Grant Final Report

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Automating Assessment of Asthma Care Quality

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Abstract

Purpose: To develop, implement, and evaluate an automated method that uses Health Information Technology (Health IT) to comprehensively assess outpatient asthma care quality among patients age twelve and older.

Scope: Robust and widespread quality measures addressing the priority condition of asthma are needed. Questions persist regarding how such measures are represented and meaningfully applied to electronic medical records (EMRs). In particular, an abundance of relevant information is locked away in the free-text clinical notes. Our method uses natural language processing (NLP) to gain access to this data.

Methods: This research involved retrospective analysis of EMR data from two distinct health systems: a mid-sized HMO and a consortium of safety-net clinics located primarily in the Pacific Northwest. We utilized an existing medical record classification technology (MediClass) to create and validate a "pipeline" of clinical data processing that included both the free-text and coded elements of clinical visits to assess adherence to care steps recommended by current outpatient asthma guidelines. We applied the method to 3-year data observation windows in the two health systems and assessed outcomes associated with the delivery of recommended care steps.

Results: We developed a comprehensive set of 22 measures for assessing the quality of outpatient asthma care and operationalized 18 of them. The measures performed well, although unwanted measurement variation across health systems remains in some cases. We identified a beneficial association between guideline-recommended care and future asthma exacerbations in patients who experience exacerbations.

Key Words: health information technology, outpatient asthma care quality

Final Report

Purpose

This research set out to demonstrate the viability of an automated method that permits routine and comprehensive assessment of the quality of outpatient asthma care. The research involved retrospective analysis of electronic medical record (EMR) data from two distinct health systems: a mid-sized HMO and a consortium of public health clinics and care organizations located primarily in the Pacific Northwest. The HMO uses an Epic-based EMR called HealthConnect, and the consortium of clinics uses another Epic-based EMR, EpicCare. By including these health systems, this project was able to leverage Health IT to address health care quality improvement for the indigent, uninsured, and underinsured populations served by the participating public health clinics. These two participating health systems include a diverse and representative sample of patients, providers, and health care practices for the entire Northwest. We developed, implemented, and evaluated a method to automatically assess the quality of outpatient asthma care in these two systems. In particular, our aims were:

1. Refine asthma care quality measures from the RAND Quality Assessment Tools Project[1] for use as a quality measure set to evaluate ambulatory asthma care performance.

2. Develop and validate an automated (generalizable and scalable) method for applying the measures identified in Aim 1, using comprehensive EMR data.

3. Apply the method developed in Aim 2 to assess ambulatory asthma care quality in two distinct health plans representing diverse patient populations and care practices.

4. Evaluate the association between our automated measures of adherence to recommended asthma care processes and measures of clinical outcomes.

Scope

A widely cited RAND study of U.S. health care found that only half of health care services recommended by consensus quality standards were actually delivered to those eligible [1]. To address this discrepancy, the Institute of Medicine (IOM) of the National Academy of Sciences has called for new quality initiatives throughout health care [2, 3]. The IOM has made asthma one if its priority areas, calling for improved asthma diagnosis, treatment, and management [4]. Each year, thousands of preventable deaths are attributed to asthma. The annual economic burden of asthma in the U.S. has been estimated (in 1998) at $12.7 billion [4]. While asthma can be managed through ambulatory and self-care, hospitalizations have been estimated to account for more than half of asthma-related medical costs [5]. Furthermore, the asthma-related health

and economic burden has increased steadily over the past three decades, and disproportionately so among minority and financially disadvantaged populations [6]. Before we can intervene to improve care processes, however, we must first accurately and cost-effectively measure care quality and its association with health outcomes. Information technology is a key component to progress in healthcare quality and quality measurement [2, 3].

Opportunities to improve asthma care quality hinge on the capacity to comprehensively and routinely assess the care that is actually delivered to asthma patients. Restricting their attention to a subset of the RAND quality measures, Mularski and colleagues found that only 53.5% of asthma care services recommended by quality standards are actually delivered to those eligible [7]. Unfortunately, these types of quality measurement studies require extensive clinical chart review that, in the absence of scalable automation, severely limits the applicability of the method.

Healthcare information technology (Health IT) could have a substantial impact on this situation. The electronic medical record (EMR) offers impressive opportunities for increasing care quality throughout the healthcare system. The EMR's systematic capture of clinical information could make comprehensive quality assessment possible, both within and across care delivery organizations. However, informatics challenges stand in the way of realizing this vision for the EMR. Warehoused EMR data typically represent an incomplete view of care delivered, and data from different EMR implementations are often difficult to compare. Free-text clinical notes are prevalent in even the most advanced EMRs, and that presents a significant challenge to automated quality assessment. It is likely that 50% or more of the data needed to perform the original RAND study in a state-of-the-art EMR system reside in free-text portions [8].

To fulfill the EMR's promise, new technologies are needed that support both clinical practice and research, including assessment of care quality. One avenue is development of systems that can automatically classify medical record contents, processing both free-text and coded elements of the record. The concept of developing systems capable of processing the free-text portions of the medical record is not new [13-15]. Natural Language Processing (NLP) systems are becoming more feasible as more clinical data is electronically captured [35], data storage capacity advances, computational power increases, and new programming techniques are developed [9-12, 16-23].

In summary, asthma imposes a huge and unnecessary burden on patients and the healthcare system, and has been targeted by the IOM as a priority in efforts to improve care quality. Guidelines for the treatment of asthma provide a way to gauge asthma care in practice. In order to improve quality, we must have methods for routinely assessing the quality of asthma care by comparing care that is actually delivered with the evidence-based care guidelines. State-of-the-art EMR implementations hold promise for carrying out these efforts, but are significantly limited in their capacity to support comprehensive and scalable assessments. Informatics research has demonstrated the feasibility of automatically coding domain-specific clinical text to enhance this capacity. In this study, we developed, implemented, applied, and evaluated a scalable method for automatically assessing the quality of asthma care in outpatient settings.

Methods

We conducted a retrospective data study of the outpatient care delivered to asthma patients in two distinct health care systems, Kaiser Permanente Northwest (KPNW) and the public health

clinics associated with OCHIN, Inc. (OCHIN). KPNW uses the HealthConnect EMR, and OCHIN uses the EpicCare EMR. Although these EMRs are different, both are based on a common ambulatory EMR from Epic Systems Corporation. The research team is made up of scientists and research staff at the primary study site, KPNW Center for Health Research (KPNW CHR), and the secondary site, OCHIN. We obtained IRB approval for this study.

OCHIN, Inc.

OCHIN, Inc. is a non-profit collaboration of public and private community clinics. OCHIN's mission is to meet the data management needs of Federally Qualified Health Centers (FQHCs) and other community health centers that care for indigent, uninsured, and underinsured populations, and thus to improve access to care and quality of care for these populations.

By providing a common set of data management resources, OCHIN gives its member clinics access to sophisticated data systems and reduces their data management burden. OCHIN has licensed from Epic Systems an integrated Practice Management (PM) and Electronic Medical Record (EMR) data system, and has adapted them for the special needs of FQHCs. Eight FQHC organizations (providing care for 173,640 patients at 44 locations through the end of 2010) were approached based on their early adoption of the EMR, and all agreed to participate in this research study.

Kaiser Permanente Northwest (KPNW and CHR)

KPNW is a non-profit, group-model HMO that provides comprehensive, prepaid health care to its members, including access to inpatient, outpatient, and emergency department (ED) services. This study was conducted in KPNW, where the Center for Health Research (CHR) is based. KPNW serves about 450,000 members in the Pacific Northwest. All patient contacts within the system and all services referred outside the system are recorded in a single, comprehensive electronic medical record—the HealthConnect system. These key features of the setting (availability of clinical information systems, integrated care system) are useful for identifying, supporting, and tracking chronic conditions, such as asthma.

Study Population

We included the electronic encounter records of patients age 12 or greater at the start of 2001 (KPNW) or 2006 (OCHIN), who had at least one diagnosis code for asthma in their entire electronic medical record. This included 35,775 individuals in KPNW and 4,477 individuals in OCHIN.

AHRQ Priority Populations

Research shows that asthma disproportionately affects minority and financially disadvantaged populations. The OCHIN clinic network—one of our two study sites—serves predominately low-income, uninsured, and underinsured people. These low-income and underserved people are AHRQ priority populations. Other AHRQ priority populations include racial and ethnic minorities, women, children, elderly people, people with special needs, and

people living in rural areas and inner cities. OCHIN serves a vulnerable, low-income population, with a large percentage of women (60%) and children (38% under 18 years), that has significant overlap with these identified AHRQ priority populations. Approximately half of the OCHIN patient population lives at or below the Federal Poverty Level (FPL), with one-third of these pateints living below 50% of the FPL. Approximately 46% of the OCHIN population is continuously uninsured and an additional 18% have only partial or occasional insurance coverage.

