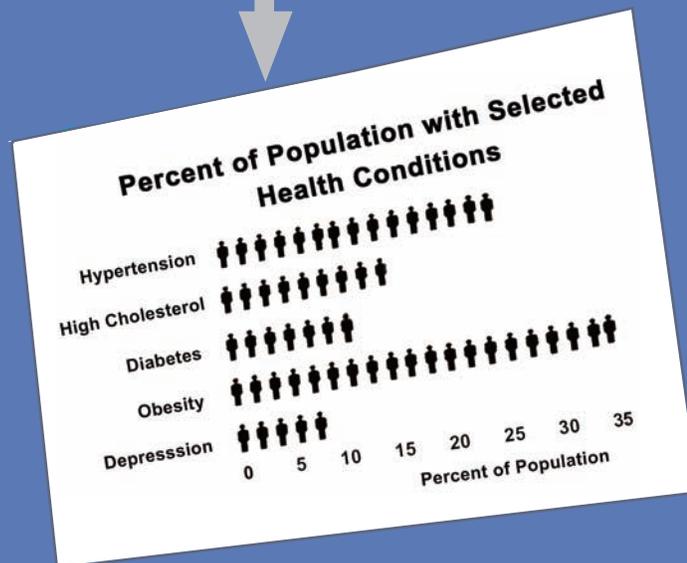




Developing an Electronic Health Record-Based Population Health Surveillance System



A Report from the
New York City Department of Health and Mental Hygiene

July 2013

Letter from the NYC Health Commissioner

Dear Reader:

New York City's Health Department is committed to using innovative, data-driven methods to improve the health of New Yorkers. Electronic health records (EHRs) are an emerging technology for managing patient care. EHR coverage is expanding rapidly, and as of 2012, 72% of office-based medical practices nationwide were using some kind of EHR system. Practice-based EHRs offer the potential to enhance general health surveillance by providing information on the prevalence, treatment, and control of health conditions that are typically managed in a primary care setting.

Our new report, *Developing an Electronic Health Record-Based Population Health Surveillance System*, describes our approach to operationalizing the NYC Macroscopic electronic health record surveillance system, and our methods of assessing the validity of NYC Macroscopic estimates. The report also discusses many important factors any jurisdiction should consider while planning to undertake such work.

We hope that this report will be useful to other agencies and researchers interested in using EHRs to monitor population health. We plan to issue a companion report in 2015 presenting our first year's data, the results of our validation studies, and a discussion of lessons learned.

Thomas Farley, MD, MPH
Commissioner
New York City Department of Health and Mental Hygiene

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Executive Summary

- Electronic health records (EHRs) are rapidly becoming the standard of care for office-based medical practices. Local, regional, and national governments, large health care organizations, insurance companies, and academic research centers are all exploring ways to use data from EHRs to monitor health and inform health care policies and programs.
- Successful development of an electronic health record surveillance system (EHRSS) requires surmounting a number of challenges, including: leadership; confidentiality; technical issues; data structure and system design; definitions and standards; data quality; selection of population health indicators; inclusion and exclusion criteria; duplicate records; measurement error; selection bias and generalizability of findings; and uncertainty when analyzing trends.
- In New York City (NYC), we are developing the NYC Macroscopic EHRSS to monitor chronic conditions managed by primary care practices. We present the design decisions that we made and the challenges that we considered. NYC Macroscopic will be validated by comparing office-based EHR data with data obtained from the 2013 New York City Health and Nutrition Examination Survey (NYC HANES 2013), a gold-standard, population-based examination survey.

Contents

I. The Use of Electronic Health Records (EHRs) for Population Health Surveillance	1
A. Introduction	1
B. International Examples of EHR Use for Population Surveillance	3
C. The United States Experience	3
II. Governance Issues in Electronic Health Record Surveillance System (EHRSS) Development	5
A. Leadership	5
B. Confidentiality	5
C. Technical Issues	6
III. Methodological Considerations in EHRSS Development	7
A. Data Structure and System Design	7
B. Standards	7
C. Data Quality	7
D. Selection of Population Health Indicators	9
E. Inclusion and Exclusion Criteria	9
F. Duplicate Records	10
G. Measurement Error	10
H. Selection Bias and Generalizability of Findings	11
I. Uncertainty When Analyzing Trends	11
IV. Plan to Operationalize the NYC Macroscopic EHRSS	12
A. Introducing NYC Macroscopic	12
B. The NYC Primary Care Information Project	12
C. NYC Macroscopic Inclusion and Exclusion Criteria	14
D. NYC Macroscopic Indicators	15
E. Sensitivity Analyses	15
F. Design and Operationalization of NYC Macroscopic	15
G. Programming and Piloting the Queries	16
H. Methods for Producing and Reporting NYC Macroscopic Data	16
V. Planned Validation Studies of NYC Macroscopic	17
A. Introduction	17
B. Evaluation of Measurement Error	17
C. Evaluation of Selection Bias and Generalizability	18
D. Other Criteria by Which NYC Macroscopic Will Be Evaluated	18
VI. Conclusion	19
VII. References	20
VIII. Appendix – Comparison of Indicators in NYC Macroscopic and in NYC HANES 2013	22

Glossary

Antihypertensive medications	Medications to reduce blood pressure.
Aggregate data	Data that have been transformed into summary counts. The process of aggregation removes individually identifying information, which is a major advantage for data exchange. However, aggregate data cannot be analyzed using multivariable modeling techniques.
BMI	Body mass index — an indicator of body fat percentage. BMI is calculated from an individual’s weight and height. BMI of 18.5 to 25 is considered healthy, and BMI of 30 or greater is considered obese. Obesity is a risk factor for serious illnesses such as heart disease and diabetes.
BP	Blood pressure — the pressure exerted by blood against the artery walls, measured in mm Hg. Elevated blood pressure is known as hypertension. BP less than 120/80 mm Hg is considered normal, and BP equal to or greater than 140/90 mm Hg is considered hypertensive. The higher the BP, the greater the risk of heart attack, heart failure, stroke, and kidney disease.
CUNY	City University of New York.
DBP	Diastolic blood pressure — the second or lower of the two BP numbers. DBP measures the pressure of blood against the artery walls when the heart is at rest between beats.
Distributed data model	A distributed data model collects only the data necessary for a particular question, instead of compiling all data to a central location or warehouse and then analyzing it. Data reside in their original location (provider’s EHR system, for example) and analytic questions (queries) are asked of the data at each location. The results of these queries are then compiled and analyzed. ¹
DOHMH	New York City Department of Health and Mental Hygiene.
Dx	Diagnosis.
EHR	Electronic health record, also known as an electronic medical record: “a longitudinal electronic record of patient health information generated by one or more encounters in any care delivery setting. Included in this information are patient demographics, progress notes, problems, medications, vital signs, past medical history, immunizations, laboratory data and radiology reports.” ² May also refer broadly to the computer technology and systems that allow the electronic documentation of patient encounters.
EHRSS	Electronic health record surveillance system.
HbA1c	Hemoglobin A1c or glycosylated hemoglobin, an indicator of average blood glucose levels over the previous 8 to 12 weeks. Normal HbA1c is 3.5% to 5.5%. Individuals with diabetes strive to keep HbA1c at 7% or lower.
HEDIS	Healthcare Effectiveness Data and Information Set — health care performance measures created and updated annually by the National Committee for Quality Assurance (NCQA) and widely used by the insurance industry. For more information, visit www.ncqa.org/HEDISQualityMeasurement.aspx .
HIE	Health information exchange — “an organization that provides services to enable the electronic sharing of health-related information.” ³
HIMSS	Healthcare Information and Management Systems Society. For more information, visit www.himss.org .
HITECH	The Health Information Technology for Economic and Clinical Health Act of 2009, which authorized the Department of Health and Human Services to spend \$27 billion over 10 years to incentivize the adoption and “meaningful use” of EHRs — that is, their use by providers to achieve significant improvements in care.” ⁴ For more information, see www.healthit.gov/policy-researchers-implementers/hitech-act-0 .
HL7	Health Level Seven, technical standards for exchanging electronic health information between systems. For more information, visit www.hl7.org .
Intake period	Unit of time that determines record inclusion in an EHRSS reporting cycle, also known as reporting period or measurement period. A 2012 intake period would include all patients who visited a health care provider in 2012. Note that intake period differs from look-back period (defined below).

