WORK-ASTHMA DOMAIN EXPERTS (WADE) FINAL REPORT

Submitted by:
Work Asthma Domain Expert Committee (American Thoracic Society)

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INTRODUCTION AND OVERVIEW

Asthma is a common chronic inflammatory disease of the lungs affecting close to 19 million adults 18 years or older in the U.S. [1]. Work-related asthma (WRA) is defined as asthma caused or exacerbated by exposures in the workplace. An estimated 17% (median) of new-onset adult asthma cases are caused by workplace exposures [2] and an estimated 21.5% (mean; range 13– 58%) have pre-existing or current asthma exacerbated by workplace exposures [3]. WRA can have long-term adverse impacts on individuals, including increased morbidity and adverse socioeconomic impacts [4,5]. Early diagnosis of WRA and elimination / reduction of exposures can reduce the likelihood of permanent asthma and reduce disability [6,7]. Recognizing WRA in one worker can lead to better exposure controls for co-workers, a form of primary prevention. Thus primary and secondary prevention are facilitated by recognizing WRA. The relatively short latency and availability of many exposure control methods make WRA an excellent candidate for linking prevention with clinical input.

However, unfortunately work-related asthma continues to be under-recognized and under- diagnosed [3,6], for multiple reasons. In a U.S survey of over 50,000 individuals with asthma, only 14.7% of ever-employed adults with current asthma communicated with a healthcare professional about the relationship of their asthma to work [8]. Clinicians frequently do not inquire about potential occupational exposures and therefore may miss important opportunities for diagnosis and intervention [9]. In addition, further work-up to clarify the diagnosis of asthma and/or evaluate work- relatedness may not be performed and /or the worker may leave the causative workplace [6,10,11].

This report provides a suggested approach and rationale for addressing work-related asthma in the primary care setting using Clinical Decision Support (CDS). The primary objective is to improve recognition and management of work-related asthma in primary care settings for working age patients with asthma. The recommendations are meant to prompt and support clinician-patient discussion and further evaluation of possible WRA, rather than provide a specific diagnostic algorithm.

The recommendations are based on the major relevant professional organizations' statements and/or guidelines that address WRA, including: the American College of Chest Physicians (ACCP) consensus statement on WRA [6], the American Thoracic Society (ATS) official statement on work exacerbated asthma [3], the European Respiratory Society (ERS) taskforce guidelines for the management of work-related asthma [12], and the British Thoracic Society (BTS) standards of care for occupational asthma [13,14], and the related British Occupational Health Research Foundation (BOHRF) evidence reviews [15]. As these guidelines and statements do not adequately address the more limited capabilities for evaluating and managing WRA in many primary care settings, WADE expertise also guided the development of these recommendations. The WADE working group discussed whether agent-specific (e.g. allergens, irritants) recommendations should be made and favored a more general approach. The working group felt that a list of WRA exposure agents / conditions as well as resources targeted to health care providers and patients would facilitate the recognition and management of WRA.

OVERALL CLINICAL OBJECTIVE:

The primary objective is to improve recognition and management of work-related asthma in primary care settings for working age patients with asthma ≥ 18 years old.

RECOMMENDATIONS

The committee recommends a systematic approach to identifying work-related asthma in primary care settings. The recommendation contains several components, which would be triggered in a sequential fashion, as summarized below:

Recommendation #1a: Administer 3 WRA screening questions to all working age (>18 years old) patients with new-onset or worsening asthma

IF: - Reason for visit =
- Asthma (ICD-9 493.XX; ICD-10: J45.XX, J63.3) that began within the last two years
-OR patient had one or more ED or acute clinic visits for asthma over the past two years

THEN ask**:**

1) Do / did your asthma symptoms start at your current / recent workplace?
2) Do / did your asthma symptoms worsen at work?
3) Are asthma symptoms different (e.g. better) on days off work and/or holidays?

Basis of Recommendation 1a

A meeting sponsored by NIOSH (September 2014) provided insight into the selection of recommendations to identify WRA that could be implemented in a primary care setting using CDS.

The ACCP Consensus statement concluded that work-related asthma should be considered in all adults with new-onset or worsening asthma [6]. Similarly, the ATS document states that "work-exacerbated asthma should be considered in any patient with asthma that is getting worse or who has work-related symptoms" [3]. Thus recommendation 1a is based on the CDS being able to identify patients with "new-onset" or "worsening" asthma. The criteria noted above to define new-onset or worsening asthma were chosen based on consensus of the committee and current understanding of CDS capabilities, recognizing that the criteria may need modification after pilot testing.

The 3 work-related questions were selected based on the literature, existing WRA documents and the expert opinion of the committee. The documents cited (including ACCP, ATS, BTS, and ERS), as well as review articles that address WRA diagnosis / surveillance [7,16-18], all recommend taking an occupational history and asking patients about asthma onset and the temporal relationship of their asthmatic symptoms to work. The working group attempted to identify the most discerning questions to screen for WRA in a primary care setting. Relevant questionnaires from prior statements and guidelines, the literature and professional colleagues were reviewed [6,12,16,19-21].

