Strategies for Help in Crowded Emergency Rooms

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Author Note

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Abstract

Objective

Pediatric patients with asthma are frequently cared for in the emergency department (ED). Many studies show early administration of corticosteroids (CS) can improve outcomes for children experiencing an asthma exacerbation. Despite the evidence, delays in care remain. The purpose of this study is to streamline the process for nurse-initiated, triage-based CS administration and determine the effect on overall length of stay (LOS).

Methods

For this quality improvement initiative, ED nurses at a large, freestanding, children's emergency department in the southwestern United States were given education on inclusion and exclusion criteria for nurse-initiated CS in ED triage. Time to CS administration, LOS, and whether the ED nurse or provider ordered the CS were evaluated through chart reviews of patients presenting with a chief complaint of difficulty breathing. These metrics were compared to charts from the previous year during the same timeframe to evaluate for improved timeliness of CS delivery.

Results

Time to CS administration decreased from a mean of 98.6 minutes to 57.6 minutes. LOS decreased from an average of 259.3 minutes to 169.6 minutes. The effect of timely CS on LOS was significant for December p =.003, January p =.002, and February p = <.001.

Conclusion

A streamlined process for CS delivery to pediatric patients experiencing an asthma exacerbation can enable providers to achieve efficient and effective care in the ED and decrease a patient's overall LOS.

Keywords: asthma, steroids, treatment, emergency department, pediatrics

Pediatric Patients with Asthma and Early Steroid Administration:

Strategies for Help in Crowded Emergency Rooms

Asthma is a common chronic disease in children and is one of the top reasons for Emergency Department (ED) visits. Pediatric patients with asthma account for a substantial number of hospitalizations each year. Systemic corticosteroid (CS) delivery is a mainstay of care for children presenting with an asthma exacerbation. Early intervention can decrease time to final disposition in the ED, overall length of stay (LOS), and the need for hospitalizations, yet several factors in the emergency setting can delay timely administration of CS.

Problem Statement

The Centers for Disease Control and Prevention estimate that one in ten American children are affected by asthma (Ross et al., 2016). Children in Arizona have a disproportionately higher rate of asthma when compared to the rest of the nation, and the prevalence continues to grow over time (American Lung Association in Arizona [ALAA], 2016). The most recent data from the Arizona Department of Health Services (ADHS) reports a cost of greater than $115 million for asthma-related ED visits and hospitalizations (ALAA, 2016).

Previously published studies demonstrate nurse-initiated, triage-based CS have significant benefits including shorter LOS in the ED and decreased hospitalization rates, yet protocols have not been widely adopted (Ross et al., 2016). One landmark study describes ED wait times, lower acuity scores, and teaching structures within the hospital as factors that can hinder timely steroid administration (Bhogal et al., 2012). The Office of Disease Prevention and Health Promotion (ODPHP, 2018) identified reducing asthma-related ED visits and decreasing hospitalizations for children with asthma as two of their Healthy People 2020 goals and strives to further decrease these numbers to meet 2030 goals. While there are national guidelines that structure the assessment of and interventions for pediatric patients with asthma, the effectiveness of guideline implementation is variable. Still, more than one-half of children presenting to the ED with wheezing, shortness of breath, chest tightness, and coughing continue to be admitted for inpatient care (Rutman et al., 2016). Guidelines developed by the National Heart, Lung, and Blood Institute (NHLBI, 2007) recommend early administration of oral systemic CS but do not recommend a timeframe in which to administer them to optimize the effect.

Purpose and Rationale

ED healthcare practitioners (HCP) caring for pediatric patients with asthma are challenged to determine when hospitalization is necessary, yet a streamlined process for initiating care is lacking. Prior studies have demonstrated that nurse-initiated CS in triage decrease LOS (Sneller, et al., 2020). Additionally, there is a relationship between admission rate and the time elapsed between the intake of steroids (Bhogal et al., 2012). The implementation of a process to standardize and streamline the initiation of treatment has the potential to increase efficiency while reducing costs related to ED visits and admissions. The purpose of this paper is to identify how the administration of nurse-initiated, triage-based CS to pediatric pateints experiencing an asthma exacerbation affects LOS in the ED.

Background/Significance

The National Institute of Health (NIH) guidelines for asthma management were developed in 1992 and revised in subsequent years to optimize care; however, asthma remains a significant cause of morbidity and mortality in children.

Pediatric Patients with Asthma

Asthma accounts for more than 600,000 pediatric ED visits and 155,000 hospitalizations per year in the United States (Rutman et al., 2016). Nationally, 9.2% of children are diagnosed with the disease. By comparison, 10.9% of children in Arizona are impacted which accounts for more than 174,000 of Arizona's youth ages 17 years of age and younger (ALAA, 2016). Less than 50% of pediatric patients with a diagnosis of asthma in Arizona have an action plan established by their primary care provider (PCP) to help caregivers manage their child's disease and improve their quality of life (ALAA, 2016). Without an action plan, many caregivers turn to the ED when their child is having difficulty breathing. Infants and young children may not have a current diagnosis of asthma and still present with asthma-related symptoms. The preschool-age child is at risk for the greatest decline in lung function and has the poorest control over their asthma (Castro-Rodriguez et al., 2016). It is important to recognize symptoms and to provide timely steroids because the age for first asthma hospitalization continues to decrease over time (Castro-Rodriguez et al., 2016).

Steroid Administration in Triage

The Institute of Medicine (IOM) Committee on the Future of Emergency Care in the United States Health System has referred to ED crowding as "a national epidemic" (Hwang et al., 2016). Standing orders (SO) enable nurses to initiate care in a specific set of circumstances and have been shown to decrease LOS, time to critical interventions, improve throughput, and increase patient comfort and employee satisfaction (Hwang et al., 2016). These orders are approved by the medical director and are derived from common practice. Prior studies have shown nurse-initiated CS in triage, before physician assessment, decrease rate of return to the ED and LOS (Sneller et al., 2020).

Bekmezian et al. (2013) found a higher ED census to be associated with delayed administration of CS for children with moderate to severe asthma exacerbations. The hourly visit pattern identified by Kang &Park (2015) in one day showed a bimodal distribution with census peaks from 10 a.m. to 11 a.m. and 8 p.m. to 9 p.m. Patient visit volumes may change over time, but they are important to be aware of to hone efficiency in care. A nurse-initiated asthma pathway that includes triage-based CS results in decreased time to CS delivery and, in turn, can decrease LOS. LOS is an important measure in the ED because it is a reflction of quality, safe, efficient, timely, and patient-centered care.

Current State

Administration of CS early in the care of patients with asthma has long been acknowledged as beneficial. While clinical guidelines recommend the administration of CS in children, the effectiveness of clinical pathways to consistently reduce hospitalizations is unclear because recommendations for timing of administration of CS are variable. In a study by Bekmezian et al. (2013), for patients who arrived during a time when the ED census was higher, the likelihood of receiving timely CS was less compared to when the ED census was lower. For every 10 additional patients in the ED, the odds of receiving steroids within 60 minutes of arrival decreased by 21% (Bekmezian et al., 2013).

