Use of electronic medical records to conduct surveillance of malaria among Peace Corps volunteers

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ABSTRACT

Objective: The Peace Corps’ disease surveillance for Peace Corps Volunteers (PCVs) was incorporated into an electronic medical records (EMR) system in 2015. We evaluated this EMR-based surveillance system, focusing particularly on malaria as it is deadly but preventable.

Materials and Methods: In 2016, we administered a survey to Peace Corps Medical Officers (PCMOs), who manage PCVs’ medical care, and semistructured phone interviews to headquarters staff. We assessed the structure of the surveillance system and its utility to stakeholders, evaluated surveillance case definitions for malaria, and compared clinical information in the EMR for malaria cases captured by surveillance during the first half of 2016.

Results: Of 131 PCMOs, 77 (59%) completed the survey. Of 53 respondents in malaria-endemic nations, 98% believed most PCVs contact them about possible malaria. Of 134 cases with a malaria clinical diagnosis in the EMR between January and August 2016, 58 (43% sensitivity) were reported to the surveillance system by PCMOs. The remaining cases in the surveillance system were added during data cleaning, which is time-intensive. Among the 48 malaria cases identified by surveillance between January and June 2016, positive predictive value was 67%.

Discussion: Areas for improvement include streamlining PCMO documentation, refining case definitions, and improving data quality. With such improvements, surveillance data can be used to inform epidemiological analysis, clinical care, health education, and policy.

Conclusion: The EMR is an important tool for malaria surveillance among PCVs and, with the refinements mentioned, could serve as a framework for other multinational organizations to monitor their staff.

Key words: Peace Corps, malaria, electronic medical records, EMR, surveillance

BACKGROUND AND SIGNIFICANCE

Public health surveillance via electronic medical records (EMR) has experienced increasing interest in recent years. Vast troves of health-care data are now accessible electronically, and public health agencies worldwide are using EMR data to monitor communicable and noncommunicable diseases.1–3 Advantages of EMR-based surveillance include easy online accessibility, the ability to monitor outbreaks in real time, and opportunities to analyze subpopulations to
find connections between cases. Furthermore, any findings generated from EMR surveillance can be easily shared with the healthcare organizations that provided the data. Disadvantages of EMR surveillance include poor interoperability between different electronic recordkeeping systems, variability in how providers document the same condition, and the need to filter through large amounts of data to find information of interest.

Most EMR-based surveillance is currently conducted in high-income countries with robust public health infrastructure. While this has been successful, EMR-based surveillance seems particularly well-suited for monitoring geographically dispersed groups in areas with limited public health infrastructure. For example, the health of missionaries from the same religious organization or employees of a multinational corporation may be difficult to monitor as a group, since they are spread out in areas with different medical records systems (from which obtaining copies of medical records may be difficult), varying levels of health infrastructure, and even multiple languages. A unified means of surveilling the health of such individuals could make it much easier for public health professionals to identify disease trends and craft preventive actions for these diverse groups. There are a few examples in the published literature of health surveillance of long-term travelers, but no studies describing EMR-based surveillance in this setting.

The Peace Corps is a US governmental program that places American volunteers in low- and middle-income countries to perform 2 years of community service and promote cultural understanding. There are currently about 7000 Peace Corps Volunteers (PCVs) serving in more than 60 countries worldwide. To inform how to best protect the health of PCVs, the Peace Corps has been conducting health surveillance on deployed PCVs since 1985. The surveillance system was originally paper-based, but in 2015, it was embedded into the Peace Corps’ newly created EMR system and transitioned online.

OBJECTIVE

In 2016, the Peace Corps’ EMR-based surveillance system was formally evaluated following the system’s transition to electronic form approximately 6 months earlier. The findings of this evaluation are presented here, including a description of this innovative method of monitoring the health of individuals deployed across multiple countries with limited healthcare infrastructure and a discussion of its benefits and challenges. The Peace Corps’ experience with EMR-based surveillance is a case study for other multinational organizations wishing to monitor and protect the health of their widely dispersed staff and volunteers.

