AHRQ Final Progress Report

Title of Project: Improving Post-Hospital Transitions and Ambulatory Care for Children with Asthma

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A. STRUCTURED ABSTRACT

Purpose: To: 1) develop two HITs to improve post-hospital transitions and ambulatory care, and determine, 2) user attitudes, acceptability and use of HITs, 3) factors associated with HIT use, and 4) HITs impacts.

Scope: Asthma readmissions are related to multiple factors: 1) hospital providers' non-compliance with preventive measures at discharge, 2) inadequate post-hospital care transitions, 3) PCP failure to monitor and manage ambulatory chronic asthma severity, and 4) patient noncompliance with asthma therapy.

Methods: We used 1) user-centered design to develop 2 HITs, 2) surveys to evaluate participant attitudes, acceptability and use of HITs, 3) surveys and regression analyses to determine factors associated with HIT use; and 4) time-series analysis to determine HIT effects.

Results: We developed and implemented 2 HITs. 48% and a third of hospital providers were favorable and satisfied with the RADS, respectively, mainly due to data entry difficulties. But, parents were satisfied (94%) with, comfortable (95%) with, and believed the AHMS (75%) improved their child's asthma. Factors associated with less AHMS use were child's age (older) and being Hispanics but being white and using quick relievers >3x/day were associated with less use. Compliance with preventive measures significantly increased and was sustained 5 years post-HIT implementation. Overall, we found a significant asthma readmission ($p=0.026$) and LOS ($p<0.001$) reductions but no change in other measured outcomes.

Conclusion: Despite moderate satisfaction, the RADS led to increased compliance with preventive asthma measures. Yet, the AHMS achieved high parent satisfaction. Overall, HITs led to significant asthma readmission and LOS reductions.

Key Words: Asthma, children, care transition, self-monitoring, factors related HIT use, and readmissions

B. PURPOSE (OBJECTIVES OF STUDY)

The current health care system is fragmented and hospitals focus primarily on providing acute treatments and expediting hospital discharge. Similarly, primary care providers (PCPs) focus on intermittent visits and often lack the tools and resources to adequately monitor patient's symptoms outside clinical encounters.[1] The purpose of this project was to ensure effective post-hospital care transitions and enhance the quality of ambulatory care for children with asthma, through ongoing self-monitoring of asthma symptoms and timely intervention, following hospital discharge in order to reduce readmissions. Specifically, we planned to develop 2 HIT applications to address post-hospital care transitions and support ongoing ambulatory care. We also planned to evaluate the attitudes, acceptability and use of these new HIT applications by hospital providers, PCPs and patients (or parents of younger children). Further, we planned to determine factors associated with effective use of the HIT tools. Finally, we planned to determine the HIT application's effects on asthma care process and readmissions. Our project had 4 main objectives (Specific Aims), including:

Objective 1: Develop two HIT applications to improve post-hospital care transitions and ambulatory care. Specifically, we planned to **1a.** Develop the RADS system to help hospital providers at discharge to: 1) comply with EB asthma preventative measures; 2) determine the patient's chronic asthma severity level; and 3) determine severity-appropriate asthma preventative medications. Upon completion of the discharge process, we planned to have the RADS system automatically fax to PCPs the discharge information with instructions regarding how to adjust therapy based on NIH guidelines.[2] **1b.** Develop the AHMS to: 1) enable at-home ongoing assessment of the patient's level of asthma control, and 2) support PCP in monitoring and managing chronic asthma symptoms.

Objective 2: Evaluate the attitudes, acceptability and use of the: **2a**. RADS system by hospital providers, **2b**. Automated asthma discharge summary and AHMS by PCPs, and **2c**. AHMS by patients
We hypothesized that hospital providers, PCPs, and patients will use the RADS system, the automated asthma discharge summary, and the AHMS, and their attitudes toward these tools will be positive.

Objective 3: Determine factors associated with effective use of new HIT applications by hospital providers, PCPs and patients. We will determine factors associated with effective use of**: 3a.** RADS system by hospital providers, **3b.** Automated asthma discharge summary and AHMS by PCPs, and **3c.** AHMS by patients/caregivers
We hypothesized that effective use of the new HIT applications will require implementation strategies that address multiple and unique factors within each user category (hospital providers, PCPs, and patients). We also hypothesize that cross-cutting themes will be identified among user categories that can be generalized to other health care settings.

Objective 4: Determine the effect of implementing new HIT applications by measuring specific process measures at the hospital provider, PCP, and patient levels, and on readmissions. We will evaluate the effect of:

- **4a.** RADS by measuring hospital provider compliance with EB preventive asthma measures and prescription of severity-appropriate preventive medications at discharge
- **4b.** Automated discharge information and AHMS by measuring impact on PCP perceived change in practice (increased awareness of preventive asthma measures, review of asthma action plan, and change in asthma preventive medications such as step-up or step-down care)
- **4c.** AHMS by measuring patient compliance with preventive asthma home medications post-discharge
- **4d**. HIT applications on overall hospital/ED readmission rates

We hypothesized that implementing the RADS, the electronic asthma discharge summary, and the AHMS will 1) improve compliance with EB preventive asthma measures, 2) enhance prescription of severity-appropriate preventive medications, 3) improve PCP practice, and 4) reduce hospital/ED readmission.

C. SCOPE: (Background, Context, Settings, Participants, Incidence, Prevalence)

C.1. BACKGROUND

Asthma is the most common chronic illness in children.[3-5] Based on 1998 information collected by the US National Center for Health Statistics, 8.65 million children (12.1% nationwide) were reported to have physician- or health care professional- diagnosed asthma in their lifetime.[6] Overall, lifetime asthma prevalence in the US is 14%. The prevalence of pediatric asthma reached this level after remarkable growth rates throughout the 1980s and early 1990s.[7] Data from the CDC-based National Center for Health Statistics also shows an increase in asthma prevalence of greater than 50 percent from 1980 to 1996.[8] During this period, the largest increase was seen in persons younger than 18 years.[5, 9-11]

Asthma is the most prevalent cause of childhood disability, with a significant impact on a child's and/or family's quality of life, and on health care use and costs.[12] In 2006, an estimated 6.8 million children under age 18 (almost 1.2 million under age 5) had asthma, 4.1 million of which had an asthma "attack" during that year, and many others had "hidden" or undiagnosed asthma.[13] Asthma is one of the most common causes of school absenteeism.[14] In 2003, children aged 5 to 17 years who reported at least one asthma attack in the previous year, missed 12.8 million school days due to the disease. Pediatric asthma entails an annual economic impact to the United States of $11.5 billion in direct health care costs, and $4.6 billion in indirect costs (loss of productivity) for a total of $16.1 billion.[15]

Asthma is also the most frequent reason for preventable hospital and ED admissions among children,[8, 16-18] accounting for 2 million ED visits in 2001 and for 1/4 of all ED visits in the US each year. About 44% of all asthma hospitalizations in the US are for children.[19] The inpatient burden of pediatric asthma includes approximately 190,000 hospital admissions[20] per year, with $2 billion[21] in direct medical expenditures per year. Despite effective interventions to treat and prevent pediatric asthma exacerbations, readmission rates remain high.[22-25] Children hospitalized for asthma also are at increased risk for subsequent admissions and death.[22, 24, 26, 27] With each asthma hospitalization, the probability of readmission increases.[28, 29] Reported readmission rates in children vary from 10% - 30% within 6 months, to 20 - 50% within 12 months following an index admission.[22-25] Hospital admissions and readmissions for children with asthma account for 54% of the direct expenditures for asthma-related medical care.[30] Importantly, more than 80% of the resources used for asthma are consumed by 20% of the affected population, who are frequent users of health care services.[31] Preventing readmissions in children hospitalized with asthma can reduce health care costs related to asthma and effective methods for preventing ED and hospital readmissions are critically needed.

Previous studies have identified several risk factors of ED and hospital asthma readmission [16, 23, 29, 32-44]. Furthermore, readmission has been related to hospital providers non-compliance with evidence-based asthma preventive measures at discharge,[45-47] poorly managed post-hospital care transitions[48] including delayed or inaccurate transfer of discharge information to primary care providers (PCPs),[49-52] failure of PCPs to monitor and manage chronic asthma disease severity, and patient non-compliance with asthma home therapy.[53] An asthma admission is also an opportunity to evaluate the adequacy of asthma care and to take actions necessary to prevent future readmissions.[54] Published guidelines recommend that preventive measures be initiated at each admission to minimize risk for future asthma readmission,[54-56] including the following: 1) chronic asthma severity assessment with determination of preventive medications according to chronic asthma severity level, 2) patient and parental participation in asthma education, 3) written asthma action plan, and 4) scheduled follow-up care after hospital discharge.[47, 57]

Ongoing evaluation of a patient's level of asthma control in ambulatory settings can determine whether or not a patient is compliant with treatment, or if the goals of therapy are being met to adjust asthma therapy.[58] Continuing evaluation of a patient of asthma control level post hospital discharge can establish care continuity, reducing subsequent ED/hospital admission risks. Studies have shown a positive relationship between asthma and preventive measures, and ongoing monitoring of asthma control.

Problems with Quality of Pediatric Asthma Care

Suboptimal Pediatric Asthma Care: Despite the broad distribution of asthma guidelines, studies reveal a significant gap between the evidence for best asthma care practices and the care provided to children with asthma. Healthcare providers often fail to comply with evidence-based preventive asthma measures both in the inpatient and ambulatory settings.[46, 47, 59-64]

Missed Opportunity during Asthma Hospitalization: Asthma admissions are often related to failed ambulatory care strategies or inadequate ambulatory management, culminating in severe exacerbations in poorly controlled patients.[65-68] An asthma hospitalization is an opportunity to evaluate the adequacy of asthma ambulatory care and to take actions necessary to prevent future readmissions.[54] Published guidelines recommend preventive measures be initiated at each hospitalization to minimize risk for future asthma readmission.[54-56] Unfortunately, this is frequently a missed opportunity.

Ineffective Post-Hospital Care Transitions to Ambulatory Settings: The Institute of Medicine (IOM) has called for a greater integration of health care delivery across different settings to improve care transitions and to reduce the risk for medical errors.[69] Effective care transitions can improve the quality of ambulatory care and are associated with better compliance with follow-up appointments, medications, and more timely care for problems, as well as reduced ED/hospital readmissions.[56, 70, 71] Ensuring care continuity after hospital discharge for children with asthma is essential to reducing the risk for hospital readmission. Yet multiple problems are reported during patient discharge including: *1) Inadequate transfer of discharge information to PCPs*.[50-52, 72-76]and 2) *discontinuity of care*[77-79] Continuity of care is associated with fewer ED visits/ hospitalizations, shorter LOS, better compliance with appointments and medications, and more timely care.[71]

Inadequate Asthma Control in Ambulatory Setting: Despite broad distribution of EB recommendations to prevent exacerbations, asthma remains a poorly controlled disease.[80][81] A primary reason for poor control is patient non-compliance with asthma home therapy including incorrect use of inhaler devices and insufficient treatment of peripheral airway inflammation. PCPs often fail to adequately monitor and manage chronic asthma disease in ambulatory settings.[80, 81] Poor asthma control is associated with increased risk for ED/hospital readmissions.[80] Ongoing evaluation of a patient's asthma control after hospital discharge can establish care continuity by monitoring if or not patients are compliant with treatment, and is essential to reducing readmissions.[58] It enables the physician to 1) determine if the goals of asthma therapy are being met, 2) identify patients at risk for readmission earlier, and 3) adjust treatment accordingly.[55, 82, 83]

Slow Translation of Evidence into Clinical Care: The IOM identified translating research findings into improved quality of care and patient safety as a priority.[69] Yet, translating research findings into routine clinical practice remains slow and lags behind 15 to 20 years after discovery of more effective treatment.[84] One reason for this gap is the difficulty translating the complex guidelines into routine practice.[85] Designing and implementing HIT applications that support the use of EB asthma care recommendations across the continuum of asthma care and meet the needs of hospital providers, PCPs and patients/families can reduce the gap and improve the care of children hospitalized with asthma, [45, 86, 87] The gap also can be addressed by identifying factors that can facilitate effective use of HIT applications in clinical practice.