In a study by Zemek et al. (2012), 19% of children were admitted after provider-initiated CS, versus 11% admitted after nurse initiation in triage. Secondary outcomes of triage-based CS include improved efficiency of children receiving steroids, progression from moderate criteria to mild exacerbation status faster, and earlier time to discharge (Zemek et al., 2012). Prompt administration of CS is also shown to reduce the need for pediatric transfers from community hospitals to pediatric hospitals (Walls et al., 2017). The recurring theme in the literature is for children to receive CS as soon as possible because early intervention can decrease the overall LOS (Walls et al., 2017).

Internal Evidence

There are over 100,000 ED visits each year at a freestanding, 433-bed, children's tertiary care center. Wait time are longest during the months of December through February when the census is highest. Because it is a teaching facility, patients are seen individually by a resident, fellow, and then an attending physician before treatment and interventions are initiated. This model of teaching leads to a further delay in care for the patient because physicians in training first need to discuss their plan with the supervising doctor.

Data indicates when ED census and wait times are high, there is a delay in the initiation of critical treatment interventions that have the potential to reduce the number of hospitalizations. To combat this, the ED has a set of standing orders (SO) for nurses to initiate care in a timely fashion for patients who meet spsecific criteria. The projecet site has a SO for nurses to administer dexamethasone to patients experiencing an asthma exacerbation, however it was identified by one ED physician that nurses do not use the SO as often as there is the opportunity to. Numeric data reveals that when the census is high and nurses do not adhere to SO, wait times have delayed CS upwards of five hours. An intervention that encourages the use of the existing dexamathasone SO supports the goals identified on the state and national levels to reduce asthma related costs and hospitalizations.

PICO

How does the administration of corticosteroids in triage to pediatric patients with asthma affect length of stay?

Search Strategy

A thorough review of the literature was conducted to investigate the current best practices. Databases searched include the Cumulative Index of Nursing and Allied Health Literature (CINAHL), PubMed, Proquest, and Cochrane Library. These databases were chosen because they are known to provide a large collection of information relating to the topic. Keywords used to generate results included; *asthma, asthma exacerbation, wheezing, steroids, corticosteroids, dexamethasone, child, kid, pediatric, early administration, initiation, triage, admit, admission, hospitalization.* Exclusion criteria included studies that were not peer-reviewed, those involving patients older than 18 years, and works written in a language other than English. The majority of articles published before 2015 were excluded to retain the most recent research; however, some key studies and gray literature, such as the NIH guidelines, were kept as they provide formative information and recommendations. Management of asthma is a widely studied topic, reflected by the number of search results. Titles and abstracts of research articles were reviewed to include the most pertinent information. Twenty-five studies were selected for inclusion and addressed one, if not more, components of the PICO question.

CINAHL

An initial search of CINAHL was ran using the keywords *asthma OR wheeze, steroids OR corticosteroids, early intervention,* and *child OR pediatric OR kid.* A large return of 2,054 sources were listed. The above filters were applied to condense results and identify articles most relevant to the topic.

PubMed

A broad search of the PubMed database yielded a total of 512 sources when the keywords *corticosteroids, early administration,* and *asthma* were searched. The search was narrowed further by adding the filters *pediatric OR child* as well as *emergency OR triage,* which resulted in 364 articles.

Proquest

An initial search repeating the above keywords returned upwards of 40,000 results. Stricter filters were applied only to include articles published within the last three years, which decreased results to 629 articles. The information contained in many of the titles did not meet all of the inclusion criteria. Variations in key terms such as *steroids OR corticosteroids OR dexamethasone,* and *early intervention, protocol OR approach OR management* helped garner more useful titles.

Cochrane Library

The Cochrane Library is an esteemed database of systematic reviews that summarize and interpret the results of medical research. The above filters were used to search, and there was a return of zero articles published within the last five years. Although not included in this evaluation, search results were reviewed, and older articles supported early initiation of corticosteroids.

Critical Appraisal and Synthesis

Melnyk and Fineout-Overholt's (2011) rapid critical appraisal checklists were referenced to analyze and assess the quality of the 10 articles included in the literature review. The majority of studies were high-level evidence and retrospective in nature, comparing pre and post-intervention cohorts. Three studies included a time series design, and one study was a systematic review (see Appendix A, Table A1). Three studies did not reference funding sources, however of those that did, two reported grants awarded, two reported national funding, two reported departmental funding, and one study stated no external funding was received (see Appendix A, Table A1). No bias was identified during the review process. The variable sample sizes were attributed to the different hospital settings and overall organization size. The largest patient sample was 189,331 and the smallest was 261. One study was conducted in a community hospital, one study was conducted in the prehospital setting, and six studies were noted to take placed in large, tertiary, academic centers (see Appendix A, Table A1). The sample populations were largely homogenous. Inclusion criteria for most studies cited pediatric patients with asthma. Six studies' authors excluded patients younger than two to eliminate confounding wheezing with bronchiolitis (see Appendix A, Table A1). One group of authors limited their sample to include only patients less than six years of age. This study focused on preschool children. Five studies' authors reported inclusion criteria for patients until 18 years of age, two groups included patients until 17 years of age, and one group included patients until 14 years of age (See Appendix A, Table A1).

There was a moderate amount of homogeneity among the independent variables. Independent variables included the implementation of an asthma pathway, assigning a respiratory severity score (RSS), nurse administration of CS in triage, prehospital administration of CS, and administration of bronchodilators (see Appendix A, Table A1). The outcome measures were consistent across all studies and included decreasing time to CS administration, hospitalization rates, and LOS (see Appendix A, Table A2). Findings were similar in all studies, and all highlight the gross importance of timely care for pediatric patients with asthma. The statistically significant results and well structured, methodical designs indicate the findings and conclusions from the research are reliable.

Evidence as Influence for Project

The literature is overwhelming with evidence that shows timely CS decreases LOS in pediatric patients with asthma. A timeframe in which CS should be administered for optimal outcomes is unclear; however, many studies state within one hour is ideal. Statistics from the literature support that a goal of 60 minutes is achievable. The homogeneity of samples in the literature suggests that triage-based CS would benefit the patients with asthma exacerbations at the project site. Regardless of the setting, taking a proactive approach in recognizing the symptoms of an asthma exacerbation decreases the need for further treatment (see Appendix A, Table A2). This translates into timely CS being effective in different settings such as urgent cares and community hospitals. A structured approach to the care of patients with asthma decreases the amount of time required for a patient to receive care and is a helpful guide for HCP and nurses in the ED (see Appendix A, Table A2). Recommendations suggest teams should create or modify an asthma pathway that incorporates nurse administration of CS in triage.

