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Use of Information Technology to Improve Asthma Care in the Pediatric Population

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Introduction

In 1998, the Institute of Medicine (IOM) Committee on the Quality of Health Care in America was asked to identify strategies for improving the quality of health care in the United States. This Committee identified the role of information technology (IT) as critical in creating a health care system capable of providing care that is “safe, effective, patient centered, timely, efficient, and equitable,” (Ortiz & Clancy, 2003). This paper examines what evidence exists in the pediatric population to improve asthma care and reduce medical errors through the use of computer-based CDS system, Web/Internet-based education, and asthma action plan tool with the Electronic Health Records (EHR) system. The literature has identified that information technology is used to: 1) improve clinician compliance with National Asthma Education and Prevention Program (NAEPP) guideline and aid clinicians in making diagnostic and therapeutic decision, 2) reduce medical errors and improve patient safety in pediatric patient care, 3) aid two way communication between patients and families and clinicians and educate patients and their families to improve their knowledge and self-management of chronic asthma, 4) measure the effectiveness and efficiency on quality of pediatric asthma care by using a comprehensive EHR database. This literature review will provide analysis and recommendations for using information technology in pediatric asthma management.

Statement of Problem

Asthma is a common chronic disorder of the airway that is complex and characterized by variable and recurring symptoms including airflow obstruction, bronchial hyper-responsiveness, and underlying inflammation (National Heart, Lung, and Blood Institute, 2013). Asthma is the most common chronic diseases of childhood, and it affecting more than 7 million children (Centers for Disease Control and Prevention, 2010). Poorly managed asthma can
cause dangerous symptoms, leading to not only missed days from school, but also expensive emergency department visits, hospitalization and even death. According to Nation Health Institute Survey (NHIS), the pediatric populations with asthma have more than 497,000 hospitalizations annually, and 4,000 die from asthma exacerbations each year. An Asthma Expert Panel Report (EPR)-1 from the National Heart, Lung, and Blood Institute (NHLBI) first published Guidelines for the Diagnosis and Management of asthma in 1993, with revisions (EPR-2) in 1997, and (EPR-3) in 2007 (NHLBI, 2007). The purpose of the guideline is to introduce the approaches for healthcare providers to control and monitor asthma. EPR-3 includes all age groups with an expanded section on childhood asthma new guidelines on medications, new recommendations on patient education in settings beyond the physician’s office and new advice for controlling environmental factors that can cause asthma symptoms. Despite the usefulness of the asthma guideline, many pediatricians do not follow the recommendation which leads to incorrect prescription and inappropriate patient management. One survey study indicated that 75% of physicians understood the recommendation related to steroid use; however, they prescribed inhaled corticosteroids to as few as 10% of patients and oral corticosteroids to as many as 28% (Bel, 2012). The numbers of Clinicians not following the guidelines became serious due to lack of resources for treatment and management. The challenge remains to offer resources to improve healthcare providers’ adherence to the existing guidelines to manage pediatric asthma care and improve quality of life.

Theoretical Framework

Information technology has the potential to greatly improve the quality of health care, reduce human medical errors, and improve patient safety (Jao & Hier, 2010). The theoretical framework for this paper combined information technology and healthcare quality and patient
safety models as developed by Graves and Corcoran (1989), Nelson (1989), and Reason (2000). This framework is helpful for an understanding how information technology that improves quality of asthma care and patient safety in pediatric population.

Initial development of a model was undertaken by Blum (1986). He introduced the concepts of data, information, and knowledge as a framework for understanding clinical information systems and their impact on health care. He began exploration of the complex relationships between these three concepts. Graves and Corcoran (1989) expanded Blum’s three concepts as follows: 1) data are discrete entities described objectively without interpretation; 2) information is data that are interpret, organized, or structured; and 3) knowledge is information that is synthesized so that relationships are identified and formalized. Graves and Corcoran (1989) placed the three concepts on a continuum known as data-information-knowledge continuum. Nelson (1989) further proposed the addition of wisdom to this continuum. Wisdom is the appropriated application of knowledge to the management and solution of human problem, it considers the use of values in decision making, and this is known as Nelson’s data to wisdom continuum. Guidelines have been used in variety of decision making systems to illustrate the important relationships between data, information, knowledge, and wisdom.
Reason’s model of human error management proposes that latent conditions and human factors, or active failures, interact to create opportunities for error (Reason, 2000). Reason’s model described the concepts of active failures which result from healthcare provider error, and latent conditions which are system or structural components of the healthcare working environment. In addition, Reason’s model advocates a system approach to error management versus a person approach. The person approach, which focuses on blaming individuals and
changing human behavior, “is ill suited to the medical domain… [and] is likely to thwart the development of safer healthcare institutions.” (Reason, 2000, p.768). The systems approach, however, views human error as a given in any workplace, even in the best organizations, and emphasizes creating systems and useful tools to decrease error and reduce opportunity for harmful patient outcomes.

By adapting Nelson’s data to wisdom continuum model and Reason’s human error model (figure 1) into the healthcare information system, a proactive approach can be developed to increase use of information technology to improve the quality of asthma care and reduce human errors in pediatric population.