Kappa coefficient	A statistical measure of inter-rater agreement that is commonly used to evaluate a new measurement instrument against a gold standard.
LDL	Low-density lipoprotein cholesterol, commonly known as “bad” cholesterol, associated with an increased risk of heart disease.
Line-level data	Data which contain one or more rows of information (records) for each individual. Line-level data may or may not include names or other identifying information that could be used to link information to data from other sources. In contrast to aggregate data, line level data may be analyzed using multivariable modeling techniques.
LOINC	Logical Observation Identifiers Names and Codes, a code compendium developed by the Regenstrief Institute and the LOINC Committee to uniquely identify individual components of lab results as well as other bio-measurements like blood pressure and electrocardiogram (EKG). Adoption of LOINC codes and mapping to locally used code systems varies by jurisdiction and company. For more information, visit www.loinc.org .
Look-back period	The window of time within which a particular data element must have been recorded in the EHR in order to be included in an EHRSS indicator. In contrast to intake periods, which determine eligibility of the patient for inclusion in the EHRSS, the look-back period determines the eligibility of the data element. The length of the look-back period is specific to each indicator.
Meaningful use	“Using certified electronic health record (EHR) technology to: Improve quality, safety, efficiency, and reduce health disparities; engage patients and family; improve care coordination, and population and public health; [and] maintain privacy and security of patient health information.” ³ Medicaid and Medicare reimburse providers for achieving meaningful use objectives.
Moving averages	When data defined by a two-year intake period are reported annually, the data for each reporting year will encompass some information that was reported in the previous reporting year and some new information. For example, estimates reported for 2012 would be based on visits occurring in 2011 and 2012, while estimates reported for 2013 would be based on visits occurring in 2012 and 2013. These estimates represent moving averages.
NYC HANES 2013	2013 New York City Health and Nutrition Examination Survey, a gold-standard survey that will be used to validate estimates produced by the NYC Macroscopic EHRSS. For more information, visit www.nychanes.org .
NYC Macroscopic	New York City’s electronic health record surveillance system.
NQF	National Quality Forum. For more information, visit www.qualityforum.org .
ONC	Office of the National Coordinator for Health Information Technology. For more information, visit www.healthit.gov/newsroom/about-onc .
PHQ-2	A two-item Patient Health Questionnaire that screens for depression. Responses to the two Likert items may trigger further depression screening using the PHQ-9. For more information, visit www.apa.org/pi/about/publications/caregivers/practice-settings/assessment/tools/patient-health.aspx .
PHQ-9	A nine-item Patient Health Questionnaire that screens for depression within the past two weeks. The PHQ-9, which incorporates the PHQ-2 as its first two questions, is used by primary care physicians to guide decisions about depression treatment and referrals.
Pre-HTN	Prehypertension — blood pressure between 120/80 and 139/89. Prehypertension is a risk factor for hypertension.
RHIO	Regional Health Information Organization — usually convened to exchange individual-level patient data for care coordination.
S&I	ONC Standards and Interoperability Framework. For more information, visit www.siframework.org .
SBP	Systolic blood pressure — the first or lower of the two BP numbers. SBP measures the pressure of blood against artery walls when the heart contracts.
Sensitivity	In epidemiology, the ratio of true positives to the sum of true positives plus false negatives (TP/(TP+FN)).
Specificity	In epidemiology, the ratio of true negatives to the sum of true negatives plus false positives (TN/(TN+FP)).

I. The Use of Electronic Health Records (EHRs) for Population Health Surveillance

A. Introduction

Population health surveillance seeks to monitor health across a range of indicators that together embody key characteristics of the health of the population in question. Historically, surveillance activities in the U.S. have focused on infectious diseases. Over the years, surveillance efforts have expanded to monitor other conditions including injuries, birth defects, chronic medical conditions, mental illness, illicit drug use, health behaviors, and environmental and occupational exposures.⁵

Traditional health surveillance has relied on census-based registries of reportable health events and population-based surveys, supplemented by sentinel studies, cohort studies, and analysis of claims data (Table 1). Researchers are seeking new, more rapid, less-expensive methods for monitoring population

health. One approach, known as syndromic surveillance, uses sophisticated computer programs to analyze the spatial-temporal patterns found in centralized electronic health data on chief complaints and other pre-diagnostic syndromes. Syndromic surveillance systems usually obtain data from acute care providers, such as hospital emergency departments and pharmacies, or from automated laboratory reporting.

While syndromic surveillance based on electronic health data has been successfully used to detect and monitor potential bioterrorism-related outbreaks and emerging infectious diseases, the development of similar methods to monitor the prevalence of chronic conditions has lagged. Given the aging population and increasing prevalence of obesity, better systems are needed to measure chronic

Table 1: Examples of Population Health Surveillance in the United States

Surveillance Data Sources	Examples
Registries	Birth, death, immunization, lead, cancer, HbA1c, tuberculosis, HIV
Population-based surveys	National Health and Nutrition Examination Survey (NHANES), Behavioral Risk Factor Surveillance System (BRFSS), National Health Interview Survey (NHIS)
Sentinel studies	Hospital or laboratory-based studies to monitor the incidence of drug-resistant tuberculosis
Cohort studies	Framingham Heart Study, Harvard Nurses' Health Studies
Financial claims data	Michigan Asthma Medicaid Surveillance System (MAMSS)
Mandatory case reports	Lab reports of positive Lyme disease tests, provider reports of tuberculosis cases
Syndromic surveillance	Counts of: emergency department visits for influenza-like illness; pharmacy sales of anti-diarrheal medications; EMS calls for overdoses; gastrointestinal symptoms recorded in ambulatory visits

disease burden, monitor changes in burden over time, evaluate the effectiveness of government policies, and prioritize scarce health resources.

Electronic health records (EHRs) are beginning to transform the clinical practice of medicine, and electronic data sharing is becoming increasingly common. Patient registries, automated laboratory reporting, and financial claims databases are some of the oldest examples of shared electronic patient data. In large health systems or provider networks like Kaiser Permanente, data may be shared within an internal network for care coordination, quality improvement, and clinical research. Health Information Exchanges (HIEs) and Regional Health Information Organizations (RHIOs) are forming across the country to facilitate the secure transfer of patient information across providers and health care delivery systems.

EHR data exchange that is designed for patient care usually uses line-level data, whereby an individual's information is exchanged between parties providing care to that individual. Line-level data can also allow public health researchers to examine relationships among multiple health outcomes, or to combine information across multiple data sources and points in time. Line-level data can be de-identified by removing information like name and date of birth that connects the data to the individual. However, line-level data may carry risks to patient

Distributed Model: "Instead of collecting all of the detailed data, a distributed model ... collect[s] only summarized data (counts, numerators and denominators, or key results) and limit[s] the data collection to the minimum needed to answer the research question."¹

confidentiality even when records have been stripped of explicit identifiers.

More recent networks are now developing to allow sharing of aggregate data, or counts of patients. These networks often use a distributed model, whereby the full electronic record remains at the institution where it is in use, and only essential information is transmitted. Aggregate data are de-identified, and most systems limit the collection of highly specific combinations which could be re-identified. Because only counts are shared, aggregate data carry low risks to confidentiality.

EHR data are already being used to learn more about patient health and physician behaviors within health care institutions. As their uptake continues to grow, EHRs could also be used to support health surveillance for more broadly defined populations. The benefits of using EHRs for surveillance include timely availability of data, cost-efficiency of data collection, access to detailed clinical and laboratory information, large sample sizes that permit reliable studies of rare conditions or of small subpopulations, and the ability to evaluate changes in health over time. Limitations include governance and methodological challenges associated with sharing data, data quality, and the need to establish standards for how EHR data are entered, analyzed, and interpreted, especially with regard to generalizability and evaluation of trends over time.

This report describes how office-based EHRs can potentially be used for population health surveillance; discusses many of the governance and methodological issues that arise when developing an electronic health record-based surveillance system (EHRSS); introduces the NYC Macroscopic EHRSS project; and describes a project to evaluate the validity of NYC Macroscopic estimates.