Clinical Decision Support Tools: These tools provide EB instructions to clinicians at the point-of-care in a simple format for incorporating evidence into routine clinical decisions. In addition, clinical-decision support can be developed to enhance patient self-management of chronic disease. Our HIT applications ensure the use of EB asthma preventive measures at discharge and timely transfer of accurate discharge information to PCPs for care continuity, as well as chronic ambulatory asthma management to help patient with on-going monitoring of asthma symptoms at home and PCPs' decision making for prescribing appropriate controller medication.

HIT Applications in Healthcare: The potential for using HIT to improve healthcare practice has been recognized over the past decade.[88-94] HIT applications are more commonly used to address inefficiency in the health care setting and are being applied successfully in a variety of clinical settings including the following: 1) systems to improve the process, delivery, and evaluation of health care, 2) systems to improve the use of and adherence to practice guidelines and 3) systems to provide clinical alerts and reminders, to generate education material and patient specific treatment recommendations.

Factors Associated with Successful Implementation and Use of HIT Applications (HITs): Several factors associated with successfully implementation and use of HITs in large healthcare settings have been reported, including user's computer skills, perceived usefulness and perceived ease of use.[101], and perceived ease of use and subjective norm.[102] Also, HIT adoption is associated with user expectations, time and training required to implement and adopt the software, availability of a leader champion, and readiness of health care providers to accept the system.[103] Electronic reminders are strongly associated with increased use of HITs.[104] Necessity, usefulness, data entry, cost, security, and confidentiality were significant factors associated with use of the EMR. [105] Primary barriers to HIT adoption in long-term facilities include costs, the need for training, and the culture change required to embrace the technology.[106] Yet, training programs,

well-defined implementation plans, and government assistance with implementation costs, support from regulatory agencies, evidence that the technology improves outcomes, and safeguards for patient privacy are facilitators of adoption.[107] Factors associated with implementation and use of HITs in small practices or to improve post-hospital care transitions and support ambulatory care in pediatric asthma are not well described.

C.2. CONTEXT

Asthma readmissions are high and related to multiple factors including hospital providers' non-compliance with evidence-based asthma preventive measures at discharge and poorly-managed post-hospital care transitions including delayed or inaccurate transfer of discharge information to PCPs. Ongoing monitoring of the patient's level of asthma control is also essential to determine if the goals of asthma therapy received in the ambulatory setting are being met. Previous studies about diffusion and evaluation of HIT applications for asthma care have not focused on post-hospital care transitions between hospital and ambulatory settings.[108] Once a patient is discharged from the hospital, there is little reported use of HIT applications to monitor a patient's ongoing level of asthma control and establish continuity of care. Our project ensured effective care transitions and continuity for children with asthma post-hospital discharge and the spread for best asthma care evidence across the asthma care continuum in order to reduce readmissions.

C.3. SETTING

The project was conducted at Primary Children's Hospital (PCH), an Intermountain facility. **Intermountain Healthcare** (Intermountain): is a regional, not-for-profit integrated health care delivery system of 22 hospitals located in Utah and Idaho. Intermountain provides health services to 1,680,000 patients in Utah (~60% of Utah's 2.8 million populations) and southeastern Idaho. PCH is a level I trauma center and serves as both the community pediatric hospital for Salt Lake County and as the tertiary care pediatric hospital for Utah and four surrounding states (Wyoming, Nevada, Idaho and Montana). PCH is located in Salt Lake City and is the only children's hospital in Utah. It is affiliated with the Department of Pediatrics at the University of Utah School Of Medicine and serves as the teaching hospital for pediatrics. It has 289 licensed beds and provides 80% of inpatient services for children in Utah. Virtually all complicated pediatric patients in the region are admitted to PCH, particularly younger patients whose illness is severe enough to require hospitalization.

C.4. PARTICIPANTS/DATA COLLECTION (Objectives 3 and 4):

Hospital providers at PCH who care for children admitted with asthma during the study period for the evaluation of the RADS system. Hospital providers were evaluated for the following:

a. Attitude, acceptability, and use of the Reminder And Decision support System (RADS): **Aim 2a** (data collection through survey)
b. Factors associated with use of the RADS: **Aim 3a** (data collection through survey)
c. Compliance with evidence-based asthma preventive measures and prescription of severity appropriate preventive medications using **Interrupted time-series (ITS)** analysis: **Aim 4a** (data collection through electronic and manual review of medical records)
    i. Hospital providers were assessed for **documentation** in the medical records of the following preventive measures: 1) Chronic asthma severity assessment or asthma control assessment, 2) Patient/parent participation in asthma education class, 3) Scheduled follow-up appointment made before discharge, and 4) .Written asthma action plan prepared before discharge.

Patients' **primary care providers (PCPs)** for the evaluation of the electronic discharge summary and AHMS (decision support). We planned to evaluate PCPs for the following: 1) Attitude, acceptability, and use of automated discharge summary/AHMS: **Aim 2b** (survey), 2) Factors associated with use of automated discharge summary/AHMS: **Aim 3b** (survey), and 3) Effects on PCPs of implementation of the automated discharge summary and AHMS, with regard to PCP's **perceived** change in practice: **Aim 4b** (survey).

Patient/parents who consent to participate in the evaluation of AHMS (home monitoring), were evaluated for the following: 1) Attitude, acceptability, and use of the AHMS: **Aim 2c** (data collection through survey), 2) Factors associated with use of the AHMS: **Aim 3c** (data collection through survey), and 3) Change in ED/hospital readmissions for asthma post AHMS implementation using **ITS** analysis: **Aim 4d** (data collection through administrative data, the enterprise data warehouse (EDW), and survey).

We will collect any subsequent hospitalization/ED admission at any Intermountain hospital/ED or urgent care facility within 6 months of index discharge. Intermountain system facilities cover about 80% of the market share regarding pediatric asthma inpatient or emergency care. Survey data complemented the EDW for patients readmitted at facilities outside the Intermountain system. Compliance with preventive asthma medication after implementation of the AHMS: Aim 4c (data collection using both survey (automated telephone survey using the AHMS) and pharmacy claims data in the EDW to validate use of preventive medications reported by the parents/patients with objective data on a set of patients with Intermountain Health Plans).

D. METHODS

D.1. SDUTY DESIGN: Cross-sectional (Aims 2 and 3, and Aims 4b and 4c) and Retrospective and Prospective cohort study (Aims 4a and 4d).

D.2. DATA SOURCES/COLLECTION/MEASURES

OBJECTIVE 1: Not applicable

OBJECTIVE 2:
Data collection: Data was collected through surveys of the study population defined above. The survey questionnaire has been adapted from seven validated survey instruments that were developed based on models of user satisfaction, technology acceptance, and technology use.[109-115] This survey uses factors proposed in those models, but decreases the number of questions asked per factor, and adjusts the wording of some questions to better align with technologies used in our study (i.e., RADS, AHMS, etc.) and the different stakeholders (e.g., hospital providers, PCPs, patients/caregivers). For instance, questions regarding organizational factors were asked only to providers not patients/caregivers. In addition, the survey assessed factors associated with effective use of the technology to achieve Aim 3. The adapted questions were pre-tested and refined on a similar study population used to test and validate the software, before implementation. After pre-test, several questions were modified. **Measurement (Data Analysis):** Summary statistics were derived from individual responses reported and aggregated scores based on categories.

OBJECTIVE 3:
Data Collection: Data were collected through the same survey described in Aim 2, augmented with 4 open-ended questions to qualitatively evaluate barriers and facilitators associated with effective use of HIT applications among subjects. Other information collected during the survey includes variables of survey instruments, providers' age, sex, practice size, and experience (year of practice). **Note**: Before actual implementation of the survey, we planned to have 2 open-ended questions to assess barriers and facilitators, but following pre-test of the survey, participants requested 2 more open-ended questions to assess the impact of the AHMS and whether providers would like to see any changes. For **Aim 3c:** Patients with persistent asthma enrolled in the study were assessed prospectively. Data were collected using the AHMS (or e-AT) through weekly self-assessment to assess their child's asthma control. Baseline ACT was completed in the hospital, followed by weekly self-assessments over 6 months post hospital discharge. At enrollment and each assessment, parents reported demographic information and also compliance with controller medications, use of quick relievers, use of oral steroids, and unscheduled acute care visits for asthma. Successful participation was defined as completing at least 60% of targeted weekly ACT assessments.

Note about Change in Methods Objective 3.a: Following RADS development, hospital leadership decided to mandate its use to support the discharge process for all patients admitted at PCH. As consequence, the RADS have functions that force users to navigate through all features before a discharge summary is created and a patient is discharged. Hospital providers did not have a choice to use or not use the RADS and therefore we were not able to assess factors associated with RADS use by categorizing providers to frequent vs. non frequent users as previously planned. To complete Aim 3.a., we used hospital provider's perceptions of the RADS system which was assessed after adding open ended questions to the survey described in Aim 2.

Note about Change in Methods Objective 3.b: Before implementation of the AHMS and during facilitated discussions with representatives of primary care providers, they decided by consensus that the AHMS be

managed at clinics by a nurse clinic care coordinator and not by them directly to reduce workflow interruption. Therefore, per this new protocol, primary care providers did not access the AHMS directly. All interaction with the AHMS was handled by clinic care coordinators, including reviewing results, receiving alerts, printing graphs for the primary care provider (before office visits) and coordinating patient follow-up visit with the primary care provider. For these reasons, we could not categorize primary care providers to frequent vs. non-frequent users to evaluate factors associated with AHMS use, and did not complete Aim 3.b.

Measurement (Data Analysis): Analyses were both **quantitative** and **qualitative.** *Quantitative Analysis*: For Aim 3.a.: Due to the modification discussed early, as all hospital providers use the RADS, we used descriptive analysis to report determine factors associated with use of the RADS by hospital providers. For Aim 3.c. we planned to separate patients/parents in 2 groups, based on how frequently they use the AHMS system: *frequent users* and *non-frequent* users. The primary outcome variable was frequency of use (frequent users vs. non-frequent users). Frequency of use was determined for the following patients/parents using stored log data regarding interaction with the AHMS. We used this information to determine frequency of use as a **continuous** variable of the IT intervention for each provider and patient/parent and for analysis. General linear models were used to assess independent associations between these factors and primary outcomes. The area under the Receiver Operating Curves were used to determine an optimal cut-off point between frequent users and non-frequent users. We used this dichotomized outcome on a multiple logistic regression model to determine factors associated with effective use of HIT innovations. Univariate logistic regression analysis was performed first for all independent variables. The predictors with a p-value of 0.25 or less in the univariate analyses were considered candidates for the multivariate logistic regression model. *Qualitative analysis:* Qualitative Analysis: Was based on thematic analysis and a grounded theory approach methodology.[116, 117] Data were sorted and coded and themes were related to relevant categories. Themes were identified based on their frequency of occurrence. Results were summarized and reported as sums or percentages.

