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Analysis of the Pediatric Health Information System Database as a Surveillance Tool for Travel-Associated Infectious Diseases

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Abstract. The Pediatric Health Information System (PHIS) database collects admission, diagnostic, and treatment data among 44 children's hospitals across the United States (U.S.) and presents an opportunity for travel-associated infectious disease (TAID) surveillance. We calculated cumulative incidence rates among children admitted to 16 PHIS hospitals for dengue, malaria, and typhoid, and pooled TAID using discharge codes from 1999 to 2012. We compared incidence rates before, during, and after the 2007–2009 economic recession. Among 16 PHIS hospitals during the study period (1999–2012), incidence of dengue and pooled TAID (malaria, dengue, typhoid fever) increased significantly, and rates of malaria and typhoid trended upward. Admissions for dengue and pooled TAIDs increased significantly among 16 children's hospitals across the United States from 1999 to 2012. The PHIS database may provide a useful surveillance tool for TAIDs among children in the United States.

International travel to other countries has increased 5% in the United States and 48% worldwide in the last decade, and more travelers visit low- and middle-income countries (LMICs) than ever before.[1] As many as 8% of U.S. travelers seek medical care, and many more suffer from milder illness while abroad.[2–4] A significant proportion of the 62 million annual U.S. international travelers develops illness after returning to the United States with infections that may be unfamiliar to local health-care providers.[5–7] Estimating incidence rates of non-endemic diseases may help public health officials direct educational resources and raise awareness among local practitioners.

Currently, surveillance systems for travel-associated infectious diseases (TAIDs) in the United States are limited. Many TAIDs are reportable to state health departments, but reporting is often unreliable.[8] The GeoSentinel Surveillance Network (GSSN) is a system of 57 travel disease clinics worldwide, including 15 clinics in the United States. Although the GSSN obtains robust clinical and diagnostic information, it surveys only those seeking care at specialty travel clinics, and only 7% of GSSN patients are children.[1]

The Pediatric Health Information System (PHIS) database was established to collect administrative and financial data from pediatric hospitals across the Unites States. More recently, the database has been augmented (PHIS+) to also collect clinical, laboratory, treatment, and outcome data at multiple health-care settings (inpatient, outpatient, and emergency departments [EDs]) among 44 freestanding children's hospitals across the United States.[9,10] It offers an opportunity for objective hospitalized TAID surveillance among the greater than 5 million children hospitalized annually at these institutions.[11] We evaluated the PHIS database as a potential TAID surveillance tool by determining cumulative incidence rates of three TAIDs (malaria, dengue, and typhoid fever) among PHIS hospitals over a 14-year period.

A total of 16 PHIS hospitals from geographically diverse metropolitan areas (median population 426,001 people, interquartile range 247,026–757,907 people)[12] had non-missing data available during the study period (1999–2012). The metropolitan areas include San Diego, CA; Norfolk, VA; St. Petersberg, FL; Orange County, CA; Corpus Christi, TX; Miami, FL; Denver, CO; Memphis, TN; Chicago, IL; Akron, OH; Little Rock, AR; Columbus, OH; Fort Worth, TX; Omaha, NE; Milwaukee, WI; and St. Louis, MO. All inpatient discharges from these sites with a principal discharge diagnosis (International Classification of Diseases 9 [ICD-9]) code[13] for malaria (0840, 0841, 0842, 0843, 0846, 0849), typhoid (0020), and dengue (061) were identified within the PHIS database. Readmissions for the same ICD-9 diagnosis were excluded from the analysis. Cumulative incidence rates of malaria, typhoid, and dengue as well as pooled TAID incidence rates for all three diseases were determined by dividing hospitalized cases by total hospital discharges per year. Individual disease and pooled incidence rates were compared over the study period (1999–2012). We hypothesized that TAID incidence rates may have decreased during the 2007–2009 economic recession due to decreased international travel, and thus, rates for before (1999–2006), during (2007–2009), and after the U.S. economic recession were compared.[7,14,15] Categorical variables were compared using χ^2 with Fisher's exact testing when appropriate.

The 16 PHIS hospitals represented 2,203,063 pediatric hospital admissions during the study period. Individual and pooled cumulative TAID incidence trended upward from 1999 to 2012, though the trend did not achieve statistical significance ($r^2 = 0.158$). When comparing cumulative incidence rates from before (1999–2006), during, and after (2010–2012) the 2007–2009 economic recession, there was a significant change in incidence rates for dengue ($P = 0.016$) and pooled TAID ($p = 0.009$), though all diseases studied showed a similar trend with decreases during the recession and highest rates after (Table 1, Figure 1).

We observed an increasing trend of three TAIDs among children in the United States over a 14-year period. Other data support this trend. From 1999 to 2011, passive surveillance from the Centers for Disease Control and Prevention (CDC) showed an increase in malaria incidence of 9%, an increase in typhoid incidence of 50%, and an increase in dengue incidence of 117%.[16–18] Although the CDC data indicate a greater increase in TAID incidence than our data, it should be noted that their sample population includes adults in addition to

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TABLE 1

Hospital admission incidence rates of travel-associated infectious diseases (TAIDs) in children before, during, and after the 2007–2009 economic recession.