Conceptual Framework and EBP Model

The Plan, Do, Study, Act (PDSA) cycle was selected to guide this quality improvement project. During the planning stages of the intervention goals for improvement are set, predictions are made about what will happen, and decisions about what data to gather are made (see Appendix B, Figure B2). A multidisciplinary team including pediatric nurses and HCPs, a pharmacist, respiratory therapist, ED nurse educator, and nursing manager convened to identify currents barriers to nurses using the SO. The project was supported by department administration and the physician group. The key process improvement identified was the need for re-education of nursing staff on the SO when it should be used. During the “do” part of the cycle, the plans are carried out, problems encountered are documented, and data continues to be gathered (see Appendix B, Figure 2). One large barrier noted by nurses is the ED Omnicells only stock dexamethasone tablets, and it is time consuming to crush pills and mix in syrup during high census times. During the “study” phase, data is fully analyzed and compared to predictions. During the “act” phase, careful consideration of changes that should take place during the next cycle are made. If no changes are identified, the intervention can be rolled out (see Appendix B, Figure B2). Metrics can be measured, analyzed, and improved by using this model. Comparing pre and post-intervention data on time to CS administration and LOS will provide valuable information on the impact of a treatment protocol and the quality of care patients receive while in the ED.

The Precede-Proceed Program Planning Model was chosen to guide project implementation (see Appendix B, Figure B1). This framework specifies the steps that precede an intervention and suggests ways to proceed with its implementation and evaluation by thinking logically about the desired end point and working “backwards” to achieve that goal (Crosby, 2011). Key factors preceeding this intervention include predisposing factors such as the project site location in a large metropolitan area, caring for a large volume of patients, a significant amount of whom are considered vulnerable and lack access to primary care. Reinforcing factors include an existing culture where the SO for CS in not routinely implemented. Existing barriers of crushing pills and the urgency to see new patients in a busy emergency setting enable the current culture. Additionally, limited accountability by nursing leadership and HCP expectations reinforce the behavior.

The proceed stages of the project are the implementation and evaluation of the project. For the intervention to be implemented, ED nursing staff will administer CS in triage while adhereing to guidelines within the SO and document their assessment. To determine the effect of the intervention, the overall percentage of SO activations and LOS will be evaluated.

Methods

Ethical Considerations and Human Subject Protection

Organizational Institutional Review Board (IRB) approval was granted for the execution of this project. The IRB considered this project to be quality improvement and not human subject research. Education and reinforcement of existing departmental protocols presented minimal risk because the SO were put in place to fulfill the standard of care for pediatric patients experiencing an asthma exacerbation. A waiver of consent was submitted and data obtained from the electronic health record (EHR) remained on locked workstations inside the organization.

Study Setting

The ED is part of a large, freestanding, children's medical center in the Southwestern United States with an annual volume of over 100,000 patients. Pediatric HCPs staff the department 24 hours per day and have the support of pediatric nurses and dedicated respiratory therapists and pharmacists. The organization is home to a large multitude of specialists including pulmonology, and coupled with its central location, make it a popular center to receive transfers from urgent cares and community hospitals around the state. Athough the organization has several satellite locations, the ED at the main hospital campus will be the only site for the project.

Population and Timeline

Patients were included in the project if they presented to the ED with a chief complaint of difficulty breathing and met the criteria listed in the ED standing order set during the months of December 2020-February 2021.

- Inclusion Criteria *per ED Standing Orders* (patients must meet all three)
    - I. History of (at least one):
        1. Asthma or reactive airways (by patient or parental report)
        2. More than one episode of wheezing
    - II. AND on physical exam have wheezing and any of:
        1. Tachypnea
        2. Hypoxia
        3. Retractions
        4. Nasal flaring
        5. Accessory muscle use
    - III. AND Age >12 months
- Exclusion Criteria:
    - I. Congenital heart disease or suspected congestive heart failure
    - II. Allergy to dexamethasone
    - III. Steroid use within <24 hours
    - IV. RSS 11-15 (indicating severe respiratory distress)

Intervention

Education was delivered to nursing staff beginning August 2020 on the inclusion and exclusion criteria listed within the existing SO for nurse-initiated CS, the importance of early CS, and the benefits of administering CS in triage. Education reinforced that patients meeting criteria would have CS ordered in triage and delivered by nurse responsible for patient care at the time that medication is available. If the patient qualifies, a single dose of 0.6 mg/kg of dexamethasone (maximum dose 16mg) will be administered orally. If the patient is roomed immediately, the bedside nurse will deliver CS and document time of administration. If no room is immediately available, the triage nurse is responsible. Education was delivered in bimonthly staff meetings, through departmental newsletters, shift huddles, and competency review days.

Data Collection

Baseline data was extracted from a retrospective review of charts for three months, from December 2019 through February 2020 (n=256). Ongoing collection of prospective data took place from December 2020 through February 2021 (n=44). Charts were identified through the organization's Reports tool that allows users to filter charts by searching specific International Classification of Disease (ICD) codes. The codes searched were J45.21 (mild intermittent asthma with [acute] exacerbation), J45.31 (mild persistent asthma with [acute] exacerbation), J45.41 (moderate persistent asthma with [acute] exacerbation), and J45.51 (severe persistent asthma with [acute] exacerbation). Charts tagged with these ICD codes were reviewed for critieria that warrants nurse-initiated CS, if a nursing RSS score was documented, and whether nursing staff of ED physician or NP ordered CS.

Data points collected for evaluation of outcome measures included chief complaint, time of arrival, time to CS administration, and time to discharge. Data points gathered were plotted in a data library using Microsoft Excel. The averages for the individual metrics of time of arrival, time to CS administration, and LOS were tracked. Time to CS administration was defined as the span of time between patient arrival and time to CS delivery. LOS was defined as the span of time between patient arrival and time to discharge order entry.

Results

Descriptive Data and Data Analysis Procedures

The correlation between time to CS administration and the secondary outcome of LOS was calculated using descriptive statistics. A two-tailed Mann-Whitney *U* test was performed to compare LOS between the months of December and January, respectfully, from both sets of data. A two-tailed independent sample *t*-test was used for the February samples due to decreased sample size.

Results

This project demonstrated a significant decrease in time to CS administration and overall LOS without an increase in the activation of the SO by nurses. Time to CS decreased from an average of 98.6 minutes to 57.6 minutes. LOS decreased from an average of 259.3 minutes to 169.6 minutes. Times subsequently decreased as a result of a reduced census because of COVID-19.

Statistical Significance

For the month of December, the result of the two-tailed Mann-Whitney *U* test was significant at $p = .003$. The mean rank for the pre-intervention group was 65.91 and the mean rank for the post-intervention group was 42.14. This suggests that the distribution of the two groups were statistically different. The median for the pre-intervention group was significantly larger at 239.5 compared to the post-intervention group at 173.

For the month of January, the result of the two-tailed Mann-Whitney *U* test was significant at $p = .002$. The mean rank for the pre-intervention group was 53.89 and the mean rank for the post-internvetion group 31.24, also suggesting that the distribution of the two groups for the month of January were statistically different. The median for the pre-intervention group was significantly larger at 247 than the post-intervention group at 155.

For the month of February, the result of the two-tailed independent samples *t*-test was significant at $p < .001$. This finding also suggests the mean of of the February groups were statistically different.

