MAJOR ARTICLE

Economics of Malaria Prevention in US Travelers to West Africa

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Background. Pretravel health consultations help international travelers manage travel-related illness risks through education, vaccination, and medication. This study evaluated costs and benefits of that portion of the health consultation associated with malaria prevention provided to US travelers bound for West Africa.

Methods. The estimated change in disease risk and associated costs and benefits resulting from traveler adherence to malaria chemoprophylaxis were calculated from 2 perspectives: the healthcare payer's and the traveler's. We used data from the Global TravEpiNet network of US travel clinics that collect de-identified pretravel data for international travelers. Disease risk and chemoprophylaxis effectiveness were estimated from published medical reports. Direct medical costs were obtained from the Nationwide Inpatient Sample and published literature.

Results. We analyzed 1029 records from January 2009 to January 2011. Assuming full adherence to chemoprophylaxis regimens, consultations saved healthcare payers a per-traveler average of $14 (9-day trip) to $372 (30-day trip). For travelers, consultations resulted in a range of net cost of $20 (9-day trip) to a net savings of $32 (30-day trip). Differences were mostly driven by risk of malaria in the destination country.

Conclusions. Our model suggests that healthcare payers save money for short- and longer-term trips, and that travelers save money for longer trips when travelers adhere to malaria recommendations and prophylactic regimens in West Africa. This is a potential incentive to healthcare payers to offer consistent pretravel preventive care to travelers. This financial benefit complements the medical benefit of reducing the risk of malaria.

Keywords. costs; benefits; malaria prevention; pretravel health consultation.

The Centers for Disease Control and Prevention (CDC) advises that international travelers seek pretravel health consultations 4–6 weeks before departure [1]. These consultations assess destination-specific risks (Figure 1) and prepare travelers to reduce illness and injury through education, vaccination, and medication. Effective consultations tailor recommendations based on medical history and travel-related activities [1].

Most travelers do not visit healthcare providers for pretravel health consultations despite CDC recommendations [2–4], because of lack of knowledge or concern about destination disease prevalence, insufficient time, or cost [2–4]. Furthermore, many commercial health insurance plans do not cover travel-related vaccinations and medications [5].

Malaria prevention is one important component of consultations for travelers visiting malaria-endemic areas.

Received 13 March 2013; accepted 19 July 2013; electronically published 6 September 2013.

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Clinical Infectious Diseases 2014;58(1):11–21

DOI: 10.1093/cid/cit570

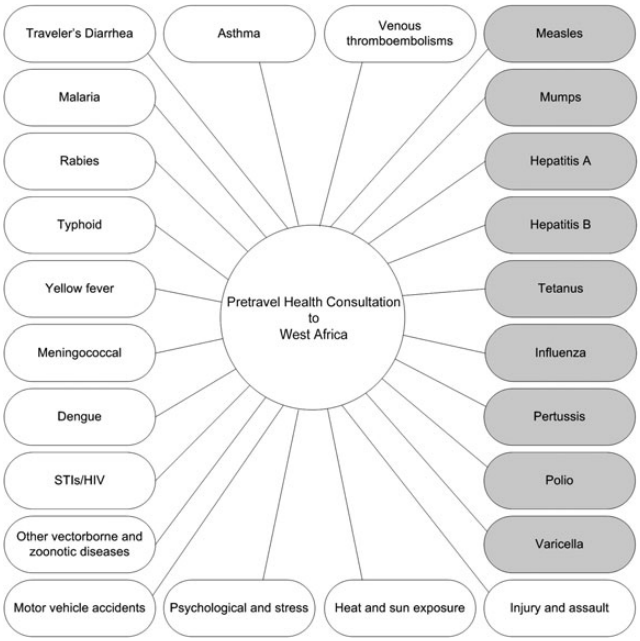

Figure 1. Examples of destination-specific diseases and health risks to a traveler to West Africa assessed via a pretravel health consultation. The pretravel health consultation will also provide an opportunity to confirm that routine vaccinations for diseases denoted in the shaded ovals are up-to-date or to administer these vaccines. Abbreviations: HIV, human immunodeficiency virus; STIs, sexually transmitted infections.

Malaria is a mosquito-borne infectious disease, caused by protozoa of the genus *Plasmodium*. In 2010, malaria caused 216 million infections and approximately 650 000 deaths worldwide [1, 6]. For travelers to West Africa, the risk of contracting malaria, especially the potentially severe *Plasmodium falciparum* form, is relatively high [1, 7].

To better understand the value of pretravel health consultations, we modeled costs and benefits of malaria education and chemoprophylaxis provided to US travelers destined for West Africa, considering both the healthcare payer's (payer) and the traveler's perspectives.

METHODS

Model Overview

Microsoft Excel (Microsoft Corporation, Redmond, Washington) was used to calculate the model estimating the expected value of the portion of pretravel health consultations targeted at malaria risk reduction. Expected value was defined as the difference between the sum of clinic visit and chemoprophylaxis costs and the monetary value of reduced risk of contracting malaria. Final outcome measures were net costs or savings using this equation:

$$\begin{aligned}&\text{Net costs or savings per traveler (expected value)}\\&= \text{Reduced risk of contracting malaria resulting from pre-travel health consultation and chemoprophylaxis adherence}\\&\times \text{Cost of malaria treatment} - [\text{Cost of pre - travel health consultation and chemoprophylaxis}]\end{aligned}$$

Disease risk reduction resulted from a combination of chemoprophylaxis effectiveness and adherence.

We evaluated the model from 2 perspectives: payer's (health insurer) and traveler's. The payer's perspective was calculated using direct costs of pretravel health consultations, chemoprophylaxis with adverse events treatment, and malaria treatment. The traveler's perspective included direct costs of copayments for these categories and assumed the traveler was insured. Opportunity costs were included for lost work time to the traveler. We did not quantify cost of death. All costs were expressed in undiscounted 2009 dollars because costs and benefits were incurred in the same year.

Pretravel Health Consultation Data: Travel Duration and Purpose

The Global TravEpiNet (GTEN) consortium clinic network represents academic, private, pharmacy-based, and public health medical practices [8]. At the time of the analysis, GTEN included 18 US clinics and systematically collected pretravel health consultation data. We identified 1029 of 13 235 GTEN travelers bound for West Africa from January 2009 to January 2011 (Supplementary Appendix, Section 1). West Africa includes Benin, Burkina Faso, Cape Verde, Côte d'Ivoire, The Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Mali, Mauritania, Niger, Nigeria, São Tomé and Príncipe, Senegal, Sierra Leone, and Togo [1].