OBJECTIVE 4 a:

Data Collection: Manual review of medical records. Baseline data were collected retrospectively for the past 2 years before initiating the study. Discharge summaries were reviewed for compliance with asthma preventive measures including prescription for preventive medications. Hospital providers were assessed for documentation in the medical records of the following preventive measures: 1) chronic asthma severity assessment or asthma control assessment, 2) patient/parent participation in asthma education class, 3) scheduled follow-up appointment made before discharge, and 4) written asthma action plan prepared before discharge. For hospital provider compliance, if a measure is not documented, the hospital provider was categorized as “non-compliant” for that measure and results were reported in aggregate (at the patient level or proportion of patients receiving a specific asthma preventive measure) rather than by individual provider. The discharge summary, progress notes, and orders were reviewed for compliance with appropriate prescriptions of preventive medications at hospital discharge. Following HIT tools implementation, data were collected prospectively. Patients identified as having inadequately controlled asthma (based on chronic asthma severity assessment) are expected to be prescribed an asthma controller—Long acting beta agonist (LABA), inhaled corticosteroid (ICS), or a leukotriene modifier (LT) or a combination of a combination—at the time of discharge. Discharging providers with patients identified as having inadequately controlled asthma without prescription(s) of any of these medications were classified as “non-compliant”.

Measurement (Data Analysis): Data (proportion) were plotted monthly over time before implementation and over the remaining months post RADS implementation to evaluate the change in compliance over time. Baseline data were collected retrospectively and post-implementation data were prospective as described above. Because the effect of implementation was not seen immediately, an interrupted time series analysis (ITS) was used to determine the effect of intervention (HIT tools) upon single times series of data through a general class of ARIMA (auto-regressive integrated moving average, a.k.a. Box-Jenkins) models.[118] The use of time series analysis helped us control for “historical threats”, events (e.g. seasonal or cyclical effects) or processes other than HIT interventions that can affect a change in performance..

OBJECTIVE 4 b:

Data Collection: We initially planned to use collect data using the same instrument described in **Aim 2**. The survey questionnaire to assess the attitudes, acceptability and use of the IT innovations was adapted from

validated survey instruments based on models of user satisfaction, technology acceptance, and technology use. Questions (section "impact on PCPs Asthma Care Practice") about the attitudes, acceptability and use of technology survey include provider **perception** about whether or not the IT tools allowed change in practice as measured by increased awareness of preventive asthma measures, review of asthma action plan and change in asthma preventive medications (such as step-up or step-down of preventive medications).

Measurement (Data Analysis): Initially, we planned to use summary statistics derived from individual responses and aggregated scores reported on the subjective effect (PCP perception) of the HIT tools on PCP practice. Specifically, we planned to report the mean, standard deviation and 95% confidence interval, along with median and interquartile range (IQR) of the scores were reported for the overall study subjects, as well as by groups (large vs. small practices, frequent vs. non-frequent users etc.)

Note about change in Aim 4.b: During facilitated discussions held before AHMS implementation, PCPs decided by consensus that interaction with the AHMS be managed by a nurse clinic care coordinator and not by them directly to reduce workflow interruption. Thus, per this new protocol, PCPs did not access the AHMS directly. All interaction with the AHMS was handled by clinic care coordinators, including reviewing results, receiving alerts, printing graphs for the PCP (before office visits) and coordinating patient follow-up visit with the PCP. For these reasons, we could not complete Aim 4.b. as this would require use of the AHMS by PCPs.

OBJECTIVE 4 c:

Data Collection: Data were collected through the AHMS and consisted of the weekly ACT questionnaire, augmented by 3 questions regarding whether or not a patient 1) has had any emergency/urgent care visits or has been hospitalized during the past week (Yes/No); 2) is receiving asthma medication (YES/NO) including controller medications; and, 3) the name of the medications if pertinent (which will be prompted for the patient to select YES or NO by touch tone).

Determination of Patient/Parent Compliance: Patients (or parents of minor children) who are not adequately controlled based on the ACT score (score < 20), who were previously prescribed a controller medication before hospital discharge and are not (at the time of the ACT assessment) on a controller medication will be categorized as "non-compliant."

Measurement (Data Analysis): The unit of analysis was the patient (not the parent) although this information may be collected directly from the parents for younger patients. Patients whose asthma was not well controlled (ACT score <20) and receiving an asthma controller medication were categorized as compliant and those not receiving an asthma controller were be categorized as non-compliant. Compliance with asthma preventive medications was compared between frequent users and non-frequent users of the AHMS (as defined in Aim 3). Chi-square analysis and logistic regression model were used to compare compliance between frequent users vs. non-frequent users.

OBJECTIVE 4 d:

Data Collection: Baseline data consisted of 6 months readmission rate over multiple years prior to implementing the HIT tools to ensure that there were no pre-existing secular trends. We used the Intermountain data warehouse (EDW) to collect any subsequent hospitalization/ED admissions to any Intermountain hospital/ED or urgent care facility within 6 months of index discharge (Note: Intermountain facilities have ~80% of the market share in Utah regarding pediatric asthma inpatient or emergency care). Readmission rates for children discharged during a specific month were plotted quarterly over time.

Measurement (Data Analysis): Readmission within 6 months of patient hospital discharge within a specific quarter was plotted over time before the implementation of HIT tools and over the remaining quarters post implementation to evaluate the change in readmission over time. For Aim 4a, we used an ITS analysis to determine the intervention effect (implementation of the HIT tools) upon single time series of data through a general class of ARIMA (Box-Jenkins) models. Readmission rates within 6 months were the primary outcome.

RESULTS/OBJECTIVE 1a (Development of the RADS (Asthma DOADI) System

Note: Information below was retrieved from a manuscript we published describing the RADS development.

We first conducted a needs assessment to identify user needs, preferences as well as requirement/ functionalities for the tool. We intended to build the RADS system by leveraging our preliminary work and using the Discharge Orders and Discharge Instructions (DOADI) tool as a platform.[119] The DOADI tool is a

tool widely used across PCH by hospital providers and serves as an electronic discharge order. Data entry is facilitated by using radio buttons rather than manual typing in many sections. Upon completing the discharge process, the RADS system automatically faxes the discharge information to the identified PCP including the patient's asthma action plan and severity-appropriate preventive medications recommended at discharge as well as specific instructions on how to adjust asthma therapy based on NIH guidelines.[2] Instructions on how to adjust asthma therapy assisted the PCP to comply with asthma guidelines. A reminder system was developed within the DOADI software to help hospital providers comply with asthma preventive measures. PCH has a process to identify PCPs for patients at the time of admission. If a PCP is not identified during hospitalization, hospital providers help patients identify a PCP before discharge. Upon hospital discharge, a paper copy of the asthma action plan will be provided to the patient.

Needs Assessment: An interdisciplinary team was established, including: a physician leader, researchers, chief resident, hospital administrators, QI staff, registered nurses, respiratory therapists, pharmacists and discharge planners. A flow diagram was developed to examine the discharge process and methods for collecting home management plan of care (HMPC) components recently recommended by the Joint Commission as Asthma Care Core Measures. Several leverage points were identified: 1) unit clerks, on 5 hospital units, have to maintain discharge forms available at all times to physicians, 2) physicians have to remember to ask for the discharge forms and to manually complete required HMPC components, 3) an RT has to ensure that patients/caregivers receive asthma education and document the training in the medical record, 4) new residents and staff physicians have to be trained on how to fill out discharge forms, 5) charge and bedside nurses have to monitor compliance with HMPC components of the discharge paperwork. The most common problem was physicians were not aware of or did not remember HMPC requirements at discharge.

Requirement analysis*:* The interdisciplinary team recognized that the asthma discharge process could benefit from automation. A solution was to develop and implement the asthma-specific *RADS* system. The new discharge process should streamline the discharge workflow by integrating the *RADS* within an existing clinical information system (CIS). Specifically, the *RADS* system should contain an explicit checklist and computerized decision support to help providers meet essential clinical and administrative tasks for asthma discharge by: 1) requiring the asthma discharge forms be completed when an asthma patient is being discharged, 2) reminding that instructions about environmental control and control of other triggers be documented, 3) developing an asthma written action plan (WAP) including instructions about home use of reliever medications, 4) reminding providers to make arrangement for follow-up care with a PCP including date, time, the provider's name and phone number, as required by JC, 5) reminding providers to document instructions about home use of controller medications, and 6) automatically creating a discharge summary with an auto-faxing mechanism to PCPs in a timely and consistent way, containing key clinical elements necessary for follow-up care.[8]

Software: We used an existing CIS, "*Patient Tracker*"[120]as a platform to develop the *RADS*. *Patient Tracker* had a previously built-in tool, the "Discharge Orders and Discharge Instructions" (*DOADI*) that support the creation of discharge documents by physicians. The resulting documents include an electronically signed discharge order for PCP follow-up and printable discharge instructions for patients/caregivers to use at home.

Patient Tracker*: Patient Tracker* is a tool for supporting discharge processes and hospital communication practices at PCH. *Patient Tracker* is a web-based application widely used across the hospital and built on the Java (Sun Microsystems Inc, Santa Clara, CA) architecture, developed using an Oracle 9i (Oracle Corporation, San Jose, CA) database. Patient information is updated multiple times daily by members of the care team to reflect changing or evolving diagnoses and treatments.

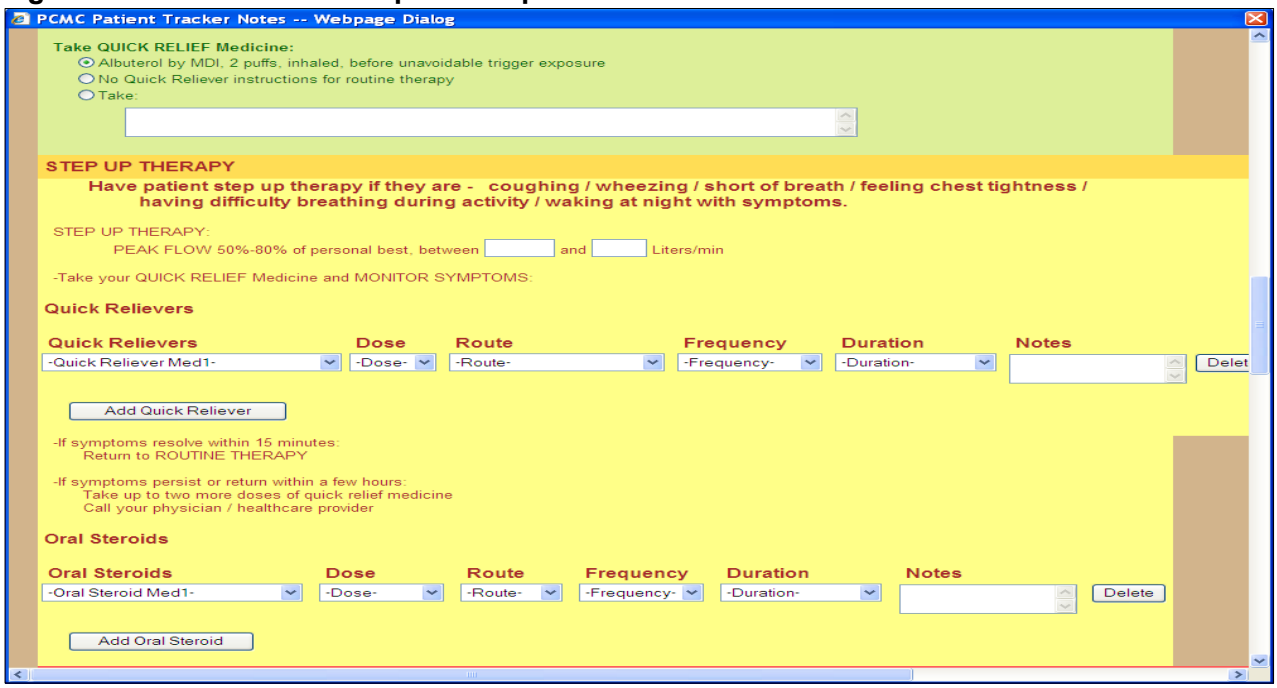
DOADI: *DOADI* is built on the same Java/Oracle architecture as *Patient Tracker*. The user interface is a web form that incorporates dynamic HTML and JavaScript. The electronic documents produced by *DOADI* are sent through an interface to a document handler of the legacy EMR for storage.[10] The document handler auto-faxes the discharge summary to the patient's PCP.