Clinical Significance and Impact

Although largely skewed due to an unexpected pandemic, this project demonstrated that timely CS delivery decreases LOS. Without the limitations of COVID-19, triage-based CS offer the potential for increased safety for patients waiting. When triage nurses identify an opportunity to intervene early, it can spare patients and HCPs the chaos and urgency that ensues when a patient suddenly decompensates. Timely CS administration can decrease the need for hospital transfers, admissions, repeated bronchodilator treatments, and invasive procedures such a peripheral intravenous access or intubation (see Appendix A, Table A2). Additionally, a successful intervention could save families and the organization hundreds to thousands of dollars in treatment that may be required when care is delayed. One study cites the cost of an ED visit for asthma as \$480 and the cost of an asthma-related hospitalization as \$2835 (Ross et al., 2016).

The impact of poorly managed asthma is far-reaching. Stakeholders need to be actively engaged in the quality improvement project. Discharging patients from the ED when it is safe allows nurses and HCPs an opportunity to educate families regarding the importance of primary care visits. PCPs can teach asthma management strategies and establish asthma action plans to help prevent exacerbations that require a trip to the ED. In turn, this can help support the Healthy People 2020 goal of reducing asthma related ED visits (ODPHP, 2018).

Sustainability

Numeric data demonstrates a positive correlation between time to CS and LOS, however quantitative and qualitative data are both vital in regard to the sustainability of the intervention. The quantitative data obtained from this project can prove to upper administration the potential for cost savings for the organization. While pharmacy was unable to stock an oral solution of dexamethasone due to cost restrictions, cost-savings may, in turn, yield funds to stock liquid CS on formulary. This would facilitate ease of administration and contribute to sustainability.

However, without buy-in from the point-of-service, the intervention will not be long-lasting. Although COVID-19 minimized the opportunity for nurses to give CS in triage during the project timeline, when the typical winter census resumes, nurses can be surveyed to assess their feelings of feasibility towards administering CS in triage when the waiting room is busy. The survey should also include open-ended questions for feedback, and suggestions for improvement as recommended by the PDSA cycle.

The expectation for nursing staff to initiate SO and established protocols in other circumstances (e.g., sepsis, neonatal fever) is vocalized by management and physicians, and metrics are tracked and shared with staff to keep on par. Ongoing encouragement for nursing to adhere to triage-based CS can foster accountability contribute to sustainability as well.

Discussion

Summary, Conclusions, and Recommendations

Timely administration of CS reduces a patient's overall LOS in the ED. Standardization of nurse-initiated, triage-based CS can increase the efficiency of care and has the potential to reduce costly hospitalizations that result from delayed treatment. It is important for other institutions to note that nurse-initiated CS does not preclude patients from other necessary interventions and can benefit patients in a variety of settings. Lastly, sustainability is multifactorial and should also include acountabilty components.

Limitations and Barriers

The greatest limitation encountered was COVID-19. Pandemic precautions greatly reduced ED census which minimized the opportunity to activate the SO in triage because of no wait time to see a provider. The inability to obtain an oral liquid solution of dexamethasone will be a hinderance when wait times increase.

Other limitations included the restriction of charts to include only those with a chief complant of difficulty breathing. This limited sample size, however difficulty breathing was selected because it is an obvious red flag for nurses to inquire about asthma history and perform subsequent assessments. For a larger sample, other chief complaints (e.g. cough) can be included if patients meet all criteria. Additionally, this project being carried out in a single department limits generalizability, however, results are consistent with the literature.

Finally, the use of the EHR as a data source revealed some documentation as lacking. One drawback to relying on the EHR as a source of data is that, occasionally, data can be incomplete or missing (Saczynski et al., 2013). In some cases the nurse in triage did not document an assessment, therefore the initiation of CS, or lack thereof, could not be validated.

The researcher can review the history and physical documented by the ED physician or nurse practitioner but would have to take into account the patient's wait time and the potential for deterioration while waiting. While some limitations exist, EMRs contain an abundance of high-quality clinical data and outcomes that are readily available for interpretation (Saczynski et al., 2013).

Recommendations for Further Research

With administration of CS in triage, there may be an increased number of patients who leave without being seen (LWBS). This could happen when families feel reassured knowing they have been medicated and decide not to wait any longer. Because of very minimal wait times during the pandemic, LWBS rates for the small, post-intervention sample were insignificant. However, this would be an opportunity for further research when typical census resumes because an increase in patients who LWBS can result in revenue loss for the organization.

A qualitative survey that inquires whether triage-based CS lead to increased feelings of nurse safety in a full waiting room and contribute to provider satisfaction regarding efficiency of care may provide additional insight to how to maintain consistent SO use.

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Appendix A

Evaluation and Synthesis Tables

Table A1

Evaluation Table Quantitative Studies

Citation	Conceptual/ Theoretical Framework	Study Design/ Method	Sample/Setting	Major Variables and Definitions	Measurement of Variables	Data Analysis	Findings/Results	Decision for Use
Bekmezian et al., (2015) Clinical Pathway Improves Pediatrics Asthma Management in the Emergency Department and Reduces Admission **Country:** United States **Funding:** NIH/NCRR UCSF-CTSI Grant Number	Health Belief Model or Social Economical Model inferred	Prospective cohort study	n=1249 **Setting:** Urban, academic tertiary care ED with 33 beds and an annual census of approximately 34,000 adult and 6,000 pediatric patients serving an adult and children's hospital. **Inclusion Criteria:** patients ≤21YOA with a moderate-severe asthma exacerbation defined as a visit	**IV:** Asthma clinical pathway **DV:** Time to CS administration	**Primary outcome measure**: Percentage of visits that received CS in under 60 minutes. **Secondary outcome measures:** ED LOS and disposition	Univariate LR models used for primary and secondary outcomes. Multivariable LR models to control for age, insurance, fever, tachypnea, time of arrival and ED patient volume at the hour of patient arrival. Separate multivariable LR models developed for each outcome measure. A 2-	Administration of corticosteroids within 1 hour of ED arrival (45% vs 18%, OR 3.5; CI 2.50–4.90) and overall corticosteroid administration occurred more frequently (96% vs. 78%, OR 6.35; CI 3.17–12.73) post-intervention. The proportion of visits with >1 BD dose received within 1 hour of ED arrival was higher (36% vs 24%, OR 1.65;	**Level of Evidence:** IV **Strengths:** Success rate significantly higher than national average (98% CS administration rate compared to 69%), AP decreased treatment delays due to young age (<2yrs) **Weaknesses:** Single center study in general ED, maybe less generalizable.