B. International Examples of EHR Use for Population Surveillance

Efforts are under way in the United Kingdom,⁶ Sweden,⁷ Australia,⁸ Canada,⁹ France,¹⁰ Norway,¹¹ and elsewhere to expand the use of office-based EHRs for both clinical and surveillance purposes. The models adopted in Canada and Norway are two examples of how this can be done.

In Canada, a network of networks approach is being used to organize primary care providers into regional HIE networks that are themselves members of a national network, the Canadian Primary Care Sentinel Surveillance Network (CPCSSN). Every three months, CPCSSN practices contribute de-identified line-level data on eight chronic and neurologic conditions to their regional network. The data are then standardized at the regional level before being combined centrally. The program is structured as a multi-site research project housed by academic medical centers in each region of the country.^{11,12}

In contrast, the Snow Agent system in northern Norway is a distributed data surveillance system that also allows peer-to-peer electronic communication. All general practitioners in northern Norway participate in the Snow Agent system, which extracts the clinical diagnoses recorded in the general practitioners' EHRs and aggregates those data into counts. The counts are then used to respond to queries, such as, the daily incidence of influenza-like illness in one region.^{11,13} The Snow Agent System focuses primarily on monitoring the incidence of infectious disease, but the infrastructure could permit chronic disease monitoring as well.

C. The United States Experience

In the United States, the linkage of medical records across providers for population health surveillance can be traced back to at least the 1960s, when both the Marshfield Epidemiologic Study Area (MESA)¹⁴ in central and northern Wisconsin and the Rochester Epidemiology Project (REP)¹⁵ in Olmsted County, Michigan, were first established. The MESA project has been electronically storing diagnoses and other elements of the medical record since 1961; REP records were computerized in 1975. The research findings generated by these projects demonstrate the utility of networking medical records for population health surveillance.^{14,15} With the advances in health information technology and infrastructure, developing such networks on a broader scale is now feasible. For example, the Chicago Health Atlas¹⁶ has developed methods to merge de-identified line-level clinical data across multiple care sites at the patient level.

In recent years, office-based health care providers in the United States have increasingly adopted EHRs in part because of financial incentives authorized as part of the 2009 Health Information Technology for Economic and Clinical Health (HITECH) Act.^{4,17} As of 2012, 71.8% of office-based medical practices report the use of some type of EHR.¹⁸ Under HITECH, practices receive incentives from Medicare and Medicaid for achieving "meaningful use," that is, for successfully adopting an EHR system and using it to record priority data elements. These incentives will improve EHR documentation of health data, particularly for a core group of health measures and diseases that are reinforced through the meaningful use criteria. This will lay the groundwork for data collection of acceptable quality for surveillance or aggregate tracking purposes.

HITECH is also supporting the development of infrastructure to share clinical data between organizations and systems. The Query Health project, convened by the Office of the National Coordinator (ONC) on Health Information Technology, aims to establish preliminary standards and services for EHR-based population health surveillance systems that rely on distributed data. The pilot sites listed in Table 2 are currently involved in validating these standards.¹⁹

Another initiative to harness data from EHRs for public health purposes is the Centers for Disease Control and Prevention’s (CDC) project “Demonstrating the Preventative Care Value of

Health Information Exchanges” (DPCV). This project is examining the feasibility of using data from HIEs to quantify the delivery of preventive care, specifically aspirin therapy, blood pressure screening, cholesterol screening, and smoking cessation. A second goal of DPCV is to document valuable lessons about the process of implementing projects that use HIE data for public health purposes. The project’s final report described challenges encountered by various project sites, such as difficulties aligning federal and local priorities, concerns from participating practices about sharing data with government analysts, and lack of interoperability among participating agencies.²⁰

Table 2: Sample Query Health Project Pilots

Project Name	Coordinating Center	Type of Data
Mini-Sentinel	Food and Drug Administration (FDA)	Medication adverse event reporting
Clinical Quality Measures	Allscripts	Aggregate meaningful use quality metrics from inpatient and ambulatory practices using the Allscripts system
Primary Care Information Project (PCIP) Query Health Pilot outpatient	NYC Department of Health and Mental Hygiene	Aggregate numerators and denominators for key quality of care metrics, collected from RHIOs sharing inpatient and data from multiple software platforms

II. Governance Issues in Electronic Health Record Surveillance System (EHRSS) Development

The DPCV study described above stresses the critical importance of governance issues including leadership, confidentiality, and technical readiness when repurposing HIE data for public health purposes.¹⁹ Although our report will not focus on these three issues, we touch briefly on each of them below.

A. Leadership

Strong and coordinated leadership is necessary to align the goals and expectations of the many entities involved in the development of an EHRSS. In particular, national and local governments need to establish a common set of goals and expectations, particularly with regard to which resources are required and how they will be obtained. In the United States, the federal government has partnered with standards organizations to promote interoperability. Local and state agencies, care networks, and research consortia have established local data exchange channels (freestanding or in partnership with HIEs and RHIOs).

EHRSS developers must negotiate the sometimes conflicting priorities of all stakeholders, including national and local government agencies, medical providers, EHR software vendors, health information technology specialists responsible for developing and operating the data exchange networks, and the analysts and policymakers who will use the data. Local and state health departments can improve this coordination in the future by expanding the list of mandatory reportable

conditions beyond communicable threats to include key chronic diseases.

B. Confidentiality

Concern for patient confidentiality is paramount in all surveillance systems, and the incorporation of established, secure technology throughout the data sharing process is critical. By using a distributed model and exchanging only aggregate data, health departments obtain population health information and health care providers retain control of individual patient information, in accordance with the Health Insurance Portability and Accountability Act (HIPAA). Distributed data offer a lower risk of confidentiality breaches than line-level data, and providers concerned about confidentiality may be more likely to participate in an HIE using distributed data.

An EHRSS based on line-level data may require many types of de-identification even after removing patient names and addresses, for example, converting birth date to birth year and suppressing any free-text references to family history. EHRSS developers need to partner with health care providers and with informatics specialists to determine the best de-identification strategies.

When an EHRSS will monitor reportable diseases, such as tuberculosis, using identifiable patient information may be appropriate. An EHRSS with identifiable patient information that seeks to monitor diseases beyond the reportable conditions may require Institutional Review Board (IRB) approval and informed consent.

C. Technical Issues

EHRSS developers face many technical challenges. Data must flow from the health care provider who collects patient information to the user who will analyze the information. Applying uniform software standards is difficult when an EHRSS pulls data from multiple EHR software platforms that have small variations on how and where data are stored. For example, some software platforms collect diagnosis in both “Assessments” and “Problem List,” while other platforms collect diagnosis in only one place. Some of these challenges can be overcome by EHRSS developers through uniform implementation of data exchange standards and through robust data examination and correction. However, even software

platforms that have implemented the same standard, such as HL7, may have interpreted the standard in different ways, impeding data exchange. Nationally, the ONC’s Standards and Interoperability (S&I) Framework Initiative¹⁹ fosters public-private partnerships to create solutions to interoperability gaps. Additionally, standards groups bring together EHR vendors and test the interoperability of their standards at “Connect-a-thon” events. At present, however, standards have not been implemented uniformly. EHRSS developers will need to decide whether to limit their system to a single EHR vendor, require parallel mapping across contributing EHR vendors’ platforms, or to run standardization algorithms after data have been collected to allow multiple sources to contribute to a single EHRSS.

III. Methodological Considerations in EHRSS Development

A. Data Structure and System Design

One of the first considerations in building an EHRSS is the structure of the dataset. If EHRSS developers can choose between aggregate and line-level data, they must consider the benefits and costs of each approach. Line-level systems are amenable to multivariable analysis, and they permit longitudinal tracking of individuals over time. However, line-level systems require more server space, resources to link patients across disparate data platforms, and special attention to ensuring patient confidentiality. Using aggregate data may alleviate some of these resource and confidentiality concerns.

B. Standards

Different medical practices often use different proprietary EHR software platforms, and each software platform, as noted above, has its own standards and conventions. One of the key challenges to combining data from multiple EHRs into one surveillance system is semantic equivalency across platforms and even across contributors using the same platform. That is, a data element must have the same meaning for each health care practice entering that element.