RADS: *Therefore, the RADS* is a specialized version of the *DOADI*, which incorporates content and decision rules specific to asthma patients. The decision rules are written in JavaScript and Java.

Description of the RADS: The *RADS* was designed to automate the multiple functions of the paper-based discharge process. Patient demographic information, admit date and time, weight at discharge, attending name, the PCP name and diagnoses are pre-populated from the *Patient Tracker* database. The tool contains web-based data entry templates that use a variety of data entry tools for data collection, including text fields, radio buttons and drop-down menus. The asthma-specific *RADS* system is composed of 5 main sections:

- *Asthma diagnosis section*: *Patient Tracker* has an "asthma flag" that allows real-time identification of asthma patients at any time during hospitalization. Physicians check the flag upon confirmation of asthma diagnosis based on 6 standardized questions in the admission order from the national asthma guidelines.[12] This flag, when checked, triggers the *RADS* system to help physicians follow the NAEPP algorithm for treatment decisions. *RADS* allows the physicians to categorize the diagnosis as new onset asthma or established asthma.[12] Category selection prompts the provider to determine the chronic asthma control level: whether the asthma is mild, moderate, intermittent, or persistent for new onset asthma, or whether the disease is well-controlled, not well-controlled or poorly controlled asthma for an established diagnosis. In addition, the *RADS* system has instructions for the provider to determine whether a patient should receive a controller medication based on chronic severity assessment, and if so, the name of the medications, dose and frequency **(Figure 1).** These instructions ensure that all patients with "not well-controlled or poorly controlled" asthma receive appropriate controller medications at discharge as recommended in the NAEPP guidelines.[12] Completion of each of these fields is required.

Figure 1: Medication Prescription Requirement



- *Asthma specific discharge instructions:* Include steps to take to minimize the risk of future asthma exacerbations and readmissions. *RADS* uses radio-buttons to select common asthma triggers. *Section 3–Discharge medications*: All medications entered in Patient Tracker during hospitalization are populated into the RADS. Providers can also select medications (**Figure 1**) to use at discharge or add/remove medications as needed including decision support to prescribe or adjust controller therapy. Medication fields contain a "drop down menu" with the most common medications, their frequency, dosage and route to facilitate data entry and avoid errors. The RADS also captures exceptions to ensure accurate quality reporting: 1) if a provider does not need to prescribe a controller medication at discharge, he or she must check the field named "no controller needed" to complete the discharge process, 2) When a patient does not have an identified PCP for a follow-up appointment, the discharging physician can select the option "Patient will make his/her own appointment-Please call your PCP within 1-3 days of hospital discharge," 3) when a patient does not need a quick reliever medication after discharge, the discharging physician can check the option "No quick reliever for routine therapy."
- *Section 4–Written action plan (WAP):* WAP with completion of require HMPC components
- *Section 5–Follow up requirements:* Adequate completion for follow-up care with a PCP requires date, time, the provider's name and phone number.

- *Auto-generation of discharge documents: RADS* allows auto-generation of 2 different discharge documents, including: discharge orders and summary for follow-up care with the PCP and discharge instructions for patients/caregivers for use at home.
  Discharge documents generated by *RADS* can be authored by multiple users or can be updated and saved. This feature allows for partial completion of the discharge documents during the hospitalization and not solely at the time of discharge. Discharge documents can also be finalized remotely at the time of discharge by a physician, then printed by the nurse and given as discharge instructions for patients/caregivers. The generated discharge summary is auto-faxed to the PCP upon completion and electronic signing of the discharge documents in the *RADS* system. The PCP identification field in *RADS* is linked to a database that stores fax numbers for each PCP to allow the auto-fax process to occur. An administrative assistant, whose previous role was to manually fax discharge summaries to PCPs, maintains the PCP database. She receives a daily report of fax logs to identify discharge summaries that failed to be auto-faxed and to update the PCP database with correct fax numbers. The finalized version of the discharge summary is part of the EMR.

RESULTS/OBJECTIVE 1b (Development of the Web-based Asthma Home Monitoring System (AHMS)
The development of the AHMS also called in the past the **electronic Asthma Symptom Tracking and Exacerbation Reduction (e-ASTER)** application and currently called the **electronic-Asthma Tracker (e-AT),** application was guided by information generated from a focus group (Needs Assessment) formed from a sample of children and their parents who used a paper-based version of the tool, which was developed and tested de-novo by the research team for reliability and validity.[121]

***AHMS* Software Requirement:** We assembled an interdisciplinary team including physicians and a nurse specialist with experience in asthma education, informaticists, a web-developer/programmer, and researchers including experts in system and process improvement to develop the initial e-AT prototype. The team developed a list of the application requirements including needed functionalities for both children/parents and PCPs. This list was augmented with additional software requirements generated from patients and parents input during the focus group. Results were used to develop the AHMS (e-AT).

***AHMS* Software Development Process:** We used a stepwise (iterative) development process and met weekly with the web-developer/programmer to review interim designs and prioritize tasks to accomplish for the following meeting. The e-AT was developed for use at home by older children (≥10 years), with or without assistance from their parents, and by parents of younger children (< 10 years).

***AHMS* Software Description:** The AHMS or e-AT (**https://asthmatracker.utah.edu/public/index.php**) has 7 main components with other feature to facilitate compliance with use, including: 1) a patient portal, 2) survey questionnaire, 3) report generator system, 4) decision support/feedback system, 5) other features:.

1. Patient Portal: allows weekly self-assessment of patient's asthma control. Weekly surveys are completed by patients or parent proxies (for younger children) through a secure web-based portal (**Figure 2**), which provides authenticated access, using Hypertext Transfer Protocol Secure, to patient-specific views.
2. Online Survey Questionnaire: The AHMS uses the Asthma Control Test (ACT) questionnaire, previously adapted and validated by our research team for weekly (rather than monthly) assessment of chronic asthma control in children 2-18 years of age.[121] The child (alone or with parental assistance) or the parent of a younger child completes the questionnaire 1x every 7 days. Users can view their prior responses and edit them. Additional information collected includes weekly compliance with controller medications, information about unscheduled clinic visits, ED or hospital admissions, and comments that users enter when they want to explain a low score, such as exposure to a known asthma trigger.
3. Report Generator System: The AHMS automatically calculates and plots the total weekly ACT scores on a color-coded graphic display (**Figure 3)** from responses provided by patients through the online survey questionnaire. A MySQL database is used to store the data.
4. Report Generator System: The AHMS automatically calculates and plots the total weekly ACT scores on a color-coded graphic display (**Figure 3)** from responses provided by patients through the online survey questionnaire. A MySQL database is used to store the data.
5. Decision Support and Feedback Mechanism: After the AHMS calculates the total score, it instantaneously generates a graph with embedded decision support including a pop-up message box containing recommendations. The graphic display determines whether the child's asthma is 1) well- (*Green*), 2) not

well- (*Yellow*), or 3) poorly-controlled (*Red*). Each color is associated with a pop-up message box containing specific recommendations, including whether the patient should 1) continue regular follow-up (Green zone), 2) schedule an early PCP follow-up visit (2 consecutive weeks or more in Yellow zone) or 3) schedule an immediate follow up appointment with the PCP (Red zone). Decision support is provided by internally developed, decision-support logic written in PHP. Short phone text messages or longer email messages tailored to the patient's specific patterns of asthma control are sent to both the patient and parent to facilitate behavioral changes through the Health Belief Model framework by increasing patients' awareness of chronic asthma symptoms, improving self-efficacy and providing cues to action (skills to respond to deterioration of asthma control and to take responsibility for managing acute exacerbations).

6. Parent Incentive Mechanism: The AHMS has an incentive mechanism using a built-in progress bar, which adds 25 points each time a patient/parent completes a weekly assessment. When total points reach 100 (~4 successful assessments), users receive a pop-up message congratulating their achievement and receive a $10 gift certificate to a local or online store, then the system resets to 0, and the cycle restarts.
7. Other Features: The AHMS has additional features for patients, including: 1) a disclaimer describing the software capabilities/expectations and their responsibilities for using the tool, 2) a profile page that stores patients and contact information and choices that determine who will be receiving alerts and reminders generated by the AHMS, 3) instruction materials/tutorials presented in 3 different formats (video, written, and online slide show), 4) links to asthma related education resources and games, 5) a print function and 6) other interactive features aimed at increasing patients' knowledge/self-management skills about asthma.

Figure 2: Patient/Parent Portal

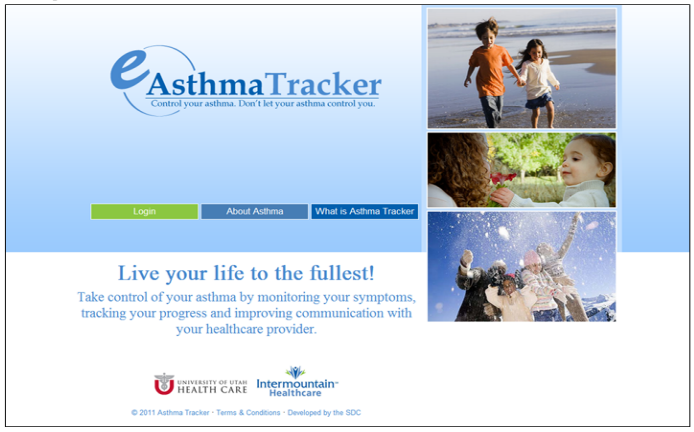
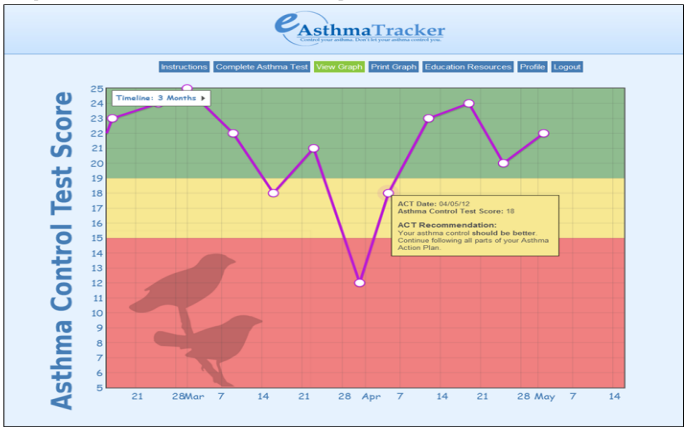


Figure 3: Graphc Display



8. PCP or Clinic Interface: The AHMS includes a provider or clinic interface that can be accessed by the PCP or representative (e.g. care manager) to directly monitor his/her asthma patients (**Figure 4**). The clinic can view the list of patients who are in the Yellow or Red zone, or drill down for detail including graphs.