Data Sources

Our primary data source was the ambulatory electronic medical record, which captures outpatient clinical visit information for each health system. However, at KPNW we also had access to additional coded data sources: (1) data that captured asthma-related medications dispensed through the KPNW pharmacy system, (2) a database produced by the centralized pulmonary function testing laboratory at KPNW to capture spirometry lab results, and (3) inpatient discharge data to identify asthma-related hospitalizations for purposes of (a) measure #16, which looks at outpatient follow-up to exacerbations and (b) outcomes data. These additional coded data sources are made available through research databases (medication dispensing, spirometry results, inpatient discharge summaries) and also are integrated into the HealthConnect system (spirometry results, inpatient discharge summaries) by KPNW.

Developing Measures of Care Quality

Our initial measure set was created from existing quality measures. We refined these measures for consistency with updated clinical recommendations and currently available guidelines using an iterative process, including four separate expert and stakeholder vetting and appraisal steps. This process was supplemented with a comprehensive search of existing asthma measures and guidelines including: RAND Quality Assessment Tools project measure set; American Medical Association Physician Consortium for Performance Improvement Ambulatory Care Quality Alliance Starter Set of Clinical Measures (ACQ); Health Plan Employer Data and Information Set (HEDIS) measures; HRSA Health Disparities Collaborative Asthma Measures; Joint Commission on the Accreditation of Hospitals (JACHO) Performance Measurement for Disease-Specific Care Certification; British Medical Association National Health System (NHS) Confederation; Institute for Clinical Systems Improvement Principle Source of Guidelines Update; National Asthma Education and Prevention Program (NAEPP), and the National Heart, Lung, and Blood Institute's Expert Panel Report 3: Guidelines for the Diagnosis and Management of Asthma. We also consulted experts for comment and critique during measure refinement, including: three (3) members of the NAEPP 2007 Consensus Panel; three (3) local and international asthma care experts; three (3) members of the internal KPNW performance measurement group; and various clinical and administrative stakeholders at care sites of the two health systems.

We first identified 25 measures from comprehensive, rigorous, process quality measure sets, primarily derived from RAND's Quality Assessment system [1,7,24]. We added six proposed measures from recently revised asthma guidelines [25] and other quality measurement sources (including HEDIS, NCQA, AMA, HRSA, and JACHO). We eliminated 10 measures that were

not applicable to ambulatory care (n=6) or inconsistent with current guidelines (n=4), resulting in a comprehensive set of 22 process measures that we call the ACQ Measure Set (see Table 1).

Quality Measurement Method

Each measure represents specific care delivery performance as a ratio. For each ratio, the denominator identifies patients who should get the recommended care and the numerator identifies those of this group who received the care. Performance on each measure across a population can then be reported as the percentage of patients who received recommended care (as operationalized by the numerator criteria) from among those for whom that care was indicated by meeting the denominator criteria. For example, the national RAND study by McGlynn and colleagues demonstrated that across 30 disease states, Americans received about 55% of recommended care [1].

For such a measurement scheme to be comprehensive, meaningful, and affordable, the necessary clinical events for each measure must be routinely available in EMR data and it must be possible to extract them from clinical data the data warehouse. Thus, we investigated providers' clinical practices related to each measure, and also examined how that care is captured (through documentation creating during patient visits) as data elements in the clinical information system and ultimately in the data warehouse. Using what we learned, we developed criteria for defining inclusion/exclusion in the denominator and numerator for each measure. Each measure's numerator requires a "measure interval," which is defined as the time window during which the recommended care events take place. The measure interval is oriented around some "index date" that is, in turn, a property of denominator inclusion. For example, for the measure that reads "patients seen for asthma exacerbation should have a chest exam," the index date is the exacerbation encounter, and the measure interval includes only that same encounter. On the other hand, for the measure that reads "patients with persistent asthma should have a flu vaccination annually," the index date is the event that qualifies the patient as having persistent asthma and the measure interval is operationalized to include encounters six months prior to, through 12 months following, the index date. Table 1 shows these high-level operationalization parameters for each measure in the ACQ measure set.

For a given measure, we first define an observation period (in our case, three years of clinical events captured in the EMR), and divide this into a period for denominator qualification (the "selection period") followed by an "evaluation period," during which, in most cases, the occurrences of prescribed care delivery are identified. In fact, each measure defines its own specific time intervals for qualification and evaluation, so this global division of the entire observation period provides only a general picture of how the three years of clinical events are partitioned and included in measurement for the population. We used a two-year selection period as an upper bound of time for identifying patients with "persistent asthma" (used in all of the measures in our set) or presenting at an office visit with an "asthma exacerbation" (used in 36% of the measures in our set). Definitions of these key qualification criteria are presented below.

For each measure, measurement consists of counting the patients who qualify for the measure and how many received the recommended care prescribed by the measure. The ratios generated for each measure can be produced at the patient, provider, clinic, and health-system levels. The technical requirements for scalable automation permitting this type of routine measurement include the reliable, maintainable, and comprehensive generation of the required clinical events, as defined by the measure set. The social and organizational requirements for achieving such

routine measurement have yet to be resolved but ultimately these must satisfy the technical requirements at a minimum.

Quality Measurement Framework

The quality measurement system is realized as a "pipeline" of transformation and markup steps taken on encounter-level electronic medical record data with the goal of capturing all of the clinical events required to assess care as specified by the measure set (see Figure 1). As shown in Figure 1 and described next, the system's pipeline can be divided into three sequential segments involving Data Extraction, Concept Markup, and Quality Measurement.

Table 1. ACQ measure set

#	Quality Measure	Denominator criteria [Index Date]	Numerator criteria [Measure Interval]	Operationalization: Data Source—Exclusion Comments (complete details in Ops Manual)
1	Patients with the diagnosis of persistent asthma should have a historical evaluation of asthma precipitants	Patients with persistent asthma [Observation Period]	Patients with a subjective evaluation of precipitants listed in provider's notes [any documentation]	(consider sensitivity analysis with further restriction of qual date = a particular outpatient visit only)
2	Patients with the diagnosis of persistent asthma should have spirometry performed annually	Patients with persistent asthma [Qualification Date]	Patients with orders for PFTs or documentation of office spirometry [next 12 months]	Numerator satisfied with evidence of referral to allergy or pulmonary specialist if no PFT known available with closed charting loop
3	Patients with the diagnosis of persistent asthma should have available short acting beta2-agonist inhaler for symptomatic relief of exacerbations	Patients with persistent asthma [Qualification Date]	Prescription for a short acting beta-2 agonist to use PRN [active Rx during any of next 12 months	Numerator satisfied if prior / existing active older Rx; also Ach or combination Rx or oral/nebulized PRN Rx Exclusion: known adverse reaction to □-agonists
4	Patients with persistent asthma who report markers of being out of control should have step-up therapy as defined by NAEPP guidelines	Patients with persistent asthma and markers of being out of control [Markers of Out of Control state any time after Qualification Date]	Documentation of a prescription of a appropriate step-up medication (e.g. LABA and/or ICS agent) [same visit]	UNABLE TO OPERATIONALIZE AT THIS TIME.
5	Patients with persistent asthma should not receive non-cardioselective beta-blocker medications	Patients with persistent asthma [Qualification Date]	Pharmacy records without non-cardioselective beta-blocker prescription [subsequent 12 months]	e.g., nadolol, propranolol, pindolol

Table 1. ACQ measure set (continued)