The top 3 self-reported travel purposes were business, leisure, and visiting friends and relatives (VFR). Initial analyses determined that purpose-groups differed in trip duration and chemoprophylaxis choice (Supplementary Appendix, Table A1, Section 1). Median trip durations were 9 days (business), 14 days (leisure), 21 days (any travel purpose), and 30 days (VFR). The median trip duration was used to model malaria risk differences assuming longer durations were associated with greater risk. Group chemoprophylaxis choices were used to calculate weighted averages of drug effectiveness, costs, and probability of drug-related adverse events requiring medical attention. The expected value (net costs/savings per traveler) was estimated for each subgroup of business, leisure, VFR, and all travelers regardless of purpose. For sensitivity analyses, costs were recalculated using only 1 chemoprophylaxis at a time, and risk was varied to reflect other behavioral factors affecting disease likelihood such as staying in air-conditioned rooms, using insect repellent and

Table 1. Input Variables and References

Item	Baseline Value[a]	Range[a]	Reference
Probability of contracting malaria without chemoprophylaxis in West Africa[b]	24.2 cases per 1000 person-mo	12–70 per 1000 person-mo	[9, 10]
Probability of hospitalization for malaria acquired in West Africa[b,c]	71%	67%–74%	[7], Unpublished 2009 US malaria surveillance data, CDC
Effectiveness of malaria chemoprophylaxis			
Atovaquone/proguanil	95.8%	91.5%–97.5%	[11]
Doxycycline	92.6%	79.9%–97.5%	[12]
Mefloquine	94.5%	84.0%–98.1%	[13]
Probability of chemoprophylaxis-related adverse events requiring medical attention			
Atovaquone/proguanil	7%	2%–11%	[14]
Doxycycline	6%	2%–10%	[14]
Mefloquine	11%	6%–15%	[14]
Percentage adherence with chemoprophylaxis regimen[d]	100%	60%; 100%	[15], Assumption
Hourly compensation (US$, 2009)	32.79	15.98–48.66	[16, 17], Supplementary Appendix
Lost workdays for malaria treatment			
Ambulatory case	5 d	2–7 d	Assumption
Hospitalized case[e]	10 d	6–24 d	[18], Assumption

Abbreviation: CDC, Centers for Disease Control and Prevention.

[a] Baseline and range values were often taken from different resources. We used expert opinion to determine the most representative baseline values, and thus the baseline values are different from the simple middle or median of the range.

[b] West Africa included Benin, Burkina Faso, Cape Verde, Côte d'Ivoire, The Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Mali, Mauritania, Niger, Nigeria, São Tomé and Príncipe, Senegal, Sierra Leone, and Togo [1].

[c] The probability was estimated by dividing the number of hospitalized malaria cases from West Africa by the number of all malaria cases from West Africa (unpublished 2009 US malaria surveillance data, CDC).

[d] Reduced adherence rate here is the equivalent of not taking the drug as per recommendations to the point where no effective protection is obtained (eg, traveler obtains prescription but takes no doses). Those who do take the drug are assumed to be fully adherent to the recommended dosages.

[e] The lost workdays for hospitalized cases included days spent at both hospital and home for recuperation. Because *Plasmodium falciparum* accounted for 87% of hospitalized malaria cases where the disease was acquired in West Africa (unpublished 2009 US malaria surveillance data, CDC), length of stay at hospital of *P. falciparum* from Nationwide Impatient Sample data [18] was used as the representative length of stay at hospital.

bed nets, or chemoprophylaxis adherence, as well as destination transmission intensity.

Epidemiologic and Clinical Assumptions

The published risk of travelers for contracting malaria in West Africa was a point estimate of 24.2 cases per 1000 person-months (Table 1) [9]. Daily risk was assumed to be spread evenly over a month (ie, 0.81 cases per 1000 person-days in a 30-day month). The malaria-contraction risk was calculated by median travel duration; for example, a leisure traveler's malaria risk during a 14-day trip was 11.3 per 1000. A 71% probability of malaria hospitalization was used (Table 1).

A weighted average chemoprophylaxis was estimated by frequency of prescription of:

- Atovaquone/proguanil: 250 mg atovaquone and 100 mg proguanil hydrochloride, 1 tablet orally, daily, for 2 days before, through 7 days after travel.
- Doxycycline: 100 mg orally, daily, for 2 days before, through 4 weeks after travel.
- Mefloquine: 228 mg base (250 mg salt) orally, once a week, for 2 weeks before, through 4 weeks after travel.

The weighted average chemoprophylaxis effectiveness for each purpose and travel duration was estimated using published values of 92.6%–95.8% (Table 1) [11–13]. The reduced model probability of contracting malaria assumed 100% chemoprophylaxis regimen adherence using the following equation:

$$\begin{aligned}&(\text{probability of contracting malaria without chemoprophylaxis})\\&\quad\times(1-\text{weighted average prophylactic effectiveness})\\&\quad\times(\text{adherence rate})\\&\quad+(\text{probability of contracting malaria without}\\&\qquad\text{chemoprophylaxis})\times(1-\text{adherence rate}).\end{aligned}$$

In the sensitivity analyses, chemoprophylaxis adherence was reduced to 60%, making 40% of travelers unprotected.

Only those malaria chemoprophylaxis-related adverse events requiring medical care were calculated with literature-based adverse event probabilities (Table 1) [14].

Table 2. Costs (US$ 2009) Associated With Pretravel Health Consultations for Malaria Chemoprophylaxis: Healthcare Payer's and Traveler's Perspectives

Item	Baseline Value[a]	Range[a]	Reference
Healthcare payer's perspective (direct medical costs)			
Travel clinic visit[b]	$148.52	$126.27–$170.77	[19]
Percentage of travel clinic visit costs related to malaria prevention	14.8%	. . .	Supplementary Appendix
Malaria chemoprophylaxis (per adult dose)[c]			
Atovaquone/proguanil	$7.87	$6.40–$11.70[d]	[20]
Doxycycline	$1.08	$0.43–$1.78[d]	[20]
Mefloquine	$13.17	$9.46–$18.03[d]	[20]
Physician visit to treat adverse events[e]	$80.50	$69.00–$92.00	[19]
Prescription drug for adverse events[f]	$11.50	$7.00–$20.00	[20]
Traveler's perspective			
Direct costs			
Copayment for travel clinic visit	$30.00	$15.00–$170.77[g]	[5], Assumption
Copayment for physician office visit to treat adverse events	$20.00	$10.00–$50.00	[21], Assumption
Copayment for prescription drug	$25.00	$10.00–$50.00	[21], Assumption
Indirect costs			
Lost work hours for travel clinic visit (120 min)[h]	$65.57	$31.96–$97.32	[16, 17], Supplementary Appendix
Lost work hours for physician visit due to adverse events (60 min)[h]	$32.79	$15.98–$48.66	[16, 17], Supplementary Appendix

[a] Baseline and range values were often taken from different resources. We used expert opinion to determine the most representative baseline values, and thus the baseline values are different from the simple middle or median of the range.