MATERIALS AND METHODS

An assessment of the Peace Corps’ EMR-based surveillance system was undertaken by staff from the Peace Corps Office of Health Services, Epidemiology and Surveillance Unit, with technical support provided by the US Centers for Disease Control and Prevention. The evaluation featured five components: a description of the surveillance system structure, a Peace Corps Medical Officer (PCMO) survey, interviews with headquarters staff, EMR records review, and an assessment of case definitions.

Although the Peace Corps’ surveillance system tracks more than 100 diseases, this evaluation focused primarily on malaria surveillance. Reducing malaria among PCVs is a key indicator for the Peace Corps’ Healthy Volunteer 2020 initiative. Furthermore, malaria is a preventable disease that has the potential to cause severe morbidity or death and is thus extremely important to accurately capture and mitigate. The disease has caused seven deaths among PCVs in service since the program’s inception in 1961, and 126 presumed or confirmed cases were recorded among all PCVs in 2017.

Malaria is caused by parasites in the Plasmodium genus, of which Plasmodium falciparum causes the most morbidity and mortality worldwide. The disease can have a range of clinical manifestations, from simple fever to multi-system organ damage. Malaria is diagnosed via rapid diagnostic test (RDT) or blood smear; RDTs are easy to perform and interpret with little medical training, while blood smears require more technical expertise. In low-resource settings such as those where PCVs serve, a positive reading with either modality is considered diagnostic and should be treated as malaria.

Surveillance system structure

Semistructured phone interviews were performed with seven staff from the Peace Corps Office of Health Services. Staffs were asked to describe the overall structure of the surveillance system, the relationship between the surveillance system and Peace Corps’ EMR, data flow, data cleaning processes, and data analysis. The variable fields for the surveillance system and EMR were also examined. No personally identifying information was collected.

PCMO survey

PCMOs are healthcare providers based in each country where Peace Corps has a presence. Among other duties, they manage the medical care of all PCVs in country and record EMR and surveillance data. An anonymous, online survey was administered to all PCMOs worldwide in October 2016. The survey was primarily multiple choice, with two free-response questions to allow respondents to provide additional comments as needed. All survey questions were optional to answer. PCMOs were queried about their medical practices, opinions of the surveillance system and surveillance codes, and their perceptions of PCV healthcare-seeking behaviors. Selected PCMO survey questions are listed in Supplementary Table 1.

Headquarters staff interviews

Semistructured phone interviews were again performed with the same headquarters staff previously mentioned. These interviews were conducted to obtain a qualitative assessment of the performance of the surveillance system as well as the usefulness of the system to stakeholders. Topics of discussion included benefits and challenges of the Peace Corps’ EMR system, how medical care of PCVs currently takes place, training and support of PCMOs, and ways in which epidemiological data affects Peace Corps policy. A selection of questions used for the semistructured interviews can be found in Supplementary Table 1. Information from phone interviews was transcribed, and recurring ideas were grouped into themes and coded.

EMR chart review

Anonymized medical records were examined for all cases of malaria captured by surveillance since the rollout of the new, EMR-based system. Forty-eight malaria cases were examined, covering a period from January to June 2016; these cases represent all records that included a malaria surveillance code after data cleaning. EMR and surveillance code documentation was examined for these cases, paying close attention to the diagnostic tests used, treatments given, and
indicators of disease severity. An analysis of anonymized, uncleaned data from January to August 2016 was also performed and the number of cases potentially missed by surveillance before data cleaning was estimated.

Case definition assessment
Using clinical information from the EMR, we determined if surveillance codes had been appropriately applied to the malaria cases captured by the system. The utility of the surveillance case definitions for malaria was then assessed, including their sensitivity and positive predictive value. No personally identifying information from patients was accessed or collected during any part of the assessment.

RESULTS
Surveillance system structure
The Peace Corps’ EMR and surveillance systems were both designed in-house on an open-source platform by information technology and informatics staff. This allowed the systems to cater closely to Peace Corps’ unique needs, including the constraints of working in low-resource environments across multiple continents. It also allowed both the EMR and surveillance systems to be adaptable as issues or modifications were identified by end users.