Choosing EHRSS indicators that pull from standardized structured fields may yield the most reliable results. Common structured fields include vital signs, diagnosis, medications, immunizations, laboratory tests, and procedure billing codes. Though some structured data elements are uniform across systems (ICD-9 codes), others may vary by software vendor or by geographic region (LOINC codes, which may be mapped to different local codes in different geographic regions). EHRSS developers

must identify which structured data elements are uniform across the software systems involved. Problems in combining data may still arise when structured data elements are stored in different parts of the record, have different variable labels, or have different coding rules. Even when developing an EHRSS drawing on a single software platform, system developers must understand how data are collected in participating practices to ensure that data meanings are uniform.

C. Data Quality

Like all surveillance systems, the usefulness of an EHRSS depends on the timeliness, accuracy, completeness, and comprehensiveness of the data. Ensuring uniformly high quality is particularly challenging, because data entry is decentralized and dependent on the care and effort of individual providers. To maximize completeness and comprehensiveness, EHRSS developers should focus on indicators of population health that are found in structured rather than free-text fields and that are consistent with areas targeted by meaningful use.

Another key strategy to maximize data quality is for EHRSS developers to familiarize themselves with the workflows of the health care practices that will contribute data. For example, if the EHRSS will collect data from pediatric practices, developers should review data definitions both with informatics experts knowledgeable about pediatric medicine and with pediatricians and their office staff who will be entering data.

By aligning the indicators of population health with common workflows, EHRSS developers can focus on

data elements that have the highest potential to be routinely and similarly collected across systems. Most practices collect height and weight data similarly, and body mass index (BMI) will likely be consistent across different software systems. In contrast, tobacco use may be captured differently across systems. Even within a single practice, some providers may use a structured field while others enter free text. Therefore, EHRSS developers must evaluate how tobacco use is captured by health care providers in their EHRs.

EHRSS developers can also maximize data quality through evaluating data completeness for each element in the proposed indicators of population health. For example, an EHRSS developer could examine the percentage of patients at each participating practice with a documented blood pressure in the last year. If more than half of patients at a given practice do not have a blood pressure entry, the low number may indicate problems with the query specifications or with data entry, rather than with the delivery of care. As with other datasets, decisions about how to handle missing data in analysis (censure or imputation) are important.

Meaningful use: “According to the ONC, meaningful use is “using certified electronic health record (EHR) technology to: Improve quality, safety, efficiency, and reduce health disparities; Engage patients and family; Improve care coordination, and population and public health; [and] Maintain privacy and security of patient health information[.] Ultimately, it is hoped that the meaningful use compliance will result in: Better clinical outcomes; Improved population health outcomes; Increased transparency and efficiency; Empowered individuals; [and] More robust research data on health systems.”²¹

Achieving meaningful use is rewarded with a series of financial incentives, administered by Medicaid and Medicare: “The Medicare and Medicaid EHR Incentive Programs provide financial incentives for the ‘meaningful use’ of certified EHR technology to improve patient care. To receive an EHR incentive payment, providers have to show that they are ‘meaningfully using’ their EHRs by meeting thresholds for a number of objectives [specific to either providers or hospitals].”²² Fifteen meaningful use core objectives span an array of provider practices, documentation habits, and clinical services. Of particular interest for data quality is the required reporting of three core or alternate core clinical quality measures and three menu clinical quality measures. For the first stage, the core or required measures for providers include the documentation and management of BMI, measurement of blood pressure among hypertensive patients, and assessment and treatment of smoking. Alternate core measures include childhood vaccination and influenza vaccination in the elderly. Additional measures are management of chronic conditions like diabetes, asthma, hypertension, ischemic vascular disease, and heart failure; cancer screening; medication management; vaccine delivery; laboratory testing; and management of behavioral health, specifically tobacco, drug, and alcohol use.

For a full list of Stage 1 2011/2012 measures, see www.cms.gov/Regulations-and-Guidance/Legislation/EHRIncentivePrograms/Downloads/CQM_EPs_2012_02_02.pdf. For upcoming Stage 2 2014 measures, see www.cms.gov/Regulations-and-Guidance/Legislation/EHRIncentivePrograms/Downloads/EP_MeasuresTable_Posting_CQMs.pdf.

D. Selection of Population Health Indicators

The selection of indicators depends upon the purposes of the system. Indicator domains could include estimates of disease incidence, disease or risk factor prevalence, disease control, receipt of recommended services, or care-seeking behavior (Table 3). Indicators can be drawn from any EHR field where data accuracy and completeness are deemed to be sufficient. Meaningful use guidelines, which are aligned with federal reimbursements, have translated indicator concepts to the EHR setting and can provide a starting point. While some indicators of behavioral health like smoking or depression may be captured, others like diet are unlikely to be uniformly captured and so should not be included.

When defining indicators of population health, EHRSS developers must identify the intake period (2011 visits), demographic group (females aged 18-64), the look-back period for each data element (BMI entered within two years of most recent visit), the in-range values for each data element (range for normal BMI is 18.5-24.9 kg/m²), how to handle repeat entries in a specific field (choose the first BMI measured in the given time period vs. the last,

average, maximum, or minimum), and patient-level inclusion and exclusion criteria (exclude pregnant women). Referring to established, standardized indicator sets like National Quality Forum (NQF) or Healthcare Effectiveness Data and Information Set (HEDIS) measures can be helpful in developing an EHRSS.

E. Inclusion and Exclusion Criteria

Practice Criteria

Simply aggregating data across all practices in a network will not be sufficient to develop a valid surveillance system. Depending on the population health indicators of interest, different types of contributing practices should be included (outpatient and inpatient, outpatient only, general practitioners only, obstetricians and gynecologists only). Documentation thresholds should be set so that only practices documenting properly in the EHR are included. Clearly defining which practices are included ensures that the data obtained are aligned with data that is sought, improves data quality, and also provides a mechanism for minimizing the number of duplicate records that could potentially distort EHRSS estimates (see more on duplicate records, below).

Table 3: Indicator Domains and EHR Examples

Domain or Type of Indicator	Example
Disease incidence	Influenza, chlamydia, breast cancer, stroke, myocardial infarction
Disease or risk factor prevalence	Hypertension, diabetes, obesity
Disease control	Cholesterol management in coronary artery disease, blood pressure control among those diagnosed with hypertension
Receipt of recommended services	Pneumococcal vaccine, colonoscopy
Care-seeking behavior	Primary care use by demographics and risk factors
Behavioral health	Tobacco use, depression

Patient Criteria

It is important to clearly define which patients contribute data to an EHRSS and which ones do not. Inclusion criteria may pertain to demographic or clinical characteristics, but should also include a specified intake period (also known as a reporting period). An intake period describes the window of dates during which a visit must have occurred for the patient's record to be included in the EHRSS, for example visits during calendar year 2012.

The length of the intake period has implications for data completeness and quality. With short intake periods, EHRSSs may differentially capture patients who visit the doctor frequently, especially those who are older or sicker. Choosing longer periods for surveillance brings the younger and healthier patients into the case mix, and attenuates the elevated rates of chronic conditions that are commonly found among those patients with frequent visits. Longer intake periods also result in more complete records for each patient. However, long intake periods sacrifice timeliness, and may not be appropriate for evaluating the burden of current illness, especially acute conditions. In addition, intake periods should not extend beyond the time at which participating practices became proficient in using the EHR.

F. Duplicate Records

Duplicate records can threaten the validity of estimates derived from an EHRSS. In an EHRSS using line-level data with unique patient identifiers, duplication is not a major threat. But, in surveillance systems where data are collected in aggregate, one patient who visits two participating practices will be counted twice. Also, information may be split across the patient's records in the two practices, resulting in what appears to be two patients, each receiving

suboptimal care. While duplication cannot be avoided in an EHRSS based on aggregate data, it can be minimized by narrowly limiting the types of providers who contribute data. For example, duplication can be reduced by excluding specialists from an EHRSS concerned with primary care outcomes, though sample size will be smaller and those patients who visit only the excluded practices will not be counted. Another way to reduce the probability of visits to multiple practices, and thereby reduce duplication, is to limit the intake period. As described above, however, this tactic might censor or exclude patients who visit health care facilities only infrequently. At a minimum, EHRSS designers should conduct sensitivity analyses using different assumptions about the length of the intake period and other factors to test different approaches for minimizing duplication.