[b] The cost for a travel clinic visit was calculated by using Current Procedural Terminology (CPT) codes in common use by the Global TravEpiNet clinics and the range of allowable billing charges associated with those CPT codes [19].

[c] The costs were calculated based on the following adult dose regimens: (1) atovaquone/proguanil, 250 mg atovaquone and 100 mg proguanil hydrochloride, 1 tablet orally, daily; (2) doxycycline, 100 mg orally, daily; and (3) mefloquine, 228 mg base (250 mg salt) orally, once a week [1].

[d] The lower and upper range values were 5th and 95th percentiles of listed wholesale prices, respectively.

[e] The cost of physician visit was estimated as the average of allowable billing charges of CPT code 99201 (office or other outpatient services, new patient level 1) [19].

[f] The cost of prescription drug was estimated based on the protocol of prochlorperazine 10 mg, 3 times daily for 4 days, for vomiting and nausea [20].

[g] In case a traveler is uninsured or his/her health insurance does not cover travel-related preventions, it was assumed the traveler paid the upper limit of $170.77 out-of-pocket costs of a travel clinic visit.

[h] The costs for lost work hours were calculated with the estimated hourly compensation of $32.79 (Table 1).

Costs Associated With Pretravel Health Consultations

Healthcare Payer's Perspective

Total payer pretravel clinic costs were calculated using allowable billing charges associated with Current Procedural Terminology (CPT) codes [19] of an average of $148 (range, $126–$170; Table 2). The portion of a consultation associated with malaria prevention was estimated at 14.8% of the total (Supplementary Appendix, Section 2.2). Weighted malaria chemoprophylaxis costs were included (weighting explained in the previous section) [20]. Adverse event medical treatment costs were estimated assuming 1 physician office visit and a prescription of prochlorperazine. Assumptions about physician-provided adverse event treatment were based on expert opinions regarding the most common complaint associated with chemoprophylaxis.

Traveler's Perspective

Total traveler's costs included out-of-pocket copayments for the consultation, adverse event treatments, prescription drugs, and opportunity costs of lost work time (Table 2). Lost work time was set at 120 minutes for a travel clinic visit and 60 minutes for adverse event medical care and was valued at $32.79 (Supplementary Appendix, Section 3). Traveler copayments and lost work time were prorated by 14.8% related to malaria prevention.

Costs Associated With Malaria Treatment

For both study perspectives, estimated treatment costs weighted the probability that travelers would need ambulatory and/or hospital medical care (Table 3).

Table 3. Costs (US$2009) Associated With Malaria Treatment: Healthcare Payer's and Traveler's Perspectives

Item	Baseline Value[a]	Range[a]	Reference
Healthcare payer's perspective (direct medical cost)			
Physician visit			
Ambulatory case[b]	$431	$365–$497	[19]
Hospitalized case[c]	$361.5	$306–$417	[19]
Test: blood film[d]			
Ambulatory case	$52.50	$46–$59	[19]
Hospitalized case	Included in hospitalization costs		[18]
Drugs for treatment[e]			
Ambulatory case	$41.75	$32–$51.5	[20]
Hospitalized case	Included in hospitalization costs		[18]
Hospitalization cost[f]	$29 320	$8545–$33 906	[18]
Inpatient physician services	20% of hospital charge	10%–40% of hospital charge	[22], Assumption
Travelers' perspective (direct and indirect costs)			
Direct costs			
Copayment for physician visits			
Ambulatory case[g]	$60	$30–$150	[5], Assumption
Hospitalized case[h]	$40	$20–$100	[5], Assumption
Copayment for prescription drug for treatment			
Ambulatory case	$25	$10–$50	[21], Assumption
Hospitalized case	Included in hospitalization costs		[18]
Hospitalization cost: copayment for hospital room and board plus Inpatient physician services charge	$250 plus 20% coinsurance of inpatient physician services charge	$0 (covered in full)–$5000 (maximum out-of-pocket)	[21], Assumption
Indirect costs			
Lost work hours for physician visit for treatment			
Ambulatory case[g,i]	$114.75	$55.93–$170.31	[16, 17], Supplementary Appendix
Hospitalized case[h,i]	$81.96	$39.95–$121.65	[16, 17], Supplementary Appendix
Lost workdays for medical care[j]			
Ambulatory case	$1311.44	$255.68–$2724.96	[16, 17], Supplementary Appendix
Hospitalized case	$2622.88	$767.04–$9342.72	[16, 17], Supplementary Appendix

[a] Baseline and range values were often taken from different resources. Baseline and range values were often taken from different resources. We used expert opinion to determine the most representative baseline values, and thus the baseline values are different from the simple middle or median of the range.

[b] The cost of physician visit for an ambulatory case was estimated using Current Procedural Terminology (CPT) codes for the total of 3 visits: the first visit for tests (CPT 99205, office or other outpatient services, new patient level 5); the second visit for diagnosis and drug prescription (CPT 99212, office or other outpatient services, established patient level 2); and the third visit for follow-up (CPT 99212, office or other outpatient services, established patient level 2). The range of allowable billing charges associated with those CPT codes was used [19].

[c] The cost of physician visits for a hospitalized case was estimated based on the total of 2 visits: the first visit for referral to a hospital (CPT 99205, office or other outpatient services, new patient level 5); and the second visit for follow-up after hospitalization (CPT 99212, office or other outpatient services, established patient level 2) [19].

[d] The cost of blood film test for malaria was estimated based on CPT code 87207 [19].