AP-Asthma protocol; AUC-Area under the receiver operating characteristic curve; β-agonist- Beta agonist; BD- Bronchodilators; CI-Confidence interval; CS-Corticosteroids; CXR-Chest radiograph; DB-double blind; DV- Dependent variable; Dx- Diagnosis; EBP-Evidence based practice; ED-Emergency Department; EHR-Electronic health record; EMS-Emergency Medical Services; GEE- Generalized estimating equations; IB-Ipratropium bromide; ICD-9-International Classification of Diseases, 9th Revision; ITS-Interrupted time series; ICU-Intensive care unit; IV: Independent variable; LASSO- Least absolute shrinkage and selection operator; LOS- Length of stay; LR-Logistic regression; n- Sample size; MA-Meta analysis; MD- Mean difference; MLA- Machine learning approach; MPI-Modified Pulmonary Index; n-Sample size; NIH-National Institutes of Health; OCS-Oral corticosteroids; OR-odds ratio; PAS- Pediatric Asthma Score; PIV-Peripheral intravenous; Pox-Peripheral oxygen; Pre-k-preschoolers; QI-Quality improvement; RCS-Respiratory Clinical Score; RCT-Randomized clinical trial; RR-Risk ratios; SD-Standard deviation; SS-Statistically significant; YOA-Years of age

Citation	Conceptual/ Theoretical Framework	Study Design/ Method	Sample/Setting	Major Variables and Definitions	Measurement of Variables	Data Analysis	Findings/Results	Decision for Use
UL1 RR024131. **Bias:** None			where the primary ED diagnosis was asthma (ICD-9 code 493.xx) and the patient required ≥2 (or continuous BD treatments. **Exclusion Criteria:** Only one BD treatment was required. Patients who received CS within 24 hours prior to their ED visit.			tailed p value of <0.05 was considered significant. Performed interrupted time series analysis by fitting separate linear trends to the data in the post-intervention and control periods to confirm that any change in the primary outcome measure was related to the intervention rather than overall unrelated trends.	CI 1.23–2.12) in the post-intervention group. CXRs were performed less often (27% vs 42%, OR 0.7; CI 0.52–0.94). Hospital admissions decreased in the post-intervention group (13% vs. 21%, OR 0.53; CI 0.37–0.76). ICU admission rate and ED LOS (for non-admitted patients) were unchanged.	**Conclusions:** Implementing an evidence-based clinical pathway was associated with a doubling of the receipt of corticosteroids within 1 hour of ED arrival and a subsequent reduction in the hospital admission proportions by half in children with moderate-severe asthma exacerbations
Castro-Rodriguez et al., (2016) Efficacy of OCS in the	Health Belief Model - inferred	**Design:** Systematic review with MA **Purpose:** To evaluate the	n=11 RCTs Five electronic databases were searched for all placebo-	**IV1:** OCS given to pre-k **IV2:** placebo **D1:** Hospital admission	Retrospective study reviews	Outcomes were pooled using MD (inverse variance method) or Mantel–	**Effect on hospital admission**: RR:1.26; 95%CI: 0.45–3.52, I^2 1⁄4	**Level of Evidence:** Level I **Strengths:** Studies included in MA were randomized,

AP-Asthma protocol; AUC-Area under the receiver operating characteristic curve; β-agonist- Beta agonist; BD- Bronchodilators; CI-Confidence interval; CS-Corticosteroids; CXR-Chest radiograph; DB-double blind; DV- Dependent variable; Dx- Diagnosis; EBP-Evidence based practice; ED-Emergency Department; EHR-Electronic health record; EMS-Emergency Medical Services; GEE- Generalized estimating equations; IB-Ipratropium bromide; ICD-9-International Classification of Diseases, 9th Revision; ITS-Interrupted time series; ICU-Intensive care unit; IV: Independent variable; LASSO- Least absolute shrinkage and selection operator; LOS- Length of stay; LR-Logistic regression; n- Sample size; MA-Meta analysis; MD- Mean difference; MLA- Machine learning approach; MPI-Modified Pulmonary Index; n-Sample size; NIH-National Institutes of Health; OCS-Oral corticosteroids; OR-odds ratio; PAS- Pediatric Asthma Score; PIV-Peripheral intravenous; Pox-Peripheral oxygen; Pre-k-preschoolers; QI-Quality improvement; RCS-Respiratory Clinical Score; RCT-Randomized clinical trial; RR-Risk ratios; SD-Standard deviation; SS-Statistically significant; YOA-Years of age

Citation	Conceptual/ Theoretical Framework	Study Design/ Method	Sample/Setting	Major Variables and Definitions	Measurement of Variables	Data Analysis	Findings/Results	Decision for Use
Treatment of Acute Wheezing Episodes in Pre-K **Country:** United States **Funding**: Grant CI 03-2015 from the Division of Pediatrics and grant HL125666 from the NIH. **Bias:** None		effectiveness of (OCS) compared to placebo in pre-k presenting with acute asthma/wheezing exacerbations	controlled, RCTs of OCS in children <6 years of age presenting with recurrent wheezing/asthma exacerbations of any severity.	**D2:** Hospital LOS **D3:** Additional course of CS **D4:** Unscheduled Visits		Haenszel RR. Estimate precision was quantified by 95% CI. Heterogeneity was measured by the I^2 test[15] (25% absence of bias; 26–39% unimportant; 40–60% moderate; and 60–100% substantial bias). A fixed-effects model was used when there was no evidence of significant heterogeneity in the analysis. MA was performed with the Review Manager 5.3.5 software.	67%, P 1⁄4 0.66 (no difference) **Additional course of steroids:** RR: 0.57; 95%CI; 0.40-1.34 (either nonsignificant or need additional steroids) **Unscheduled visits: N**o significant statistical difference between OCS and placebo RR: 0.73; 95%CI: 0.35–1.52; I^2 1⁄4 54%, P 1⁄4 0.11 **Hospital LOS:** No reported differences	DB, placebo controlled. **Weaknesses:** Pre-k age group has highest rate of non-adherence to treatment, doesn't consider setting of OCS administration. **Conclusions:** Use of OCS in pre-k. Current evidence inadequate to form any broad conclusions about OTC in pre-k.
Dondi et al., (2017)	Health Belief Model-inferred	**Design:** Retrospective analysis	n=603	**IV1:** Patients <6yrs **IV2:** Patients >6yrs	**Primary outcome measure:**	A descriptive analysis was performed for continuous	The median age of the patients was 3.1 YOA (range: 2	**Level of Evidence:** IV

AP-Asthma protocol; AUC-Area under the receiver operating characteristic curve; β-agonist- Beta agonist; BD- Bronchodilators; CI-Confidence interval; CS-Corticosteroids; CXR-Chest radiograph; DB-double blind; DV- Dependent variable; Dx- Diagnosis; EBP-Evidence based practice; ED-Emergency Department; EHR-Electronic health record; EMS-Emergency Medical Services; GEE- Generalized estimating equations; IB-Ipratropium bromide; ICD-9-International Classification of Diseases, 9th Revision; ITS-Interrupted time series; ICU-Intensive care unit; IV: Independent variable; LASSO- Least absolute shrinkage and selection operator; LOS- Length of stay; LR-Logistic regression; n- Sample size; MA-Meta analysis; MD- Mean difference; MLA- Machine learning approach; MPI-Modified Pulmonary Index; n-Sample size; NIH-National Institutes of Health; OCS-Oral corticosteroids; OR-odds ratio; PAS- Pediatric Asthma Score; PIV-Peripheral intravenous; Pox-Peripheral oxygen; Pre-k-preschoolers; QI-Quality improvement; RCS-Respiratory Clinical Score; RCT-Randomized clinical trial; RR-Risk ratios; SD-Standard deviation; SS-Statistically significant; YOA-Years of age