WRA questionnaires used in selected settings have shown an ability to identify workers at risk for WRA [20-24]. However, validation has been limited, focused largely on occupational asthma (rather than all WRA), and rarely in a primary care setting. Additionally most questionnaires are too long and time-intensive for application in primary care settings given current time constraints on providers. For example, Pralong's Occupational Asthma Screening Questionnaire showed fair discriminative ability to identify occupational asthma and work-exacerbated asthma when used in a WRA referral center, but has not yet been evaluated in a primary care setting [20,21]. Killorn et al evaluated a shorter WRA screening questionnaire (WRASQ) in 37 patients with asthma in a primary care asthma program, finding substantial agreement between testing and good reproducibility, including exposure questions [19,25]. The WRASQ identified additional work-related symptoms and exposures compared to usual-practice, but the limited number of WRA cases limited further validation [19].

Considering available WRA questionnaires and practical considerations, the WRASQ was considered most applicable to current needs based on: its prior implementation in a primary care setting, reproducibility, and applicability to both occupational and work-exacerbated asthma. Three questions addressing the temporal relationship of symptoms to work, questions common to most WRA questionnaires were chosen, as the 14-item questionnaire was considered too lengthy for use in a busy primary care practice.

Anticipated Benefits and Harms

The anticipated benefits of the brief questionnaire include ease of administration and targeting patients most likely to have WRA. Potential harms are minimal.

Limitations of the Recommendation

The use of a simple screening questionnaire may not identify all cases of possible WRA.

Gaps in the Recommendation
As noted above, the best screening questions to ask to identify WRA have not been determined. The specific questions chosen could be modified in the future.

Recommendation #1b: Evaluate diagnosis of asthma

IF: patient responds positively to any of the 3 screening questions
THEN: clarify the diagnosis of asthma with spirometry testing.
Spirometry showing airflow obstruction (FEV1/FVC ratio < LLN) plus a significant response to bronchodilator (defined as improvement in either FEV1 or FVC by 200 ml and a 12% improvement over baseline) supports a diagnosis of asthma.

SPIROMETRY EXPLANATION (Provided to patient if spirometry is recommended):
Spirometry is a simple breathing test to measure lung function. It provides useful information to help your clinician determine if asthma is present. For more information, click here [26]: http://www.thoracic.org/patients/patient-resources/resources/pulmonary-function-tests.pdf
Your providers should discuss the results of your spirometry testing with you, and whether the test results help show that you have asthma. You should also discuss your respiratory symptoms and their relationship to work with your provider when you review your spirometry. Like most medical tests, spirometry is not a perfect test; normal results make asthma less likely but do not rule out possible asthma. Also, patients can develop respiratory symptoms related to work even though spirometry testing does not show asthma, as work exposures can lead to other respiratory conditions. For more information, click here [27]: http://www.thoracic.org/patients/patient-resources/resources/occupational-lung-disease.pdf

Basis of Recommendation 1b

The spirometry criteria used are consistent with ATS and ERS guidelines [28,29] and The Global Initiative in Asthma (GINA), which defines asthma as a disease with symptoms such as wheezing, shortness of breath, chest tightness, and cough that vary over time and are associated with variable expiratory airflow obstruction due to bronchoconstriction, airway wall thickening and increased mucus. Other conditions can cause respiratory symptoms that are hard to distinguish from asthma, such as rhinitis and upper airway irritation, conditions that can also precede and/or co-exist with asthma. Spirometry testing, used to document reversible airflow obstruction, is performed in patients with asthmatic-like symptoms to help assess whether they have asthma or another

condition. While asthma in primary care practice is commonly diagnosed based on a typical clinical presentation and response to treatment, when WRA is being considered, it is important to try to document asthma, which is defined as reversible airflow obstruction in existing WRA documents [6,12,13,15].

It is recognized that asthma is a variable heterogeneous condition, and patients with asthma can have negative bronchodilator testing. However, such a finding greatly reduces the likelihood of asthma. Medications used to treat asthma and removal from causative agents can improve airflow obstruction and reduce airway hyper-responsiveness, and thus should be considered in interpreting spirometry finding.

Anticipated Benefits and Harms

Clarifying the diagnosis of asthma benefits patient care by limiting use of medications with potential adverse effects to those likely to benefit. In addition, documenting that asthma is present will help clarify the patient's diagnosis, which can impact a patient's job as well as health. Making such decisions without adequately documenting asthma can lead to diagnostic uncertainty and adverse socioeconomic consequences. Spirometry is regarded as a safe test with very rare complications.

Limitations of the Recommendation

Patients in the clinical setting may not have easy access to standard high quality spirometry testing. As noted some patients with asthma can have normal spirometry, and WRA or other work-related respiratory conditions that impact the patient's health or ability to work could be missed.