Figure 4: Clinic Interface (General Patient View)

The PCPs' office can choose to receive real time feedback through auto-email and auto-fax messages to alert them when a patient's asthma control deteriorates.

Usability Test of the AHMS (e-AT). Note: *Information was retrieved from a published literature.* After development of the first prototype of the AHMS, we submitted the prototype to 2 iterative usability testing cycles to identify issues with the application and refined it to fit user needs and preferences. Results of the usability test were published. The usability testing was led by a trained observer and moderator and was supported by a note taker with audiotaped recordings.[122, 123] User responses and suggestions were used to drive changes to finalize AHMS user interface.

INTERVENTION: Implementation of HI tools including the RADS and AHMS

RADS Implementation: We created an interdisciplinary implementation team consisting of informatics technicians, clinicians, researchers, and administrators. The *RADS* was rolled-out during a four-week period. Implementation at the hospital began in August 2009 after a pilot test on a hospitalist-only team. The *RADS* system was then extended to the 5 house staff teams that include attending hospitalists. Finally, the medical student team was included. Training consisted of physician and nurse education on the electronic asthma discharge process. Hospital providers were educated in multiple sessions about the RADS system including the reminder and decision support components. Physician education was conducted at the initiation of the implementation. PCH has a weekly Grand Rounds that is well attended by hospital providers as well as many primary care providers who admit their patients to PCH. Grand Round was be used as a venue for provider education about the new HIT tools. We discussed with them the general aspects of the project including the reminder and decision support systems and the evidence supporting the project. We also discussed how the HIT tools can be integrated into work-flow and the benefits of the systems. A contact number was provided for questions and support regarding any technical aspects of the project.

AHMS Implementation: We created an interdisciplinary implementation team consisting of informatics technicians, clinicians, researchers, and administrators. We also developed training materials in the form of a flip chart (**Appendix**), instructions for users and provided training (one-one training, email link for education material, presentation at physician education meeting, presentation at patient asthma education training etc.). PCPs in Salt Lake County were sent a letter to explain the need for an automated asthma discharge summary including instructions on how to access the e-AT for their patients. Also, a letter was attached to the automated asthma discharge summary to remind PCPs about the e-AT for the patient as well as the email alerts that they received from the AHMS system. A link to the Web Portal was be provided at each discharge for the PCP to access as needed. A contact number was provided to PCPs for questions and support regarding any technical aspects of the project. PCP email addresses were collected using the same process in place at PCH for collecting PCP telephone numbers.[124] **Note:** as stated earlier PCPs did not access the AHMS directly. All interaction with the AHMS was handled by a clinic care coordinator. Thus, we could not categorize PCPs to frequent vs. non-frequent users to assess factors associated with AHMS use, and did not complete Aim 4.b.

Patients/Parents were approached by the study coordinator to participate in the study if their PCP resides in Salt Lake County (SLC). The study coordinator obtained a signed consent forms from patients/parents to participate in the study. After enrollment, parents were trained about the e-AT. A Web link to the Web portal and temporary password were given to the patient/caregiver to access the system and establish a permanent password. Patients were trained in how to use the system and its potential benefits before discharge. Patients also were encouraged to bring the form to their primary care provider at the time of follow-up visit. A contact number was available for questions and support regarding any technical aspects of the e-AT

Leadership Support as One Factor that Facilitated Implementation and Use of HIT Applications: Opinion leaders were critical to ensure implementation success and use of the HIT tools. We used a clinician champion and an opinion leader to facilitate dissemination the new HIT tools at PCH and to PCPs.

RESULTS/OBJECTIVE 2a: The survey to evaluate the attitudes, acceptability and use the RADS system by hospital based providers included overall 19 structured questions and 4 open-ended questions.

Responses to Structured Questions: Of the 62 hospital providers who were sent the survey, including 36 hospitalists and 26 residents, 31 providers responded (50% response rate). Of these respondents, 51.6% (16/31) were female, 51.6% had less than 5 years of experience, 25.8% had 5-10 years of experience, and 12.9% had more than 20 years of experience. Of the respondents, 29% were between ages 20-30, 38.7% between ages 31-40, 22.6% between ages 41-50, 3.2% between 51-60 and 3.2% > age 61. **Table 1** includes summary of hospital provider attitudes about the RADS.

Overall, participants were moderately favorable (**Table 1**) to the RADS and thought the tool improved their ability to make good medical decisions. However, only a third of participants were satisfied with the RADS and thought the tool improves their ability to make good decisions and was valuable. Despite the fact that participants recognized that the tool provided them with all information they need, the tool was accurate, that they received support and training necessary to use the tool and they had previous experience with computers.

Table 1: Summary of Hospital Providers' Attitudes about the RADS

QUESTION	Agree/Strgly Agree (%)	Respondents
1. My attitude toward using the Asthma DOADI is favorable.	48.39%	31
2. Using the Asthma DOADI improves my ability to make good decisions.	48.39%	31
3. I am satisfied with the Asthma DOADI.	32.26%	31
4. The Asthma DOADI is easy to use.	29.03%	31
5. The Asthma DOADI provides me with all the information I need.	64.52%	31
6. The information provided by the Asthma DOADI is clearly presented.	25.81%	31
7. The information provided by the Asthma DOADI is accurate.	77.42%	31
8. The information from the Asthma DOADI is always up to date.	45.16%	31
9. The Asthma DOADI makes information easy to access.	41.94%	31
10. The Asthma DOADI provides information in a timely fashion.	41.94%	31
11. I have the resources, support and training necessary to use the Asthma DOADI.	83.87%	31
12. In my group, best practice information is frequently discussed.	87.10%	31
13. My group is innovative.	80.65%	31
14. My group's leaders are strongly committed to using the Asthma DOADI to share best practice information.	67.74%	31
15. My colleagues think the Asthma DOADI is a valuable tool.	38.71%	31
16. I feel comfortable working with computers.	100.00%	31
17. I like to experiment with new health information technologies.	70.97%	31
18. I have fun when using health information technologies.	70.97%	31
19. I frequently use computers to find health related information.	100.00%	31

RESULTS/OBJECTIVE 2b: Note: As described earlier, PCPs decided during facilitated discussions that the AHMS be managed at clinics by a clinic care coordinator (CCC) and not by them directly to reduce workflow interruption. Therefore, PCPs did not access the AHMS or RADS directly. All interactions with these tools were handled by CCCs. Therefore, we were unable to survey PCPs about their perceptions of AHMS or RADS.

RESULTS/OBJECTIVE 2c: Of 180 patients enrolled in the study, 65 completed the survey (Response rate 36.1%). Average compliance rate (with weekly use of the e-AT) of respondents vs. non-respondents were 56% vs. 23%, showing that respondents were more engaged with the e-AT than non-respondents. Overall, most respondents found the e-AT easy to use and had a general positive view of the tool (**Table 2**). Overall, 75.38% of participants believed their child's asthma improved since using the e-AT. 55.38% strongly agreed/agreed vs. 21.5% Disagreed/Strongly Disagreed (21.54%) that the e-AT reduced number of days of school missed due to asthma. 38.46% strongly agreed/agreed vs. 13.85% disagreed/strongly disagreed that the tool helped in reducing numbers of days of work missed due to asthma. Despite the fact that the study ended and that incentive was no more provided, 76.9% of participants expressed willingness to continue with e-AT.

Table 2: Attitudes, Acceptability and Use of the AHMS (e-AT) by Patients

Question	Agree/Strgly Agree (%)	Yes (%)
I am satisfied with how easy it was to use the e-AT	93.9%	N/A
It was difficult learning how to use the e-AT	4.6%	N/A
I felt comfortable using the e-AT	95.4%	N/A
The instructions provided with the e-AT were clear	93.9%	N/A
The e-AT did everything I wanted it to be able to do	92.3%	N/A
The extra time it took to use the e-AT was worth what I got out of it	83.1%	N/A
The e-AT made it easier to monitor more effectively asthma symptoms and seek help from a physician when needed	80.0%	N/A

The e-AT has increased my awareness how to identify and prevent asthma attacks	78.5%	N/A
The e-AT has improved how I manage asthma	78.46%	N/A
I think my child's asthma (or my asthma if patient) has improved since using the e-AT	75.38%	N/A
The e-AT was helpful in reducing the number of days of school missed due to asthma	55.38%	N/A
The e-AT was helpful in reducing the number of days of work missed due to asthma	38.46%	N/A
Do you feel the e-AT is user-friendly?		100%
Do you feel the e-AT is something you would continue to use in the future?		76.9%

Responses about the questions "Do you feel the e-AT is something you would continue to use in the future? Why and why not?" Of the 50 participants who wanted to continue to use the e-AT in the future, 41 (82%) stated that it was useful for tracking asthma symptoms/or tracking asthma triggers like the tool (**Table 6 in Appendix**). Of the 15 participants who responded "No" to future use of the e-AT, the reasons provided were as follows: lack of time (4 participants), no needed (8 participants), personal preference (1 participant) and no a good tool (1 participant). 1 participant did not provide any answer. Participants who said they did not need the e-AT either have a child with a mild asthma or a child with a well-controlled asthma or got a second opinion concluding that their children didn't have asthma.

RESULTS/OBJECTIVE 3a:
Note: Following development of the RADS system, hospital leadership decided to mandate use of the RADS to support the discharge process for all patients admitted at PCH. For the RADS system to be used by all hospital providers as recommended by hospital leadership, we added functions that force them to navigate through all features before they can create a discharge summary and discharge a patient. Therefore, hospital providers did not have a choice to use or not use the RADS system and we were not able to assess factors associated with use of the RADS system after categorizing providers to frequent vs. non frequent users as previously planned. To complete Aim 3.a., we used hospital provider's perceptions of the RADS system which was assessed after adding open ended questions to the survey described in Aim 2.

Overall, 24 participants responded to the 4 open-ended questions. Specifically, only 30% respondents thought that the Asthma DOADI allowed creation of asthma action plan and improved patient care and was useful (13%). **Overall,** 20 participants responded to the following question: **What do you feel were important factors that make using the Asthma DOADI easy? Table 3** is the list of common factors highlighted by respondents. The majority of respondent thought dropdown menus and radio buttons, auto populated date and easy format of the tool were important factors that made use of the asthma DOADI easy.

Table 3: What do you feel were important factors that make using the Asthma DOADI easy?

Dropdown menus/radio buttons	6
Autopopulate Data	5
Easy format	5
Guide treatment	2
Auto generation of AAP	1
Not useful/cumbersome	1
Forced data entry	1
Previous experience	1
Consistency	1

23 participants responded to the following question: **What do you feel were important factors that make using the Asthma DOADI difficult?** Almost all (83%) participants find difficulties data entry as an important factor that make the use of the asthma DOADI difficult. 20 participants responded to the following question: **What would you change in the current version of the Asthma DOADI?** Almost all (80%) participants thought that the format of Asthma action plan generated by the asthma DOADI needs to be improved.