Citation	Conceptual/ Theoretical Framework	Study Design/ Method	Sample/Setting	Major Variables and Definitions	Measurement of Variables	Data Analysis	Findings/Results	Decision for Use
Acute Asthma in the Pediatric ED: Infections are the Main Trigger of Exacerbations **Country:** Italy **Funding:** Not stated **Bias:** None		**Purpose:** To analyze the differences among age groups in terms of triggering factors and seasonality to identify if there are any patients' groups which are more at risk of severe exacerbations and hospitalizations	394 males, 209 females **Inclusion Criteria:** Children aged 0–14 YOA who were visited for acute asthma from 1/1/16-12/31/16 Pediatric ED of S. Orsola-Malpighi University Hospital of Bologna, Italy. All the patients with a dx of "acute asthma," "wheezing bronchitis," and "bronchospasm" were included.	**DV1:** Age **DV2:** Etiology **DV3:** Previous asthma/wheezing diagnosis **DV4:** Triage code **DV5:** Severity of exacerbation	Retrospective chart reviews	variables (median, 25th and 75th percentiles). Data distribution was checked using MedCal Statistical Software. The associations between qualitative variables were evaluated with Chi-square test. Results were deemed as significant for $p < .05$. STATA 7.0 was used for the analysis.	months–14 YOA). 459 patients < 6 YOA (median 2.1 YOA; $n = 206 <$ 2 YOA; $n = 253$ ≥ 2 YOA and <6 YOA), while the rest of them 24% were school-aged children and adolescents (median 8.7 YOA). At triage, 15.6% were given white color tag, 46.8% green, 37.3% yellow, 0.3% red. Pox (SpO2) upon arrival was <92% in 5.3% of cases, 92–95% in 34.4%, and >95% in 60.2%. The severity was classified as mild 56%, moderate 39%, and severe 4%. Most episodes in children <6 years had infectious	**Strengths:** Highlights differences in asthma exacerbations between pre-k and school age children **Weakness:** Retrospective, single center study over only 1 year. All ages included, however those <12months may have had confounding wheezing (Bronchiolitis) **Conclusions:** Infections and allergy are the most frequent triggers in asthma exacerbations

AP-Asthma protocol; AUC-Area under the receiver operating characteristic curve; β-agonist- Beta agonist; BD- Bronchodilators; CI-Confidence interval; CS-Corticosteroids; CXR-Chest radiograph; DB-double blind; DV- Dependent variable; Dx- Diagnosis; EBP-Evidence based practice; ED-Emergency Department; EHR-Electronic health record; EMS-Emergency Medical Services; GEE- Generalized estimating equations; IB-Ipratropium bromide; ICD-9-International Classification of Diseases, 9th Revision; ITS-Interrupted time series; ICU-Intensive care unit; IV: Independent variable; LASSO- Least absolute shrinkage and selection operator; LOS- Length of stay; LR-Logistic regression; n- Sample size; MA-Meta analysis; MD- Mean difference; MLA- Machine learning approach; MPI-Modified Pulmonary Index; n-Sample size; NIH-National Institutes of Health; OCS-Oral corticosteroids; OR-odds ratio; PAS- Pediatric Asthma Score; PIV-Peripheral intravenous; Pox-Peripheral oxygen; Pre-k-preschoolers; QI-Quality improvement; RCS-Respiratory Clinical Score; RCT-Randomized clinical trial; RR-Risk ratios; SD-Standard deviation; SS-Statistically significant; YOA-Years of age

Citation	Conceptual/ Theoretical Framework	Study Design/ Method	Sample/Setting	Major Variables and Definitions	Measurement of Variables	Data Analysis	Findings/Results	Decision for Use
							etiology (95% versus 56% in children ≥6 years; *p* < .01), children ≥6 years 33% triggered by allergies (versus 3% in children <6 years; *p* < .01) Among the children previous asthma dx, 95 (49%) were ≥6 years and 63 of them (67%) were not using controller therapy (either for no prescription or for no use).	
Fishe et al., (2018) EMS Administration of CS for Pediatric Asthma **Country:** United States **Funding:** National Center for	Transtheoretical Model inferred	**Design:** Retrospective observational cohort study **Purpose:** To examine a statewide population of pediatric asthma patients to determine the effects of EMS administration of	n= 3,812 Patients 2-18 YOA, identified from Florida's EMS Tracking and Reporting System database, transported by EMS with initial impression of respiratory distress and administered	**IV:** EMS administration of CS - Scene and transport time - Systolic and diastolic blood pressure - Sex - EMS administration of IB, oxygen, magnesium sulfate, normal	**Primary outcome measure**: Rate of admission vs discharge: This study does not provide a clear description of how outcomes were measured. A large number of patients were lost to follow up because EMS	Multivariable logistic regression model Demographic, clinical, and EMS variables were analyzed using descriptive statistics. Continuous variables were	Of 11,667 patients that met the study's criteria for asthma exacerbation, only 3,812 has known ED outcomes. OR = 0.7, 95% CI= 0.5–0.9.	**Level of Evidence:** Level II (2) **Strength:** Large sample **Contributions:** This is the largest study linking EMS to ED outcomes.

AP-Asthma protocol; AUC-Area under the receiver operating characteristic curve; β-agonist- Beta agonist; BD- Bronchodilators; CI-Confidence interval; CS-Corticosteroids; CXR-Chest radiograph; DB-double blind; DV- Dependent variable; Dx- Diagnosis; EBP-Evidence based practice; ED-Emergency Department; EHR-Electronic health record; EMS-Emergency Medical Services; GEE- Generalized estimating equations; IB-Ipratropium bromide; ICD-9-International Classification of Diseases, 9th Revision; ITS-Interrupted time series; ICU-Intensive care unit; IV: Independent variable; LASSO- Least absolute shrinkage and selection operator; LOS- Length of stay; LR-Logistic regression; n- Sample size; MA-Meta analysis; MD- Mean difference; MLA- Machine learning approach; MPI-Modified Pulmonary Index; n-Sample size; NIH-National Institutes of Health; OCS-Oral corticosteroids; OR-odds ratio; PAS- Pediatric Asthma Score; PIV-Peripheral intravenous; Pox-Peripheral oxygen; Pre-k-preschoolers; QI-Quality improvement; RCS-Respiratory Clinical Score; RCT-Randomized clinical trial; RR-Risk ratios; SD-Standard deviation; SS-Statistically significant; YOA-Years of age