[e] The average cost of prescription drugs for malaria treatment was estimated as the weighted average costs of recommended drugs by the Centers for Disease Control and Prevention for uncomplicated malaria with *Plasmodium malariae*, *Plasmodium ovale*, or *Plasmodium vivax* [20, 23]. The weights were the proportion of those cases from West Africa in 2009 US malaria surveillance data [7]. West Africa included Benin, Burkina Faso, Cape Verde, Côte d'Ivoire, The Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Mali, Mauritania, Niger, Nigeria, São Tomé and Príncipe, Senegal, Sierra Leone, and Togo [1].

[f] Because *Plasmodium falciparum* was 87% of hospitalized malaria cases where the disease was acquired in West Africa (unpublished 2009 US malaria surveillance data, CDC), hospitalization costs of *P. falciparum* from Nationwide Inpatient Sample [16] data were used as the representative costs. The hospitalization cost is "the amount the hospital charged for the entire hospital stay. It does not include professional (MD) fees." [18] The lower and upper range values were 5th and 95th percentiles of hospitalization costs, respectively [18].

[g] The cost of physician visits for an ambulatory case was estimated based on the total of 3 visits (initial admission, diagnosis based on lab tests, and follow-up). A copayment for 1 physician visit was set at $20.

[h] The cost of physician visit for a hospitalized case was estimated based on the total of 2 visits (initial admission and follow-up). A copayment for 1 physician visit was set at $20.

[i] The costs for lost work hours were calculated with the estimated hourly compensation of $32.79 (Table 1). The time that a patient would miss work was estimated at 90 minutes for the initial physician visit and 60 minutes for each additional visit.

[j] Hours of lost workdays were estimated based on an 8-hour workday multiplied by the number of lost workdays (5 days for ambulatory care and 10 days for hospital care) and estimated hourly compensation of $32.79 (Table 1).

Healthcare Payer's Perspective

The payer's direct medical costs for hospitalized patients were 2 physician office visits and hospitalization care. Ambulatory patient medical costs were 3 physician visits, lab tests, and prescription drugs. Direct medical costs were obtained from the Nationwide Inpatient Sample (NIS) [18] and other publications [19, 20, 22, 23]. Because 87% of West Africa–acquired malaria cases requiring hospitalization were caused by *P. falciparum* (unpublished 2009 US malaria surveillance data, CDC), NIS hospitalization costs for *P. falciparum* were used.

Traveler's Perspective

The traveler's direct medical cost categories for ambulatory and hospitalizations were the same as the payer's and were modeled as copayments (Table 3). Opportunity costs (ie, lost work time), were estimated using (1) 10 days for hospital medical care and 5 days for ambulatory care (8 hours a day); and (2) multiple physician visits, 90 minutes for the initial visit and 60 minutes for additional visits. Lost workday estimates were a sum of NIS [18] data and adjustments for recuperation.

Sensitivity Analyses

Multiway sensitivity analyses from both perspectives recalculated model results using upper and lower input ranges for each purpose and duration of travel (Tables 1–3). For example, to establish a maximum upper estimate, net costs and savings were calculated using only upper input values for the risk range (instead of averages). This reflects a variety of unmeasurable behavioral factors that likely affect contracting malaria. These calculations were done at both 100% and 60% chemoprophylaxis adherence.

Furthermore, multiway sensitivity analyses included varying the transmission intensity at the destination; we assumed the risk-range of malaria contraction was the range of estimated incidence rates of pediatric nonsevere malaria in West Africa [10]. The range reported (151–853 per 1000 person-years) was assumed to be distributed evenly for each day (0.4–2.3 per 1000 person-days). We chose pediatric incident rates because travelers would be immunologically naive with respect to malaria and would have some similarity to young children in endemic areas.

We also calculated 1-way sensitivity analyses for both perspectives using 1 chemoprophylaxis at a time instead of weighted average costs and prescription rates of all malaria chemoprophylaxis options. Our final calculation was the break-even risk point where net cost/savings is equal to zero (Supplementary Appendix, Section 8).

RESULTS

From the payer's perspective, a weighted average cost to treat 1 malaria case was $25 250. The payers' costs for pretravel health consultations, malaria chemoprophylaxis, and adverse event treatment ranged from $161 to $208. When travelers adhered to chemoprophylaxis regimens, the likelihood of contracting malaria was reduced by 95%–96%; this greatly reduced the likelihood that payers would pay $25 250 for malaria treatment (Table 4). For example, the risk of contracting malaria was reduced from 11.3 to 0.52 per 1000 for leisure travelers and from 24.2 to 1.28 per 1000 for VFR travelers. This reduction produced per-traveler net savings for payers between $14 and $371, with respective ranges (lower bound and upper bound) of −$212 to $614 and −$218 to $2324 (Table 5; Figure 2).

From the traveler's perspective, weighted average out-of-pocket malaria treatment costs were $3387 per case. Out-of-pocket costs of pretravel health consultations and malaria chemoprophylaxis ranged from $44 to $46 (Table 5). With the 95%–96% reduction in disease risk from chemoprophylaxis adherence, the expected value (net cost or savings) ranged from a net cost of approximately $20 (lower and upper bounds, −$101 to $223) for a 9-day trip to a savings of $30 (lower and upper bounds, −$99 to $788) for a 30-day trip (Table 5; Figure 2).

Multiway sensitivity analyses resulted in wide ranges of net costs to savings; the range depended on travel duration and chemoprophylaxis adherence (Figures 2 and 3). For travelers, varying inputs at 100% adherence for short trips (9–14 days) were likely to have a net cost; net savings were more likely for longer trips. From the payer's perspective, varying inputs at 100% adherence, even for short trips, resulted in more net savings than costs. At 60% adherence, shorter trips usually resulted in net costs from both perspectives. However, as travel duration and malaria risk increased, net savings were more likely from both perspectives.

For the payer's-perspective, 1-way sensitivity analyses, assuming 1 chemoprophylactic drug, only the less expensive doxycycline increased net savings (Supplementary Appendix, Table A5). In addition, for the "all travelers" group, the break-even risk point at which net costs/savings is equal to zero was 8.6 per 1000. If only doxycycline was prescribed, the break-even risk point fell to 3.5 per 1000, resulting in net savings for the wider range of risk (Supplementary Appendix, Table A5). Therefore, assuming use of doxycycline and 100% adherence, we found that net savings to healthcare payers would result when the risk of malaria at a destination exceeds 0.13–0.33 per 1000 person-days of travel, indicating that even when risk approaches 0, chemoprophylaxis not only reduces the risk of malaria, but results in cost savings. The more expensive atovaquone/proguanil resulted in decreases in net savings of 26%–60%.