	1999–2006	2007–2009	2010–2012
Malaria	6.7	6.4	8.4
Typhoid	5.0	4.4	7.0
Dengue*	1.1	0.6	2.5
Pooled*†	12.9	11.3	18.0

Cumulative incidence rates (cases per 100,000 admissions) from before (1999–2006), during, and after (2010–2012) the U.S. economic recession.
*Reached statistical significance between 2007–2009 and 2010–2012.
†Reached statistical significance between 1999–2006 and 2010–2012.

children and their surveillance systems have improved over the same time period, thus increasing disease detection and raising estimated incidence rates. Improved diagnostics, especially for dengue, may have influenced our increased case detection as well.

The PHIS database offers several strengths as a surveillance tool. Cases are determined by ICD-9 code, which is consistently documented in hospital records between hospitals and over time, whereas passive reporting may be incomplete.[8] The scope of the PHIS database is another significant advantage. Our study with 16 PHIS hospitals demonstrated an upward trend in TAIDs over a time period that included an economic recession. Though our data were limited by low case numbers, the PHIS database has since grown significantly larger, consisting of 44 pediatric hospitals with 605,966 admissions, 2,803,675 ED visits, and 1,504,384 outpatient visits in 2013, reflecting a large proportion of children seeking medical care across the United States. Although our primary aim was to estimate incidence of TAIDs using ICD-9 coding, the PHIS database also offers additional data, including diagnostic tests performed, epidemiologic information, clinical data, and mortality, which can be used for a variety of purposes such as determining risk factors for acquiring disease. Regional data among PHIS hospitals can be compared as well.

There are several notable weaknesses to our use of the PHIS database in disease surveillance. Data in the PHIS database are made available every 3 months, so real-time data are unavailable. We analyzed only hospitalization discharge data from selected pediatric hospitals, likely representing a small fraction of all clinical illness in traveling children. We used only principal ICD-9 diagnosis code in our analysis assuming the TAID would be the primary reason for hospitalization. Using all ICD-9 codes as well as including ED and outpatient visits may increase the sensitivity of detection, but coding variation may also bias estimates of disease incidence. ICD-9 codes may also not always reflect a patient's actual diagnosis, though appropriate laboratory testing for TAIDs is available and should be used in the United States to increase diagnostic accuracy. Typhoid and, more recently, dengue are endemic within the United States, though they remain strongly associated with travel. Another limitation of the PHIS database is that it collects limited epidemiologic data such as travel history. As a result, we were unable to further characterize risk factors for acquiring TAIDs such as type of travel, reason for travel, and immigration status. Although our analysis defined the U.S. economic recession as 2007–2009, the decrease in outbound international travel appears to have continued early into the recovery, reaching a nadir in 2011.[7] Given our restricted sample population of 16 pediatric hospitals, we did not perform a comparison of TAID hospitalization incidence using outbound international travel data as an unspecific denominator because it was unlikely to produce meaningful results.

In summary, we identified a novel tool for TAID surveillance among children in the United States. Consistent with passive reporting data, the PHIS database demonstrated an increased trend of individual and pooled TAIDs over the last 14 years. The database also demonstrated significantly increased rates in dengue and pooled TAIDs when comparing before, during, and after the 2007–2009 economic recession. The increased incidence rates should remind providers to remain vigilant about TAIDs, especially as outbound U.S. travel continues to increase. Now with 44 participating children's hospitals across the United States, the PHIS database may provide a useful and objective instrument for disease