Review of the Literature

I developed a search strategy to find any publications about the health information technology, communication and information technology, Internet/Web applications that related to pediatric asthma and use these to search MEDLINE, CINAHL, and PubMed database. The key phase clinical decision support, asthma education, asthma action plan, asthma database, information system, and pediatric population. There were hundreds of articles related to pediatric asthma care. I chose 30 articles initially that published after 1989. 17 of 30 articles were used in this review and were appropriated downloaded from the online source and printed out at library (book and journal) source. This literature review will focus on the health information technology: Clinic Decision Support (CDS) system, Web/Internet based application, and EHR asthma database that have been effectively used in pediatric asthma management.

Clinical Decision Support Systems

A Clinic Decision Support (CDS) system is a computerized system that uses case-
based reasoning to assist clinicians in assessing disease status, making a diagnosis, selecting appropriated therapy or making other clinical decision (Jao et al., 2010). According to National Action on Clinical Decision Support (NACDS), the goal of CDS systems are to provide the right information, to the right person, in the right format, through the right channel, at the right point in workflow to improve health and health care decisions and outcomes (Osheroff et al., 2006). Introducing the CDS will provide clinicians with a useful guideline through which they can apply their decisions on similar clinical cases and reduce the variation of clinicians’ practices plans that plagues the process of healthcare delivery. More than 1,600 clinical practice guidelines have been written to help form recommendations for the appropriate delivery of care in specific clinical situation. These guidelines have little impact upon actual clinical practice unless they are effectively integrated into the clinical setting (Lobach & Hammond, 1997). Computer based CDS system can be used to integrate practice guidelines into the process of health care.

Porter et al. (2013) reported on the development and evaluation of the CDS system: asthma kiosk that promotes capture of critical information necessary to drive guideline-based care for pediatric asthma. They created asthma kiosk through a series of design, and three prototypes of the asthma kiosk were tested over eight months. Structured qualitative interviews conducted one on one with parents of children with asthma during the process of developing regard to symptoms, treatment, and medication use. The final version of the asthma kiosk underwent formative evaluation at Children’s Hospital Boston. The asthma kiosk demonstrated its ability to capture patient specific data during real time care in the emergency department with a mean completion time of 11 minutes, and also the asthma kiosk successfully linked patient data to guideline recommendations (inhaled corticosteroid medications recommended as
first line therapy to treat the inflammatory component of asthma). However, identifying data critical to health improvements for asthmatic children remains undocumented during ED based care.

National Heart, Lung, and Blood Institute (NHLBI) asthma guideline stresses four essential elements of asthma management: diagnosis and monitoring using objective measure of lung function; control of inflammation and bronchospasm; trigger identification and avoidance; and patient education and collaboration in care (NHLBI, 2007). Shegog et al. (2006) examined the feasibility of the Stop Asthma Clinical System (SACS): computer-based decision support that comprises the NHLBI four elements and designed to facilitate asthma management and communication effectiveness of clinicians who treat children with asthma. This system is related to both clinical asthma management and the enhancement of patient/family self-management. The computer-based decision support comprises 142 multilayered decision rules that describe clinical and behavioral management in three domains: 1) determination of asthma severity and control, 2) pharmacotherapy including prescription of medicine for chronic maintenance, acute exacerbation, exercise pretreatment and rhinitis relief, and 3) patient self-management, including the process of intervening to facilitate the patient’s asthma medication management, environmental control and visit scheduling.

A convenience sample of seven physicians, one nurse educator, and 26 patients (4-15 years old) were recruited to take part in this pilot study. Two tailed t-test was used to compare the sample response. SACS was perceived to be significantly more useful when compared to usual care without SACS in assessing severity and control (p=.003), and in developing an asthma plan (p=.003), medication management (p=.006), and environmental control (p<.001). In an overall assessment of SACS in managing patients, the system was found to provide value
to the clinic encounter through increased thoroughness ($p=.003$), accuracy ($p=.012$), and communication ($p<.05$). The authors conclude that SACS is a feasible strategy to enhance clinical communication and behavior change strategies. However, the effect of the use SACS on patient outcome has not been established, to evaluate the clinical outcome, a randomized controlled trial of SACS in a large sample is indicated.

Redier et al. (1995) described Asthmaexpert, an expert system to help clinician to better understand the medical decision made clinical experts in managing an asthmatic patient. Asthmaexpert assesses the severity of the disease and identifies the trigger factors involved, suggests any further investigations that may be required, and offers a treatment strategy. The clinical experts provided 20 case reports with their conclusion regarding asthma management. Those 20 case reports were programmed into the Asthmaexpert which provided its own conclusions about the same subject. The clinical experts evaluated those 20 case reports conclusion given by Asthmaexpert. There was no difference in concordance of opinions on severity between the clinical experts and the Asthmaexpert (Kappa=0.72 and 0.69), the overall conclusion given by Asthmaexpert were as good as or better than those clinical experts.

Lieu et al. (1998) developed and validated prediction computer-based models to identify high risk children with asthma. The computer-based models used computerized data from data warehouse to predict asthma related hospitalization and emergency department visits. There were 210,125 children aged 0 to 14 years old at selected clinic during the identification period, and 16,520 had asthma related health services utilization including hospitalization, ED visits, and medication use, and were included in this study cohort. Proportional-hazard models were used to obtain estimates of relative risk of hospitalization associated with predictor variables. Classification trees were used to identify predictors of hospitalization and ED visit. The study
found that prediction models that use routinely available computerized utilization data can identify children at high risk for adverse asthma outcomes. The authors concluded that these models can identify asthmatic children at high risk for future hospitalization and emergency department visits and may direct attention toward some high risk patients who have not been found by clinicians.