G. Measurement Error

Aggregate EHR data are subject to measurement error that is difficult to quantify. At the most general level, care must be taken to make sure that EHRSS indicators are conceptually similar to commonly used indicators from other sources. The indicators must also be reliable across patients, providers, and practices, and should accurately classify health status. Levels of measurement error will vary across indicators, but should improve with time as providers become more experienced using EHRs. Studies that include manual review of a sample of individual EHRs can be helpful in evaluating measurement error for an indicator by comparing the indicator result to information available in the complete medical record, or to data from an external standard such as an examination survey. When measurement error is quantified using criteria such as sensitivity and specificity, that information can be used to calculate margins of error around EHRSS point estimates.

H. Selection Bias and Generalizability of Findings

Selection bias presents a challenge to the interpretation of EHRSS data. EHR data are only available for individuals who seek health care. Those who seek health care most frequently, and thus have the most complete records, may be more likely to have underlying health conditions that require regular monitoring. Practices contributing data to the EHRSS may see patient populations that are not representative of the general population. Identifying the most appropriate population to which EHRSS estimates can be generalized is important. In addition, care must also be taken to consider how selection bias will change over time. In the United States, adoption of EHRs is rapidly increasing, but the increase is not uniform across all types of patients. Patient case mix in an EHRSS with an open cohort of practices may vary considerably depending on the time period selected for analysis.

Several approaches can be taken to address selection bias. The simplest approach is to report crude estimates along with a description of the population from whom the data were drawn, including all limitations associated with underrepresentation of specific demographic or geographic subgroups. A better approach is to limit the EHRSS to a representative sample of practices and patients. The most feasible approach may be to standardize the crude estimates to the age, sex, race, and income distribution of the population to which the data are to be generalized (defined as post-stratification adjustment), using neighborhood-level income as a proxy in the likely event that zip code but not income is present in the EHR. Such post-stratification adjustment will control for selection bias associated with the variables used for stratification, and will be particularly useful when evaluating trends over time. However, decisions will need to be made about what standard to use and whether the standard is fixed, so that changes in

outcome are isolated from changes in population composition, or whether the standard is continually updated, so that the estimates better approximate the health of the population.

Standardization: Standardization permits comparison of rates of disease across populations with different demographic profiles. Direct standardization methods involve weighting stratum-specific rates of disease by a standard population distribution and then summing the weighted rates to get the overall standardized population rate.

	% of Population		Rate in Sample
	Standard	Sample	
Male	49%	30%	21.7%
Female	51%	70%	28.7%

Crude Rate:

$$(.30 \times .217) + (.70 \times .287) = 0.266 = 26.6\%$$

Standardized Rate:

$$(.49 \times .217) + (.51 \times .287) = 0.253 = 25.3\%$$

I. Uncertainty When Analyzing Trends

During this period of rapid adoption of EHRs, trends will be influenced by true changes in the health outcomes, as well as by changes in measurement error and selection bias. As a first level of defense against misinterpretation of meaningless variability, EHRSS developers should use available information about measurement error to compute margins of error around their point estimates. These margins of error may need to be recalibrated over time. Sensitivity analyses comparing estimates from the original cohorts of providers and patients with estimates from new cohorts may be useful in evaluating the effect of changing case mix. Frequent, perhaps quarterly, monitoring of EHRSS estimates and comparison with other data sources may be a useful way to identify sudden unexplained differences from one period to the next.

IV. Plan to Operationalize the NYC Macroscopic EHRSS

A. Introducing NYC Macroscopic

In 2012, the New York City Department of Health and Mental Hygiene in collaboration with the City University of New York School of Public Health (CUNY SPH) began developing an EHRSS called NYC Macroscopic. Using data from participating primary care practices across the city, NYC Macroscopic is intended to produce annual estimates of the prevalence, treatment, and control of selected indicators of population health. At present the system is limited to adult outcomes, although extending it to include pediatric outcomes may be considered in the future. During this initial development phase, the indicators are limited to high-priority conditions that are: 1) key measurements of public health, 2) likely to be captured in EHRs, and 3) amenable to improvement by clinical action or public health intervention. The goals of the NYC Macroscopic project are to develop and pilot indicators of population health that will inform municipal health policy and to develop methods for analyzing, validating, interpreting, and reporting NYC Macroscopic estimates and trends.

B. The NYC Primary Care Information Project

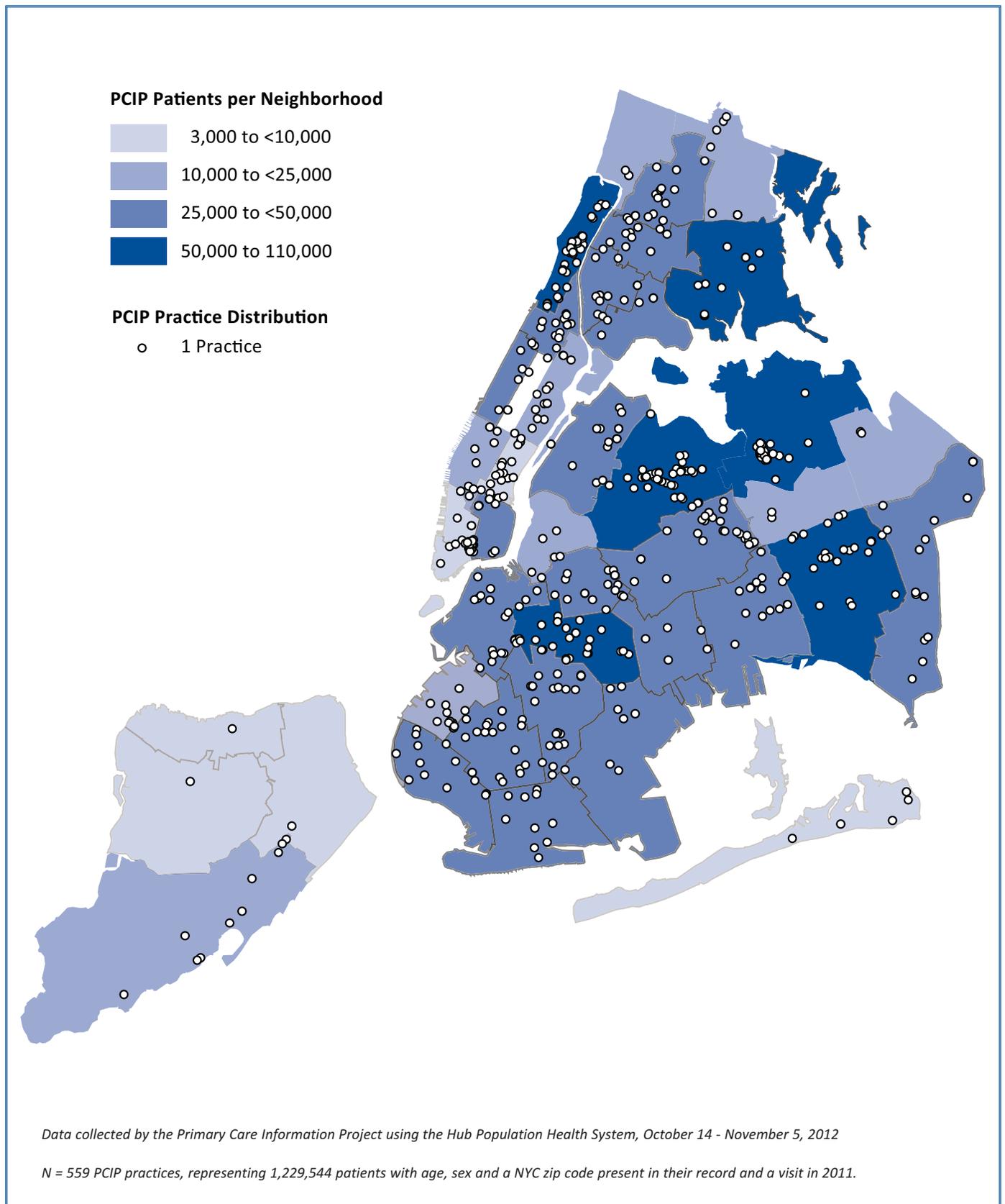
NYC Macroscopic derives its data from more than 500 adult primary care practices participating in electronic data exchange as affiliates of the NYC Primary Care Information Project (PCIP). PCIP was launched as a Mayoral initiative in 2005 with the goal of improving the quality of health care for the most vulnerable New Yorkers by helping providers in underserved areas to adopt EHRs with population management tools like real-time alerts and patient

registries. Since its inception, PCIP has provided assistance to more than 8,000 providers using a variety of EHR software platforms through the federally recognized Regional Electronic Adoption Center for Health (REACH). PCIP has established data exchange with more than 3,200 of those providers using the eClinicalWorks system, representing more than three million patients seen by those practices since 2009. The mechanism of this information exchange is called the Hub Population Health System (Hub), and it allows PCIP to send out priority public health messages to and receive aggregate data from about 600 independent ambulatory practices (including adult and pediatric primary care and specialty practices), as of January 2013. (See Figure 1 for a map of Hub coverage.)