#	Quality Measure	Denominator criteria [Index Date]	Numerator criteria [Measure Interval]	Operationalization: Data Source—Exclusion Comments (complete details in Ops Manual)
6	Patients with persistent asthma should have a documented flu vaccination in the fall/winter of the ensuing year or recent prior year vaccine	Patients with persistent asthma [Qualification Date]	Documentation of flu vaccination [prior 6 months or subsequent 12 months]	Exclusion if documented egg allergy or patient refusal Numerator satisfied if vaccine doc for period regardless of where administered
7	All patients seen for an acute asthma exacerbation should have current medications reviewed	Patients with persistent asthma meeting criteria for outpatient exacerbation [exacerbation encounter]	Documentation of medications in provider's notations consistent with review of medications [same visit]	Numerator satisfied if provider-level review or history of medications are documented
8	All patients seen for an acute asthma exacerbation should have a history taken or reviewed for prior hospitalizations and emergency department visits	Patients with persistent asthma meeting criteria for outpatient exacerbation [exacerbation encounter]	Documentation in provider notations of history of prior hospitalizations and emergency department visits for asthma [same visit]	Numerator satisfied if provider-level review or history
9	All patients seen for acute asthma exacerbation should have history taken or reviewed for prior episodes of respiratory failure requiring intubation.	Patients with persistent asthma meeting criteria for outpatient exacerbation [exacerbation encounter]	Documentation of prior respiratory failures requiring intubation [same visit]	Numerator satisfied if provider-level review or history
10	Patients presenting to the physician's office with an asthma exacerbation with acute worsening of asthma symptoms should be evaluated with PEF (peak expiratory flow).	Patients with persistent asthma meeting criteria for exacerbation OR acute worsening consistent with NAEPP out of control status [exacerbation encounter]	Documented PEF or FEV1 in provider notes OR order for spirometry/PEF [same visit] Exclude: notation of no testing for patient in extremis or severity too great to perform safely	Numerator satisfied with forced expiratory volume 1 second (FEV1) by spirometry; also if referred to ED/RT/PFT Exclusion if documented no spriometry or PEF equipment available
11	At the time of an exacerbation, patients on theophylline should have serum theophylline level measured	Patients with persistent asthma meeting criteria for exacerbation AND have pharmacy records, prescription, or text notes indicating use of theophylline. [exacerbation encounter]	Lab order for serum theophylline test OR recorded level [same visit]	Exclusion if documentation that patient is not taking medication

Table 1. ACQ measure set (continued)

#	Quality Measure	Denominator criteria [Index Date]	Numerator criteria [Measure Interval]	Operationalization: Data Source—Exclusion Comments (complete details in Ops Manual)
12	A physical exam of the chest should be performed on patients presenting with an asthma exacerbation	Patients with persistent asthma meeting criteria for exacerbation [exacerbation encounter]	Documentation of chest exam in provider's notes [same visit]	
13	Patients with an asthma exacerbation and an FEV1 or PEF <70% of baseline should be treated with beta2-agonists	Patients with persistent asthma meeting criteria for exacerbation AND w/documentation of FEV1 or PEF <70% of baseline [exacerbation encounter]	Eligible patients documented to have received beta2-agonist in office [same visit]	UNABLE TO OPERATIONALIZE AT THIS TIME.
14	Patients who receive treatment with beta2-agonists at an exacerbation visit for reduced airflow should have an FEV1 or PEF repeated prior to discharge	Patients with persistent asthma meeting criteria for exacerbation AND w/documentation of FEV1 or PEF <70% of baseline [exacerbation encounter]	Eligible patients with documentation of repeat FEV1 or PEF [same visit]	UNABLE TO OPERATIONALIZE AT THIS TIME.
15	Patients newly prescribed inhaled therapy should receive provider instructions and education in proper use of inhaler or MDI	Persistent asthma and a new prescription for inhaled therapy [outpatient visit encounter with new pharmacy dispensing / Rx]	Documentation of MDI use instructions or inhaled therapy education [same visit]	Numerator satisfied if provider level or provide referral to designee e.g. nurse clinical educator
16	Patients with persistent asthma and a hospitalization for asthma exacerbation should be scheduled for outpatient follow-up contact within 4 weeks	Patients with persistent asthma and a hospital admit code for asthma who have a discharge date/code [hospital discharge date]	Eligible patients with documented provider office or telephone contact [within 4 weeks of discharge]	(See PQI definition for exacerbation; plan sensitivity analysis on steroid requiring)
17	Patients with persistent asthma should be prescribed anti-inflammatory controller medications	Patients with persistent asthma [Qualification Date]	Prescription or dispensing for inhaled corticosteroids or EPR3 equivalent controller [subsequent 12 months]	See ICS alternatives per NAEPP 2008, e.g. LTM, LABA, MCS, methylxanthine, immunomodulator Exclusion: on systemic steroids or other immunosuppressive therapy
18	Patients with persistent asthma should be queried about tobacco use annually	Patients with persistent asthma [Qualification Date]	Documented smoking status in EMR or provider note [subsequent 12 months]	Exclusion: documentation in 12 month measure interval of never or ex-smokers

Table 1. ACQ measure set (continued)

#	Quality Measure	Denominator criteria [Index Date]	Numerator criteria [Measure Interval]	Operationalization: Data Source—Exclusion Comments (complete details in Ops Manual)
19	Patients with persistent asthma who smoke should be counseled about smoking and/or referred for smoking therapy	Patients with persistent asthma documented to smoke [Visit Date where documented or Qualification Date if existing medical record documentation of smoking status]	Documentation of discussion in the provider's notes or order for cessation therapy [subsequent 12 months]	Exclusion: documented never or ex-smokers Numerator satisfied for counsel or provision of external resource (e.g. Oregon quit line number)
20	Patients with persistent asthma should have assessment of control at least every 6 months	Patients with persistent asthma [Qualification Date]	Documentation of NAEPP control assessment [subsequent 6 months]	UNABLE TO OPERATIONALIZE AT THIS TIME.
21	Patients with persistent asthma should have a self-management plan	Patients with persistent asthma [Observation Period]	Documentation of self-management plan [any documentation]	Numerator satisfied with any mention or review of an asthma self-management plan
22	Patients with persistent asthma should receive a pneumococcal vaccine	Patients with persistent asthma [Observation Period]	Documentation of pneumococcal vaccine [any time in medical record]	Pneumococcal vaccine or Pneumovax (note no egg allergy exclusion)

Table 2. ACQ events dataset schema

Table 2a. Each row in an events dataset file represents a single event with the following comma separated fields

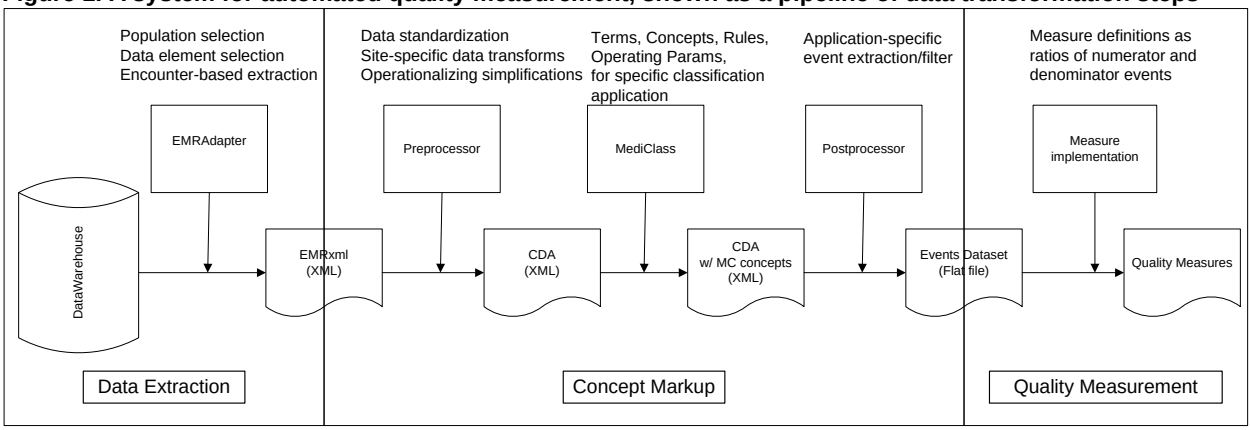
Field	
PatientID (StudyID)	
HealthSystemID (KPNW or OCHIN)	
PatientYOB (Year)	
PatientGender	
Patient Race Primary	
Patient Race Secondary	
Patient Ethnicity	
ClinicID (StudyID)	
Provider Department	
ProviderID (StudyID)	
SourceID (Outpatient, Inpatient, RxDispense, Labs)	
EncounterID (combines sourceID and encounterID)	
Event Type (Etype)	See below
Event Subtype (Esubtype)	See below
EventDate (date of event)	
Event Numeric Data, field 1 (Edata1)	See below
Event Numeric Data, field 2 (Edata2)	See below
Event Numeric Data, field 3 (Edata3)	See below
Event String Data, field 1 (Estring1)	See below
Event String Data, field 2 (Estring2)	See below
Event String Data, field 3 (Estring3)	See below
Event String Data, field 4 (Estring4)	See below