The Peace Corps’ surveillance system consists of a single field, the surveillance code. There are approximately 150 surveillance codes, encompassing acute, chronic, communicable, and noncommunicable illness. Epidemiology staff and all PCMOs receive basic training in these codes’ case definitions and use; annual continuing medical education and individualized support for new staff is also offered. The surveillance code field is included as part of the Peace Corps’ EMR, which also contains myriad data fields for vital signs, free-text physician assessments, laboratory results, and clinical diagnosis codes (using the SNOMED CT nomenclature, with thousands of possible diagnosis codes to choose from).15 While every clinical encounter has a diagnosis code, not every encounter meets criteria for a surveillance code, and these two codes are chosen independently of each other.

Data first reaches the surveillance system when a PCV contacts a PCMO with a medical concern, either over the phone or in person (Figure 1). PCMOs document each encounter with PCVs in the EMR, including selecting a clinical diagnosis code to describe the encounter. If the encounter meets criteria for one of the surveillance codes, the PCMO should also choose a surveillance code. After input by the PCMO, EMR data (and any associated surveillance data) are accessible to epidemiology staff at the Peace Corps Office of Health Services for data cleaning and analysis.

Cleaning of surveillance data aims to correct surveillance codes that were inappropriately applied outside of the codes’ case definitions and add surveillance codes to records where they are potentially missing. EMR data are used to provide corroborating information as to which records may have missing or incorrect surveillance codes. However, such corroborating information is not universally documented nor present in a standardized location in the EMR, which complicates data cleaning. For example, data on laboratory test results (RDT or blood smear) are often used to determine if a case meets criteria for malaria, but there are four different fields in the EMR where such information can be documented. Lab test results can be included in the field where lab orders are placed, recorded in a separate field intended for lab results, uploaded into the EMR as PDFs from outside testing facilities, described in the free-text physician assessment section of the record, or not documented at all. In addition, sometimes PCMOs note preliminary lab results or working diagnoses in the EMR but neglect or forget to update the record when final results are available.

Clinical diagnosis codes from the EMR are also sometimes used to corroborate or add surveillance code choices, but there are many more possible malaria-related diagnosis codes than surveillance codes, and the two do not always match up. For example, a record may have a clinical diagnosis code of “malaria” or “episodic fever,” which provides a clue that a surveillance code for malaria should also be applied, but no further guidance as to which particular malaria surveillance code would be most appropriate.

Cleaned data are copied into a surveillance code database, which is then used to tabulate case counts for the various conditions under surveillance, and surveillance reports are disseminated to the public annually.13

The Peace Corps used four surveillance codes to monitor malaria in 2016: “Malaria, falciparum;” “Malaria, falciparum, complicated;” “Malaria, non-falciparum;” and “Malaria, presumptive.” The case definitions for these codes are listed in Table 1.

PCMO survey
Of 131 PCMOs worldwide, 77 (59%) responded to the survey. PCMOs reported that most consultations with PCVs occurred remotely, via phone call or text message, rather than in person. However, they believed that most PCVs do contact them when ill, rather than seeking care from other providers. Most (79%; 56/71) PCMOs thought that most PCVs contacted them for every illness they sustained, and 98% (42/43) of PCMOs working in malaria-endemic countries believed they were contacted for all potential malaria cases.

PCMOs had overall positive attitudes toward the surveillance system and surveillance codes. Most PCMOs (74%; 54/73) agreed that surveillance was very important or essential to understanding the health of PCVs. Furthermore, 62% (45/73) found that the case definitions for the surveillance codes were overall appropriate for their practice environments, and 73% (49/67) found the case definitions overall easy to apply. When queried specifically about malaria surveillance codes, however, only half of PCMOs found the case definitions to be appropriate for their practice environments (52%; 31/60) and easy to apply (51%; 32/63).

Headquarters staff interviews
Interviews with headquarters staff revealed the heavy burden of data cleaning required to make surveillance data usable. Staff in the Peace Corps Office of Health Services, Epidemiology and Surveillance Unit reported spending approximately 50 hours per month on data cleaning, primarily to correct records for which surveillance codes were inappropriately applied or for which codes should have been applied but were missing. Staff focused their efforts on cleaning data for the highest-impact diseases, such as malaria; due to the large volume of data and competing priorities for their time, staff were not able to clean all records.