DISCUSSION

Pretravel health consultations for malaria prevention, including education for insect bite prevention and chemoprophylaxis

Table 4. Risk of Contracting Malaria and Reduction in Risk Associated With Malaria Chemoprophylaxis to Travelers to West Africa[a]

Probabilities of Contracting Malaria	Purpose of Travel[b] (Median Planned Length of Travel)[c]			
	Business (9 d)	Leisure (14 d)	All Purposes (21 d)	VFR[b] (30 d)
Probability of contracting malaria without chemoprophylaxis[d]	7.3 per 1000	11.3 per 1000	16.9 per 1000	24.2 per 1000
Probability of contracting malaria with chemoprophylaxis[e]	0.33 per 1000	0.52 per 1000	0.83 per 1000	1.28 per 1000
Reduction in probability of contracting malaria (weighted average efficacy of malaria chemoprophylaxis)[f]	95.51%	95.41%	95.09%	94.70%

100% adherence for malaria chemoprophylaxis regimens was assumed.

Abbreviation: VFR, visiting friends and relatives.

[a] Costs were in 2009 dollars. West Africa included Benin, Burkina Faso, Cape Verde, Côte d'Ivoire, The Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Mali, Mauritania, Niger, Nigeria, São Tomé and Príncipe, Senegal, Sierra Leone, and Togo [1]. Travelers to West Africa were identified as those travelers who planned to visit 1 or more countries only in West Africa (Supplementary Appendix Section 1).

[b] For their pretravel health consultations, travelers were asked to report their purpose(s) of travel from the following (multiple choices were allowed): leisure, business, returning to region of origin of self or family to visit friends and relatives, adoption, providing medical care, receiving medical care, research/education, nonmedical service work, missionary work, military service, adventuring, attending large gathering or event, or other activities [8]. For this analysis, travelers who reported only 1 of the 3 purposes (ie, business, leisure, and VFR) were selected. All purposes denote all travelers to West Africa.

[c] The median planned length of travel for each category of the purposes of travel was calculated among travelers to West Africa (Supplementary Table A1).

[d] Daily risk was assumed to be spread evenly over a month (ie, 0.81 cases per 1000 person-days in a 30-day month). The probability of contracting malaria without chemoprophylaxis was calculated by median travel duration; eg, a leisure traveler's malaria-risk during a 14-day trip was 0.81 per 1000 × 14 days = 11.3 per 1000.

[e] The probability of contracting malaria with chemoprophylaxis was calculated by multiplying the probability of contracting malaria without chemoprophylaxis by (1 – weighted average efficacy of chemoprophylaxis), eg, (7.3/1000) × (1–0.9551) = 0.33/1000 for business travelers.

[f] The frequency of chemoprophylaxis prescription (Supplementary Table A1) was used as weights.

prescriptions, more often than not resulted in net savings. Specifically, from the payer's perspective, malaria prevention in pretravel health consultations were, on average, cost savings at the baseline and upper bound inputs, regardless of trip duration. Pretravel health consultation payments and chemoprophylaxis (assuming 100% adherence) reduced per-traveler risk-adjusted treatment costs. This result was consistent regardless of travel duration (9–30 days) for baseline inputs. For upper bound inputs, savings increased sharply as risk increased, whereas the lower bound resulted in decreasing net costs as risk increased for each travel duration.

From the traveler's perspective, net costs or savings changed according to travel duration and malaria risk. Recalling that purpose and travel duration were calculated together lends a qualitative layer to the result interpretation. VFR travelers took the longest duration of trips, and results show that those traveling longer durations were more likely to save money with pretravel health consultations and chemoprophylaxis because their risks of contracting malaria were higher. VFR travelers may also be more likely to have increased risk of malaria because they may stay in familial communities where malaria is endemic, as opposed to shorter-duration business travelers who may stay in larger cities and hotels. Regardless of duration, purpose, or behavior patterns, travelers who engaged in higher-risk behaviors (eg, no bednets, no insect repellent) would be more likely to have a net savings from malaria pretravel care. As with the payer's perspective, the lower bounds of inputs into the traveler's perspective resulted in decreasing net costs as risk increased for each trip duration.

The few published economic studies of pretravel health consultations have focused on European travelers [24–26] where all travelers are assumed to take only 1 type of chemoprophylaxis: atovaquone/proguanil [26], mefloquine, or chloroquine and proguanil [24]. These studies conclude that pretravel healthcare and chemoprophylaxis are economically advantageous for travelers to West Africa. By comparison, our study was based on more detailed traveler characteristics and incorporated multiple chemoprophylaxis types based on GTEN practices, a large national consortium. These factors most likely improve the real-world applicability of our results, especially as several antimalarial drugs remain in use for US travelers. Our study found that payers, in most cases, saved money when travelers follow pretravel health recommendations and chemoprophylaxis regimens. Because malaria prevention saves money for third-party payers, these results can help payers consider expanding reimbursements and more strongly emphasize the benefits of pretravel health consultations and malaria chemoprophylaxis.

Many travelers do not understand their risk of contracting malaria, whether in West Africa or elsewhere [27]. Where travelers are insured, a payment of $44 could reduce their risk of contracting malaria by at least 93%. This $44 expenditure to receive both a pretravel health consultation and chemoprophylaxis

Table 5. Results of Baseline Analysis: Net Costs or Savings due to Pretravel Health Consultations Among Travelers to West Africa[a]

Stakeholder Cost Categories by Perspective	Purpose of Travel[b] and Median Planned Length of Travel[c]			
	Business 9 d	Leisure 14 d	All Purposes 21 d	VFR[b] 30 d
Healthcare payer's perspective				
Weighted average direct cost for treatment, US$[d]	25 250			
Cost of pretravel health consultation, chemoprophylaxis, and treatment of adverse events associated with chemoprophylaxis (Supplementary Appendix Table A2), $	161.42	189.76	207.59	207.03
Net cost/savings per person per trip, $[e]	13.65 (net savings)	82.32 (net savings)	199.14 (net savings)	371.64 (net savings)
(Lower bound, upper bound)	(−212.25, 613.72)	(−240.08, 1003.94)	(−246.79, 1571.12)	(−218.43, 2324.12)
Traveler's perspective				
Weighted average out-of-pocket cost (direct plus indirect) for treatment, $[d]	3387			
Out-of-pocket cost of pretravel health consultation, chemoprophylaxis, and treatment of an adverse event associated with chemoprophylaxis (Supplementary Appendix Table A3), $	43.78	44.15	44.70	45.58
Net cost/saving per person per trip, $[e]	−20.30 (net costs)	−7.66 (net costs)	9.86 (net savings)	32.04 (net savings)
(Lower bound, upper bound)	(−100.72, 223.21)	(−100.16, 357.19)	(−99.51, 545.19)	(−99.11, 787.85)

100% adherence for malaria chemoprophylaxis regimens was assumed.