Kuperman et al. (2007) conducted a system review on medication related CDS in Computerized Provider Order Entry System (CPOE). They divided the CDSs categories to two stages: basic and advanced. In the basic categories, they included drug-allergy checking, basic doing guidance, formulary decision support, duplicated therapy checking, and drug-drug interaction checking. Advanced categories included dosing support for renal insufficiency, guideline for medication-related laboratory testing, drug-disease contraindication checking, and drug-pregnancy checking. Through the system review, the authors concluded prescription related CDS within CPOE systems can improve the quality and safety of medication prescribing and reduce medical errors and costs. The authors indicated even though the DCSs have achieved many benefits, however, there are many issues remain for futures work. Healthcare organizations should actively adopt medication related CDS safeguards and must monitor the effectiveness of CDS.

**Web/Internet-based Education Applications**

A web/Internet-based application is an application that is accessed by patients over a network such as the internet or an intranet. It offers opportunities to enhance patient education and self-management and patient-provider communications. Effective management of pediatric asthma requires the collaboration between patient/family and their care providers. Ahmed et al. (2011) reported that a Web-based technology: My Asthma Portal (MAP) was developed to
allow patients to: 1) view their asthma medications; 2) view general asthma health information and receive new asthma education; 3) facilitate monitoring and feedback to better self-manage their asthma; 4) access their asthma action plan. MAP system provides opportunity to facilitate the communication and information exchange between the patient and care team. MAP provides patients with timely access to their health information.

Improved education and monitoring of children with asthma have been shown to be highly effective in controlling symptoms and preventing failure of outpatient therapy (Smith et al., 1997). Chan et al. (2003) developed the utilization of an Internet-based store-and-forward video home telehealth system to manage asthma in children (6-17 years). According to the patients’ severity, the clinicians determined an appropriate management plan by using the NHLBI guideline. Web-based group and office-based group were monitored by pulmonologist and case manager. Feedback was provided electronically to each patient. Disease control was assessed by examining quality of life, utilization of services, rescue therapy use, symptom control, and satisfaction with home telemonitoring and retention of asthma knowledge. Data were compared prior to implementation of the program, immediately following implementation, two and six week, and three and six months after implementation. Significance was calculated with a paired t-test which indicated there is significantly differences in outcomes between Web-based group and office-based group (p<.01). Authors conclude that the Internet-based, store-and-forward video assessment of children’s use of asthma medications and monitoring tools in their homes appeared effective and well accepted. The Internet-based monitoring tools may improve adherence to asthma medication that require careful technique.

New York City Office of School Health (OSH) introduced the Managing Asthma in School (MAS) program during the 2004-2005 school years. All information related to a
student’s asthma was entered into the Automated Student Health Record (ASHR), a Web-based application. This system was able to retrieve health records for all students, so the school nurses can view a students’ asthma profile that list asthma diagnosis, severity, home and school medications, clinic visits related to asthma, standardized rescue medication order, asthma action plan. This system allowed school nurse to identify students with asthma and avoid mismatch between severity and treatment plan and focus on care management efficiently (Barbot et al., 2006).

McPherson et al. (2006) conducted a randomized, controlled trial of an interactive educational computer package: The Asthma File. This trial was conducted at pediatric outpatient respiratory clinics, and 101 children aged 7-14 years who under the care of hospital based asthma services. Asthma knowledge, asthma locus of control, lung function, use of oral steroids, and school absence were the primary outcomes measure. T-test and Mann Whitney U tests were used at baseline to compare the characteristics of the 2 groups. ANOVA was used to investigate the effect of the asthma file educational package on change in knowledge and on locus of control. Logistic regression was used to examine the impact of intervention on outcomes. At 1-month follow up (N=90), children in the computer group had improved knowledge compared with the control group (F=12.7, df=1, 90, p=.001) and a more internal locus of control (F=7.53, df=1, 95, p=.007). There were no differences in objective lung function measures, hospitalization, or oral steroid use. At 6-month follow up (n=90), significantly fewer children in the intervention group required oral steroids (z=-2.22, p=.026) and had fewer school absences (z=2.1, p=.034) for asthma in the previous 6 months. Children in the control group were significantly more likely to have required oral steroids ($\chi^2=4.24; \text{df}=1, p=.047, \text{or}=2.956, 95\% \text{ CIs [1.014, 8.126]}$) and to have had time off school ($\chi^2=4.127, \text{df}=1,$
p=.45, OR=2.394, 95% CIs [1.021, 5.618]) than children in the intervention group. Authors concluded that the asthma file was found to be an effective and popular health education tool for promoting asthma self-management skills within pediatric care.

In last decade, the care for asthma patients has emphasized self-management. Meer et al. (2011) conducted a randomized controlled study that implemented the asthma guide self-management program which showed better clinical outcomes when compared to usual clinicians provides care with regard to asthma related quality of life, asthma control, symptoms-free days, and lung function. 200 patients participated in a 12-month multicenter, non-blinded, randomized controlled trial. The Internet-based asthma self-management program involved weekly on-line monitoring of asthma control with self-treatment advice, remote Web communications, and Web-based information. The author reported the probability that Web-based self-management was both effective and less costly than usual care was 33%. The study showed statistically significant clinical effects in favor of Internet-based self-management of asthma related to quality of life, asthma control and lung function.