The Hub uses a distributed model to protect patient confidentiality.²³ Clinical practices house all of their EHR data and no confidential information is transmitted to the Hub. DOHMH uploads routine and customized requests for specific data to the Hub, which distributes a query formatted in structured query language (SQL) to the EHRs of each participating practice. Each practice's EHR system automatically calculates the count of patients that meet the definition of that query and returns that count to the Hub overnight. (See Figure 2 for a diagram of the Hub.)

PCIP's role in health surveillance has evolved as the network has grown. During the 2009 H1N1 pandemic, PCIP data were used to monitor influenza-like illness in ambulatory care settings, demonstrating the potential of ambulatory care data to provide real-time information on syndromes.²⁴ PCIP is also one of the sites validating the ONC

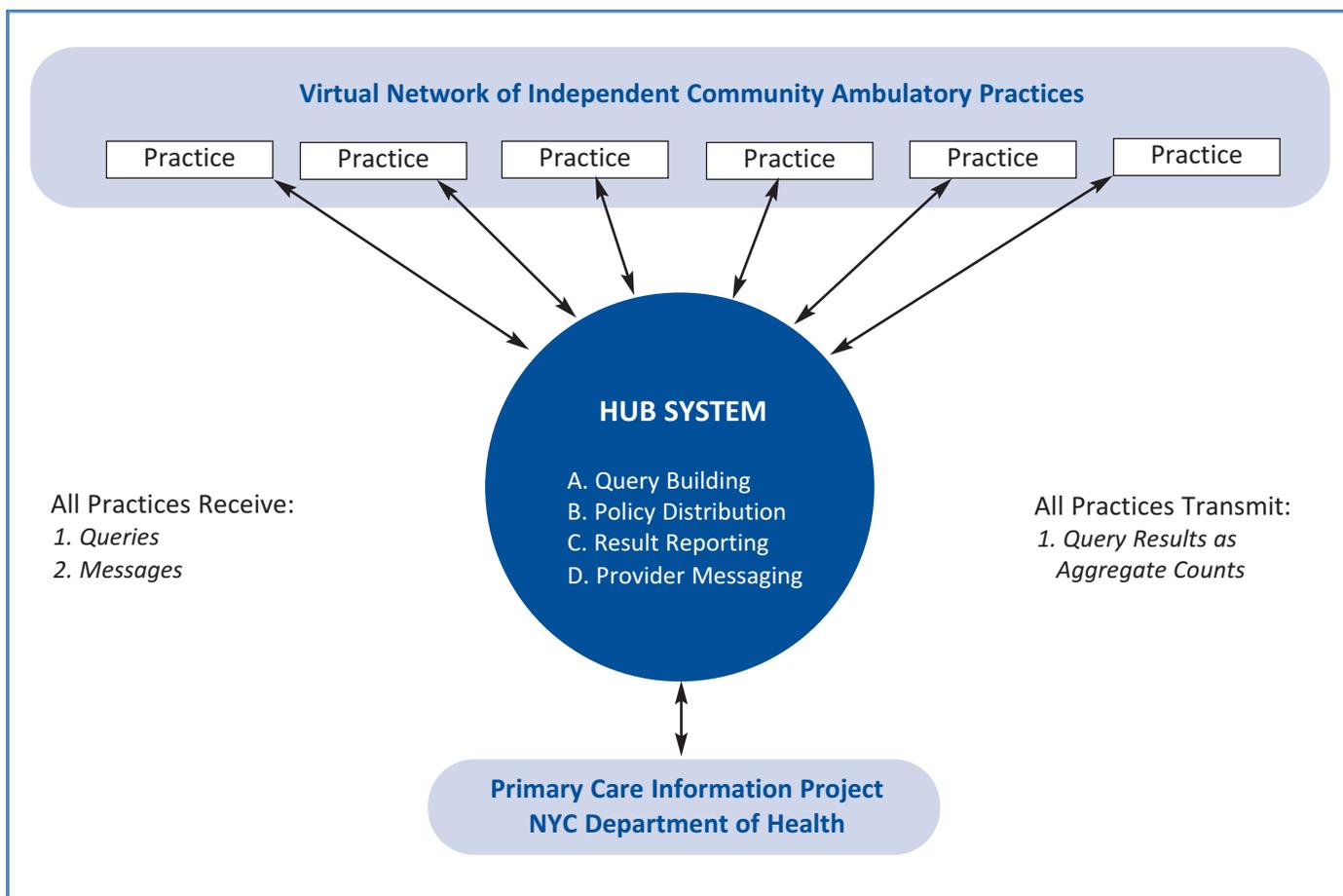
Figure 1. Hub Coverage of NYC in 2012



Data collected by the Primary Care Information Project using the Hub Population Health System, October 14 - November 5, 2012

N = 559 PCIP practices, representing 1,229,544 patients with age, sex and a NYC zip code present in their record and a visit in 2011.

Figure 2. Diagram of the PCIP Hub



standards for distributed data surveillance systems through the Query Health project (Table 2). Thus, PCIP is well-positioned to design and implement an EHRSS for monitoring population health.

C. NYC Macroscopic Inclusion and Exclusion Criteria

In developing the NYC Macroscopic EHRSS, we have established the following inclusion and exclusion criteria to reduce measurement error and selection bias:

Patients (N >700,000)

Inclusion Criteria:

- Are adults (age 20-100 for the validation study).

- Have gender recorded as male or female.
- Have a valid NYC zip code of residence.
- Had at least one visit within the 12-month intake period.

Practices (N > 500)

Inclusion Criteria:

- Have at least one primary care provider (primary specialty of internal medicine, family medicine, geriatrics, adolescent medicine, or pediatrics).
- Have regularly responded to Hub queries since December 2012.
- Return reliable data that meet data completeness criteria.

D. NYC Macroscopic Indicators

The initial set of NYC Macroscopic indicators were selected based on their public health impact and based on our expectation that these indicators, as core elements of an adult primary care visit, would be well-documented in the EHR. We selected hypertension, diabetes, cholesterol, and BMI as indicators that would likely be accurately documented across practices. For each indicator, we developed one or more measures of prevalence, treatment, and control. We also selected smoking, immunization against influenza, and depression screening as indicators to explore the accuracy of EHR documentation for behavioral risk factors and clinical preventive services. The appendix contains a complete set of indicators to be developed and evaluated during this first phase of NYC Macroscopic.

E. Sensitivity Analyses

A fundamental component of NYC Macroscopic development will be conducting sensitivity analyses to determine which approaches to indicator definition, record selection, and practice inclusion provide the most complete and representative data. Here, we detail some of the planned sensitivity analyses that will be conducted by comparing different ways of configuring the EHR indicators.

Our planned sensitivity analyses include evaluation of:

- Inclusion and exclusion criteria, specifically the impact of including specialty practices (obstetricians and gynecologists, endocrinologists); extending the intake period from one to two years; and assigning different thresholds for data completeness (greater than 20% of patients have BP entered vs. greater than 50%).
- Indicator definitions, specifically how to handle repeated measurements (BP readings) in a record; length of the look-back period; and, the location of contributing data elements within

the record (looking for diagnosis in the problem list vs. the assessments section of the EHR).

- Other factors that might affect NYC Macroscopic performance, specifically the number of contributing practices and patients, the length of time that a practice's EHR has been in use, and the proportion of patients who have visited the practice on more than one occasion.