Table 2b. Field detail

M	Etype	Esubtype	Edata1	Edata2	Edata3	Estring1	Estring2	Estring3	Estring4
All	MedsDisp	cat1, cat2,…. Cat16	Daily-Dose	Qty	# Refills	NDC	SIG	Name	Route
All	MedsOrd	cat1, cat2,…. Cat16	DailyDose	Qty	# Refills	NDC	SIG	Name	Route
3	MedCur	cat1, cat2,…. Cat16	DailyDose	Qty	# Refills	NDC	SIG	Name	Route
All	AsthmaVisit	Dx, Hx, Px, Note	493.xy (acute exacer-bation when y=1 or 2)	DxOrder		"Persistent" or empty	"Exacer-bation" or empty		
1	Precipitant	Note							
10	PeakFlow	Note							
2	Spiro	Ox, Lab, Note							
2	Referral	Ox				"Pulmon-ology" or "Allergy" or "Asthma-CaseMgr			
3,6, 22	Allergy	Albut, Egg, Fluvac, Pneumovac				Allergen name			
6	Fluvac	HM, Immun, Ox				"Done, "Credit", "NoCredit"	Raw status		
7	MedsReview	Note							
8	AsthmaHosp	Note							
9	Intubation	Note							
11	TheoMeds	Note							
11	TheoLab	Ox, Note							
12	ChestExam	Note							
15	InhalerEd	Ox, Note, Inst							
18	SmokeAsk	Note, Inst, Dx, RFV, Ox, Smk, HM, Px							
19	Smoker	Smk	1=yes, 0=no						
19	SmokeAssist	Note, Inst, RFV, Ox, Smk, HM				Assist Class			
21	ActionPlan	Note, Inst							
22	PneumoVac	HM, Immun, Ox				"Done, "Credit", "NoCredit"	Raw status		

The following abbreviations are used in "Esubtype" field to indicate the data element that is the source for the event: HM = Health Maintenance Alerts, Immun = Immunization, Ox = Order, Dx = Visit Diagnosis, RFV = Reason For Visit, Px = Problem List, Hx = Medical History, Lab = Spirometry Result, Note = Progress Note (text), Inst = Patient Instructions (text), Smk = Tobacco Social History. The following "Etypes" come from the noted data element sources: Allergy = Allergy, MedsOrd = Medication Orders, MedsDisp = Medication Dispense, MedsCurr = Current Medications The 16 medication categories "Esubtypes" ("cat1"…"cat16") are created by sorting on various attributes of brand name, generic name, GPI code, route, and dose form.

Figure 1. A system for automated quality measurement, shown as a pipeline of data transformation steps



Data Extraction. The data pipeline begins with extracts from the data warehouse of each EMR system. These extracts are produced by a component called the "EMR Adapter," and contain the data required by the study, captured at the clinical-encounter level for all patients in the study population. In our study, this included the coded diagnoses, problems, and medical history updates generated at the visit; the medications ordered, dispensed and noted as current or discontinued; the immunizations, allergies, and health maintenance topics addressed at the visit; as well as procedures ordered and progress notes and patient instructions generated for the visit. This project extended an existing EMR Adapter component in KPNW to include several types of data unique to this study, and built an EMR Adapter component from scratch at OCHIN.

The data are exported from the EMR data warehouse (a relational database) into file-based eXtensible Markup Language (XML) documents according to a specification that is local to each data environment. The first transformation step in the pipeline involves converting these locally-defined XML formats into a common, standard XML format conforming to the HL7 CDA specification for encounter data [26]. An XSLT [27] program written specifically for each data environment accomplishes this translation. We anticipate that EMR vendors will soon make available facilities for extracting CDA-formatted encounter data directly from their EMR systems, potentially rendering this step unnecessary. However, whether these facilities will include the flexibility required to define the wide range of data needed for research purposes remains to be seen.

Concept Markup. The CDA provides a canonical representation of encounter-level data that is used as an input to our medical record classification system called MediClass [9]. MediClass uses natural language processing and rules defining logical combinations of marked up and originally coded data to generate concepts that are then inserted into the CDA document and passed along to the next step. This system has been previously used to assess guideline adherence for smoking cessation care [28], to identify adverse events due to vaccines [29], and other applications that require extracting specific clinical data from text notes of the EMR. In our ACQ measure set, 11 measures (50%) require processing the providers' text notations to generate numerator events and another 5 measures (23%) were demonstrably improved by this processing.

Up to this point in the sequence, data processing is performed on-site within the secure data environments of each study site. This arrangement permits local control of sensitive data that

resides in text notes and also in the comprehensive encounter record captured in CDA format. The next step filters these data to identify only those clinical events (including specific concepts identified in the text notes) that relate to the quality measures of the study. This step uses an XSLT program to process the marked-up CDA documents to produce a single file of measure-set specific clinical event data in comma-delimited format. This file is called the "Events Dataset." Each line in this file identifies the study-coded patient, provider, and encounter, along with a single "event" (and attributes specific to that event) that relates to one or more measures of the measure set. Table 2 shows the schema we developed for our ACQ events dataset file. The events dataset file generated at OCHIN (under a provision of the Data Use Agreement executed between the respective research organizations) was transferred from OCHIN to KPNW-CHR for producing measure values.

Quality Measurement. The distinct pipelines located at each health system converge into a single analysis environment for computation of quality measures. Here, information contained in the events dataset is processed across events to provide the clinical (e.g., exacerbation or medication status) and temporal (e.g., measure interval) criteria for identifying patients who meet numerator and denominator criteria for each measure. Finally, the proportion (numerator/denominator) of patients receiving recommended services is computed at the desired level (e.g., patient, provider, or health care organization).

Qualification for ACQ Measures. As shown in Table 1, all 22 ACQ measures require determination that the patient has "persistent asthma." In addition, 8 measures also require that the patient is being seen for an "asthma exacerbation." Below we document the operationalization of these key qualifying criteria.

Persistent Asthma

A patient in the study population who meets any of the following qualifying criteria (a-d) within any 12 month window during the first 24 months of the 36-month observation period:

a) Medications: A total of four "fills" events of unique asthma-related medications categories equivalent to providing four prescriptions lasting 30 days each. Note: One order is equivalent to one "fill" if no refill info is available. Multiple prescriptions of the same medications category occurring on the same date of service will count as a single event (the order with the highest number of refills will be counted).

b) Medications and outpatient visits: A total of two "fills" (as described above) for unique asthma-related medications categories **AND** four distinct asthma-related outpatient visits. Note: Distinct visit events may occur on the same date and will be counted as such; however, the same event identified by different data sources will only be counted once. Hospitalization and ED visits are excluded here (see below).

c) For KPNW only, any asthma-related hospitalization or ED visit

d) Any visit in which the clinician explicitly notes that the patient has persistent asthma

Asthma Exacerbation

A patient in the study population who is defined to have "persistent asthma" (see above) and meets either of the following qualifying criteria (a-b) during any visit of the first 24 months of the 36-month observation period is said to have an "asthma exacerbation" during the identified visit:

a) Any explicitly coded asthma exacerbation diagnosis code documented for the visit (includes both inpatient and outpatient visits in KPNW)

b) Any outpatient asthma visit with an order for or dispense of an exacerbation-related medication (e.g., steroid order) at any time during the 6 days following the visit **and** the clinician makes a text notation of the exacerbation in her progress note for the visit.

Limitations

We were unable to operationalize 4 of the 22 measures at this time. Measure #20 quantifies asthma control and measure #4 addresses the appropriateness of step-up therapy with poor asthma control. Measure #12 entails capturing a quantified spirometry result and measure #13 requires capture of a repeat spirometry reading during the visit. We did not believe that our current tools could adequately decipher this recommended care from EMR documentation. We will continue to pursue avenues to operationalize these measures in future work. Below we report on our implementations of the remaining 18 measures in the ACQ measure set.

One goal of this work is producing a method to measure asthma care within a common framework, unbiased by data system differences. Although much of this goal was met, some bias due to system differences remains. Some of the underlying differences are relatively easy to address, such as choosing a common timeframe for the observation period across sites (ours were different for the two sites). Other sources of bias, such as data which are not available at one site, or differences in documentation practices which lead to data dropout, create ongoing challenges to meeting our goals for generalizability of the method. We continue to seek ways to remove system-specific biases from our measurement method.

Results

Measure Validation

Validation of the ACQ measures was carried out based on chart review at the patient level on a total of 821 patients, 443 at KPNW and 378 at OCHIN. The rightmost columns of Table 3 report the overall accuracy, sensitivity, specificity and predictive values of positive and negative tests for the ACQ measures by site, relative to results obtained by chart abstraction as a reference standard.