**EHR Database: Asthma Action Plan Database**

EHR database is an evolving concept defined as a systematic collection of electronic health information about individual patients or population. Data are shared across different health care settings. In some cases this sharing can occur by way of network-connected enterprise-wide information systems and other information networks or exchanges. EHR database includes demographic, medical history, medication and allergies, immunization status, laboratory test results, radiology images, vital signs, personal stats like age and weight, and billing information. Asthma action plan database is a database for use with asthma management consistent with national guidelines for asthma. It is used for asthma action plan that can be
shared between provides caring for patients with asthma.

Hazlehurst et al. (2012) reviewed a data study of outpatient asthma care in two healthcare systems: Kaiser Permanente Northwest (KPNW) and the Federally Qualified Health Centers (FQHCs) associated with the Oregon Community Health Information Network (OCHIN). KPNW and OCHIN which care for 173,640 patients at 44 locations created 22 automated quality measures addressing guideline-recommended outpatient asthma care. They identified 22 measures to Asthma Care Quality (ACQ) measure set. They included EHRs of asthma patients 12 years or older during a 3-year observation window and narrowed this group to those with persistent asthma to reach the target population of interest (total 15,734 patients). The measures were performed in both system, and data was retrieved from each EHR system’s data warehouse and converted into a single analysis environment at the data coordinating center, where quality measure are computed. The Authors concluded that adaptable health information technology platform that enables measurement of complex clinical practices. Electronic Health Records (EHRs) have become prevalent as a result of make routine and comprehensive quality measurement.

The key aspect of asthma management is to establish a partnership with the patient and allow them to take provider-directed actions if their asthma getting worse. The Asthmas Action Plan (AAP) is the most important tools for manage the asthma exacerbation. There are numerous versions of AAPs, however, these versions are primarily in the form of handwritten, photocopied, or printed actions plans that are provided to the patients to help guide them. Mangold and Salzman (2005) evaluated using electronic asthma action plan database for creation of asthma action plans to assist patients in the management of their asthma. AAP database was designed in Microsoft Access 2000, and it is consistent with the national
guidelines for asthma with up to date lists of medications that can be used to treat asthma.

This database was first used at Truman Medical Center-Hospital Hill (TMC-HH) in Kansas, Missouri, and then extended to Truman Medical Center-Hospital Lakewood. The asthma action plan is stored in the database and color copy provided and reviewed with the patient. Currently, they have 400 asthma action plans and those asthma action plans can be retrieved when needed or shared with other providers. The HER database provide longitudinal data to evaluate the outcomes of patients with AAP and provides more consistent asthma care for the patients.

One promising approach to improve care in clinical practice is through information technology EHRs. EHRs can make guideline available to clinicians and provide clinical decision support at the point of care (Gill et al., 2011). Bell et al. (2010) conducted a cluster randomized trial on EHR based CDS in 12 primary care sites over one year period. A total of 19,450 children 12 to 18 years were included in the analysis over the course of the consecutive time periods of the study: pre-education, education, intervention1, and intervention 2. The asthma management tools available to all practices and available in HER are the Pediatric Asthma Control Tool (PACT) for capture symptom frequency, standardized documentation templates to facilitate severity classification, order sets to facilitate ordering controller medications and spirometry, and asthma care/action plan that can be supplied to families. The intervention practice sites have CDS alerts and reminders to guide clinicians to these tools. The results show an increased in the number of prescriptions for controller medications was 6% greater (p=.006) and 3% greater for spirometer (p=.04) in the intervention practices. Filling an up-to-date asthma plan improved 14% (p=.03) and spirometry improved 6% (p=.003). The authors conclude that use the EHR based CDS tools at the point of care improved clinicians
compliance with NAEPP guidelines. However, the authors also indicated that there is no difference in the number of asthma visits and type of the groups (intervention group and controlled group).

Having existence of patient’s clinical history can enhance providers’ decision making and ensure continuity of care. Theera-Ampornpunt et al. (2009) conducted a study to investigate the impact of prior clinical information that is available in an EHR on quality and efficiency of emergency department asthma patient care. Study sample was drawn from the Minnesota-based three designed Emergency Department (ED) in an 18-month period. The first ED visit of each identified patient during the timeframe serves as that patient’s index ED visit. They extracted from each system’s data warehouse both patient-level data and encounter-level data. An indicator was created to assess the value of the EHR clinical information. The study did find evidences that prior clinical information accessible in an HER is associated with better patient outcomes and more efficient care. The logistic regression showed that in almost all patient subgroups and study sites, ED patients with prior clinical information who were hospitalized had lower odds of mortality during the hospital compared to patients without clinical information.

**Discussion**

Incorporating guidelines and education into routine practice and facilitating asthma management along with communication is required for high quality of care. The National Asthma Education Prevention Program (NAEPP) guideline has been developed at national and international levels; however, there still are significant gaps that exist between current management and best practice in children. This can be explained by the fact that there has been a focus on developing guidelines, but little attention to the implementation of these guidelines.
The NAEPP should be adopted in healthcare settings. Health information systems and CDS systems, which provide support to users at the time they make decisions, may enable health clinicians to accelerate the adoption of guidelines and eventually close the gap between optimal and actual practice (Bates et al., 2003).