F. Design and Operationalization of NYC Macroscopic

Many NYC Macroscopic design decisions were driven by the architecture underlying PCIP. For example, PCIP collects aggregate data using a distributed model, so an evaluation of the relative costs and benefits of aggregate versus line-level data was not necessary. Although aggregate data maximizes privacy and minimizes HIPAA concerns, many queries are required to obtain a population distribution. The personnel time required to write, test, schedule, and analyze queries and the time each query takes to execute on practice EHR systems must be balanced against the desired number of data elements to set the scope of the EHRSS.

We decided to focus NYC Macroscopic development on population health indicators assessed in primary care visits, because they align with the leading causes of morbidity and mortality in NYC. Additionally, primary care practices comprise the majority of PCIP's provider population. In the future, running specific surveillance modules aimed at specialists (gynecologists, cardiologists, and endocrinologists) may become desirable. Because of the planned validation studies (described below), all NYC Macroscopic indicators target adults, but pediatric populations could be included in the future. We decided to limit data collection to visits that occurred within a one-year intake period to be consistent with definitions of population health indicators used nationally. Based on the results of

sensitivity analyses comparing intake periods of different lengths, we may report annual estimates that represent multi-year moving averages in the future.

G. Programming and Piloting the Queries

A dedicated SQL programmer has been hired to write, test, and execute the approximately 6,000 queries that are budgeted for this project. Part of that job will include comparing alternative approaches toward selecting records in order to optimize query runtime while obtaining reliable data. In addition, the SQL programmer will create complex code, for example, code for “relative dates,” such as an HbA1c lab value returned six months before or one year after the most recent 2013 visit. Queries will be written to maximize both data quality and speed of execution.

H. Methods for Producing and Reporting NYC Macroscopic Data

NYC Macroscopic estimates will be reported primarily in standardized form so that they can be compared

with estimates collected at other times or from other jurisdictions. NYC Macroscopic data will be collected for each of 24 strata defined by age group (3 levels), sex (2 levels), and neighborhood poverty (4 levels). Data on race/ethnicity are not reliably available and so will not be incorporated into NYC Macroscopic queries at this time. Each stratum will be weighted to reflect the proportion of adults in the standard population who can be characterized by that combination of age group, sex, and neighborhood poverty. Selection of the standard population will be made based on the results of NYC Macroscopic validation studies described below, and may include all adult New Yorkers, those who have a regular source of medical care, and those who have seen a primary care provider in the past year. Data from the validation studies will also be used to compute margins of error around NYC Macroscopic estimates. We are continuing to explore methods and criteria for evaluating changes in NYC Macroscopic estimates over time. At a minimum, we plan to document obvious secular changes within our presentation of trend data, and describe changes in the NYC Macroscopic case mix.

Neighborhood Poverty: Neighborhood poverty is defined as the proportion of individuals living in poverty in each patient’s zip code of residence. A NYC DOHMH working group developed both a six-level and a four-level version of neighborhood poverty, and stratification by neighborhood poverty has become standard throughout NYC DOHMH.²⁵ For parsimony, we have chosen to use the four-level classification.

Classification	Percent of individuals in the zip code who live below 100% of the Federal Poverty Level
Low poverty:	< 10%
Medium poverty:	10% to <20%
High poverty:	20% to < 30%
Very high poverty:	≥ 30%

V. Planned Validation Studies of NYC Macroscopic

A. Introduction

The launch of any new surveillance system is usually accompanied or followed by attempts to evaluate its validity. Such an evaluation often involves the use of an alternative data source (i.e., a “gold-standard” surveillance system) to confirm and quantify differences between the two systems.²⁶ EHR-based surveillance, especially in the context of tracking burden and management of chronic conditions, is new and thus the comparison with a strong gold-standard data source is particularly important.

We will compare NYC Macroscopic data with data derived from a concurrently conducted population health survey that includes an examination component. Modeled on the National Health and Nutrition Examination Survey, the NYC Health and Nutrition Examination Survey 2013 (NYC HANES 2013) has been designed to estimate population prevalence, treatment, and control of priority health conditions. The highly rigorous sampling design and data collection procedures give us confidence that data from NYC HANES 2013 will provide accurate estimates of the health of NYC residents.*

Two specific threats to the validity of NYC Macroscopic estimates will be evaluated: measurement error and selection bias. Measurement error exists when NYC Macroscopic estimate and the true value differ either because NYC Macroscopic is measuring something different from what it purports to measure, or because NYC Macroscopic provides unreliable measurements. Selection bias exists when NYC Macroscopic estimates differ from the true values of population health because of

NYC Health and Nutrition Examination Survey 2013: NYC HANES 2013 is being carried out by CUNY School of Public Health in collaboration with DOHMH. NYC HANES 2013 will initially sample approximately 3000 NYC homes to obtain a final sample size of approximately 2,000 New Yorkers (for more information, visit www.nychanes.org). Selected adults will be interviewed in their homes and asked to undergo medical examinations and laboratory testing to evaluate key measures of health status including hypertension, high cholesterol, diabetes, smoking, depression, diet and physical activity, substance use, and use of preventive medical services. All data collection techniques have been benchmarked against methods used in the National Health and Nutrition Examination Survey. NYC HANES 2013 will be used to describe the health status of New Yorkers and evaluate changes since 2004, as well as to validate NYC Macroscopic.

selective inclusion of certain sub-populations conditional on their health status. Both measurement error and selection bias will be assessed through the comparison of NYC Macroscopic data against the gold-standard data obtained by NYC HANES 2013.

B. Evaluation of Measurement Error

Measurement error will be assessed for NYC Macroscopic with a chart review validation study. Based on data from PCIP, we anticipate that approximately 200 NYC HANES study participants will have visited a PCIP provider within the previous

* Note of caution: While HANES surveys represent the gold standard in health examination surveys, sample sizes are small.

12 months and will consent to participate in the chart review validation study. These participants provide us with an opportunity to assess measurement error at an individual level by comparing data abstracted from their PCIP-affiliated EHR with data collected as part of their participation in NYC HANES 2013.

For each indicator of population health, the percent agreement, Kappa coefficient, sensitivity, specificity, and other evaluation metrics will be assessed. These analyses will provide information to compute margins of error around NYC Macroscopic point estimates, and will enable us to evaluate whether the similarity of NYC Macroscopic estimates to the gold standard is higher for some health conditions, types of measures, or population subgroups than for others. We will also use the information we learn from this study to describe how PCIP patients differ from other NYC HANES 2013 study participants, to refine our indicator definitions, and to identify indicators that perform poorly and should be excluded.

C. Evaluation of Selection Bias and Generalizability

It will be important to determine the population to which NYC Macroscopic estimates can be generalized. To assess the representativeness of NYC Macroscopic, aggregate EHR-derived estimates will be compared with similar estimates from NYC HANES 2013 calculated for three target populations: 1) the total NYC adult population, 2) the subpopulation of NYC adults with a regular source of

health care, and 3) the subpopulation that has seen a primary care provider in the past 12 months. For each comparison, NYC Macroscopic estimates will be standardized to the age, sex, and neighborhood poverty distribution of the NYC HANES 2013 target population.

NYC Macroscopic estimates will be considered generalizable to the target population if they fall within the 95% confidence intervals of the corresponding NYC HANES 2013 estimates. For NYC HANES 2013 estimates with 95% confidence interval half-widths greater than 10, the 99% confidence interval will be used. If aggregate NYC Macroscopic data do not align with aggregate NYC HANES 2013 data despite having good correspondence at the individual level, further evaluation of the difference between the PCIP population and the NYC population, as well as other factors contributing to selection bias, will be examined.

D. Other Criteria by Which NYC Macroscopic Will Be Evaluated

In addition to reliability, validity, and generalizability, a quality surveillance system must meet other criteria defined in the CDC's "Updated Guidelines for Evaluating Public Health Surveillance Systems," including acceptability, adaptability to changing needs, timeliness, and system simplicity.²⁷ As part of our validation studies, we will also evaluate the extent to which NYC Macroscopic meets these criteria.