Citation	Conceptual/ Theoretical Framework	Study Design/ Method	Sample/Setting	Major Variables and Definitions	Measurement of Variables	Data Analysis	Findings/Results	Decision for Use
Advancing Translational Sciences of the National Institutes of Health **Bias:** None		CS on ED outcomes.	albuterol at least one time. **Exclusions:** Patients <2 YOA. to avoid confounding with wheezing from bronchiolitis. Patients not linked to database, classified as a trauma/injury, seizure, pregnancy-related complication, or interfacility transport.	saline, and subcutaneous epinephrine - PIV access -Electro-cardiogram **DV1:** **A**dmissions **DV2:** Discharges	did not know ED outcomes. There was no discussion of formal follow up process.	compared using Student's t-test and Kruskal-Wallis tests, as appropriate. Categorical variables were compared using the chi-square test or Fisher's exact test.		**Weaknesses:** CS were administered to the most severe patients (<10%), perhaps due to emergency medical services protocols authorizing only intravenous methylprednisolone Large number of unknown outcomes due to no structured follow-up process. **Conclusions:** EMS administration of CS is associated with *decreased* odds of ED discharge.
Kaiser et al., (2018) Effectiveness of Pediatric AP for Hospitalized Children: A Multicenter National Analysis	Health Belief Model-inferred	**Design:** Retrospective multicenter cohort study **Purpose:** To determine if clinical pathways affect care and outcomes for children	n = 189,331 (42 hospitals) **Inclusion Criteria:** Children age 2-17 YOA admitted for asthma from 2006 to 2015 in 42 children's hospitals.	**IV:** Implementation of AP **DV1:** LOS in days **DV2:** Admin of BD **DV3:** Admin of CS **D4:** CXR utilization	**Primary Outcome Measure:** Retrospective chart analysis of all the Pediatric ED visits for asthma	GEEs, cluster = hospital) with an ITS approach to determine the influence of pathway implementation on our primary and secondary outcomes	Clinical pathway implementation was associated with an 8.8% decrease in LOS (95% CI 6.7%-10.9%), 3.1% decrease in hospital costs (95% CI 1.9%-4.3%), increased odds of	**Level of Evidence:** II **Strengths:** Large sample size. Pathways were associated with total reductions of 22,000 hospital days and $18 000 000 in hospital costs.

AP-Asthma protocol; AUC-Area under the receiver operating characteristic curve; β-agonist- Beta agonist; BD- Bronchodilators; CI-Confidence interval; CS-Corticosteroids; CXR-Chest radiograph; DB-double blind; DV- Dependent variable; Dx- Diagnosis; EBP-Evidence based practice; ED-Emergency Department; EHR-Electronic health record; EMS-Emergency Medical Services; GEE- Generalized estimating equations; IB-Ipratropium bromide; ICD-9-International Classification of Diseases, 9th Revision; ITS-Interrupted time series; ICU-Intensive care unit; IV: Independent variable; LASSO- Least absolute shrinkage and selection operator; LOS- Length of stay; LR-Logistic regression; n- Sample size; MA-Meta analysis; MD- Mean difference; MLA- Machine learning approach; MPI-Modified Pulmonary Index; n-Sample size; NIH-National Institutes of Health; OCS-Oral corticosteroids; OR-odds ratio; PAS- Pediatric Asthma Score; PIV-Peripheral intravenous; Pox-Peripheral oxygen; Pre-k-preschoolers; QI-Quality improvement; RCS-Respiratory Clinical Score; RCT-Randomized clinical trial; RR-Risk ratios; SD-Standard deviation; SS-Statistically significant; YOA-Years of age

Citation	Conceptual/ Theoretical Framework	Study Design/ Method	Sample/Setting	Major Variables and Definitions	Measurement of Variables	Data Analysis	Findings/Results	Decision for Use
Country: United States **Funding:** Agency for Healthcare Research and Quality **Bias:** None		hospitalized with asthma	**Exclusion Criteria:** Children transferred into or out of the hospital were excluded due to inability to accurately determine LOS.27 Children were also excluded if they were discharged against medical advice, transferred to the ICU or died during the admission.	**D5:** IB administration >24hrs **D6:** Antibiotic administration			bronchodilator administration (OR 1.53[1.21-1.95]) and decreased odds of antibiotic administration (OR 0.93[0.87-0.99]) (n = 189 331). No associations between pathway implementation and CS administration, IB administration for >24 hours, CXR utilization, or 30-day readmission.	**Weaknesses:** Analysis only represents approximately 30% of pediatric hospitalizations nationally, not randomized, limited generalizability outside of similar healthcare settings (large tertiary care centers) **Conclusions:** Clinical pathways can decrease LOS, costs, and unnecessary antibiotic use without increasing rates of readmissions, leading to higher value care.
McIver et al., (2017) Improving Timeliness of	Health Belief Model-inferred	**Design:** Time series design with baseline data obtain from 5months prior.	n= 582 **Inclusion Criteria:** Children ages 2 to 18 YOA with	**IV:** Revision and implementation of new scoring system (PAS)and asthma	A statistical process control chart was used to monitor improvement for all measures.	A statistical process control chart was used to monitor improvement for all	Time to beta agonist decreased from 76 minutes to 27 minutes. Time to steroid admin decreased	**Level of Evidence:** Level II

AP-Asthma protocol; AUC-Area under the receiver operating characteristic curve; β-agonist- Beta agonist; BD- Bronchodilators; CI-Confidence interval; CS-Corticosteroids; CXR-Chest radiograph; DB-double blind; DV- Dependent variable; Dx- Diagnosis; EBP-Evidence based practice; ED-Emergency Department; EHR-Electronic health record; EMS-Emergency Medical Services; GEE- Generalized estimating equations; IB-Ipratropium bromide; ICD-9-International Classification of Diseases, 9th Revision; ITS-Interrupted time series; ICU-Intensive care unit; IV: Independent variable; LASSO- Least absolute shrinkage and selection operator; LOS- Length of stay; LR-Logistic regression; n- Sample size; MA-Meta analysis; MD- Mean difference; MLA- Machine learning approach; MPI-Modified Pulmonary Index; n-Sample size; NIH-National Institutes of Health; OCS-Oral corticosteroids; OR-odds ratio; PAS- Pediatric Asthma Score; PIV-Peripheral intravenous; Pox-Peripheral oxygen; Pre-k-preschoolers; QI-Quality improvement; RCS-Respiratory Clinical Score; RCT-Randomized clinical trial; RR-Risk ratios; SD-Standard deviation; SS-Statistically significant; YOA-Years of age