To perform data cleaning, staff examined clinical information from the EMR to determine if the surveillance code associated with an encounter had been appropriately applied or if the encounter met criteria for a surveillance code that had not been applied. Unfortunately, relevant information needed to designate surveillance codes, such as laboratory results, is dispersed throughout the medical
record and recorded in different locations by different PCMOs, making this process time-consuming.

**EMR chart review**

Chart review identified a gap between the number of cases assigned a malaria diagnosis code and the number of cases reported through the surveillance system. To calculate the system’s sensitivity, the number of cases given a malaria clinical diagnosis code was compared with the number of cases assigned one of the four malaria surveillance codes. Of 134 cases with a malaria diagnosis code between January and August 2016, only 58 (43% sensitivity) were also given a surveillance code by PCMOs and were thus captured by the surveillance system prior to data cleaning. More than half of these cases would require addition of surveillance codes during data cleaning, adding to the time burden of the cleaning process. To calculate the positive predictive value (PPV) of the four malaria surveillance codes, each case’s surveillance code was compared to clinical information from the EMR to determine if the code had been applied appropriately. Overall, the PPV of all malaria surveillance codes was 67%; in other words, 67% of cases with malaria surveillance codes met the case definition for the codes they were assigned. The PPV for individual malaria surveillance codes ranged from 61% to 100% (Table 2). Of note, 9 of 23 cases given a “Malaria, presumptive” surveillance code had negative malaria test results, meaning that these cases likely did not represent true disease.

Of 48 cases assigned a malaria surveillance code between January and June 2016, 21 (44%) had a positive RDT documented in the EMR, and 17 (35%) had a positive blood smear documented in the EMR. A total of 9 cases (19%) had only negative laboratory results.

**Table 1. Malaria surveillance codes and their definitions in use by the Peace Corps in 2016**

| Surveillance code          | Definition                                                                                                                                                                                                 |
|----------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Malaria, falciparum        | Infection with *Plasmodium falciparum* transmitted by *Anopheles* mosquitoes. The initial symptoms of malaria may include tachycardia, tachypnea, chills, malaise, fatigue, diaphoresis (sweating), headache, cough, anorexia, nausea, vomiting, abdominal pain, diarrhea, arthralgias, and myalgias. Falciparum malaria is confirmed by demonstration of the parasite on Giemsa-stained blood smears by light microscopy or rapid diagnostic tests performed by United States Embassy or Peace Corps Medical Unit approved facility, preferably followed-up with blood smears by microscopy. Laboratory evaluation may demonstrate parasitemia, anemia, thrombocytopenia, elevated transaminases, mild coagulopathy, and elevated blood urea nitrogen and creatinine. |
| Malaria, falciparum        | Severe falciparum malaria is generally defined as acute malaria with signs of severity and/or evidence of vital organ dysfunction including consciousness with a Glasgow Coma Score <11 in adults, prostration, multiple convulsions, shock, pulmonary edema, renal impairment, jaundice, significant bleeding, severe malarial anemia, hypoglycemia, or hyperparasitemia: *P. falciparum* parasitemia >10% (>50 000/mcL). |
| Malaria, non-falciparum    | Infection with *Plasmodium malariae*, *Plasmodium vivax*, or *Plasmodium ovale*, transmitted by *Anopheles* mosquitoes, may result in a wide variety of symptoms. Confirmed by demonstration of the parasite on Giemsa-stained blood smears by light microscopy or approved rapid diagnostic tests followed-up with blood smears by microscopy or polymerase chain reaction after the diagnosis has been established by either smear microscopy or other specific techniques. |
| Malaria, presumptive       | Presumptive malaria is an illness consistent with malaria (eg, unexplained fever >38 degrees C in a malarious area) in which treatment for malaria was administered, but was not confirmed by blood smears or other specific techniques including rapid diagnostic tests. Laboratory evaluation may demonstrate parasitemia, anemia, thrombocytopenia, elevated transaminases, mild coagulopathy, and elevated blood urea nitrogen and creatinine. |
testing documented, and 6 cases (13%) had no malaria testing documented; these cases were all assigned the “Malaria, presumptive” surveillance code.