In this literature review, there were a couple of studies that had evaluated the implementation of Clinical Decision Support (CDS) systems to improve the management of asthma care; however, there were no significant impact on the patient outcomes. Having access the CDS system should improve health outcomes; it is also true that they have the potential to have an opposite effect. This could happen if program function is designed poorly, education is ineffective, information is not accurate, or systems that are integrated do not fit into the clinicians’ workflow. One of the studies showed that CDS can help clinicians make choices, reduce errors in drug prescribing by offering real-time alerts regarding the adverse reactions. However, clinicians often suffer “alert fatigue”. As a result, clinicians pay less attention to or ignore some vital alerts. Lieu et al. (1998) developed tree models to identity children at high risk for adverse asthma outcomes; but they are too complex with lower sensitivity on the test set. The clinician may choose not to use it because they prefer a simpler tree with higher sensitivity. From these finding, there are important lessons to learn about successful deployment of CDS system.

Kawamoto et al. (2005) did a literature review and identified design characteristics of successful deployment of CDS system: 1) CDS systems are more effective than manual process for decision support, 2) CDS system intervention that are presented automatically and fit into the workflow of the clinicians are more likely to be used, 3) CDS system that recommend actions for the user to take are most effective than CDS system that simply provide
assessments, 4) CDS system interventions that provide information at the time and place of decisions are likely to have an impact. With attention to the concepts above, CDS systems have great potential to improve the quality of care. Attention must be paid to the implementation process, not only for the quality of improvement to be realized, but also avoid negative effects of CDS.

Recent evidence indicates that asthma self-management education is effective in improving outcomes of chronic asthma (Centers for Disease Control and Prevention, 2010). Computer based systems have been used in health promotion and disease prevention as tools for education on asthma management and provide behavior change message according to the client’s health beliefs and demographic characteristics (Shegog et al., 2001). The literature review shows that the Web/Internet-based applications are highly effective in controlling the asthma symptoms and preventing therapeutic failure. Also Web/Internet based applications are associated with increased knowledge levels and enhances feelings of disease control. However, in a couple of studies, Web/Internet-based asthma self-management education program requested the case managers to assume the role of coordinators and acted as an interface between the different disciplines. One of the concerns was the increased demand on case manager’s time. The Web-based application design should have minimized the needed time on the case manager to facilitate access to information. Cost should be considered for the nurse case managers who are involved with long term ongoing monitoring and providing education.

Another challenge for Web/Internet-based self-management education program was to keep a daily symptom diary such as peak flow monitoring, patient clinical status, and regimen changes. The diary is time consuming and inconvenient, and it could be the result of the diary
Pediatric Asthma Care

system function. This may suggest the Web/Internet-based monitoring tool needs to be viewed with caution as patients may not be honest about completing their diary.

Children who use the Web/Internet-based applications were able to provide a more extensive array of behavioral strategies for asthma management. The strength of the Web/Internet-based applications for children was entertaining, and children were motivated to engage and receive the new information about asthma management. However, most of the researches excluded the children without a home computer, and the children’s ability to use the computer and Internet was not addressed. The potential challenge for Web/Internet-based application is the training needed for individuals who will use the system. Some children are more motivated to learning new technologies; some require more training and support. With any Web/Internet-based tools a further concern is the users’ comfort level with technology, in general for poorer, less educated people who are less likely to adapt the Web/Internet-based systems.

Research developed by Hazlehurst (2012) on automating care quality measurement with health information technology compared asthma care quality between Kaiser Permanente Northwest (KPNW) and Oregon Community Health Information Network (OCHIN). Measurement performed well in the KPNW system where the practice is more standardized. This suggested that the EHR data elements need to be standardized, so the asthma care quality analysis can be performed in diverse healthcare EHR systems. The literature review demonstrated information technology enable clinicians to adopt guidelines quickly and eventually close the gap between optimal and actual practice. The embedding of CDS and Web/Internet-based applications into the EHR offers opportunities to improve clinician adherence to the existing NAEPP guidelines, reduce medical errors as well as to improve
patient safety, improve preventive care, and be able to quickly to identify problems at point of care. One of the best ways to improve asthma care quality and efficiency is taking advantage of EHRs to achieve meaningful use.

There are several important limitations for this literature search. First, most studies only addressed the usefulness of the health information technology and did not evaluate the risks that were inherent in the use of the systems such as reliability, validity, and integrity of the software itself. For example, the computer-based prediction models developed in the study needs to be validated in settings outside the one in which they were developed.

Another limitation in the literature is that outcomes evaluation was limited. Many studies concluded effective or positive if the studies showed a statistically significant improvement (p<.05) but did not address the clinical significant. These findings could be real but could also be due to multiple testing. Readers should refer to the method section for a more detailed account of their effect assessment.

Third, the literature review of CDS system critical for improving clinical practice also demonstrates that the decision support should be part of the clinicians’ workflow and use of the health information technology to generate decision support leads to improved patient care. Future research should focus how CDS fits into the clinicians’ workflow and how the systems are used in practice and their impact on users. Also, there is a need to evaluate the process of implementation, impact on quality, user satisfaction, and other factors may affect the outcome of intervention.

The fourth limitations in the literature review is despite the benefits of using web/internet-based applications for monitoring, education, and self-management; there are some considerable drawbacks, such as the use in lower socioeconomic group, lack of internet
access, and the use for the illiteracy population. Future Web/Internet based interventions must be evidence based, and detailed evaluation work is essential.