Gaps in the Recommendation

The recommended approach may not identify patients who have (or had) WRA, but whose spirometry is currently normal, possibly because they have left the workplace, and/or are taking asthma medications. More detailed recommendations could include methacholine challenge testing to further clarify the diagnosis of asthma and peak flow monitoring (see below). This approach will also not identify patients with work-related rhinitis or other respiratory conditions. The literature regarding these other work-related respiratory conditions is more limited, but could be addressed in future CDS efforts.

Recommendation #1c: Provide WRA tools to clinician and patient, and encourage discussion

IF: patient responds "yes" to any of the 3 screening questions **AND** patient has asthma
THEN: Provide WRA tools to the clinician and patient
AND Document in EHR the discussion regarding the patient's work and respiratory symptoms
The WRA information tools should include 3 components:

1) Checklist of selected high-risk exposure situations:
    - Adhesives/glues
    - Agricultural agents (e.g. grain)
    - Animal/fish materials
    - Biologic agents, enzymes
    - Molds, viruses
    - Chemicals
    - Cleaning agents
    - Cold air
    - Dust
    - Dyes
    - Food agents (e.g. flour)
    - Fumes (e.g. exhaust)

- Insects/insect materials
- Isocyanates
- Natural rubber products
- Pharmaceuticals
- Plants/plant materials
- Metal working fluids
- Metals
- Smoke
- Textile fibers
- Wood dust

2. Educational materials for providers and patients, including information on diagnosis and management of WRA: Education materials are from the ATS, OSHA, and the medical literature [27,30-32].

3. Referral Resources: Information on local clinicians with specialized knowledge of occupational respiratory disorders (and referral instructions / forms), and additional local resources such as local state / city health departments and American Lung Association / ATS.

Basis of Recommendation 1c:

Clinicians not asking patients about their work has been identified as a major obstacle to recognizing WRA. The approach recommended here is derived from the previously cited ACCP, ATS, ERS, BTS, and BOHRF WRA documents [3,6,12-14], which all stress the importance of obtaining a thorough focused work and exposure history and referral to clinicians with specialized expertise in WRA.
If Recommendations #1a and b are triggered (patient responds yes to ≥1 of the 3 screening questions AND asthma is confirmed), the patient will be scheduled for a longer follow-up visit with his/her provider. Educational materials and resources regarding WRA, including a list of work exposures that can cause or exacerbate asthma, adapted from the WRASQ questionnaire [25], will be provided. The WRASQ-based list was selected as it includes the major types of work exposures reported to cause or exacerbate asthma [3,6,18,33] and is in an easily usable format. As the WRASQ- based list is not exhaustive, the comprehensive AOEC (Association of Occupational and Environmental Clinics) web-based list of agents associated with new onset WRA [33], will be available as an online resource (http://www.aoecdata.org/ExpCodeLookup.aspx).

Providing user-friendly educational resources should facilitate the evaluation of WRA by enabling the clinician to obtain a relevant occupational / exposure history (including job title, tasks, changes, exposures, use personal protective equipment) in relation to asthma (onset of asthma symptoms, temporal associations of symptoms with work / work changes). Clinicians will be prompted to document information obtained in the patient's electronic medical record.
Resources to facilitate referral to a clinician with specialized knowledge related to WRA will be tailored to the specific location.

Anticipated Benefits and Harms

Potential benefits are substantial. The diagnosis of WRA can lead to appropriate exposure control, job modification, and / or compensation. Early recognition of WRA and exposure reduction improves health outcomes [6,7,18]. Identification of a sentinel case may also lead to workplace protections for other workers, preventing other cases of WRA. Potential harms include over or under diagnosis of WRA. Patients may be subject to income or job loss if WRA is diagnosed, which can be mitigated

by accurate diagnosis, and exposure reduction. Costs related to clinician and patient time for obtaining the occupational history will be incurred.

Limitations of the Recommendation

This recommendation depends upon the commitment of patient and clinician to discuss work exposures, and the ability of the patient to provide work information. The availability of referral expertise varies substantially by geographic location. Given the limited numbers of clinicians with such expertise, additional tools could be developed in the future to inform primary care and pulmonary physicians about additional diagnostic approaches, including better exposure assessment (MSDS/SDS, industrial hygiene data, NIOSH Health Hazard Evaluations, OSHA), and peak flow monitoring. The recommended questions and educational materials are in English, but translation into other languages could be implemented with limited difficulty. The availability of specific testing such as spirometry may differ from site to site.

Gaps in the Recommendation

The diagnosis and management of WRA can be challenging, even when an occupational lung specialist evaluates a patient. Over and under-diagnosis can occur. Common misconceptions should be clarified, including: the level of diagnostic certainty for work-related conditions in the U.S. is generally more probable than not (over 50% likely), that WRA can be diagnosed without confirming a specific causative agent(s), and also that there may be multiple work triggers, as is common with work-exacerbated asthma. Patients with work-related respiratory symptoms who do not have asthma also warrant close follow-up and further evaluation, which could be addressed in another CDS.