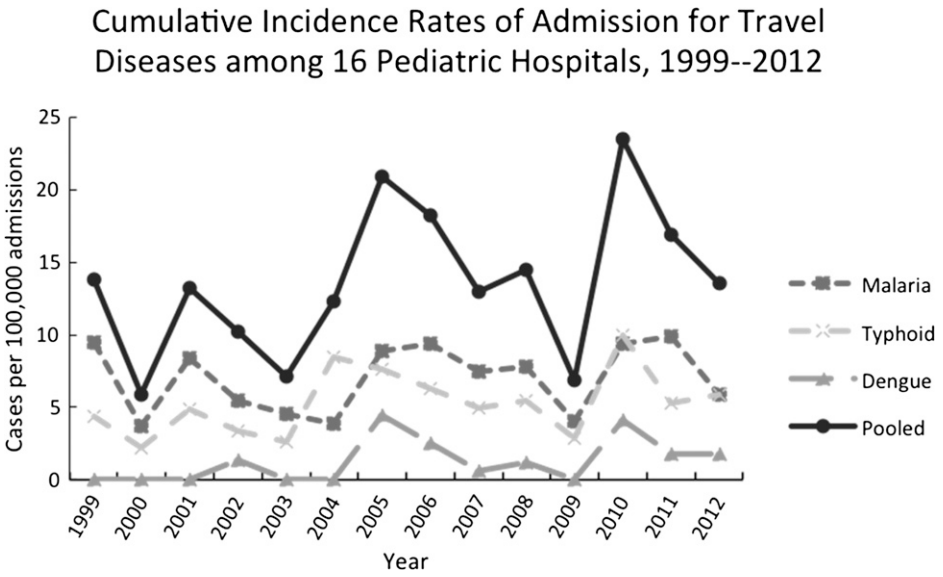

FIGURE 1. Comparison of pooled and individual travel-associated infectious diseases (TAIDs) in the Pediatric Health Information System (PHIS) database, 1999–2012.

surveillance, including an assessment of the economic impact of diseases.

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REFERENCES

1. Harvey K, Esposito DH, Han P, Kozarsky P, Freedman DO, Plier DA, Sotir MJ, 2013. Surveillance for travel-related disease–GeoSentinel Surveillance System, United States, 1997–2011. *MMWR Surveill Summ 62:* 1–23.
2. Steffen R, Rickenbach M, Wilhelm U, Helminger A, Schar M, 1987. Health problems after travel to developing countries. *J Infect Dis 156:* 84–91.
3. Hill DR, 2000. Health problems in a large cohort of Americans traveling to developing countries. *J Travel Med 7:* 259–266.
4. Steffen R, deBernardis C, Banos A, 2003. Travel epidemiology–a global perspective. *Int J Antimicrob Agents 21:* 89–95.
5. Hagmann S, Neugebauer R, Schwartz E, Perret C, Castelli F, Barnett ED, Stauffer WM, 2010. Illness in children after international travel: analysis from the GeoSentinel Surveillance Network. *Pediatrics 125:* e1072–e1080.
6. Wilson ME, Weld LH, Boggild A, Keystone JS, Kain KC, von Sonnenburg F, Schwartz E, 2007. Fever in returned travelers: results from the GeoSentinel Surveillance Network. *Clin Infect Dis 44:* 1560–1568.
7. NTTO, 2013. *U.S. Travel to International Destinations Increased Two Percent in 2013*. Office NTaT, ed. International Trade Administration, Department of Commerce, Washington DC, United States of America.
8. Doyle TJ, Glynn MK, Groseclose SL, 2002. Completeness of notifiable infectious disease reporting in the United States: an analytical literature review. *Am J Epidemiol 155:* 866–874.
9. CHA, 2014. *PHIS+: Augmenting the Pediatric Health Information System with Clinical Data*. Children's Hospital Association. Available at: http://www.childrenshospitals.org/phisplus/index.html. Accessed October 27, 2014.
10. Narus SP, Srivastava R, Gouripeddi R, Livne OE, Mo P, Bickel JP, de Regt D, Hales JW, Kirkendall E, Stepanek RL, Toth J, Keren R, 2011. Federating clinical data from six pediatric hospitals: process and initial results from the PHIS+ Consortium. *AMIA Annu Symp Proc* 2011: 994–1003.
11. Hickey PW, Cape KE, Masuoka P, Campos JM, Pastor W, Wong EC, Singh N, 2011. A local, regional, and national assessment of pediatric malaria in the United States. *J Travel Med 18:* 153–160.
12. United States General Services Administration, 2014. *United States Census Bureau*. Washington, DC: U.S. General Services Administration.
13. ICD-9-CM Coordination and Maintenance Committee (U.S.), National Center for Health Statistics, (U.S.), Centers for Medicare & Medicaid Services (U.S.), Stat!Ref (Online service), Teton Data Systems (Firm), 2015. *ICD-9-CM*. Volumes 1, 2, and 3. Jackson, WY: Teton Data Systems.
14. Stock JH, Watson MW, National Bureau of Economic Research, 2012. *Disentangling the Channels of the 2007–2009 Recession*. Cambridge, MA: National Bureau of Economic Research, 1 online resource.
15. Papatheodorou A, Jaume R, Honggen X, 2010. Global economic crisis and tourism: consequences and perspectives. *J Travel Res 49:* 39–45.
16. Centers for Disease Control and Prevention (CDC), 2000. Summary of notifiable diseases, United States, 1999. *MMWR Morb Mortal Wkly Rep 48:* 1–104.
17. Centers for Disease Control and Prevention (CDC), 2000. Preliminary FoodNet data on the incidence of foodborne illnesses-selected sites, United States, 1999. *MMWR Morb Mortal Wkly Rep 49:* 201–205.
18. Adams DA, Gallagher KM, Jajosky RA, Kriseman J, Sharp P, Anderson WJ, Aranas AE, Mayes M, Wodajo MS, Onweh DH, Abellera JP, 2013. Summary of notifiable diseases, United States, 2011. *MMWR Morb Mortal Wkly Rep 60:* 1–117.