I am unable to assess the risk of publication bias in this literature. Most systems were studies by their own developers, I suspect that publication bias is likely, and even our findings of modest effects may over or under estimating the true likelihood of benefit from health information technologies such as CDS system, Web/Internet based application, and EHR database.

Summary

This literature review contributes to the information of understanding the use of health information technology to improve pediatric asthma care through the examination of the CDS, Web/Internet-based applications, and EHR database. Structure, process, and patient-specific contributors to pediatric asthma management are identified and presented within an integrated data to wisdom continuum model and human error management model, developed for this literature review, to facilitate using health information technology to diagnose, treat, monitor, and educate the pediatric population. The theoretical framework, adopted form Nelson’s data to wisdom continuum model and Reason’s human error model into the healthcare information system facilitate the healthcare provider’s adherence the guideline and communication between healthcare providers and patients. In conclusion, the preponderance of evidence indicates that health information technologies are effective in pediatric asthma management. It improves the quality and efficiency of pediatric asthma care, improves pediatric patient safety, prevents medical errors, and alerts clinician behaviors and influences the process of care and decision making. However, healthcare organizations will face many cognitive, technical,
administrative, and financial challenges in transitioning to full adoption of health information technology.

**Recommendations**

Clearly, the health information technology has achieved many benefits but many issues remain for future work. The recommendations below are for individual and organizations involved in applying health information technology to improve quality and safety of pediatric asthma care.

1. Healthcare organizations should actively adopt health information technology related asthma management such as the CDS, Web/Internet-based application tools, and asthma action plan database.

2. Workflow integration: workflow is the key issues that must be taking into account for both system designers and providers implementing health information technologies. Engaging the clinician in the process of health information technology design and implementation is very important.

3. Application developers and knowledge developers should work together to improve CDS, Web/Internet-based education application, and EHR database functionality.

4. The pediatric asthma management information technology needs be custom developed by the institutions that will implement the system.

5. Guideline based practices should be standardized and improve the quality of care given to people with asthma resulting in improved outcomes.

6. Future detailed Web/Internet based intervention research is needed to evaluate lower socioeconomic group that lack internet access and the illiteracy population.
7. Knowledge maintenance: maintain the accuracy of the patient record. Also frequent updating is needed due to new medical knowledge, new evidenced guidelines, new drug and diagnoses that are continually being discovered.

8. For health information technologies to be effective, clinicians must be motivated to use these systems.
References


Retrieved from: http://www.amia.org
Appendix A

Melnyk's Hierarchy of Evidence

<table>
<thead>
<tr>
<th>Level</th>
<th>Description</th>
<th>Strength</th>
</tr>
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<tbody>
<tr>
<td>I</td>
<td>Evidence from a systematic review or meta-analysis of all relevant randomized controlled trials (RCTs), or evidence-based clinical practice guidelines based on systematic reviews of RCTs</td>
<td>Strongest</td>
</tr>
<tr>
<td>II</td>
<td>Evidence from at least one well-designed RCT</td>
<td></td>
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<tr>
<td>III</td>
<td>Evidence from well-designed controlled trials without randomization</td>
<td></td>
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<tr>
<td>IV</td>
<td>Evidence from well-designed case-control and cohort studies</td>
<td></td>
</tr>
<tr>
<td>V</td>
<td>Evidence from systematic reviews of descriptive and qualitative studies</td>
<td></td>
</tr>
<tr>
<td>VI</td>
<td>Evidence from a single descriptive or qualitative study</td>
<td></td>
</tr>
<tr>
<td>VII</td>
<td>Evidence from the opinion of authorities and/or reports of expert committees</td>
<td>Weakest</td>
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Appendix B