OVERALL EVALUATION OF RECOMMENDATION SET

Sources of Recommendations / Quality of Evidence

As noted, these recommendations are based on the most recent guidelines / statements on WRA from the American College of Chest Physicians (ACCP) [6], American College of Occupational and Environmental Medicine (ACOEM)[34], European Respiratory Society (ERS) [7,12], American Thoracic Society (ATS) [3], British Occupational Health Research Foundation (BOHR) and the British Thoracic Society (BTS) Standards of Care [13-15], which are all based on systematic reviews of the WRA literature. The documents acknowledge the generally low to moderate quality of the literature cited, mainly case-control and smaller cohort studies, given the lack of randomized controlled trials. The ERS and BOHR documents used the Scottish Intercollegiate Guidelines Network (SIGN), Royal College of General Practitioners (RCGP) and / or Grading of Recommendations Assessment, Development and Evaluation (GRADE) systems to evaluate the quality of the evidence and the strength of the recommendations. The ACCP and ATS documents used a consensus approach. Despite lower quality evidence and different rating systems to evaluate the literature, the recommendations regarding WRA in these different documents are remarkably similar, as noted in a quality appraisal of these WRA documents [35].

Strength of the Recommendations

The recommendations made here overall are considered strong recommendations based on the potential benefits significantly outweighing potential harm, assessed from the perspective of the individual patient and on a population basis. The ERS Statement, the only one that used the GRADE system, rated the strength of almost all recommendations as strong, despite being based on generally moderate quality evidence, given that the benefits outweighed harm [12].

Limitations / Gaps in the Recommendations
As noted above, there are potential limitations. For example, misdiagnosing WRA could lead to loss of a job or reassignment. The CDS components may lead to longer duration patient visits, reducing the number of patients seen by the healthcare provider. However, properly recognizing and managing WRA should improve patient outcomes and thereby attenuate the costs of health services.

NECESSARY INFORMATION & SYSTEMS
As a minimum, the system must include ICD diagnostic codes for each patient encounter. In addition, a means for delivering the WRA agent list and educational materials must be present, preferably with direct access from within the electronic health record. The recommended approach is adjustable depending upon data linkages available at the implementation site. The system can be augmented on an incremental basis as the site electronic health record system can access more complete information. (E.g. this will be useful even if initially limited to diagnostic codes, but pharmacy and prescription data can subsequently be incorporated if available). In summary, this approach is immediately implementable but can expand as the electronic health record system is further developed. Interoperability and connections among clinics, external providers, pulmonary function laboratories, and pharmacies will further improve this approach.

QUALITY MEASURE EVALUATION APPROACHES FOR CDS-EHR INTEGRATION

Systematic objective evaluation of the effectiveness of the program to incorporate occupational health clinical decision support systems (CDS) within modern electronic health record (EHR) systems should follow generally accepted evaluation principles. This section briefly summarizes recommendations from the Work Asthma Domain Expert committee. These suggestions are based upon:

- expertise of committee members as clinicians and researchers
- input from the NIOSH liaisons to the committee and special orientation arranged by NIOSH including:
    - presentations by Dr. Richard Schiffman of Yale University
    - webinar provided by The Joint Commission
- Summary report of primary care provider interviews by Dr. Joan Ash and colleagues of the Oregon Health Sciences University
- Limited Literature Review

Relevance to Occupational Health

Quality measures are applied to systems or populations rather than to individuals [36] to measure health care processes and outcomes. AHQR emphasizes the importance of defining "the dimensions to be measured before embarking on data collection", and notes that the quality measure should be based upon the "specific population" and should be selected to be most useful in guiding the "health care team in improving quality of care".

There is no single "best quality measure". Rather, the quality measure should be selected based upon the specific population and the purpose for which the program is instituted. There are libraries of available quality measures (e.g.,NHQR database, National Quality Forum [1]) from which one or more appropriate measures may be chosen, or if necessary a new quality measure can be developed. The Joint Commission webinar outlined a systematic approach for developing quality measures to assure they meet the needs of all stakeholders and are reasonably implementable.

Review of the available resources identified several existing candidate measures useful for measuring quality of care for asthma. However, none of them appropriately incorporated the occupational health perspective per se. Work-related asthma measures should consider the impact upon the working life of the patient and also incorporate input from the multiple stakeholders including patients, primary care providers, employers, worker representative groups, and healthcare systems. Since work-related asthma is a Sentinel health event, a quality measure should also reflect public health surveillance needs.

The quality measure must also be feasible in the *specific setting* in which it will be implemented. The cost or burden of measurement may differ depending upon accessibility to patient specific longitudinal outcome data.