Abbreviation: VFR, visiting friends and relatives.

[a] Costs were in US 2009 dollars. West Africa included Benin, Burkina Faso, Cape Verde, Côte d'Ivoire, The Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Mali, Mauritania, Niger, Nigeria, São Tomé and Príncipe, Senegal, Sierra Leone, and Togo [1]. Travelers to West Africa were identified as those travelers who planned to visit 1 or more countries only in West Africa (Supplementary Appendix Section 1).

[b] For their pretravel health consultations, travelers were asked to report their purpose(s) of travel from the following (multiple choices were allowed): leisure, business, returning to region of origin of self or family to visit friends and relatives, adoption, providing medical care, receiving medical care, research/education, nonmedical service work, missionary work, military service, adventuring, attending large gathering or event, or other activities [8]. For this analysis, travelers who reported only 1 of the 3 purposes (ie, business, leisure, and VFR) were selected. All purposes denote all travelers to West Africa.

[c] The median planned length of travel for each category of the purposes of travel was calculated among travelers to West Africa (Supplementary Table A1).

[d] Treatment cost of a malaria case was a weighted averaged between costs for ambulatory and hospital medical care using the probability of each care among travelers to West Africa as the weight (Table 1).

[e] A negative value indicates that pretravel health consultation for malaria prevention will result in a net cost to healthcare payer or a traveler, whereas a positive value indicates a net savings to a healthcare payer or a traveler. The lower and upper ranges were calculated by using lower and upper values of input and cost parameters in Tables 1–3.

may seem reasonable in contrast to the possibilities of serious illness, and of personally needing to pay approximately $3400 for treatment. When the traveler is uninsured, potential direct costs would be at least those of the payer (approximately $200 for consultation and chemoprophylaxis, and $25 250 for malaria treatment). Because of this, uninsured travelers possibly would be more likely than insured travelers to receive a net savings from pretravel care and chemoprophylaxis; however, we did not specifically calculate the potential net savings for uninsured travelers in this analysis. Knowledge of cost considerations may encourage travelers to schedule a pretravel health consultation. Furthermore, our analyses of the impact of reduced adherence illustrated the importance of following mosquito avoidance practices and adhering to the prescribed malaria chemoprophylaxis regimens.

Our study focused solely on the single measure of the economics of preventing malaria, but pretravel health consultations encompass many aspects of travel medicine (Figure 1). During consultations, practitioners provide comprehensive advice to assist travelers with issues such as adverse conditions resulting from extreme heat and cold, motor vehicle accidents or other activities, or altitude sickness. Practitioners administer vaccines for destination-specific infectious diseases and provide counseling on infectious disease prevention. These consultations are also an opportunity to confirm that travelers are up-to-date on routine vaccinations. Practitioners also provide advice on food and water precautions and prescribe medications to treat travelers' diarrhea. Evaluating costs and benefits of all features encompassed in pretravel health consultations could provide more comprehensive estimates of overall costs and benefits.

Our study had several limitations. First, the major limitation is the uncertainty regarding the risk of malaria for travelers not taking malaria chemoprophylaxis. We have based our primary