RESULTS/OBJECTIVE 3b: Note: During facilitated discussions with PCPs, decided by consensus that the AHMS be managed at clinics by a nurse clinic care coordinator (CCC) and not by them directly to reduce

workflow interruption. Therefore, per this new protocol, PCPs did not access the AHMS directly. All interaction with the AHMS was handled by CCCs, including reviewing results, receiving alerts, printing graphs for the PCP (before office visits) and coordinating patient follow-up visit with the PCP. For these reasons, we were unable to survey PCPs about their interactions with the new tools and did not complete this aim.

RESULTS/OBJECTIVE 3c: Of the 224 patients that were enrolled in the study, 61% were male. The study population had a median age of 5 (IRQ: 3-9) years. Overall 35% were successful participants (those who completed at least 60% of targeted weekly ACT assessments during the 6-month follow-up period). In univariate analysis, older patient age and being Hispanic were associated with less parent participation, while using quick relievers > 3x/day, high number of unscheduled visits and higher income were associated with successful participation. In multivariate analysis, age (0.86; 0.78-0.96) and Hispanic (0.42; 0.26-0.69) were associated with less participation, while being white (1.99; 1.19-3.35) and using quick relievers > 3x/day (1.29; 1.04-1.61) were associated with successful participation.

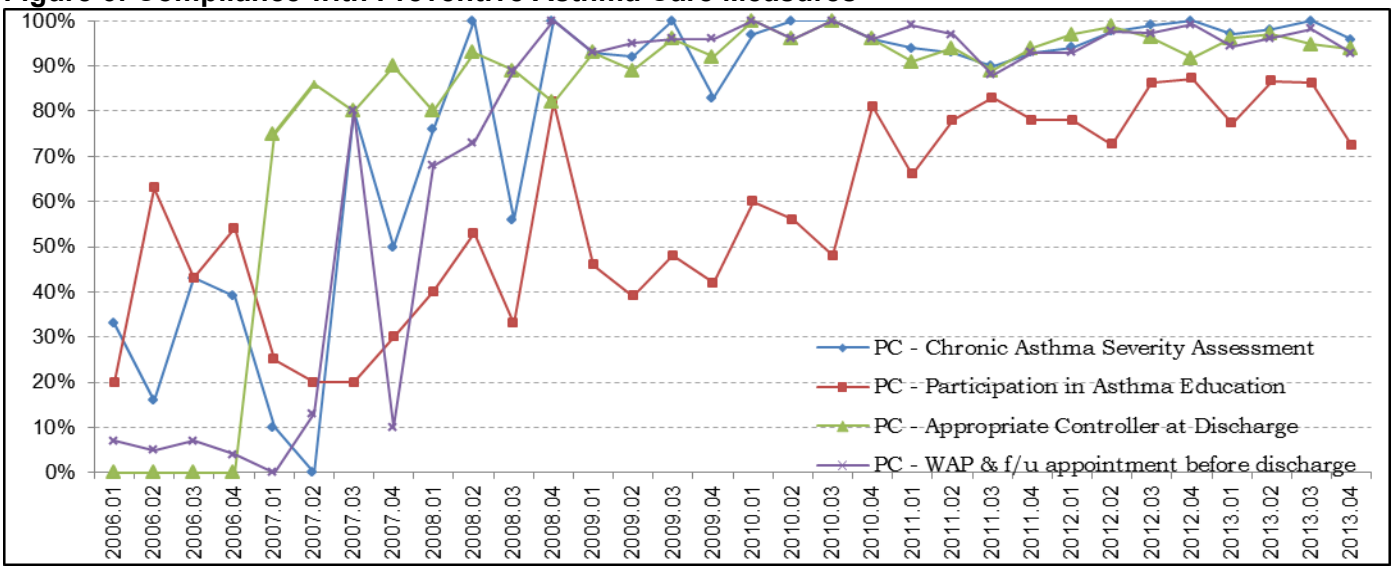
RESULTS/OBJECTIVE 4a. Overall, there were 3510 children with asthma discharged from PCH during the study period: 46.7% (1640/3510) during pre-implementation, and 53.3% (1870/3510) during the post-implementation periods, respectively. **Table 4** compares demographic characteristics between pre- and post-implementation populations. We noted significant differences in age, gender, race/ethnicity, insurance, and severity of illness (more severe post-implementation).

Table 4: Patient Demographic Characteristics

Primary Children's Hospital (PCH)				
Characteristics	**Categories**	**Pre-Implementation** (Jan 2003 - Mar 2009) n= 1640 (46.7%)	**Post-Implementation** (Apr 2009 - Dec 2013) n= 1870 (53.3%)	**p-value**
Admit Age (years): Avg, (sd)	n/a	5.5 (3.5)	5.8 (3.5)	**<0.001**
Gender, n (%)				
	Male Female	914 (55.7%) 726 (44.3%)	1119 (59.8%) 751 (40.2%)	**0.014**
Race/Ethnicity, n (%)				
	White Hispanic Other Unknown	1178 (71.8%) 282. (17.2) 140 (8.5%) 40 (2.4%)	1250 (66.8%) 187 (10.0%) 397 (21.2%) 36 (1.9% %)	**< 0.001**
Insurance, n (%)				
	Medicaid Private Self-pay	449 (27.4%) 1094 (66.7%) 97 (5.9%)	635 (33.9%) 1140 (60.9%) 95 (5.1%)	**< 0.001**
Severity of illness, n (%)				
	1 2 3 4	1128 (68.8%) 403 (24.6%) 94 (5.7%) 15 (0.9%)	1204 (64.4%) 466 (24.9%) 172 (9.2%) 28 (1.5%)	**0.001**

Overall, baseline quality measure compliance was low pre-implementation (**Figure 6**). Post-implementation at PCH, compliance with quality measures significantly increased (p>0.01) for all measures and was sustained high over 5 years. Except for use of quick relievers and systemic corticosteroids, increased compliance with individual quality measures at PCH showing progressive improvement with individual measures overall.

Figure 6: Compliance with Preventive Asthma Care Measures



RESULTS/OBJECTIVE 4b: As stated earlier, PCPs opted out from using the AHMS (e-AT) directly and recommended all interactions with the tool be done by the clinic care coordinator to reduce workflow interruption. Therefore, per this new protocol, PCP did not access the AHMS directly. All interaction with the AHMS was handled by clinic care coordinators, including reviewing results, receiving alerts, printing graphs for the PCP (before office visits) and coordinating patient follow-up visit with the PCP. For these reasons, we were unable to survey PCPs about their interactions with the new tools and did not complete this aim.

RESULTS/OBJECTIVE 4c: Overall, there were about 3921 individual assessments of asthma control following hospital discharge. Of these, 24.3% (953) of assessments were during the time asthma control score was < 20 (~ not well or poorly controlled asthma) and 78.7% (2968) during well controlled period. Compliance with preventive medications among patients with not well or poorly controlled asthma were higher at 84.1%, Only about 15.9% of assessments with not well or poor asthma control did not receive any preventive medications. Among the 2968 assessments where patients were well-control, 76.5% were receiving preventive medications.

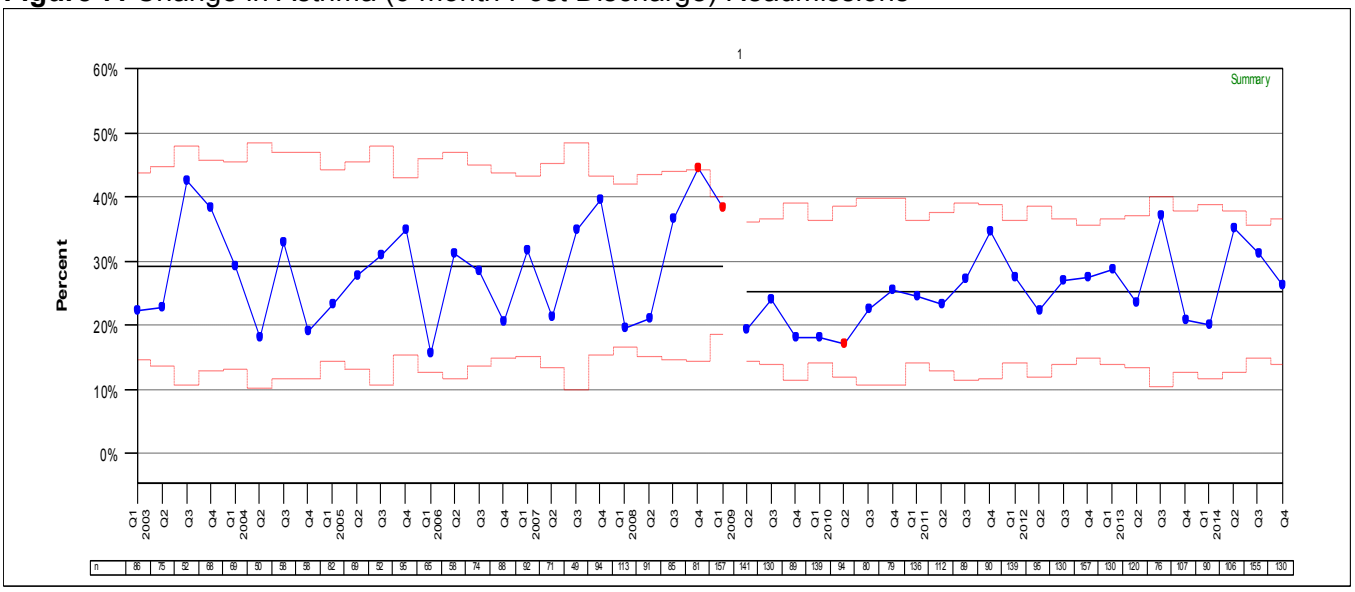
RESULTS/OBJECTIVE 4d: **Table 5** summarizes results of regression analyses comparing hospitalization outcomes (readmission, LOS, cost and RRU) between the pre- and post-implementation periods, and provides odds ratios (OR) or beta coefficient (β) with 95% confidence intervals. We found a significant reduction (**Figure 7)** in asthma readmission (OR: 0.81; p: 0.026) and LOS (β: -0.08; p< 0.001), and a non-significant reduction in costs (β: -0.04; p: 0.094). Overall, improved asthma outcomes occurred without any increase in hospital resource use and no change in PICU transfer or death. **Figures 8** show SPC charts depicting changes in LOS.