Sensitivity measures the percentage of patients that are correctly identified by the ACQ automated system as having received recommended care (as ascertained by chart review). In

general, higher sensitivity results in identification of more patients receiving care and a decreased likelihood of missing a patient who received the care. Specificity measures the percentage of patients that are correctly identified as not receiving care. Overall accuracy is measured as the total percentage of patients classified correctly. We note that the chart review process is itself imperfect and it is not uncommon, e.g., for the automated approach to identify cases that are missed by chart review. In this context the sensitivities and specificities reported here are "relative" to the chart review reference. Depending on the sensitivities and the specificities of the chart review reference to the true status (i.e., recommended care delivered vs. not), bias in the assessment of the comparison method (here the automated system) can be conservative or anti-conservative. Further work in this area would require a more in-depth chart review process carried out by a panel of experts to establish a "gold standard" reference set to obtain more accurate and precise estimates of the automated system.

Most ACQ measures performed relatively well in the KPNW system. Overall accuracy ranged from 63% to 100% and averaged 88% across all measures. Sensitivity was 60% or greater for 16 of the 18 implemented measures (and 90% or greater for nine of those). Similarly, 15 measures had specificity of 60% or higher (nine with 90% sensitivity or greater). There are two measures for which specificity was over 90% but which had poor sensitivity: The measure attempting to ascertain whether a history or review of prior hospitalizations and ED visits had been obtained failed to identify any of the five patients noted by abstractors to have this received this care measure. In addition, documentation of instructions for a new inhaled therapy only had sensitivity of 12%, identifying just 3 of 22 patients noted by the abstractors to have received this care. There was only one patient on theophylline in the KPNW chart review sample, precluding estimation of validation measures.

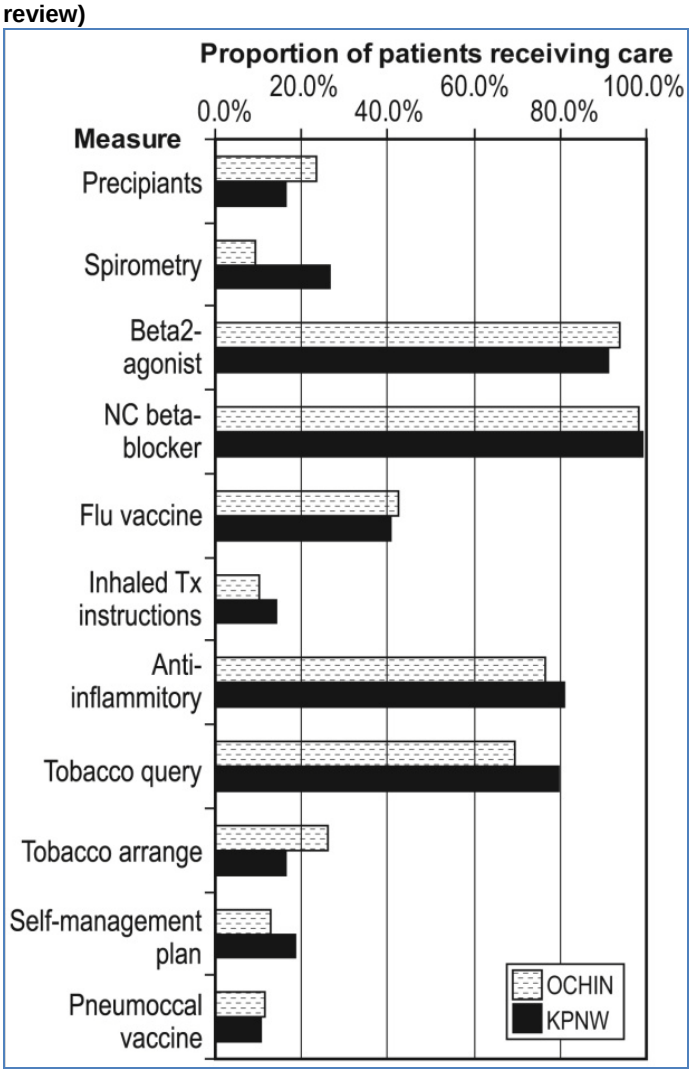
Overall, the automated ACQ measures performed less well in the OCHIN system. Mean overall accuracy was 85% and ranged from 72% to 99%. Among the 11 routine care measures (1, 2, 3, 5, 6, 15, 17, 18, 19, 21, 22) eight had specificities over 80% and five had sensitivities over 80%. Three measures (3, 5 and 18) had specificities of 50% or lower while another five (1, 2, 6, 15 and 21) had sensitivities of 50% or lower. Of the seven exacerbation-related measures (7, 8, 9, 10, 11, 12, and 16), five were evaluable at OCHIN (assessment was not possible for two of the exacerbation measures: no patients were identified on theophylline and, since hospital discharge information is currently unavailable, the 4-week follow-up contact was not evaluable). Among the five evaluable exacerbation-related measures, mean overall accuracy was 70% (range 36%-96%). Sensitivity tended to be relatively low, ranging from 5.3% to 58.1%, while specificities were generally high (minimum of 67%, with remaining four measures greater than 90%). Potential explanations for the discrepancy in performance of the automated measures between OCHIN and KPNW include the possibility that chart reviewers may have had differential access to sections of the medical record accessed by the automated method across sites, and that, for many of the text-based measures, there may be much greater variability in how/where OCHIN providers document visits. Additional effort may be needed in the specifications of the automated method to capture variations across sites.

Asthma Performance Measures

This section describes the prevalence of ACQ recommended care as determined by chart review and by our automated method. Based on chart review results, delivery of *routine* (non-exacerbation) care (measure numbers, 1, 2, 3, 5, 6, 15, 17, 18, 19, 21 and 22) appears to be

similar between the two sites, as shown at right. Of these measures, both organizations performed well (better than 90%) in providing prescriptions for beta2-agonists (M3) and assuring that their persistent asthma patients were not taking non-cardioselective beta-blockers (M5). Providers in both organizations preformed moderately well (60%-80%) in providing anti-inflammatory controllers (M17) and querying patients about tobacco use (M18). Flu vaccination (M6) was documented in about 40% of patients. The remaining measures were only present between 10%-30% of the time.

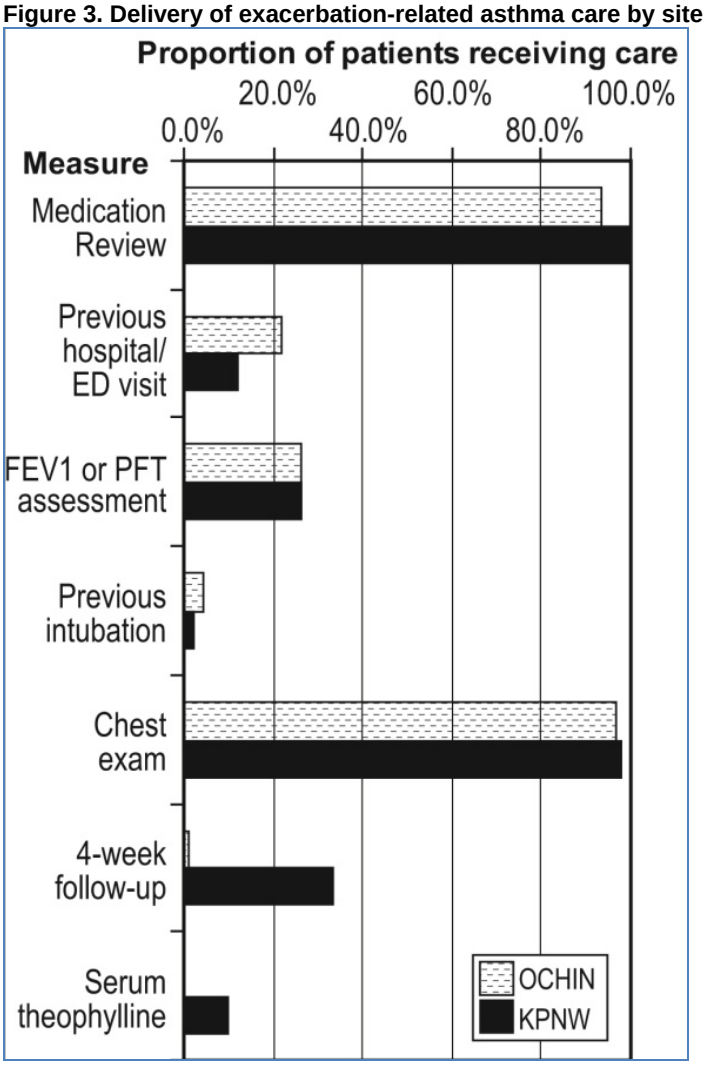
Figure 2. Delivery of asthma care measures by site in patients with persistent asthma (ascertained by chart review)



Among the *exacerbation-related care measures* (7, 8, 9, 10, 11, 12, and 16) there was similar agreement across sites in the chart review results, as shown below. Both organizations performed well on the review of current medications (M7) and the performance of a chest exam (M12). Performance was poor on the remaining exacerbation-related measures: documenting prior histories of intubation (M9) and asthma-related hospital or ED visits (M8), assessment of lung function (M10) and, in KPNW, 4-week follow-up contact post-hospitalization (M16) and

assessment of serum theophylline level in those (few) patients on theophylline (at the OCHIN site hospitalization information was not available nor were any patients identified who were on theophylline).