VI. Conclusion

EHRs are rapidly being incorporated into health care settings throughout NYC, the United States, and nations worldwide. EHR technology has the potential to improve the quality and efficiency of medical care and provides data that can be harnessed to monitor population health. This report seeks to facilitate the development of EHR-based surveillance systems by describing the many governance and methodological challenges that

must be overcome, and by providing an example of how those challenges are being addressed in New York City. It is our intention that this report will serve as a reference and a catalyst for jurisdictions wishing to develop their own systems, and that it will lay the groundwork for an ongoing conversation about the best ways to use EHR technology for population health surveillance.

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VIII. Appendix – Comparison of Indicators in NYC Macroscope and in NYC HANES 2013

The appendix presents the initial set of indicators that will be monitored as part of the NYC Macroscope electronic health record surveillance system. Findings from NYC Macroscope will be compared with findings from a gold-standard surveillance tool, the New York City Health and Nutrition Survey 2013 (NYC HANES 2013).

NYC Macroscope derives data from a subset of health care practices that participate in the New York City Primary Care Information Project (PCIP). Queries will be uploaded to the PCIP Hub Population Health System (HUB), and the Hub will distribute the queries to the EHRs of each participating health care practice. At present, the Hub draws data only from eClinicalWorks EHRs. Although individual documentation habits may vary by site, all eClinicalWorks EHRs share a common table structure which we will use to construct these queries. Aggregate count data responses to queries will be returned by each practice to the Hub overnight. Those data will be standardized to the age, sex, and neighborhood poverty distribution of the NYC population.

The indicators have been selected because of their public health importance. Many of the indicators have been selected because they constitute core elements of an adult primary care visit and, as such, are expected to be well-documented by the health care practices in PCIP. Some of the indicators have been selected because of questions about the extent of EHR documentation and the need for further analysis.

Data from both HANES 2013 and NYC Macroscope will be stratified by age (20-39, 40-59, 60+, except for total cholesterol, which will be restricted to the ages specified), gender (male, female), and neighborhood poverty (quartiles).

ALL ABBREVIATIONS ARE DEFINED IN THE GLOSSARY ON PAGE ii

Table A1. Diabetes		
Indicator of Population Health	NYC HANES 2013	NYC Macroscope
Measured HbA1c levels (%)		
Normal < 5.7 Prediabetes ≥ 5.7 and < 6.5 Diabetes ≥ 6.5	Lab value of HbA1c	Last lab value of HbA1c returned via electronic lab interface
Prevalence/Diagnosis		
Diabetes	Lab value of HbA1c ≥ 6.5 OR Ever told diabetes	Last lab value of HbA1c ≥ 6.5 OR Dx of diabetes ever entered in assessments
Diabetes history/diagnosis (Dx)	Ever told diabetes	Dx of diabetes ever entered in assessments
Prediabetes	Lab value of HbA1c ≥ 5.7 and < 6.5 OR Ever told prediabetes	Last lab value of HbA1c ≥ 5.7 and < 6.5 OR Dx of either abnormal glucose or prediabetes ever entered in assessments
Abnormal glucose metabolism	Lab value of HbA1c ≥ 5.7 OR Ever told diabetes or ever told prediabetes	Last lab value of HbA1c ≥ 5.7 OR Dx of diabetes or of abnormal glucose or of prediabetes ever entered in assessments
Treatment with Medication		
Prescribed insulin, for each diabetes prevalence definition	Prescribed insulin in the past year	Prescribed insulin in the past year
Prescribed non-insulin medication, for each diabetes prevalence definition	Prescribed non-insulin medication in the past year	Prescribed non-insulin medication in the past year
Control		
Poor control, for each diabetes prevalence definition	Lab value of HbA1c > 9.0	Last lab value of HbA1c > 9.0
Poor control among prescribed insulin	Lab value of HbA1c > 9.0	Last lab value of HbA1c > 9.0
Poor control among prescribed non-insulin medication	Lab value of HbA1c > 9.0	Last lab value of HbA1c > 9.0

Table A2. Cholesterol		
Indicator of Population Health	NYC HANES 2013	NYC Macroscope
Measured Cholesterol (mg/dL)		
Total Cholesterol: Limit to women age 45 and older, men age 35 and older	Lab value	Last lab value returned via electronic lab interface
LDL Cholesterol: among those with diabetes history/diagnosis (standard age categories)	Lab value	Last lab value returned via electronic lab interface
Prevalence/Diagnosis		
High cholesterol	Lab value of total cholesterol ≥ 240 OR prescribed cholesterol-lowering medication in past year	Last lab value of total cholesterol ≥ 240 OR prescribed cholesterol-lowering medication in past year
High cholesterol expanded definition	Lab value of total cholesterol ≥ 240 OR prescribed cholesterol-lowering medication in past year OR ever told high cholesterol	Last lab value of total cholesterol ≥ 240 OR prescribed cholesterol-lowering medication in past year OR Dx of hyperlipidemia ever entered in assessments
High cholesterol history/diagnosis	Ever told high cholesterol	Dx of hyperlipidemia ever entered in assessments
High LDL cholesterol among those with diabetes history/diagnosis	Lab value of LDL > 100	Last lab value of LDL > 100
Treatment with Medication		
Prescribed cholesterol-lowering medication for each cholesterol prevalence definition	Prescribed cholesterol-lowering medication in the past year	Prescribed cholesterol-lowering medication in the past year
Control		
Controlled cholesterol for each total cholesterol prevalence definition	Lab value of total cholesterol < 240	Last lab value of total cholesterol < 240
Controlled total cholesterol among those prescribed cholesterol-lowering medication	Lab value of total cholesterol < 240	Last lab value of total cholesterol < 240

Table A3. Hypertension

Indicator of Population Health	NYC HANES 2013	NYC Macroscope
Measured Blood Pressure (mm Hg)		
Normal: SBP < 120 and DBP < 80 Pre-HTN: SBP 120-139 or DBP 80-89 Stage I: SBP 140-159 or DBP 90-99 Stage II: SBP ≥ 160 or DBP ≥ 100	Three or four measurements are taken at one sitting. The first is discarded and average numerators and denominators are derived for each patient. Ratio of averages is compared to classification standards.	Last BP in reporting year, recorded in vitals
Prevalence/Diagnosis		
Hypertension	Measured BP ≥ 140/90 OR prescribed antihypertensive medication in past year	Last BP ≥ 140/90 in past year OR prescribed antihypertensive medication in past year
Hypertension expanded prevalence	Measured BP ≥ 140/90 OR prescribed antihypertensive medication in past year OR ever told BP high	Last BP ≥ 140/90 in past year OR prescribed antihypertensive medication in past year OR Dx of hypertension ever entered in assessments
Hypertension history/diagnosis	Ever told BP high	Dx of hypertension ever entered in assessments
Treatment with Medication		
Prescribed antihypertensive medication for each hypertension prevalence definition	Prescribed antihypertensive medication in past year	Prescribed antihypertensive medication in past year
Control		
Controlled hypertension among those treated	Prescribed antihypertensive medication past year AND BP < 140/90	Prescribed antihypertensive medication past year AND BP < 140/90

Table A4. Obesity

Indicator of Population Health	NYC HANES 2013	NYC Macroscope
Measured Body Mass Index (kg/m²)		
Underweight: < 18.5 Normal weight: ≥ 18.5 and < 25.0 Overweight: ≥ 25.0 and < 30.0 Obese: ≥ 30.0	Height and weight measured to calculate BMI	Last BMI in vitals in reporting year
Prevalence/Diagnosis		
Prevalence of obesity	BMI ≥ 30.0	BMI ≥ 30.0

Table A5. Smoking

Indicator of Population Health	NYC HANES 2013	NYC Macroscope
Prevalence of current smoking	Smoked in past 30 days AND smoked more than 100 cigarettes in lifetime	Listed as a current smoker in a form capturing smoking status updated in the past year

Table A6. Flu Vaccine

Indicator of Population Health	NYC HANES 2013	NYC Macroscope
Prevalence of flu vaccination	Flu vaccine in the past year	Flu vaccine entered in immunizations in the past year

Table A7. Depression

Indicator of Population Health	NYC HANES 2013	NYC Macroscope
Prevalence of depression	Score on PHQ-2 or PHQ-9	Score on PHQ-2 or PHQ-9, among those with a standardized depression form updated in the past year
Expanded prevalence of depression	Score on PHQ-2 or PHQ-9 OR ever told depression	Score on PHQ-2 or PHQ-9 OR Dx of depression ever entered in assessments

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