Table 5: Regression Analysis of Outcomes: Primary Children's Hospital

Variable	**Pre-Implementation**	**Post-Implementation**	Odd Ratio/β	95% CI	p-value
	Section A: Primary Children's Hospital				
6-month Readmission rate (%, SD)	16.4 (37.0)	13.6 (34.3)	0.81**	0.67, 0.97	**0.026**
LOS, hours (median, IQR)	49 (35-77)	45 (33-69)	-0.08	-0.13, -0.04	**< 0.001**
Hospitalization Costs, adjusted for 2013 dollars (median, IQR)	1816.8 (1300.5-2614.2)	1703.6 (1144.9-2894.6)	-0.04	-0.08, 0.01	0.094
RRU*** (median, IQR)	22.6 (16.4-33.6)	22.6 (15.5-39.3)	0.03	-0.02, 0.07	0.218

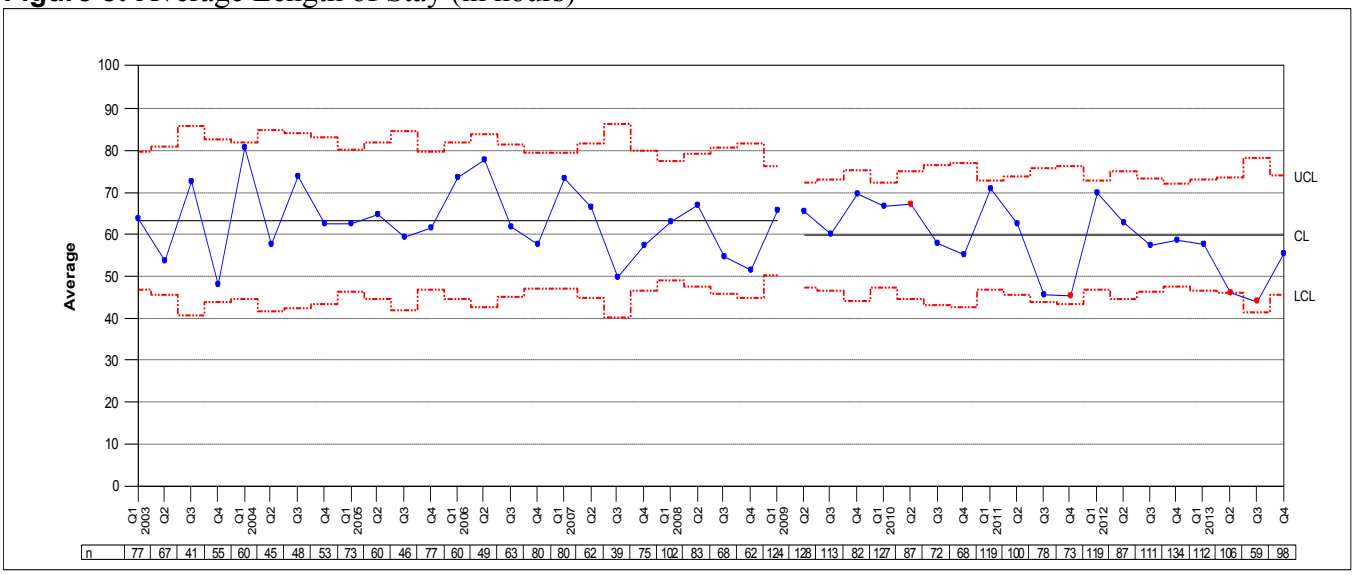
Analysis was controlled for age, sex, race, insurance, severity and month of year *Direct or variable costs related to inpatient asthma care ** Odd Ratio *** RRU: Relative Resource Unit (~Hospital Resource Use)

Figure 7: Change in Asthma (6 month Post Discharge) Readmissions



Note: This figure is showing a significant and sustained reduction in 6-month asthma readmission rates

Figure 8: Average Length of Stay (in hours)



Slight but significant reduction in LOS following EB-CPM implementation

CONCLUSION: Using user-centered design approach, we successfully developed and implemented both the RADS, also called asthma-Discharge Orders and Discharge Instructions" (asthma-DOADI), and the AHMS, called the electronic-AsthmaTracker (e-AT) or the electronic-Asthma Symptoms Tracking and Exacerbation Response system (e-ASTER). However, despite the fact that the RADS improved hospital provider's ability to make good medical decisions only about half of hospital providers were favorable about it due to difficulty of data entry. An improvement in format of RADS user interface was suggested to enhance use. Contrarily, the AHMS was highly valued by patients/parents and most were satisfied with it and believed it improved their child's asthma. We also found that older child's age and being Hispanics were associated with less use of the AHMS system by patients/parents, suggesting that they may need additional support to achieve successful participation in their child asthma self-management. However, being white and using quick relievers >3x/day were associated with effective use of the RADS. Post-implementation of HIT applications, average compliance with provider use of preventive quality measures at PCH increased and remained high over 5 years. Compliance with preventive medications for patients whose asthma was not well controlled was high. Overall,

our project led to a significant reduction in asthma readmission and LOS without any increase in hospital resource use and no change in PICU transfer or death.

SIGNIFICANCE: Children who are hospitalized for asthma are at increased risk for subsequent hospital/ED admissions. Through the RADS system, our project established an effective post-hospital care transition for children with asthma following hospital discharge, and enhanced their quality of ambulatory care. The RADS also enabled hospital providers to comply with evidence-based asthma preventive measures to be initiated at hospital discharge in order to reduce the risk of asthma readmissions. Lastly, through the AHMS, our project established an ongoing asthma home monitoring system to monitor patients and identify signs of asthma control deteriorations so that action can be taken early to avoid an asthma attack. Use of such proactive model can lead to improvements in the overall quality of care for children with asthma with possible reductions in hospital resources use and costs, resulting in indirect delayed benefits to patients with asthma.

IMPLICATIONS: Overall, our study provides evidence of effective use of HIT tools to post-hospital care transitions and ambulatory care continuity in order to improve outcomes. Results of our study are useful to hospitals and ambulatory care settings and provide evidence a proactive care model for enhancing management of patients with chronic diseases in general. Additionally, through the use of IT tools, this study will benefit policy makers and payers working to reduce hospital/ED uses and costs associated not only with asthma but also with care of other chronic diseases.

LIMITATIONS: Our study was limited in the assessment of primary care providers (PCPs). As stated in the text, before AHMS implementation, we conducted a facilitated discussion session with representatives of primary PCPs. During this meeting decided by consensus that interaction with the AHMS be managed at clinics by nurse clinic care coordinators not by them directly to reduce workflow interruption. Thus, we could not categorize primary care providers to frequent vs. non-frequent users to determine factors associated with AHMS use, and did not complete Aim 3.b. and Aim 4.b. as these require direct interaction with the AHMS.

LIST OF PUBLICATIONS AND PRODUCTS (Bibliography of Published Works and Electronic Resources from Study—Use AHRQ Citation Style for Reference Lists)
We published 4 manuscripts related completely or in part to this proposed project, including:

1. Nkoy F, Fassl B, Wolfe D, et al.Sustaining compliance with pediatric asthma inpatient quality measures. AMIA Annu Symp Proc. 2010 Nov 13;2010:547-51. PMID: 21347038

2. Fassl B, Nkoy F, Stone B, et al. The Joint Commission Children's Asthma Care quality measures and asthma readmissions. Pediatrics. 2012 Sep;130(3):482-91. PMID: 22908110

3. Nkoy F, Stone B, Fassl B, et al. Development of a novel tool for engaging children and parents in asthma self-management.AMIA Annu Symp Proc. 2012;2012:663-72. PMID: 23304339

4. Nkoy F, Fassl B, Stone B, et al. Improving Pediatric Asthma Care and Outcomes Across Multiple Hospitals. Pediatrics. 2015 Dec;136(6):e1602-10. doi: 10.1542/peds.2015-0285. PMID: 26527553

This is project also led to the development of an innovative tool for use by parents for ongoing self-monitoring and self-management of their child's asthma control status, the **AHMS, currently called the electronic-Asthma Tracker.**

AHRQ Final Progress Report References and Appendix

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Appendix:

Patient Education Materials (Flip chart)/Implementation Manual

Taking Charge of Your Asthma

Live your life to the fullest!

Take control of your asthma by monitoring your symptoms, managing your triggers and improving communication with your asthma provider

1

About Asthma and Asthma Tracker

The ***"About Asthma"*** tab on the login page describes asthma.

The ***"What is Asthma Tracker"*** tab gives you a brief introduction about the eAsthma Tracker for those who do not have an account yet. It also lists the contact information for the eAsthma Tracker Team.

2

Did You Know?

- Within 1 year, up to 40% of children hospitalized for asthma need to be admitted to the hospital again.
- It is very difficult to tell how active your asthma is unless you have an obvious asthma attack (flare up).
- With good asthma control, you can feel much better than you ever thought you would!
- We can help you take CONTROL OF YOUR ASTHMA!

Here Is How

3

How It Works

- Log on to the eAsthma Tracker website once a week with your username and password.
- Complete the **Asthma Control Test**—it takes less than 5 minutes.
- Answer some additional questions about your current asthma treatment.
- See your score and follow the recommendations.

4

Instructions

The instructions on how to use the eAsthma Tracker will always be available for you on the ***"Instructions"*** page. You can refer back to these at anytime.

5

Asthma Test About Symptoms

You will complete the Asthma Control Test once every week.

After answering the questions, click "Next".

6

Questions About Treatment

Once you complete the first page, your new score will show here.

These questions are required to submit your Asthma Test.

If you have any comments about the week's asthma control, you can note them in the comments box—this is optional.

After answering the questions, click ***"Submit ACT"*** to see your graph.

Controller Medications

When you mouse over the underlined words (for instance, "controller medications" in this case), a box will appear with more information.

Reviewing Your Score

Three Months view is the default, but you can change the Timeline to view your graph for 1 Month, 3 Months, 6 Months, or 12 Months.

You can view your previous answers to any of your Asthma Tests by clicking the dot on the graph.

It will also show your answers to the second page of questions with your comments (if you included any).

Asthma Control Test Score

The asterisk (*) indicates that there is a comment for the score.

Reviewing Your Previous Answers

This is the page that shows your previous answers when you click on the dot on your graph.

Recommendations & Taking Action

Asthma Control Test Score

Your weekly Asthma Control Test scores higher than 19 are in the green zone.

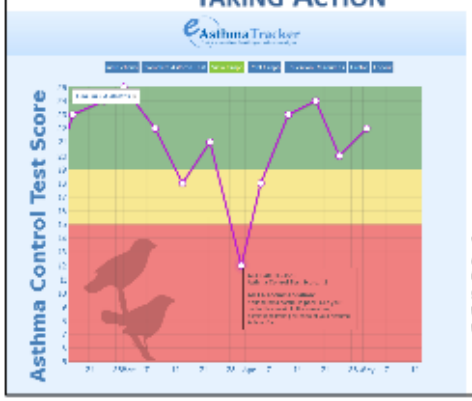
Follow the recommendations of your asthma care according to your score.

Taking Action

Asthma Control Test Score

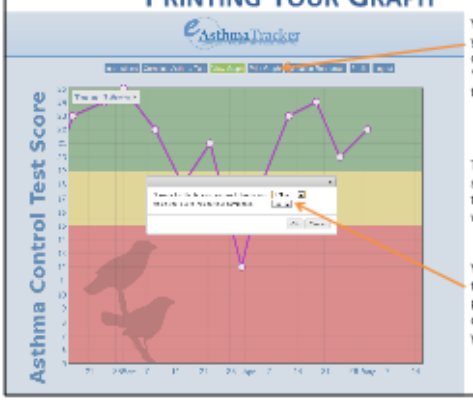
Your weekly Asthma Control Test scores from 15-18 are in the yellow zone.

Taking Action



Your weekly Asthma Control Test scores lower than 15 are in the red zone.

Printing Your Graph

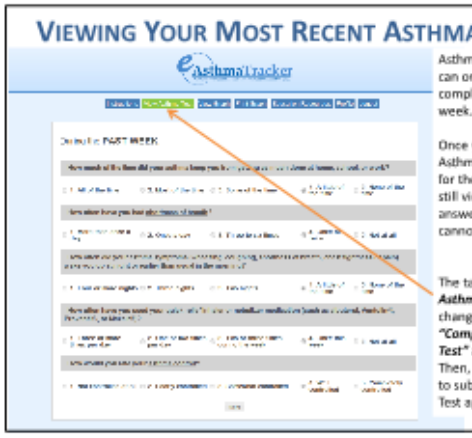


You can print your graph by clicking the "Print Graph" tab.