Figure 3. Delivery of exacerbation-related asthma care by site (ascertained by chart review)

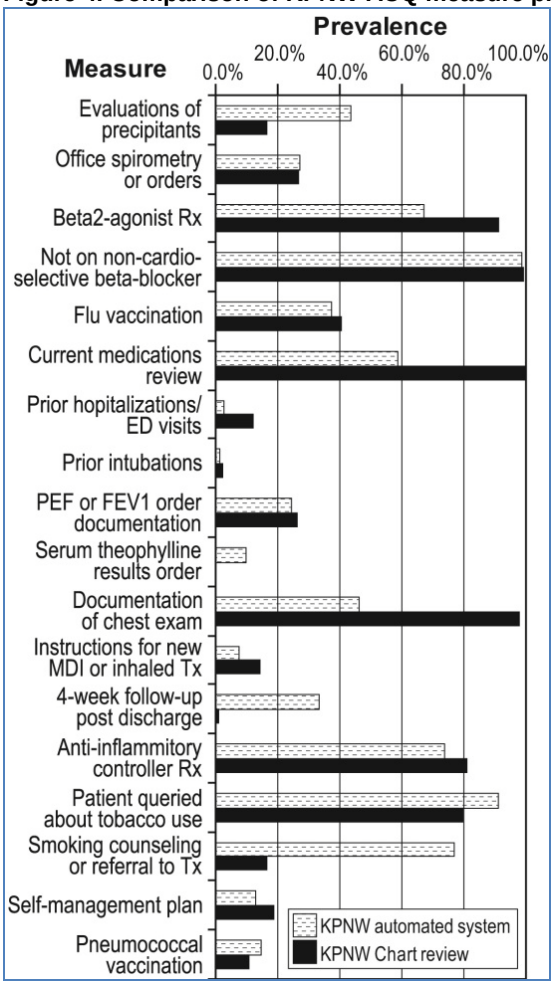


We also compared prevalences of the ACQ recommended care as determined by the automated method and by chart review. At KPNW there is generally good agreement between the two methods with a few exceptions. Among the routine care measures, chart reviewers found more cases of β2-agonist prescriptions while the automated system found more cases of precipitants evaluations and counseling or referral to smoking therapy.

Among the exacerbation-related measures, chart reviewers found more chest exams and current medications reviews while the automated method found more evidence for 4-week follow-up contacts post hospital discharge. Data for the theophylline measure was too sparse to evaluate adequately. These results confirm that there are significant gaps between recommended care and real world practice. Only six measures (β2-agonist Rx, absence of non-cardioselective

β-blocker Rx, medications review, chest exam, anti-inflammatory Rx and tobacco use query) were performed 80% or more of the time according to either the chart review or the automated method. With a modest amount of refinement in a small number of measures, our automated method for assessing the ACQ measure set could be implemented in this setting to monitor asthma care and supply feedback to providers and administrators to improve care delivery.

Figure 4. Comparison of KPNW ACQ measure prevalences (automated system vs. chart review)



A similar analysis was performed comparing chart-review prevalences with those of the automated method at the OCHIN site for each care measure. Among the routine (non-exacerbation) care measures, chart reviewers found more evidence of flu vaccinations and MDI/inhaler instructions while the automated system detected more instances of smoking status queries and tobacco counseling or referral. Among the measurements of exacerbation-related care, prevalences were higher based on chart review for all measures except the theophylline lab measure, for which the data were, again, to sparse to evaluate. Care gaps in the OCHIN system appear to be very similar to those in the KPNW system, with only five measures (β2-agonist Rx, absence of non-cardioselective β-blocker Rx, medications review, chest exam, and tobacco use query) performed 80% or more of the time according to either the chart review or the automated

system. Table 3, below, summarizes our findings regarding each measure by site for both the chart review and automated methods, including performance statistics for the automated method using chart review as the reference standard.

Figure 5. Comparison of OCHIN and KPNW ACQ measure prevalences (automated system vs. chart review)

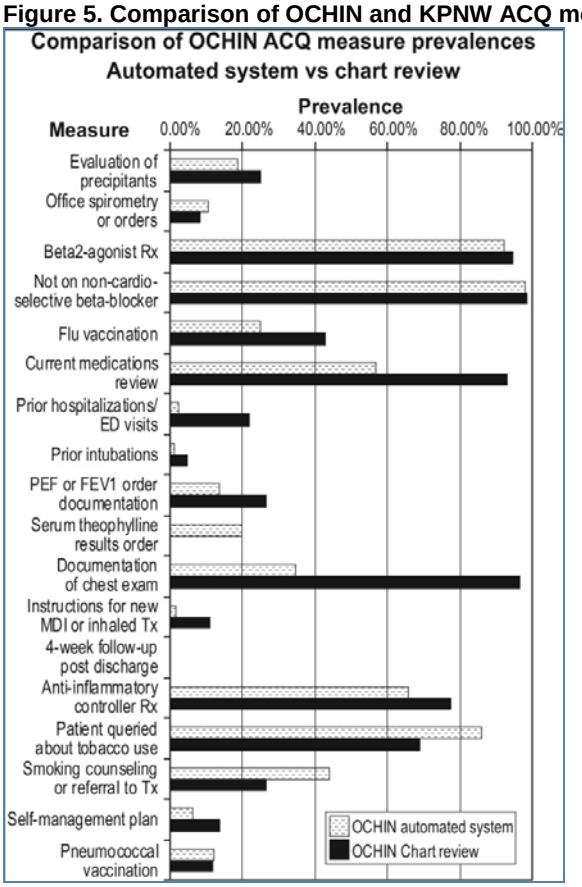


Table 3.

Table 3a. Measure delivered per automated ACQ algorithm

ACQ Measure	Population	Site	Numerator/ Denominator	Excl.	%
1. Documentation of evaluation of asthma precipitants	Persistent asthma (PA)	KPNW	6036/13918	0	43.4%
1. Documentation of evaluation of asthma precipitants	Persistent asthma (PA)	OCHIN	449/2411	0	18.6%
2. Documentation of office spirometry or orders for spirometry	PA	KPNW	3753/13918	0	27.0%
2. Documentation of office spirometry or orders for spirometry	PA	OCHIN	259/2411	0	10.7%
3. Prescription for short acting beta2-agonist inhaler	PA, no adverse reaction to β–agonist	KPNW	9310/13900	18	67.0%
3. Prescription for short acting beta2-agonist inhaler	PA, no adverse reaction to β–agonist	OCHIN	2220/2411	0	92.1%
5. Not on non-cardioselective beta blocker	PA	KPNW	13736/13918	0	98.7%

Table 3a. Measure delivered per automated ACQ algorithm (continued)