Case definition assessment

The difficulty with correctly applying malaria surveillance codes may be related to the design of the codes' case definitions. At the time of the evaluation, the case definitions for malaria surveillance codes were long, somewhat vague, and more akin to clinical descriptions of disease than case definitions (Table 1, Figure 2). For example, the “Malaria, falciparum” and “Malaria, falciparum complicated” surveillance codes were not mutually exclusive. Furthermore, although non-falciparum malaria may also cause complicated or severe disease, no surveillance code existed to describe complicated non-falciparum malaria.

The case definitions also contained criteria that were difficult to achieve in the low-resource settings where many PCVs serve. To meet the case definition for the “Malaria, falciparum” surveillance code, for example, a PCV must have had a positive malaria RDT or blood smear performed at a Peace Corps Medical Unit, United States embassy health clinic, or a Peace Corps-approved facility, all of which are generally distant from PCV work sites. Positive malaria tests reported from other sources must be categorized as “Malaria, presumptive” unless later confirmed by one of these facilities. In practice, however, PCVs who reported any positive malaria RDT or blood smear to a PCMO were almost universally treated as malaria cases.

In addition, the Peace Corps provides RDT test kits and oral antimalarial treatment courses to PCVs serving in malaria-endemic areas and instructs them in their use. PCVs who identify a positive result on a self-administered RDT are trained to immediately start antimalarial treatment and then report to a PCMO for further evaluation. Follow-up testing performed at one of the Peace Corps-approved facilities after initiation of antimalarial treatment may result in a false negative result and thus a misclassification of this case in the surveillance system.

Finally, the “Malaria, presumptive” surveillance code was also being used outside of its case definition by PCMOs to identify cases in which malaria was suspected and treated but confirmatory testing was negative or not performed.

**DISCUSSION**

The Peace Corps’ surveillance system is the first published example of EMR-based surveillance functioning in areas with limited public health systems or monitoring groups spread across multiple countries. The system offers a simple, standardized, and accessible means of monitoring myriad diseases among a population dispersed internationally in disparate health settings. The benefit of the EMR to this surveillance system is the accessibility of clinical data to validate surveillance data and real-time reporting for timely recognition of and response to disease trends. However, there are challenges to using the EMR for dual purposes, as public health and clinical priorities may differ, and the EMR was primarily developed as a clinical tool. These challenges are demonstrated in the need to refine the surveillance case definitions and to ensure that clinicians are trained in the correct use of these definitions.

Although there are no other published reports of multinational organizations using EMR-based surveillance to continuously monitor the health of overseas personnel, there is great potential for such surveillance to be used more extensively for groups whose members are widely dispersed in areas of inconsistent healthcare quality. For this reason, our surveillance methods are described in detail so that others can learn from the Peace Corps’ experience.

With improved data quality, the Peace Corps’ surveillance data can be used to inform epidemiological analysis, clinical care, health education, and policy. Corroboration of surveillance data with EMR data allows for nuanced data analysis, such as identifying commonalities between cases to target preventive action to disproportionately affected groups. For example, EMR surveillance data during the 2009 H1N1 influenza pandemic helped public health professionals direct vaccines to the highest-burden areas in New York.

A surveillance system that is integrated into the EMR provides additional clinical data that can also be used to monitor the management of certain diagnoses or to tailor staff training to diseases that are most prevalent locally. The Peace Corps uses surveillance data to create annual country health profiles, which help give their staff a better idea of the health issues facing PCVs in different areas. In addition, a 2015 meta-analysis demonstrated that EMRs can improve healthcare quality, including provider adherence to guidelines.

Surveillance data can help assess the impact of health interventions or inform policies, and EMR-based surveillance takes this to new heights by repurposing existing data in novel ways. For example, Louisiana used EMR surveillance to identify human immunodeficiency virus-positive patients without infectious disease care and to monitor the effect of this program on follow-up rates by employing EMR visit registration data to immediately notify clinicians and public health personnel when a high-risk patient accessed any medical care. The Peace Corps uses surveillance data to help shape national-level budget allocations, as those countries with more malaria are likely to incur greater expenses for medical evacuations and treatment of critical illness.