Focus: Structure, Content, or Outcome

Structure quality measures describe the facilities, resources, and structures supporting a healthcare provision for the specific problem and population.

For CDS-EHR integration, structure measures may include:

[1] http://www.ncqa.org/tabid/59/Default.aspx

- Does the setting meet the pre-specified goals? Is it a primary care setting? As a developmental/research effort, is this setting representative so that measures can be generalized?
- Has the computer based system been effectively incorporated within the existing EHR system?
- Are the IT and other professionals adequate to sustain the system after project specific federal funding has been exhausted?
- What proportion of the recommendations of the WADE report are implemented? (E.g., can automated capture of information from emergency department records be included?)

Process measures are objective performance measures. Traditionally, these measure actions performed by and under the control of the health care provider. [37] These include measures such as:

- How many patients with asthma and primary providers use the system? (This measure has been effectively utilized in the CanadianWRA EHR trial to identify remediable barriers). [19]
- How frequently does the CDS-EHR implementation lead to positive responses to the 3 key questions? (This process measure is very similar population surveillance). [38]
- Does the frequency of diagnoses of work-related asthma increase after the implementation of the system? Can this be automatically captured with low measurement burden by reviewing ICD-9 or 10 diagnoses in the EHR?

Outcome measures directly measure the health outcome of interest. Outcome quality measures should be based upon the health priorities of all stakeholders.

Several measures of symptomatic status are available for asthma (e.g., measures of severity such as hospitalizations and medications, Asthma Control Test). [39]

In addition to asthma specific measures, generic patient reported health status measures or satisfaction with care measures are available.

Suggested measures have included [39]

- number of days of limited activity
- number of… Workdays missed due to asthma
- "percent of asthma population… advised by health professional… to change things in… work to reduce asthma triggers"

Viewing health more broadly, patient centered outcomes may also include measures such as job retention, quality of work life, and income. As positive and adverse effects of diagnosing work- related asthma have been well documented, we recommend that specific quality measures be developed, pilot tested, and implemented. These quality outcome measures should include factors such as:

- employment and income status
- implementation of appropriate accommodations
- changing work environmental conditions benefiting other workers

Project Specific Quality Measures:

The quality measures should meet the needs of this specific NIOSH project in addition to the needs of specific site where the CDS-EHR is implemented. The project is a developmental, research, and demonstration project. As such, an optimal quality measure for WRA should be capable of measurement before, during, and after implementation of the system. Further, it should be designed to identify opportunities and barriers for effective implementation.

Appropriate benchmarks against which results may be compared should be available. These may include pre-/post implementation change within the same location or regional benchmarks. [40]

SUMMARY

Several asthma related quality measures are available in standard sources. They do not appear to adequately measure the long-term outcomes and occupational health dimensions. The committee therefore suggests that prior to system implementation, NIOSH systematically obtain two categories of information: (1) What objective quality measures about work/employment status can be implemented at the demonstration sites? (2) The priorities of patient/workers about which outcomes are most important should be identified. Input from healthcare providers should be complemented by input from patients, workers, employers, and worker representative groups. The Joint Commission and PCORI both provide general approaches.

In summary, process measures such as the frequency with which the system is utilized and outcome measures such as the frequency of diagnosing work-related asthma are likely to be feasible and easily incorporated in the sites selected. Concomitantly, development of appropriate work outcome measures should be encouraged. Recognizing the constraints, the committee recommends proposing the following measures for the initial implementation sites:

- Structure: Can the system triggered by emergency room of vents, and does it document responses to the 3 questions?
- Number of times the system is triggered and leads to documented answers to the 3 questions
- Number of ICD based new diagnoses of work-related asthma

REVIEW AND ASSESSMENT OF ASTHMA CLINICAL DECISION SUPPORT SYSTEMS

Gaps between evidence-based medicine and real clinical practice limit implementation of evidence-based guidelines. Incorporation of real-time clinical decision support (CDS) at the point of care may help bridge this gap. Now, with widespread use of electronic health records (EHRs), electronic interfaces pose as a resource to implement electronic-based CDS (e-CDS) at point of care. Use of e-CDS may significantly improve concordance with evidence-based guidelines in management of asthma. Work-related Asthma (WRA) bears similarities in diagnosis and management to asthma that is not work-related. However, some of the recognition tools are different, as are recommendations for management. We created a CDS tool designed to help increase recognition of WRA among primary care providers. As part of this effort, we reviewed the literature to understand what current e-CDS tools exist related to recognition, diagnosis, and treatment of occupational asthma. While currently, no publically-available CDS tools for WRA have been described, a 2014 systematic review summarized a variety of e-CDS tools for asthma and COPD in primary care. [41] We focused on this comprehensive review as a summary of available literature on asthma-related CDS tools, owing to its recent yet broad time-frame for inclusion of articles (2003- 2013) of high quality, and exclusion of paper-based tools, inpatient hospital-based systems, and conference/meeting abstracts.