Information technology developments for pediatric asthma management

<table>
<thead>
<tr>
<th>Author</th>
<th>Design/Sample</th>
<th>Interventions</th>
<th>Outcomes</th>
<th>Level</th>
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<tr>
<td>Ahmed et al. (2011).</td>
<td>The study is a parallel multi-centered 2-arm pilot randomized controlled trial. N=67 randomly assigned to one of two conditions: 1) MAP and usual care, 2) usual care only.</td>
<td>Patients receive ongoing asthma care from a respirologist. An asthma nurse provides education and follow-up as needed. Topics such as the importance of avoiding triggers, taking all asthma medications as prescribed, and using the written action plan as needed. Follow-up phone calls between visits are provided by the asthma nurse, when appropriate.</td>
<td>MAP system allow real time visual representation of asthma control over time, and study also found when patient have greater asthma knowledge of how to use their action plan effectively and are given appropriate tools to monitor symptoms and document changes, they are better able to learn and develop skills needed to optimize asthma control.</td>
<td>II</td>
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<td>Barbot et al. (2006).</td>
<td>Descriptive case study.</td>
<td>Using pre-preprinted medication orders. Using ASHR, a Web-based applications to manage student’s asthma profile that includes asthma diagnosis, severity, home and school medications, clinic visits related to asthma, standardized rescue medication order, asthma action plan</td>
<td>This system allows school nurse to identify student with asthma and avoid mismatch between severity and treatment plan and focus on care management efficiently</td>
<td>VI</td>
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<td>Bell et al. (2010).</td>
<td>Cluster-randomized controlled trial.</td>
<td>The asthma management tools available to all</td>
<td>Using a cluster-randomized trial design, CDS in the</td>
<td>I</td>
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<td>Study</td>
<td>Population</td>
<td>Intervention</td>
<td>Outcomes</td>
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<td>Chan et al. (2003)</td>
<td>N=19,450 12-18 years old with persistent asthma identified by international classification of disease at 12 primary care sites.</td>
<td>Convenience sample of Pediatric patients ages 6-17 with persistent asthma.</td>
<td>EHR, at the point of care, improved clinician compliance with National Asthma Education Prevention Program guidelines. There was no important difference in number of asthma visits per child. practices and available in HER: the PACT data entry tool for capture symptom frequency, standardized documentation templates to facilitate severity classification, order sets to facilitate ordering controller medications and spirometry, and ACP that can be supplied to families. The intervention practice sites has CDS Alerts and reminders to guide clinicians to these tools. Utilization of an Internet-based store-and-forward video home telehealth system to manage asthma in children. Computer and internet access provided to children with persistent asthma. Children were monitored bi-weekly over internet and seen in clinic at 0, 2, 4, 6, 12, 24 weeks. Feedback was provided to each patient bi-weekly via store-and-forward technology. 50% patients received education. Inhaler technique scores and Peak flow values improved significantly. There was no change in quality of life reported by patient. ED visit and hospital admissions for asthma were avoided. A high rate of satisfaction was reported and telemonitoring was well accepted.</td>
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<td>Duvvuri et al. (2007)</td>
<td>Systematic review of descriptive studies</td>
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<td>Hazlehurs et al. (2012)</td>
<td>Randomized controlled study N=200, 18-50 years old with diagnosed asthma</td>
<td>The Internet-based self-management program involved weekly online monitoring of asthma control with self-treatment advice, remote Web communications, and Internet-based information.</td>
<td>Internet-based self-management of asthma can be as effective as current asthma care and less costly than usual care. The study showed statistically significant clinical effects in favor of Internet-based self-management with regard to asthma related to quality of life, asthma control and lung function.</td>
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<td>Lieu, et al. (1998)</td>
<td>Randomized Control group N=16,520, 0-14 years old had asthma related health services</td>
<td>Prediction models to identify high-risk of asthma by classification tree.</td>
<td>The predication model may draw attention to some high risk patients who have not been found by clinicians.</td>
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<td>Kuperman et al. (2007)</td>
<td>System review</td>
<td>To assess feasibility, seven clinicians used SACS to guide well visits with 26 predominantly persistent pediatric asthma patients.</td>
<td>SACS improved assessment of asthma severity and control, classification of and intervention in medicine and environmental trigger management problems, and development of an action plan (all $p &lt; 0.5$). Clinician–patient communication was enhanced. SACS can enhance clinician behavior to improve patient asthma self-management.</td>
<td>V</td>
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<td>Meer et al. (2011)</td>
<td>Convenience sample of seven physicians, one nurse, 26 patients, 4-15 year olds has 1-5 hospital visit for asthma</td>
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<td>Mangold et al. (2005)</td>
<td>Descriptive study</td>
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<td>Study</td>
<td>Design and Methodology</td>
<td>Description</td>
<td>Findings</td>
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<td>McPherson et al. (2006)</td>
<td>Random controlled trail. N=101 children aged 7-14 years attending asthma outpatient clinic</td>
<td>The asthma files interactive CD-ROM using secret agent theme providing information about asthma self-management. It stores information about the child and produces a printable, individualized self-management plan.</td>
<td>Computer group had greater knowledge than controlled at 1 month. Controlled group more likely to have required oral steroids or time off school than controlled group during 6 month flow-up period. Program popular across age-range.</td>
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<td>Porter et al. (2013)</td>
<td>Well-designed control trial</td>
<td>Developed three prototype asthma kiosk to capture data</td>
<td>Kiosk successfully linked to patient to guideline recommendation.</td>
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<td>Redier et al. (1995)</td>
<td>Well-designed control trial, each expert provides 20 cases.</td>
<td>To assess the asthma severity using knowledge-based expert system. Implemented with Nexpert and Hypercard, it runs on a Macintosh personal computer. After compiling data from a patient, Asthma Expert assesses the severity of the disease and identifies the trigger investigations that may be required and offers a treatment strategy. At validation stage eight clinical experts will involve, who provide 20 cases report forms with their conclusion about management of asthma. Case report forms were than programmed into the Asthma Expert</td>
<td>All the experts evaluated the ES conclusions. Experts judged that the severity scores given by Expert System were as good as those proposed by their colleagues and that the overall conclusion given by Expert System was was good as or better than those given by their colleagues.</td>
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<td>Study</td>
<td>Sample Description</td>
<td>System Description</td>
<td>Conclusion</td>
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<td>Shegog et al. (2006)</td>
<td>A convenience sample of 7 physicians, 1 nurse educator, and clinician saw 26 patients age form 4-15 years old.</td>
<td>The SACS is a clinic decision support system. This system is related to both the clinical asthma management and the enhancement of patient and family self-management. The resultant knowledge base comprises 142 multilayered decision rules that describe clinical and behavioral management in three domains: 1) determination of asthma severity and control; 2) pharmacotherapy including prescription of medicine for chronic maintenance, acute exacerbation, exercise pretreatment and rhinitis relief; and 3) patient self-management, including the process of intervening to facilitate the patient’s asthma medication management, environmental control and as well as visit scheduling.</td>
<td>The SACS expert system provides a systematic approach for intervening with family asthma related behaviors. The authors conclude that SACS is a feasible strategy to enhance clinical communication and behavior change strategies. SACS improved assessment of asthma severity and control, classification and intervention in medicine and environmental trigger management problems, and development of an action plan.</td>
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<td>Theera-Ampornpunt et al. (2009)</td>
<td>A convenience sample was drawn from three</td>
<td>The first ED visit of each identified patient during the timeframe serves as that patient’s</td>
<td>The existence of prior clinical information accessible in the EHR would be associated</td>
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Minnesota-based health system during 18-month period. They extracted from each system’s data warehouse both patient-level data and encounter-level data. An indicator was created to assess the value of the EHR clinical information. with better quality and efficiency of care compare to patients for whom such information was not available at the time of the index ED visit.
Use the Health Information Technology to Improve Asthma Care in the Pediatric Population