Finally, the real-time nature of EMR-based surveillance allows for instantaneous monitoring of emerging disease trends and timely response. The Electronic Medical Record Support for Public Health Surveillance platform collects EMR data in real time, identifies conditions of public health interest, and transmits notifications to health departments. Furthermore, both short-term and long-term travelers can import contagious diseases when they return home, and it is critical to have good disease surveillance of travelers for global health security purposes. However, the ability to identify and mitigate emerging disease trends among long-term travelers is currently limited. Further development of tools to monitor the health of long-term overseas personnel, such as the system created by the Peace Corps, is essential to assuring the global public health community’s preparedness for future disease outbreaks.

Areas for improvement to the Peace Corps’ surveillance system center around streamlining PCMO documentation, refining case definitions, and improving data quality. After this evaluation, the Peace Corps began and continues to correct the data quality issues.
identified. Many improvements have focused on making the system easier to use for PCMOs, as headquarters staff have noted that optimizing the workflow for PCMOs at the point of initial data entry would result in a more efficient surveillance system from the start. Case definitions have been rewritten to increase utility and clarity. Additional training opportunities on surveillance codes have been created for PCMOs to increase their understanding of the system. New computer algorithms have been developed to reduce data cleaning burden; for example, the EMR has been configured to suggest the addition of relevant surveillance codes when certain diagnoses are entered. Surveillance data is being monitored in real time by Peace Corps leadership.21

This evaluation has a few limitations. The surveillance system was assessed less than a year after the Peace Corps transitioned to the new EMR; it is possible that some PCMOs were still unfamiliar with the new surveillance system’s format at the time of the evaluation, reducing surveillance data quality. Although all PCMOs were educated in surveillance code use, many unexpectedly applied the malaria surveillance codes to cases not meeting their case definitions or failed to apply surveillance codes to cases that did fit the definitions. It is unclear why this occurred; anecdotally, many PCMOs reported charting fatigue as a reason for inadequate use of surveillance codes, but this was not directly assessed in the PCMO survey. Understanding PCMO motivations in choosing surveillance codes is an important area for future study, particularly as the Peace Corps undertakes EMR design changes.

In addition, while surveyed PCMOs believe that most PCVs are using Peace Corps’ healthcare resources, and hence their illnesses can be captured by surveillance, no PCVs were able to be interviewed for this assessment. Therefore, there are perceptions of the surveillance system and healthcare-seeking behaviors are unknown.

This assessment of the Peace Corps’ surveillance system, the first to occur since the system transitioned to electronic form and became embedded in the EMR, has identified many opportunities to better the Peace Corps’ disease surveillance. A repeat evaluation of the system is critical to follow up on the issues identified, further investigate the questions raised, and analyze the effectiveness of the database design, case definition, and user training improvements currently in progress. Another important area to monitor would be how changes in the EMR and surveillance system balance the unique needs of clinical medical documentation versus public health surveillance.

CONCLUSION

The Peace Corps’ EMR-based surveillance system, and the lessons learned in its implementation, can serve as a case study for other multinational organizations wishing to monitor and protect the health of their staff.

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.

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AUTHOR CONTRIBUTIONS

ED, KRT, and SH planned and designed the study. SH and RWF coordinated with the Peace Corps to facilitate semi-structured interviews with headquarters staff. All authors supported the design of the PCMO survey, while SH and RWF led survey dissemination and analysis. ED performed the remaining data analysis and prepared the manuscript drafts. All authors provided feedback on multiple drafts of the manuscript and approved the final product.

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SUPPLEMENTARY MATERIAL

Supplementary material is available at Journal of the American Medical Informatics Association online.
CONFLICT OF INTEREST
The authors have no competing interests to declare.