CDS Tools for Asthma

The Fathima review included 19 studies, out of 1044 sources initially identified. Eleven of the 19 evaluated asthma care, 5 both asthma and COPD and 3 focused on broader medical conditions that included COPD. Of the studies that included asthma, 4 were based on adults, 5 based on children, and 7 either children or adults. The CDS intervention targeted patients in four studies and practitioners in 15. Thirteen of the 19 trials were embedded in an existing EMR or computerized physician order entry (CPOE), while 6 interventions had a stand-alone system: 4 of which were internet based, and two of which the intervention was administered to practitioners by the study researchers. The CDS interventions were classified into three main categories: 1) Screening/Diagnosis (1 trial), 2) Drug therapy management (5 trials), and 3) multifaceted interventions (13 trials) to include physician management and patient advice. Of these latter 13, CDS tools ranged from simple activation of electronic alerts to identify people at risk of an asthma exacerbation, or prompts to alert the physician to modify treatment, to interventions involving a series of care suggestions on drug therapy and disease management.

Evaluation of CDS Tools for Asthma

In the Fathima review, a CDS tool was considered effective if it produced a statistically-significant improvement in the primary outcome or improvement in ≥ 50 % of multiple relevant pre-specified outcomes. Most of these primary outcomes were health care process measures, clinical outcomes, user work load and efficiency and use and implementation outcomes. Fourteen showed positive effect from the use of CDS on the primary outcome, and 9 of which showed a “significantly” positive effect. Significant improvement was found in the rate of diagnosis of asthma in children by implementation of a parent survey linked to physician prompts using CDS. Significant improvement was also found in ACQ and AQLQ using an electronic diary to record symptoms among patients. The effects sizes for the studies showing significant improvement in the primary clinical outcomes ranged from 0.24 to 0.94, with three studies showing reasonably large effect sizes. Ten trials assessed health care process measures as the primary outcome, of which four showed significant improvements. The effect size calculated for the two studies with significantly positive improvement, however, was poor. Only one of the three trials designed to target user workload and efficiency outcomes showed significant improvement in the rate of asthma documentation by ED doctors in the management of acute asthma. Four trials addressed use and implementation outcomes.

Eighty-three percent (5/6) of the studies that utilized CDS with a stand-alone design showed positive outcomes, as compared to studies testing CDS that were integrated with the HER or CPOE (38%) (5/13). One possible explanation for the lower outcome in improvement is that systems with integrated alerts could be overwhelming to the system users and ultimately ignored. The reasons postulated of this result were that the threshold for the medication alerts generated was too low and became overwhelming, which resulted in ignoring the alerts. The suggested remedy would be to reduce alerts generated and require physician to type a reason for overriding the alert. Four of the five studies that utilized CDS as a stand-alone design were internet-based interventions, which targeted the patients. Stand-alone, internet based systems that included an active self- management component outside the clinical encounter, were shown to be more effective than physician driven systems, which underscores the importance of collaborative care in clinical medicine. These interventions included feedback and monitoring along with patient education. Sixty percent of the 5 studies measuring clinical outcomes showed significantly positive impact on outcomes, compared to 40% of the 10 studies focused on improvement in health care process outcomes. Economic effects of the CDS tools could not be readily assessed based on the available data.

Comparison of Proposed Tool with Existing Asthma CDS Tools

Our CDS tool is aimed at providers, and meant to increase recognition of WRA by asking a series of screening questions. Based on the screening questions, it directs the practitioner to obtain a diagnostic test, which, if positive, triggers generation of educational materials for the patient and practitioner, and prompts the practitioner to document. Of the CDS interventions reviewed, three of the interventions had somewhat parallel structures to ours. The one bearing the most similarity was Carroll et al.'s intervention aimed to increase physicians' diagnosis of childhood asthma based on prompts by the CDS. This study had a positive effect, with a significant difference in children being diagnosed with asthma in the intervention group compared to usual care (8.6 vs. 5.8%, $p<0.002$, with effect size of 0.24). Another CDS intervention by Taylor et al. aimed to improve the quality of asthma documentation using a decision support tool by ED physicians also had a positive effect, demonstrating significantly higher rates of documentation in 7 out of 10 variables, with an effect size of 0.78. Finally, Bell et al.'s CDS tool targeted physicians to improve health care process outcomes by evaluating adherence with the National Asthma Education Prevention Program Guidelines. In this intervention, there was a 3% increase in spirometry ($p=0.04$) in the group receiving the intervention compared to the control group, which has relevance to efficacy for our CDS tool.