ACQ Measure	Population	Site	Numerator/ Denominator	Excl.	%
5. Not on non-cardioselective beta blocker	PA	OCHIN	2364/2411	0	98.1%
6. Documented flu vaccination	PA , no egg allergy or patient refusal	KPNW	5205/13900	18	37.5%
6. Documented flu vaccination	PA , no egg allergy or patient refusal	OCHIN	597/2395	1	24.9%
7. Documentation of current medications review	Acute Exacerbation (AE)	KPNW	1346/2301	0	58.5%
7. Documentation of current medications review	Acute Exacerbation (AE)	OCHIN	232/407	0	57.0%
8. Documentation of history/review of prior hospitalizations and ED visits	AE	KPNW	61/2301	0	2.7%
8. Documentation of history/review of prior hospitalizations and ED visits	AE	OCHIN	10/407	0	2.46%
9. Documentation of history/review of prior episodes requiring intubation	AE	KPNW	28/2301	0	1.2%
9. Documentation of history/review of prior episodes requiring intubation	AE	OCHIN	5/407	0	1.2%
10. Order for PEF or FEV1 or documentation in notes	AE	KPNW	565/2301	0	24.6%
10. Order for PEF or FEV1 or documentation in notes	AE	OCHIN	55/407	0	13.5%
11. Documentation of serum theophylline lab order or measure	AE and on theophylline	KPNW	4/41	0	9.8%
11. Documentation of serum theophylline lab order or measure	AE and on theophylline	OCHIN	1/5	0	20.0%
12. Documentation of chest exam	AE	KPNW	1067/2301	0	46.4%
12. Documentation of chest exam	AE	OCHIN	141/407	0	34.6%
15. Documentation of MDI or inhaled therapy instructions	PA and new Rx for inhaled Tx	KPNW	406/5293	0	7.7%
15. Documentation of MDI or inhaled therapy instructions	PA and new Rx for inhaled Tx	OCHIN	28/2075	0	1.4%
16. Documented follow-up contact within 4 weeks of hospital discharge	AE	KPNW	333/1004	0	33.2%
16. Documented follow-up contact within 4 weeks of hospital discharge	AE	OCHIN	*	*	*
17. Prescription for anti-inflammatory controller.	PA	KPNW	10265/13918	0	73.8%
17. Prescription for anti-inflammatory controller.	PA	OCHIN	1589/2411	0	65.9%
18. Documentation that patient was queried about tobacco use	PA	KPNW	12695/13918	0	91.2%
18. Documentation that patient was queried about tobacco use	PA	OCHIN	2071/2411	0	85.9%
19. Documentation of counseling or referral to smoking therapy	PA	KPNW	1678/2176	0	77.1%
19. Documentation of counseling or referral to smoking therapy	PA	OCHIN	86/195	0	44.1%
21. Documentation of self-management plan	PA	KPNW	1818/13918	0	13.1%
21. Documentation of self-management plan	PA	OCHIN	154/2411	0	6.4%
22. Documented pneumococcal vaccination	PA	KPNW	1811/12395	0	14.6%
22. Documented pneumococcal vaccination	PA	OCHIN	272/2264	0	12.0%

*Documentation not available.

Table 3b. Measure delivered per chart review

ACQ Measure	Population	Site	Numerator/ Denominator	%
1. Documentation of evaluation of asthma precipitants	Persistent asthma (PA)	KPNW	73/443	16.5%
1. Documentation of evaluation of asthma precipitants	Persistent asthma (PA)	OCHIN	93/375	24.8%
2. Documentation of office spirometry or orders for spirometry	PA	KPNW	119/443	26.7%
2. Documentation of office spirometry or orders for spirometry	PA	OCHIN	31/375	8.3%
3. Prescription for short acting beta2-agonist inhaler	PA, no adverse reaction to β–agonist	KPNW	395/434	91.0%
3. Prescription for short acting beta2-agonist inhaler	PA, no adverse reaction to β–agonist	OCHIN	355/375	94.7%
5. Not on non-cardioselective beta blocker	PA	KPNW	439/443	99.1%
5. Not on non-cardioselective beta blocker	PA	OCHIN	369/375	98.4%
6. Documented flu vaccination	PA , no egg allergy or patient refusal	KPNW	180/443	40.6%
6. Documented flu vaccination	PA , no egg allergy or patient refusal	OCHIN	161/375	42.9%
7. Documentation of current medications review	Acute Exacerbation (AE)	KPNW	42/42	100.0%
7. Documentation of current medications review	Acute Exacerbation (AE)	OCHIN	81/87	93.1%
8. Documentation of history/review of prior hospitalizations and ED visits	AE	KPNW	5/42	11.9%
8. Documentation of history/review of prior hospitalizations and ED visits	AE	OCHIN	19/87	21.8%
9. Documentation of history/review of prior episodes requiring intubation	AE	KPNW	1/42	2.4%
9. Documentation of history/review of prior episodes requiring intubation	AE	OCHIN	4/87	4.6%
10. Order for PEF or FEV1 or documentation in notes	AE	KPNW	11/42	26.3%
10. Order for PEF or FEV1 or documentation in notes	AE	OCHIN	23/87	26.4%
11. Documentation of serum theophylline lab order or measure	AE and on theophylline	KPNW	0/1	0.0%
11. Documentation of serum theophylline lab order or measure	AE and on theophylline	OCHIN	0/0	----
12. Documentation of chest exam	AE	KPNW	41/42	97.6%
12. Documentation of chest exam	AE	OCHIN	84/87	96.6%
15. Documentation of MDI or inhaled therapy instructions	PA and new Rx for inhaled Tx	KPNW	63/443	14.2%
15. Documentation of MDI or inhaled therapy instructions	PA and new Rx for inhaled Tx	OCHIN	41/375	10.9%
16. Documented follow-up contact within 4 weeks of hospital discharge	AE	KPNW	4/442	0.9%
16. Documented follow-up contact within 4 weeks of hospital discharge	AE	OCHIN	*	*
17. Prescription for anti-inflammatory controller.	PA	KPNW	359/443	81.0%
17. Prescription for anti-inflammatory controller.	PA	OCHIN	291/375	77.6%
18. Documentation that patient was queried about tobacco use	PA	KPNW	353/443	79.7%

*Documentation not available.

Table 3b. Measure delivered per chart review (continued)

ACQ Measure	Population	Site	Numerator/ Denominator	%
18. Documentation that patient was queried about tobacco use	PA	OCHIN	258/375	68.8%
19. Documentation of counseling or referral to smoking therapy	PA	KPNW	58/353	16.4%
19. Documentation of counseling or referral to smoking therapy	PA	OCHIN	68/258	26.4%
21. Documentation of self-management plan	PA	KPNW	82/443	18.5%
21. Documentation of self-management plan	PA	OCHIN	52/375	13.6%
22. Documented pneumococcal vaccination	PA	KPNW	48/443	10.8%
22. Documented pneumococcal vaccination	PA	OCHIN	44/375	11.7%

Table 3c. Comparison of Automated to chart review as reference standard

ACQ Measure	Population	Site	Acc.	PPV	NPV	Sens.	Spec.
1. Documentation of evaluation of asthma precipitants	Persistent asthma (PA)	KPNW	63.0%	26.9%	91.9%	72.6%	61.1%
1. Documentation of evaluation of asthma precipitants	Persistent asthma (PA)	OCHIN	73.3%	44.4%	79.2%	30.1%	87.6%
2. Documentation of office spirometry or orders for spirometry	PA	KPNW	95.3%	91.5%	96.6%	90.8%	96.9%
2. Documentation of office spirometry or orders for spirometry	PA	OCHIN	88.0%	28.1%	93.6%	29.0%	93.3%
3. Prescription for short acting beta2-agonist inhaler	PA, no adverse reaction to β–agonist	KPNW	70.5%	94.9%	17.5%	71.4%	61.5%
3. Prescription for short acting beta2-agonist inhaler	PA, no adverse reaction to β–agonist	OCHIN	92.0%	96.5%	30.8%	94.9%	40.0%
5. Not on non-cardioselective beta blocker	PA	KPNW	99.1%	99.8%	50.0%	99.3%	75.0%
5. Not on non-cardioselective beta blocker	PA	OCHIN	98.9%	99.2%	75.0%	99.7%	50.0%
6. Documented flu vaccination	PA , no egg allergy or patient refusal	KPNW	95.7%	94.9%	96.2%	94.4%	96.6%
6. Documented flu vaccination	PA , no egg allergy or patient refusal	OCHIN	74.3%	89.0%	70.2%	45.6%	95.8%

Table 3c. Comparison of Automated to chart review as reference standard (continued)

ACQ Measure	Population	Site	Acc.	PPV	NPV	Sens.	Spec.
7. Documentation of current medications review	Acute Exacerbation (AE)	KPNW	95.1%	100%	0.0%	95.1%	----
7. Documentation of current medications review	Acute Exacerbation (AE)	OCHIN	58.8%	95.6%	11.4%	58.1%	66.7%
8. Documentation of history/review of prior hospitalizations and ED visits	AE	KPNW	85.4%	0.0%	87.5%	0.0%	97.2%
8. Documentation of history/review of prior hospitalizations and ED visits	AE	OCHIN	76.3%	50.0%	76.9%	5.3%	98.4%
9. Documentation of history/review of prior episodes requiring intubation	AE	KPNW	100%	100%	100%	100%	100%
9. Documentation of history/review of prior episodes requiring intubation	AE	OCHIN	96.3%	100.0%	96.2%	25.0%	100.0%
10. Order for PEF or FEV1 or documentation in notes	AE	KPNW	87.8%	80.0%	90.3%	72.7%	93.3%
10. Order for PEF or FEV1 or documentation in notes	AE	OCHIN	80.0%	72.7%	81.2%	38.1%	94.9%
11. Documentation of serum theophylline lab order or measure	AE and on theophylline	KPNW	Only one case identified on theophylline	Only one case identified on theophylline	Only one case identified on theophylline	Only one case identified on theophylline	Only one case identified on theophylline
11. Documentation of serum theophylline lab order or measure	AE and on theophylline	OCHIN	No cases identified on theophylline	No cases identified on theophylline	No cases identified on theophylline	No cases identified on theophylline	No cases identified on theophylline
12. Documentation of chest exam	AE	KPNW	90.2%	100%	20.0%	90.0%	100%
12. Documentation of chest exam	AE	OCHIN	36.3%	100.0%	3.8%	34.6%	100.0%
15. Documentation of MDI or inhaled therapy instructions	PA and new Rx for inhaled Tx	KPNW	81.9%	25.0%	86.2%	12.0%	93.8%
15. Documentation of MDI or inhaled therapy instructions	PA and new Rx for inhaled Tx	OCHIN	88.1%	33.3%	89.1%	5.4%	98.6%
16. Documented follow-up contact within 4 weeks of hospital discharge	AE	KPNW	77.8%	28.6%	95.0%	66.7%	79.2%
16. Documented follow-up contact within 4 weeks of hospital discharge	AE	OCHIN	*	*	*	*	*
17. Prescription for anti-inflammatory controller.	PA	KPNW	83.1%	94.7%	53.6%	83.8%	79.8%
17. Prescription for anti-inflammatory controller.	PA	OCHIN	85.9%	94.7%	64.2%	86.6%	83.3%

*Documentation not available.