Then you can select the timeline you want to print.

You also have the option of printing your comments with your graph.

Viewing Your Most Recent Asthma Test

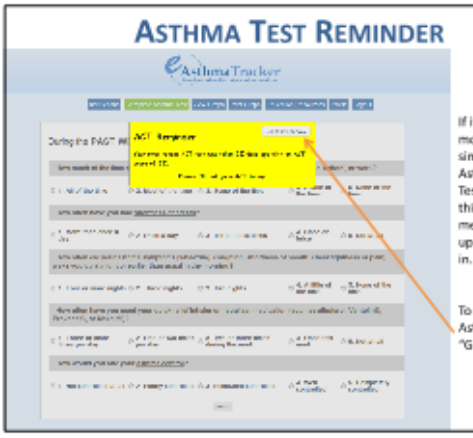


Asthma Control Test can only be completed once a week.

Once you submit your Asthma Control Test for the week, you can still view your answers, but you cannot change them.

The tab ***"View Asthma Test"*** will change back to ***"Complete Asthma Test"*** after a week. Then, you will be able to submit the Asthma Test again.

Asthma Test Reminder



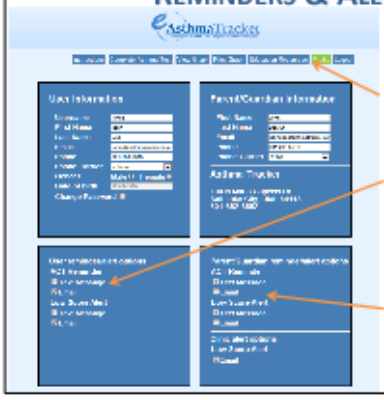
If it has been more than 7 days since your last Asthma Control Test submission, this reminder message will pop up when you log in.

To complete your Asthma Test, click "Go to my survey".

Reminders & Alerts

- You have the option of receiving reminders and alerts about your eAsthma Tracker participation via text message and/or email.
- Definitions
  - Reminder: a message reminding you to complete your Asthma Control Test if you have not completed it for more than 7 days
  - Alert: a message alerting you of a low score

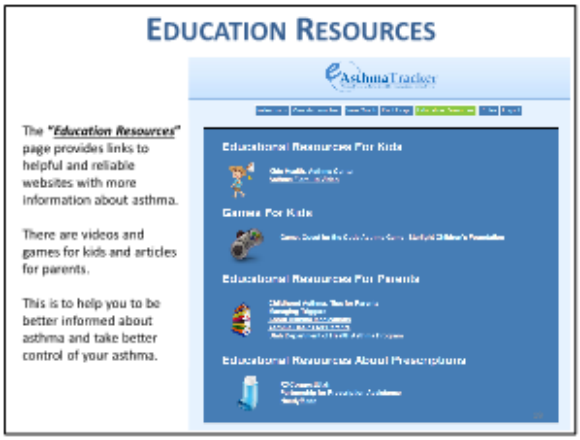
Reminders & Alerts



You can change your preferences to receive these messages on your profile.

Check the box if you want to receive a message via text and/or email.

Note: For children, a parent or guardian is required to receive reminders and alerts by email and/or text.



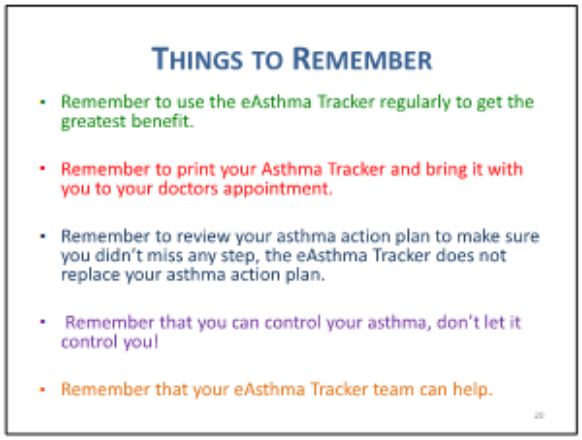


Table 6: Questions and Respondent Responses

Do you feel the e-AT is something you would continue to use?	Why or Why Not?	Theme
NO	Sometimes I am busy and forget	Lack of time
NO	I hope my children get better.	No response
NO	I don't think it is necessary any longer. She is under the care of an asthma specialist at this time.	Not needed
NO	It's a preference I rather not continue tracking every week	Personal Preference
NO	Don't really have time and hate the reminder texts they are annoying	Lack of time
NO	The only time my child has lung problems is when he gets a cold virus. He doesn't technically have asthma. His doctor has completely taken him off all asthma medicine during the summer months.	Not needed
NO	My asthma is very mild and happens infrequently.	Not needed
NO	I never found time to use this tool	Lack of time
NO	Honestly, I use an app on my phone that tracks my son's asthma. It has more features and it is more convenient.	Not a good tool
NO	I haven't yet seen how it can help us reduce symptoms of asthma or identify oncoming exacerbations. This may be alleviated through using it over time and seeing patterns after more months using it.	Not needed
NO	Our regimen is easy and the e-asthma tracker is just one more thing to do that we would fair fine without.	Not needed
NO	My child's asthma is non chronic and almost unpredictable with an undiagnosed cause. Only one possible episode has occurred since the onset.	Not needed
NO	Asthma is well controlled 99.9% of the time. I can see how this would be useful for	Not needed

	someone that has more issues with their asthma.	
NO	Because my child had a second opinion and does not have asthma.	Not needed
NO	One - I didn't remember to do this on time each week. Was really bad at it. Two - I felt having my baby girl in the hospital was the # one thing that made me realize how serious her asthma was and what I actually need to look for and how to manage it.	Lack of time
YES	It helps me keep track of my son and his progress. When his asthma acts up and when his attacks are less.	Useful for tracking symptoms
YES	yes	No response
YES	That way I can continue to track on a full time basis rather than just 6 months.	Useful for tracking symptoms
YES	It was a helpful tool to keep things in check.	Useful for tracking symptoms
YES	It serves as a reminder to be diligent with our son. It also helps us to know where he is on how controlled his asthma is.	Useful for tracking symptoms
YES	I liked seeing the progress all around and it kept us all in check on watching our daughter, Leah and how her asthma was doing. User friendly for sure. I liked I could also access it on my phone.	Useful for tracking symptoms
YES	It helps me with my daughter's asthma since this is kinda new to the both of us.	Useful for tracking symptoms
YES	it is easy	Easy to use
YES	Because it is very helpful	No response
YES	Ease of keeping track of when my daughter's asthma flares	Easy to use
YES	It's just easy to use	Easy to use
YES	used the Asthma Tracker for my daughter and I enjoyed being able to see at a glance how her asthma has been and was able to print and take it in to a doctor for help trying to keep her a little more consistent. I also learned how to watch for signs of he	Useful for tracking symptoms
YES	I really loved how it helped me to figure out what triggers his asthma.	Useful for Identifying Triggers
YES	I love the alerts it sends via text. I login on my phone, and we're good to go. I like viewing the graph to determine which months are hardest on Brock's asthma. We will definitely continue to use it! Thanks!!	Useful for tracking symptoms
YES	I would continue to use it to keep track my son progress or see how his condition is doing.	Useful for tracking symptoms
YES	I like the clear location of storing data, and charting historical performance. It was a great tool at my son's last doctor	Useful for tracking symptoms

	appointment and allowed my doctor to make some changes that really helped my son. We have not been back in the hospital since	
YES	I love that it helps keep track of everything & it is a great tool to use with my sons doctors. It helps keep everything recorded so I don't forget anything.	Useful for tracking symptoms
YES	nice to look back and see specific dates	Useful for tracking symptoms
YES	I feel that I might use it in the future, because it charts my asthmas down moments in the year	Useful for tracking symptoms
YES	It helps me keep track of my breathing.\	No response
YES	It is simple to use and track progress	Easy to use, Useful for tracking symptoms
YES	I love that I can look back and see what months are the worst months for my child's asthma so that we can keep a closer eye on it in the coming year. I will continue to use this tracker as it is very useful. Thank you for developing it.	Useful for tracking symptoms
YES	It helps me keep track of my child's asthma for use when we do go to the doctor for visits.	Useful for tracking symptoms
YES	I need to use it more regularly, however I have not had any issues so it's been easy to set aside and not worry about it.	Useful for tracking symptoms
YES	I just like it.	Like it
YES	It will help keep track of things better	Useful for tracking symptoms
YES	It is a great way to track history because it is very user friendly and I especially liked the simple graph of how she was doing.	Useful for tracking symptoms
YES	I appreciate being able to look back and see how my child has done with his asthma. And if needed I can use as a medical reference.	Useful for tracking symptoms
YES	It is a great way to keep track of flare ups	Useful for tracking symptoms
YES	It was easy.	Easy to use
YES	It's easy enough to access and I can access the information quickly if I need to know what the history has been like.	Easy to use, Useful for tracking symptoms
YES	It provides a nice graph that helps keep track of asthma. It is nice to look back and visualize to see if asthma is truly under control & what the triggers are.	Useful for tracking symptoms, Useful for identifying triggers
YES	More like, maybe. We haven't used it much because my child's asthma hasn't been a problem. If we were dealing with it on a more regular basis (even monthly), I think the Asthma Tracker would be more helpful.	Useful for tracking symptoms
YES	I liked being able to weekly think about what	Useful for tracking

	we did for that week.	symptoms
YES	My son's asthma is very well managed right now and the tracker seems redundant.	No response
YES	I found that entering the information weekly helped me to remember to have my son take his medicine daily.	Helps with medication compliance
YES	Yes, the e-Asthma Tracker is something I could continue to use in the future. In fact, I really don't know what I ever did without it. It forces me to document my son's asthma. I love that when the doctor asks me about my son's asthma history I have con	Useful for tracking symptoms
YES	It has been great to be able to look ahead based on my son's past performance and predict when he might be getting sick and watch more carefully and be prepared with time & meds.	Useful for tracking symptoms
YES	It is nice to see how often and why he was having asthma problems. Sometimes I just forgot to do it	Useful for tracking symptoms
YES	I like it	Like it
YES	Helps manage my sons asthma so we can keep it under control	Useful for tracking symptoms
YES	Because when we fill it out if he ends up in the \good\" category--then we increase his controller meds and then we don't have the same problems that led to hospitalization earlier this year. I want to know if we can keep using it after we are done with the study	Useful for tracking symptoms
YES	It helps see what triggers asthma and how many down falls you have in a certain amount of time	Useful for tracking symptoms, Useful for identifying triggers
YES	Great tracking tool	Useful for tracking symptoms
YES	The fact that my daughter was hospitalized for her asthma is what caused me to manage her asthma much better, but this did help as a reminder why.	Useful for tracking symptoms
YES	Because I really liked to keep track of my daughter asthma. I was easy to talk with her doctor and I learned a lot.	Useful for tracking symptoms
YES	It's very easy to do the survey and also u can look on the chart and see how your asthma been doing.	Easy to use, Useful for tracking symptoms
YES	I like it	Like it
YES	Makes it easier to track his asthma	Useful for tracking symptoms
YES	In fact I would like to sign up another one of my child to help me track her asthma as well	Useful for tracking symptoms