REFERENCES
1. Birkhead GS, Klompas M, Shah NR. Uses of electronic health records for public health surveillance to advance public health. *Annu Rev Public Health* 2015; 36 (1): 345–59.
2. Elliott AF, Davidson A, Lum F, et al. Use of electronic health records and administrative data for public health surveillance of eye health and vision-related conditions in the United States. *Am J Ophthalmol* 2012; 154 (6): S63–70.
3. Klompas M, McVetta J, Lazarus R, et al. Integrating clinical practice and public health surveillance using electronic medical record systems. *Am J Public Health* 2012; 102 (Suppl 3): S325–32.
4. Perlman SE, McVeigh KH, Thorpe LE, Jacobson L, Greene CM, Gwynn RC. Innovations in population health surveillance: using electronic health records for chronic disease surveillance. *Am J Public Health* 2017; 107 (6): 853–7.
5. Paul MM, Greene CM, Newton-Dame R, et al. The state of population health surveillance using electronic health records: a narrative review. *Popul Health Manag* 2015; 18 (3): 209–16.
6. Heisey-Grove D, Wall HK, Helwig A, Wright JS. Using electronic clinical quality measure reporting for public health surveillance. *MMWR Morb Mortal Wkly Rep* 2015; 64 (16): 439–42.
7. Woestenberg PJ, van Oeffelen AA, Stirbu-Wagner I, van Benthem BH, van Bergen JE, van den Broek IV. Comparison of STI-related consultations among ethnic groups in the Netherlands: an epidemiologic study using electronic records from general practices. *BMC Fam Pract* 2015; 16 (1): 70.
8. Flood TL, Zhao YQ, Tomayko EJ, Tandias A, Carrel AL, Hanrahan LP. Electronic health records and community health surveillance of childhood obesity. *Am J Prev Med* 2015; 48 (2): 234–40.
9. Hemingway H, Feder GS, Fitzpatrick NK, Denaxas S, Shah AD, Timmis AD. Programme Grants for Applied Research. Using Nationalwide ‘Big Data’ from Linked Electronic Health Records to Help Improve Outcomes in Cardiovascular Diseases: 33 Studies Using Methods from Epidemiology, Informatics, Economics and Social Science in the Clinical Disease Research Using Linked Bespoke Studies and Electronic Health Records (CALIBER) Programme. Southampton, UK: NIHR Journals Library; 2017.
10. Chen LH, Wilson ME, Davis X, et al. Illness in long-term travelers visiting GeoSentinel clinics. *Emerg Infect Dis* 2009; 15 (11): 1773–82.
11. Peppiatt R, Byass P. A survey of the health of British missionaries. *Br J Gen Pract* 1991; 41 (345): 159–62.
12. Bernard KW, Graitter PL, van der Vlugt T, Moran JS, Pulley KM. Epidemiological surveillance in Peace Corps Volunteers: a model for monitoring health in temporary residents of developing countries. *Int J Epidemiol* 1989; 18 (1): 220–6.
13. Peace Corps. *The Health of the Volunteer 2017*. Washington DC: Peace Corps Office of Medical Services; 2018.
14. Centers for Disease Control and Prevention. *CDC Health Information for International Travel*. New York: Oxford University Press; 2018.
15. U.S. National Library of Medicine. *Overview of SNOMED CT*. Bethesda, MD: National Institutes of Health; 2016.
16. Calman N, Hauser D, Lurio J, Wu WY, Pichardo M. Strengthening public health and primary care collaboration through electronic health records. *Am J Public Health* 2012; 102 (11): e13–8.
17. Camppanella P, Lovato E, Marrone C, et al. The impact of electronic health records on healthcare quality: a systematic review and meta-analysis. *Eur J Public Health* 2016; 26 (1): 60–4.
18. Herwehe J, Wilbright W, Abrams A, et al. Implementation of an innovative, integrated electronic medical record (EMR) and public health information exchange for HIV/AIDS. *J Am Med Inform Assoc* 2012; 19 (3): 448–52.
19. Klompas M, Murphy M, Lankiewicz J, et al. Harnessing electronic health records for public health surveillance. *Online J Public Health Inform* 2011; 3 (3); doi: 10.5210/ojphi.v3i3.3794[published Online First: Epub Date].
20. Global Health Security Agenda. *About*. 2019.
21. Wilkinson T, Murphy D, Ferguson R, Evans A, Henderson S. Data cleaning for Peace Corps’ population health surveillance. *American Medical Informatics Association Annual Symposium*; 2017; Washington DC.