Table 3c. Comparison of Automated to chart review as reference standard (continued)

ACQ Measure	Population	Site	Acc.	PPV	NPV	Sens.	Spec.
18. Documentation that patient was queried about tobacco use	PA	KPNW	87.4%	87.8%	84.0%	97.7%	46.7%
18. Documentation that patient was queried about tobacco use	PA	OCHIN	71.5%	72.1%	64.7%	95.3%	18.8%
19. Documentation of counseling or referral to smoking therapy	PA	KPNW	90.2%	87.8%	100%	100%	66.7%
19. Documentation of counseling or referral to smoking therapy	PA	OCHIN	83.3%	92.9%	70.0%	81.3%	87.5%
21. Documentation of self-management plan	PA	KPNW	89.8%	80.3%	91.4%	59.8%	96.7%
21. Documentation of self-management plan	PA	OCHIN	91.2%	90.9%	91.2%	39.2%	99.4%
22. Documented pneumococcal vaccination	PA	KPNW	97.7%	82.8%	100%	100%	97.5%
22. Documented pneumococcal vaccination	PA	OCHIN	92.0%	65.2%	95.7%	68.2%	95.2%

Outcomes Analysis

The primary outcome measure was defined as the count of asthma-related hospitalizations, ED visits and (outpatient) exacerbations (defined as an ICD-9 coded AE visit or an outpatient visit in conjunction with an AE-related medication order/dispensing [e.g. steroids] and an AE-related text notation) occurring between 12 and 24 months after the persistent asthma index date. For each measure (assessed in the KPNW data only), propensity scores were developed using logistic regression to predict the probability that a patient received the care measure as a function of their asthma-related utilization (hospitalization, ED and office visits and medications). Poisson regression was used to model the count of exacerbation events and estimate incidence rate ratios associated with each asthma care measure, adjusting for age category, sex, the propensity score and the number of months observed during the 12 month follow-up period. Results for individual quality measures are shown in the table below. Several of the measures are statistically significantly related to the outcome; however, in several cases, the association is in the opposite direction of what would be hypothesized, i.e., receiving the care is associated with a higher incidence rate of exacerbation events. For example, for measure #1, evaluation of precipitants (or causes), patients receiving this care are expected to have an exacerbation incidence rate 1.614 times greater than patients who do not receive this care measure. It is interesting to note that, of the 11 routine care measures (i.e., measures, 1, 2, 3, 5, 6, 15, 17, 18, 19, 21 and 22), eight are highly significant and positively associated with the outcome, one is marginally significant and all but one (non-cardioselective β-blocker) have IRR estimates greater than 1. However, for the seven exacerbation-related measures (7, 8, 9, 10, 11, 12, and 16) four (7-Medications review, 10-PEF/FEV1 documentation or order, 11-serum theophylline check and 12-chest exam) are highly statistically significant and associated with lower incidences of exacerbations, while only review of prior intubation (M9) is associated with a higher incidence of exacerbation events.

Table 4. Individual asthma care measures

Table 4a. Routine care measures

	IRR	P>z	95% CI lower	95% CI upper	N
1. Evaluation of precipitants (causes)	1.614	<.001	1.438	1.811	11741
2. Office spirometry or orders for spirometry	1.929	<.001	1.772	2.101	11741
3. Prescription for short acting beta-agonist (relief) inhaler	1.031	0.509	0.941	1.130	11741
5. Not on non-cardioselective beta blocker	0.781	0.143	0.562	1.087	11741
6. Flu vaccination	1.168	0.001	1.063	1.283	11725
15. Instruction for new Metered Dose Inhaler or inhaled therapy	1.269	0.070	0.981	1.643	4526
17. Anti-inflammatory controller	2.104	<.001	1.855	2.385	11741
18. Patient queried about tobacco use	1.277	0.012	1.055	1.546	11741
19.Patient counseled or referred to smoking therapy	1.362	0.053	0.995	1.862	1707
21. Self-management plan	2.855	<.001	2.608	3.125	11741
22. Pneumococcal vaccination	1.485	<.001	1.328	1.660	11741

Table 4b. Exacerbation related measures

Exacerbation Related Measures	IRR	P>z	95% CI lower	95% CI upper	N
7. Medications review	0.550	<.001	0.487	0.622	1940
8. Review of prior hospitalizations/Emergency visits	1.188	0.291	0.863	1.637	1940
9. Review of prior episodes requiring intubation	2.042	<.001	1.393	2.995	1940
10. Order or documentation for PEF (peak expiratory flow) or FEV1 (forced expiratory volume in 1 second)	0.733	<.001	0.634	0.847	1940
11. Serum theophylline lab order or measure	0.003	<.001	0.0000	0.034	28
12. Chest exam	0.611	<.001	0.541	0.690	1940
16. 4-week follow-up contact post discharge	1.700	<.001	1.474	1.961	802

In addition to the individual ACQ measures, two composite measures were created. A routine care composite measure was created by calculating the proportion of measures 1, 2, 3, 5, 6, 17, 18, 21 and 22 that were completed in eligible patients (measures 15 and 19 were not included since they only applied to selected subsets of the primary population). Similarly, an exacerbation-related composite measure was created by computing the proportion of measures 8, 8, 9, 10 and 12 that were completed in patients experiencing exacerbation, excluding the theophylline measure due to the small population. Propensity scores and Poisson models were developed as described above, and results are reported below.

Table 5.

Composite Asthma Care Measures	IRR	P>z	95% CI	95% CI	N
Composite (average) of exacerbation-related measures*	0.336	0.000	0.260	0.433	1940
Composite (average) of routine asthma care measures	19.668	0.000	15.162	25.514	11741

* Theophylline lab measure excluded due to small number of patients on the drug

Not surprisingly, the trends noted in the individual routine and exacerbation-related measures are strengthened in the composite measures. Patients receiving all of the exacerbation-related measures (i.e., the composite AE measure = 1) are expected to have an exacerbation incidence rate 0.336 times lower than patients who do not receive any care measures. Conversely, patients receiving all of the measures included in the routine care composite score are expected to have an incidence rate 19 times greater than patients who receive none of the routine care measures. It is likely that providers are more rigorous about dispensing guideline-recommended care to patients with more severe disease or that sicker patients seek more care, thus inducing a positive association between the delivery of care and outcome. We attempted to adjust for this issue using propensity scores. In addition, we created a surrogate severity classification measure based on prior utilization and carried out analyses within each severity level; however results were still similar. In this situation the utilization data available to us may not provide enough information to adequately adjust for disease severity in the larger persistent asthma population. However, it may be that once a patient is in exacerbation, severity level is more homogeneous and hence less predictive of whether a patient receives guideline based care. More work needs to be done to assure that severity of disease can be adequately adjusted for in these types of studies.

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List of Publications and Products

1. McBurnie MA, Mularski RA, Hazlehurst BH. Automating asthma care quality performance measurement for clinical effectiveness research. 15th Annual HMO Research Network Conference, Danville, PA, April 26-29, 2009.

2. Mularski RA, Hazlehurst BH, McBurnie MA, Chauvie S. Asthma care quality measure set for automated performance assessments in electronic medical records. AHRQ Annual Conference, Bethesda, MD, Sept 2008.

3. Mularski RA, Hazlehurst BH, McBurnie MA. Building an automated asthma care quality performance measure set. American Thoracic Society International Conference 2009, San Diego, CA, May 15-20, 2009

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