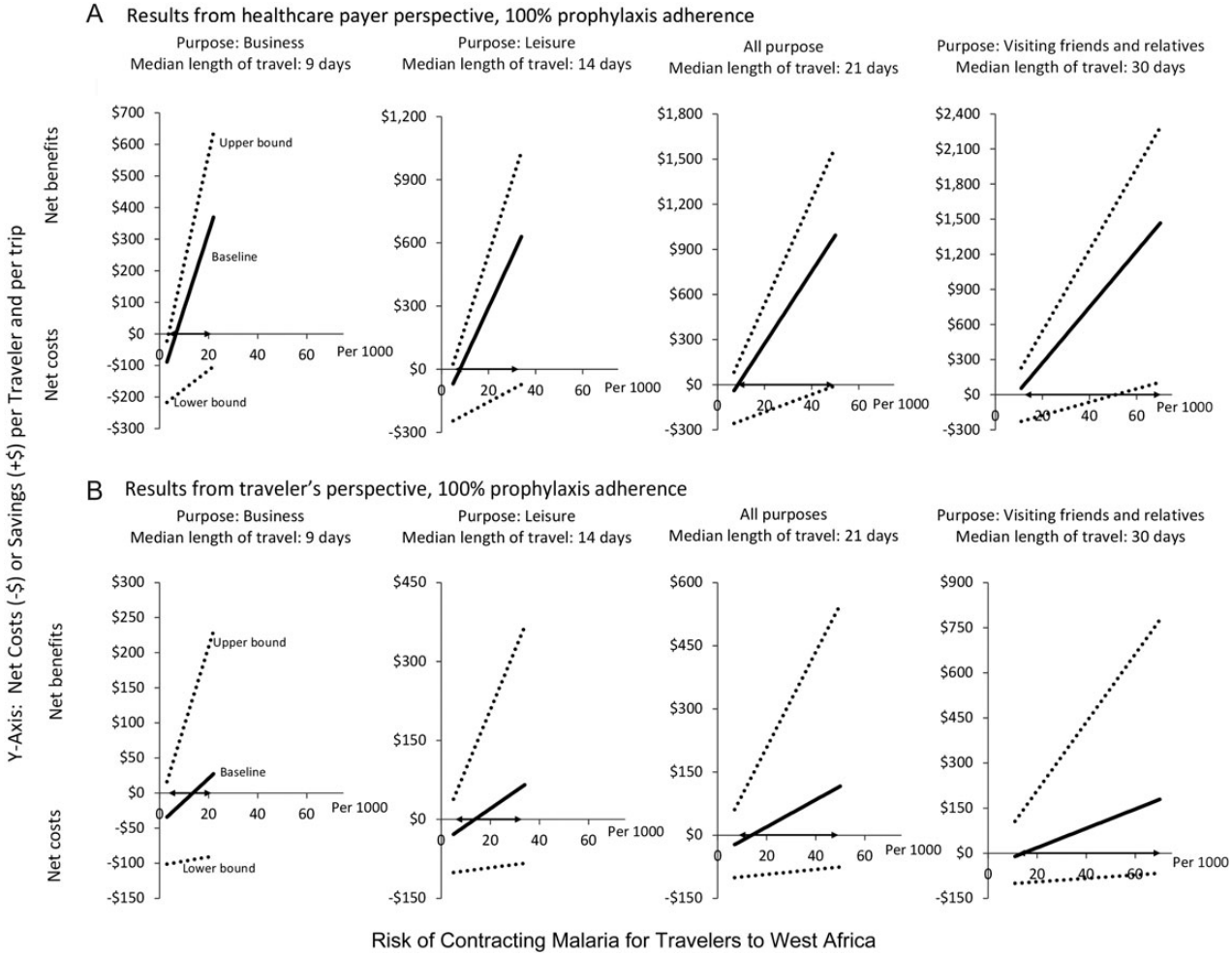

Figure 2. Net costs/savings for pretravel health consultations against malaria with 100% adherence to recommended malaria chemoprophylaxis regimens: healthcare payer's perspective (*A*); traveler's perspective (*B*). The estimations were carried out by simultaneously varying the risk of contracting malaria, input parameters, and various cost categories by using upper, baseline, and lower bounds of ranges (Tables 1–3). A negative value on the vertical axis indicates that pretravel health consultations against malaria will result in a net cost to a healthcare payer or traveler, whereas a positive value indicates a net savings to a healthcare payer or traveler. West Africa included Benin, Burkina Faso, Cape Verde, Côte d'Ivoire, The Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Mali, Mauritania, Niger, Nigeria, São Tomé and Príncipe, Senegal, Sierra Leone, and Togo [1]. The arrow line (↔) on the horizontal axis indicates the range of risk of contracting malaria adjusted for the length of travel using the estimated incidence rate (0.4 per 1000 person-days to 2.3 per 1000 person-days) [10]. The daily risk was assumed to be spread evenly over the median length of travel; eg, for a leisure traveler, the range of malaria risk during a 14-day trip was from 5.6 per 1000 (0.4 per 1000 × 14 days) to 32.2 per 1000 (2.3 per 1000 × 14 days).

analysis on the last risk assessment in the absence of chemoprophylaxis of which we are aware [9]. To mitigate this, we have also included a sensitivity analysis assessing across a range of risk. A reanalysis might be warranted if reliable and more up-to-date malaria risk estimates of travelers who take no chemoprophylaxis become available. A second limitation is that our models did not include impact of individual traveler behavior, which could be more influential than travel duration in determining the risk for contracting malaria. To mitigate this limitation, we performed additional sensitivity analyses taking varying risk levels into account, although risk remains difficult to quantify. Third, our model does not incorporate costs for rarer but more serious potential adverse events associated with chemoprohylactic regimens, but instead assumes a relatively high rate of the most common adverse events. Fourth, we did not quantify the potential travel costs incurred from early departures from West Africa due to illness, the pain and suffering associated with disease, or the cost of death. As a result, our findings are most likely an underrepresentation of the costs associated with malaria. Fifth, we assumed that travelers were insured because the proportion of insured versus uninsured travelers is unknown. Finally, our model also focused solely on travel to West Africa, a region of particular risk