Summary

In summary, there is a paucity of literature examining the effectiveness of CDS in diagnosing asthma in any context, let alone, the specific circumstances of WRA. However, the literature demonstrates that CDS tools were found effective in the diagnosis and management of Asthma. This indicates that if correctly developed, taking care to avoid pitfalls demonstrated in previous studies, an e-CDS tool could be effective in diagnosing WRA. Specifically, developing a system that incorporates interventions by both the physician and patient will be most effective. While it was found that stand-alone e-CDS can be more effective than EHR-embedded CDS, this may be due to an inherent design flaw that generated an overwhelming number of alerts that then were easily dismissed by the provider. These points highlighted by successful CDS tools, fit well with the WRA CDS Decision Logic Flowchart, which requires both provider and patient interaction. The initial patient interaction is made via the questions "Are you working?", "Do/did your asthma symptoms start at work?", etc. which could be done online via an electronic questionnaire or in person and then uploaded into the EHR. Positive results to the initial questions would then alert a provider to interpret those responses and require a comment to override a recommendation for objective

asthma testing, rather than just generating an alert that can be easily dismissed. Finally, the WRA decision algorithm results in documentation for both the patient and provider which could be in the form of disease education and follow-up instructions.

(Wesley Boose, MD, provided assistance in the preparation of this section).

ILLUSTRATIVE CASE SCENARIO

Mr. Jones is 35 year-old male with complaint of worsening cough and wheeze over the past 6 months who comes in for evaluation. In the past month, he missed work for two "sick days" for breathing problems and went to a local emergency room where the diagnosis was asthma. He received a "breathing treatment" and was given a prescription for albuterol, which he has been using several times a day to control his cough and wheeze. He is a non-smoker with no prior history of asthma. He denies recent fever, weight loss, or sputum production.

Pertinent findings on his Physical exam included the following: Pulse: 86, Respiratory Rate: 14 Afebrile. Blood Pressure: 138/ 84. General: normal appearing fit male not in distress. HEENT: unremarkable. Heart: regular rhythm, without murmur. Lungs: breath sounds heard equally throughout lung fields, expiratory wheeze on forced expiration otherwise no rubs or crackles. Abdomen: unremarkable. Extremities: unremarkable.

CDS ACTIONS: *The integrated electronic health record system automatically initiates the WRA CDS algorithm, as the patient has a new ICD asthma diagnosis and an emergency room visit for asthma, which triggers the three screening questions.* ***(Recommendation #1a).***

The patient completes the questionnaire electronically with a positive response to two of the three questions regarding work-associated asthma symptoms. This triggers an alert to the clinician and patient to confirm asthma by spirometry, and the clinician orders a spirometry test with bronchodilator. The testing is performed and shows mild airflow obstruction with a positive bronchodilator response, supporting the diagnosis of asthma *(**Recommendation # 1b).***

CDS ACTIONS: *CDS notifies the patient (and the healthcare provider) to make an appointment for an extended visit to carefully review his occupational history with his primary provider. CDS provides the patient and provider with a list of exposures that can cause WRA and additional information on the diagnosis of WRA (**Recommendation # 1c).***

Mr. Jones returns for his longer appointment. He identifies "adhesives" on the WRA agent list, and he and his primary care provider review his spirometry results, and discuss in detail his job, work exposures and associated respiratory symptoms, learning that:

> Mr. Jones worked for the same company, an aircraft engine manufacturer, for the past 10 years. About 8 months ago he switched to a new job at the same manufacturer, which involves preparing engine parts for assembly. This work involves inspecting the parts for defects, cleaning them with an air-gun, and spraying an adhesive to contact surfaces prior to final assembly. He wears gloves, but no other protective gear, when he applies the adhesives. His asthmatic symptoms started about 2 months after he started his new job, worsen at work and improve on weekends. He denies ever having asthma or prior pulmonary function testing. A co-worker worker has also been diagnosed with asthma.

Mr. Jones' primary care provider documents the discussion regarding Mr. Jones' work history and asthmatic symptoms in his electronic medical record including: dates of employment / job changes / job title, the timing of onset of his asthma symptoms, temporal associations of his symptoms with work /away from work, and any other asthma triggers.

His primary care provider makes a diagnosis of asthma, suspect work-related, based on: his patient's clinical presentation, work-related symptoms, spirometry results, and occupational history, including identification of exposure to "adhesives" at work, a substance on WRA agent list. He refers Mr. Jones to a local occupational pulmonary specialist for further evaluation and management

*(**Recommendation # 1c),*** and also prescribes standard asthma treatment (inhaled steroids, bronchodilator), based on NAEPP guidelines.

Mr. Jones next sees the occupational pulmonary specialist (Dr. X), who performs additional evaluation, including: review of MSDS that Mr. Jones obtained from his workplace and peak flow recordings at and away from work. MSDS for the spray adhesive documents that MDI (methylene diphenyl diisocyanate), a known potent sensitizer that can cause occupational asthma, is one of main components of the adhesive.

