0.32 (0.21, 0.43)**	**0.34 (0.25, 0.43)**
Malaria with renal failure	**0.23 (0.15, 0.32)**	**0.16 (0.09, 0.23)**
Malaria with ARDS	**0.62 (0.47, 0.78)**	**0.65 (0.52, 0.78)**
Malaria with jaundice	−0.05 (−0.18, 0.08)	0.01 (−0.08, 0.11)
Pre−existing conditions (referent: no)		
HIV infection	**0.32 (0.16, 0.47)**	**0.24 (0.12, 0.37)**
Diabetes mellitus (type II)	**0.12 (0.02, 0.22)**	0.06 (−0.03, 0.14)
Essential hypertension	0.00 (−0.09, 0.09)	−0.03 (−0.10, 0.04)
Length of stay (referent: 0–1 days)		
2–3 days	**0.54 (0.45, 0.63)**	**0.52 (0.45, 0.59)**
4–6 days	**1.12 (1.02, 1.22)**	**1.08 (1.01, 1.16)**
7+ days	**1.82 (1.69, 1.96)**	**1.79 (1.67, 1.91)**
Income by zip code (referent: high)		
Low	0.00 (−0.07, 0.07)	**−0.07 (−0.12, −0.02)**
Primary payer (referent: Medicare)		
Medicaid	**−0.17 (−0.32, −0.02)**	−0.01 (−0.13, 0.12)
Private insurance	−0.13 (−0.27, 0.01)	−0.10 (−0.22, 0.02)
Self−pay	**−0.18 (−0.32, −0.03)**	**−0.14 (−0.27, −0.02)**
No charge	−0.03 (−0.26, 0.21)	−0.01 (−0.19, 0.17)
Other payer	−0.17 (−0.35, 0.00)	−0.08 (−0.23, 0.08)
Hospital region (referent: West)		
Northeast	**−0.23 (−0.35, −0.12)**	**−0.19 (−0.28, −0.11)**
Midwest	**−0.39 (−0.51, −0.27)**	**−0.23 (−0.35, −0.10)**
South	**−0.58 (−0.68, −0.48)**	**−0.37 (−0.46, −0.28)**
Hospital Location (referent: urban)		
Rural	**−0.37 (−0.58, −0.17)**	0.07 (−0.10, 0.24)
Hospital Control (referent: gov., public)		
Private, non−profit	0.00 (−0.12, 0.11)	−0.09 (−0.19, 0.01)
Private, investor owned	**0.47 (0.32, 0.62)**	**−0.21 (−0.34, −0.09)**
Hospital bed size (referent: large)		
Small	0.04 (−0.08, 0.16)	**0.09 (0.02, 0.16)**
Medium	**−0.12 (−0.22, −0.03)**	0.01 (−0.05, 0.07)

Bold text represents estimates significant at the $p < 0.05$ level.

serve confidentiality. Other potential factors of interest, including wealth, baseline health, laboratory results, pre-travel consultation, travel history, destination and purpose of travel, immigration and immunity status, and vector avoidance and chemoprophylaxis use were not available in NIS data to determine their distribution and association with direct and indirect costs of malaria.

Conclusion

This study demonstrates the magnitude of the economic impact of malaria in the US, which remains substantial despite its elimination in the early 1950s. Primary and secondary prevention measures should be emphasized in high-risk groups to reduce the economic burden. Health care providers and prospective travelers are encouraged to be familiar with malaria risk and prevention recommendations by country [22], which is publicly available from the CDC.

Conflicts of interest

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