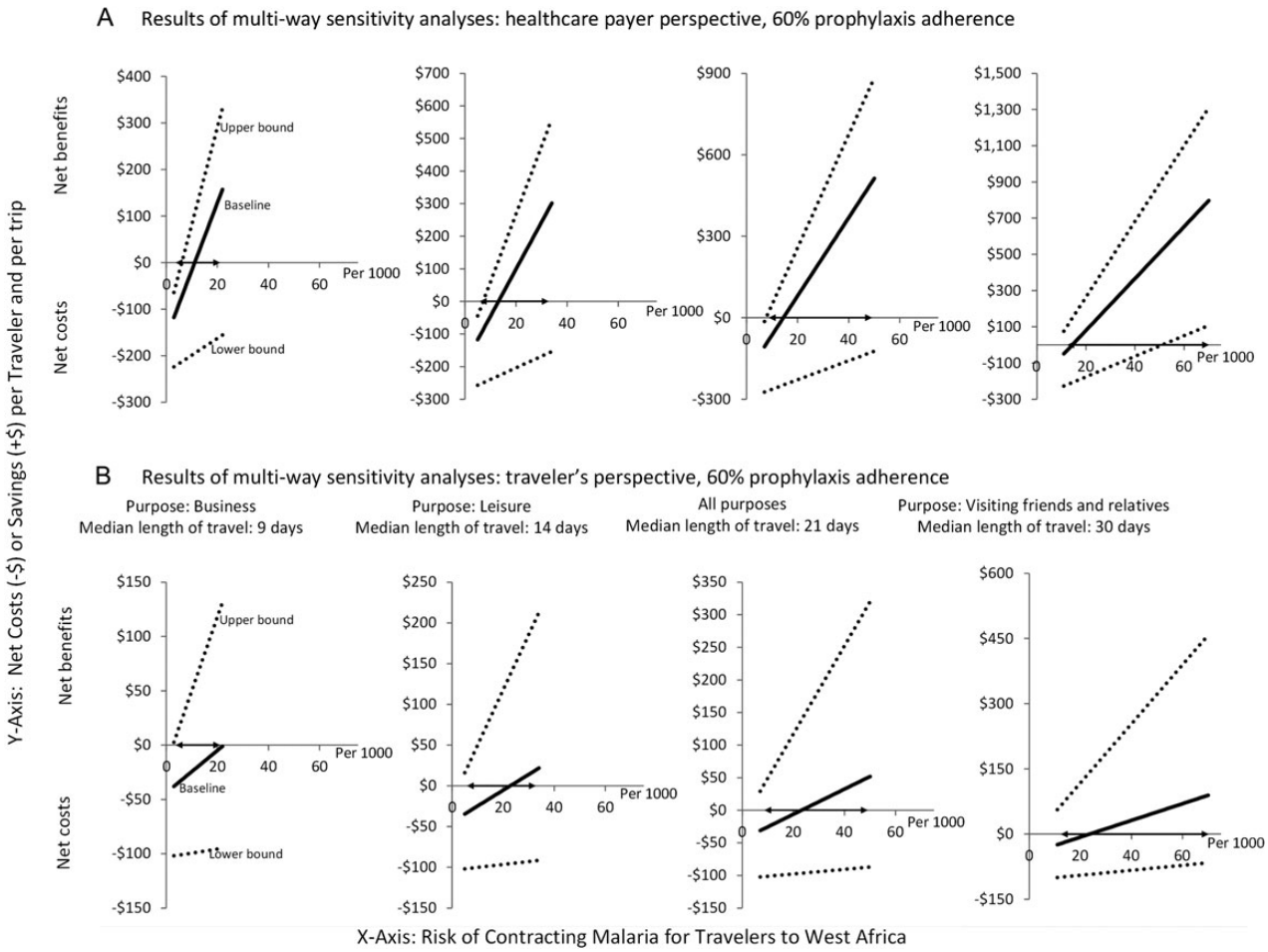

Figure 3. Multiway sensitivity analyses: 60% adherence to recommended malaria chemoprophylaxis regimens—net costs/savings for pretravel health consultation against malaria: healthcare payer's perspective (*A*); traveler's perspective (*B*). Multiway sensitivity analyses were conducted by simultaneously varying the risk of contracting malaria, input parameters, and various cost categories by using upper, baseline, and lower bounds of ranges (Tables 1–3). A negative value on the vertical axis indicates that pretravel medical consultation against malaria will result in a net cost to a healthcare payer or a traveler, whereas a positive value indicates a net savings to healthcare payer or a traveler. West Africa included Benin, Burkina Faso, Cape Verde, Côte d'Ivoire, The Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Mali, Mauritania, Niger, Nigeria, São Tomé and Príncipe, Senegal, Sierra Leone, and Togo [1]. The arrow line (↔) on the horizontal axis indicates the range of risk of contracting malaria adjusted for the length of travel using the estimated incidence rate (0.4 per 1000 person-days to 2.3 per 1000 person-days) [10]. The daily risk was assumed to be spread evenly over the median length of travel; eg, for a leisure traveler, the range of malaria risk during a 14-day trip was from 5.6 per 1000 (0.4 per 1000 × 14 days) to 32.2 per 1000 (2.3 per 1000 × 14 days).

for malaria. Future analyses could include economic evaluation of travel to areas of the world with differing risks for malaria, although our sensitivity analyses suggest parameters for costs and savings for such trips. For instance, our model suggests that a pretravel consultation and malaria chemoprophylaxis (assuming, for example, use of doxycycline and 100% adherence) would result in net savings to healthcare payers when the risk of malaria at a destination exceeds 0.13–0.33 per 1000 person-days of travel.

In conclusion, our study highlights that pretravel health consultations with advice on insect bite prevention and malaria chemoprophylaxis (assuming 100% adherence) cannot only reduce the risk of contracting malaria for a traveler to West Africa, but also likely save money to healthcare payers overall and to travelers with high-risk situations, such as longer visit duration (2 weeks or more). Thus, there is a potential monetary incentive for payers to offer pretravel preventive care to travelers.

Supplementary Data

Supplementary materials are available at *Clinical Infectious Diseases* online (http://cid.oxfordjournals.org). Supplementary materials consist of data provided by the author that are published to benefit the reader. The posted materials are not copyedited. The contents of all supplementary data are the sole responsibility of the authors. Questions or messages regarding errors should be addressed to the author.

Notes

Acknowledgments. We thank the following for their contributions of data or conceptual discussions: Anna Newton, Christopher de la Motte Hurst, Katrin Kohl, Ava Navin, Clive Brown, and David McAdam. Members of the Global TravEpiNet Consortium (in alphabetical order) include George M. Abraham, Saint Vincent Hospital (Worcester, MA); Salvador Alvarez, Mayo Clinic (Jacksonville, FL); Vernon Ansdell and Johnnie A. Yates, Travel Medicine Clinic, Kaiser Permanente (Honolulu, HI); Elisha H. Atkins, Chelsea HealthCare Center (Chelsea, MA); John Cahill, Travel and Immunization Center, St Luke's-Roosevelt (New York, NY); Holly K. Birich and Dagmar Vitek, Salt Lake Valley Health Department (Salt Lake, Utah); Bradley A. Connor, New York Center for Travel and Tropical Medicine, Cornell University (New York, NY); Roberta Dismukes and Phyllis Kozarsky, Emory TravelWell, Emory University (Atlanta, GA); Ronke Dosunmu, JourneyHealth (Maywood, NJ); Jeffrey A. Goad, International Travel Medicine Clinic, University of Southern California (Los Angeles, CA); Stefan Hagmann, Division of Pediatric Infectious Diseases, Bronx Lebanon Hospital Center (Bronx, NY); DeVon Hale, International Travel Clinic, University of Utah (Salt Lake City, UT); Noreen A. Hynes, John Hopkins Travel and Tropical Medicine, Division of Infectious Diseases, John Hopkins School of Medicine (Baltimore, MD); Frederique Jacquerioz and Susan McLellan, Tulane University (New Orleans, LA); Mark Knouse, Keystone Travel Medicine, Lehigh Valley Health Network (Allentown, PA); Jennifer Lee, Travel and Immunization Center, Northwestern Memorial Hospital (Chicago, IL); Regina C. LaRocque and Edward T. Ryan, Massachusetts General Hospital (Boston, MA); Alawode Oladele and Hanna Demeke, DeKalb County Board of Health Travel Services–DeKalb North and Central–T.O. Vinson Centers (Decatur, GA); Roger Pasinski and Amy E. Wheeler, Revere HealthCare Center (Revere, MA); Sowmya R. Rao, University of Massachusetts (Worcester, MA); Jessica Rosen, Infectious Diseases and Travel Medicine, Georgetown University (Washington, DC); Brian S. Schwartz, Travel Medicine and Immunization Clinic, University of California (San Francisco, CA); William Stauffer and Patricia Walker, HealthPartners Travel Medicine Clinics (St Paul, Minnesota); Lori Tishler, Phyllis Jen Center for Primary Care, Brigham and Women's Hospital (Boston, MA): and Joseph Vinetz, Travel Clinic, Division of Infectious Diseases, Department of Medicine, University of California, San Diego School of Medicine (La Jolla, CA).

Financial support. This work was supported by the CDC (Cooperative Agreements U19CI000514 and U01CK000175).

Disclaimer. The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the Centers for Disease Control and Prevention.

Potential conflicts of interest. All authors: No reported conflicts.

All authors have submitted the ICMJE Form for Disclosure of Potential Conflicts of Interest. Conflicts that the editors consider relevant to the content of the manuscript have been disclosed.

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