Based on this additional information Dr. X diagnoses Mr. Jones with WRA (new onset sensitizer occupational asthma), and makes recommendations regarding exposure reduction / elimination, medical follow-up and also instructs Mr. Jones to inquire about workers compensation. Although the clinicians informed Mr. Jones that complete elimination of exposure to MDI is preferable to exposure reduction, they agreed to a trial of significantly reducing exposure levels.

Working collaboratively with the employer, Mr. Jones initially was provided protective clothing, an appropriate respirator, and local ventilation was improved, but Mr. Jones's work-associated asthmatic symptoms persisted. The employer was unable to switch to an alternative adhesive that did not contain MDI. Subsequently the employer decided to fully enclose and automate the adhesive application process so that Mr. Jones and his co-workers could avoid exposure to the adhesive.

Mr. Jones's continues to work for the same aircraft manufacturer and sees his primary care physician on a regular basis for management of his asthma, which has improved, with less frequent use of his albuterol inhaler. He applied for workers compensation given his diagnosis of work- related asthma.

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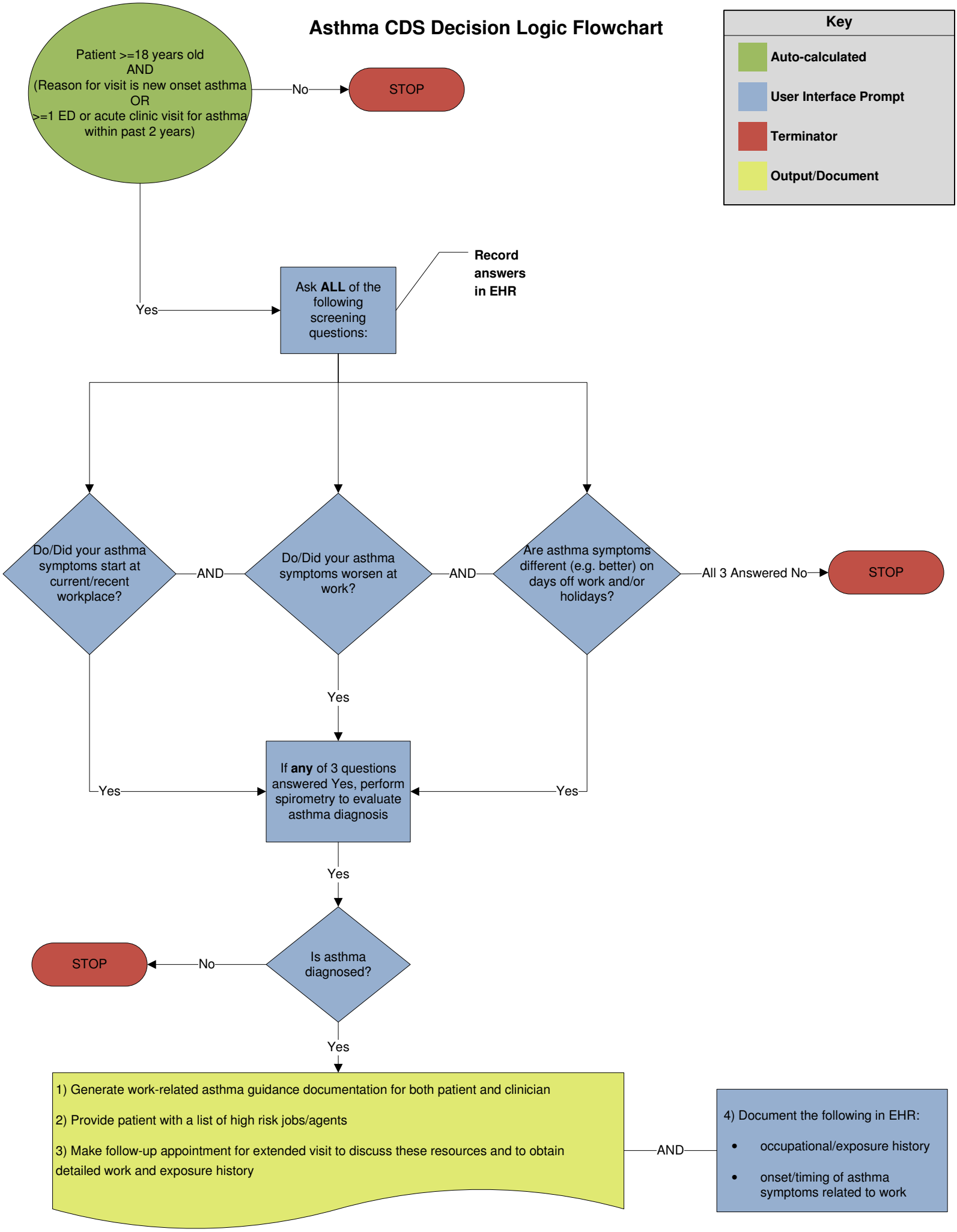
Asthma CDS Decision Logic Flowchart



This flow diagram was developed by Stacey Marovich, MS, MHI, of NIOSH based upon the information in this report.