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What evidence exists in the pediatric population to improve asthma care and reduce medical errors through the use of computer based Clinical Decision Support (CDS) system, Web/Internet-based application, and asthma action plan database tool.
Examine the health information technology used

- Improve clinicians’ behaviors to following the National Asthma Education Prevention Program (NAEPP) guidelines and making diagnostic and therapeutic decisions.
- Reduce medical errors and improve patient safety.
- Aid two-way communication between patients/families and clinicians and educate patients/families to improve their knowledge and self-management of chronic asthma.
- Measure the effectiveness and efficiency on quality of pediatric asthma care.
Background

- Asthma is the common chronic disease of childhood that affects more than 7 million children; 497,000 hospitalization annually, and 4,000 die from asthma exacerbation.
- Problems: clinicians are not following the guidelines and recommendations due to lack of resource.
- Needs for continue monitoring, education, and self-management.
- Role of Information technology: providing safe, effective, patient centered, timely, efficient, equitable care.
This framework is essential for understanding the improvement of asthma care and patient safety in the pediatric population.
Search strategy

• MEDLINE, CINAHL, and PubMed database.
• Key words: clinical decision support, education, action plan, asthma database, information system, and pediatric population
• Hundreds of studies related to my topic.
• 17 used in this literature review.
Review of Literature

- Web/Internet based applications: is an application that is accessed by user over a network such as the internet or an intranet.
- Clinical Decision Support systems (CDSs): is a computerized system that uses case-based reasoning to assist clinicians in assessing disease status, in making a diagnosis, in selecting appropriated therapy or in making other clinical decision.
- EHR database: is a systematic collection of electronic health information about individual patients or population.
Finding

- Clinical Decision Support (CDS)
  - Incorporating guidelines into practices to facilitate asthma management is required for high quality of asthma care.
  - Adoption of practice guidelines.
  - CDS may enable clinicians to accelerate the adoption of the guidelines.
- There was no significant impact on patient outcomes
- Usability: speed, ease of use.
- Alert fatigue.
Finding (cont)

- Effective CDS design
  - Needs to integrate into clinicians’ workflow (consider organization policies, norms, practices, and rules).
  - Automatic prompting, speedily delivered when needed, provide accurate recommendations.
  - CDS systems have great potential to improve the quality of care.
• Web/Internet based Applications
• Associated with increased knowledge levels and enhanced feelings of control over asthma.
• Highly effective in controlling the symptoms.
• Engage the child in decision-making and problem-solving exercises.
• Computer and internet access and technical difficulties.
• Cost-effective analysis: cost for software, hardware; cost for case managers to monitoring and training patients.
Discussions (cont)

- EHR database has been extremely beneficial in quality assurance and performance improvement; improve clinicians compliance with guidelines; enhance provides’ decision; better patient outcomes.
- Embedding of CDS and Web/Internet based applications into the EHR offers opportunities to improves providers adherence to the existing NAEPP guidelines, reduce medical errors, improve patient safety.
Discussions (Limitations)

- First is most studies only addressed the usefulness of health information technology, but not risks and costs.
- Outcomes evaluation was limited (statistically significant vs. clinically significant).
- How the health information technology impact users and their practice.
- Drawbacks of web/internet based interventions: lower socioeconomic group, lack of internet access, illiteracy population.
Summary

The evidences indicate that health information technologies are effective in pediatric asthma management. It improves the quality and efficiency of pediatric asthma care, improves pediatric patient safety, prevents medical errors, and alerts clinician behaviors and influences the process of care and decision making.
Recommendations

• Healthcare organizations should actively adopt health information technology related asthma management such as the CDS, Web/Internet-based application tools, and asthma action plan database.
• Workflow integration: workflow is the key issues that must be taking into account for both system designers and providers implementing health information technologies. Engaging the clinician in the process of health information technology design and implementation is very important.
Recommendations (cont)

• Application developers and knowledge developers should work together to improve CDS, Web/Internet-based education application, and EHR database functionality.
• The pediatric asthma management information technology needs be custom developed by the institutions that will implement the system.
• Guideline based practices should be standardized and improve the quality of care given to people with asthma resulting in improved outcomes.
Recommendations (cont)

- Future detailed Web/Internet based intervention researches are need to evaluate lower socioeconomic group that lack of internet access and illiteracy population.
- Knowledge maintenance: maintain the accuracy of the patient record. Also frequent updating is needed due to new medical knowledge, new evidenced guidelines, new drug and diagnoses that are continually being discovered.
- For health information technologies to be effective, clinicians must be motivated to use these systems.
Questions???