Citation	Conceptual/ Theoretical Framework	Study Design/ Method	Sample/Setting	Major Variables and Definitions	Measurement of Variables	Data Analysis	Findings/Results	Decision for Use
β Agonist and Corticosteroids **Country:** United States (North Carolina) **Funding:** UNC Chapel Hill Dept. of Pediatrics **Bias:** None		**Purpose:** primary initiative aims were to administer the first β-agonist treatment to children with wheezing symptoms within 20 minutes of arrival and CS within 60 minutes of arrival.	a history of asthma or recurrent wheezing who presented with wheeze, cough, upper respiratory infection symptoms, difficulty breathing, or hypoxia.	management pathway. **DV1:** Time to first β agonist treatment **DV2:** Time to steroids **DV3:** Rate of admission **DV4:** ED LOS	Primary outcomes focused on time to first β agonist treatment Secondary outcomes focused on ED LOS and admission rate. Key process indicators for adherence to pathway include assignment of PAS, administrations of CS for PAS ≥3 and ED LOS.	measures (DV) with control limits set at 3 SD and a shift of 7 or more points above or below the mean being indicative of special cause variation (equivalent to P < 0.01).	from 108 min to 49 min. Mean monthly admission rate remained at 19%. LOS did not increase as a result of initiative	**Strengths:** Large sample. **Weaknesses:** Inability to modify existing triage process. **Conclusions:** By standardizing asthma care and redesigning care delivery processes, care variation decreased and significant improvements in timeliness of β-agonist and steroid administration occurred. **Contributions:** Easily adaptable for healthcare systems that use standing order sets.
Miller et al., (2015) AP Improved Adherence to Evidence Based	Transtheoretical Model inferred	**Design:** Retrospective pre and post protocol cohort design.	n=261 (193 pre-protocol, 68 post protocol) **Inclusion Criteria:**	**IV:** Implementation of nurse-initiated AP **DV1:** Time to CS administration	IV measured by how many times nurses implemented protocol when MPI was >6 (22%).	Data were analyzed with statistics software. Continuous data are presented as	The improvement in the meantime to CS administration was not	**Level of Evidence** Level II **Strengths:** Results consistent with

AP-Asthma protocol; AUC-Area under the receiver operating characteristic curve; β-agonist- Beta agonist; BD- Bronchodilators; CI-Confidence interval; CS-Corticosteroids; CXR-Chest radiograph; DB-double blind; DV- Dependent variable; Dx- Diagnosis; EBP-Evidence based practice; ED-Emergency Department; EHR-Electronic health record; EMS-Emergency Medical Services; GEE- Generalized estimating equations; IB-Ipratropium bromide; ICD-9-International Classification of Diseases, 9th Revision; ITS-Interrupted time series; ICU-Intensive care unit; IV: Independent variable; LASSO- Least absolute shrinkage and selection operator; LOS- Length of stay; LR-Logistic regression; n- Sample size; MA-Meta analysis; MD- Mean difference; MLA- Machine learning approach; MPI-Modified Pulmonary Index; n-Sample size; NIH-National Institutes of Health; OCS-Oral corticosteroids; OR-odds ratio; PAS- Pediatric Asthma Score; PIV-Peripheral intravenous; Pox-Peripheral oxygen; Pre-k-preschoolers; QI-Quality improvement; RCS-Respiratory Clinical Score; RCT-Randomized clinical trial; RR-Risk ratios; SD-Standard deviation; SS-Statistically significant; YOA-Years of age

Citation	Conceptual/ Theoretical Framework	Study Design/ Method	Sample/Setting	Major Variables and Definitions	Measurement of Variables	Data Analysis	Findings/Results	Decision for Use
Guidelines for Pediatric Patients with Status Asthmaticus **Country:** United States **Funding:** "Departmental Funding" **Bias:** None		**Purpose:** To examine the effects on time to initial treatment and adherence to EBP for status asthmaticus after the implementation of an evidence-based, nurse-initiated pediatric AP	Asthma subjects age 2-17 YOA requiring continuous albuterol therapy were retrospectively identified through an electronic record search of respiratory care service documentation **Exclusions:** Not clearly stated. Only mention subjects requiring albuterol and that there are no specific criteria for albuterol therapy.	**DV2:** IB administration **DV3:** Adherence to NIH recommendations	All DV were evaluated by comparing post protocol results with pre-protocol data.	mean ± SD. Pre- and post-protocol values were compared with the unpaired *t* test for continuous variables and the Fisher exact test for categorical data as appropriate. $P < .05$ was considered statistically significant	statistically significant. Number of subjects who received BD within the a priori cutoff of 30 min (60% vs 77%, $P = .02$), at least one inhaled dose of IB (55% vs 87%, $P < .001$) NIH-recommended 3 doses of IB (14% vs 54%, $P < .001$)	other similar studies **Weaknesses:** Only subjects who received continuous albuterol were chosen for inclusion as a marker for status asthmaticus; however, there were no set criteria for continuous albuterol initiation Order set was initiated by triage nursing in 22% of cases. **Conclusions:** AP resulted in improved adherence to. NIH guidelines in children with status asthmaticus and improved efficiency in the administration of

AP-Asthma protocol; AUC-Area under the receiver operating characteristic curve; β-agonist- Beta agonist; BD- Bronchodilators; CI-Confidence interval; CS-Corticosteroids; CXR-Chest radiograph; DB-double blind; DV- Dependent variable; Dx- Diagnosis; EBP-Evidence based practice; ED-Emergency Department; EHR-Electronic health record; EMS-Emergency Medical Services; GEE- Generalized estimating equations; IB-Ipratropium bromide; ICD-9-International Classification of Diseases, 9th Revision; ITS-Interrupted time series; ICU-Intensive care unit; IV: Independent variable; LASSO- Least absolute shrinkage and selection operator; LOS- Length of stay; LR-Logistic regression; n- Sample size; MA-Meta analysis; MD- Mean difference; MLA- Machine learning approach; MPI-Modified Pulmonary Index; n-Sample size; NIH-National Institutes of Health; OCS-Oral corticosteroids; OR-odds ratio; PAS- Pediatric Asthma Score; PIV-Peripheral intravenous; Pox-Peripheral oxygen; Pre-k-preschoolers; QI-Quality improvement; RCS-Respiratory Clinical Score; RCT-Randomized clinical trial; RR-Risk ratios; SD-Standard deviation; SS-Statistically significant; YOA-Years of age

Citation	Conceptual/ Theoretical Framework	Study Design/ Method	Sample/Setting	Major Variables and Definitions	Measurement of Variables	Data Analysis	Findings/Results	Decision for Use
								rescue BD and CS therapy
Patel et al., (2018) A Machine Learning Approach to Predicting Need for Hospitalization for Pediatric Asthma Exacerbation at the Time of Emergency Department Triage **Country:** United States and United Kingdom **Funding:** Not stated **Bias:** None	Social Ecological Model inferred	**Design:** Retrospective analysis **Purpose:** To compare the performance of four common machine learning approaches to predict need for hospital-level care in pediatric asthma at the time of triage by combining available clinical data with information about weather, neighborhood characteristics, and community viral load.	n= 29,392 **Setting:** A large, academic, tertiary care, children's hospital and serves a predominantly African American population. The ED treats 5,000 to 7,000 ED visits for asthma each year, with 15% resulting in admission. **Inclusion Criteria:** all patient visits age 2-18 YOA with asthma exacerbation evaluated at two urban pediatric EDs affiliated	**IV:** MLA **DV:** Hospital admission	Collected data on demographic information, patient acuity in triage, vital signs, as well as weather information and community viral load as factors that could be used to predict hospitalization. Model performance was measured on the accuracy in predicting hospitalization in the test data set. For each model, an AUC was computed. Calibration was measured by reporting observed	Data randomly splint into an 80% training data set and a 20% test data set. Once data set was split, each feature was normalized so that it would have a zero mean and unit SD in the training data set. Normalization is required for logistic regressions with L1 (LASSO) regularization so that all variables have the same magnitude range. The	The mean (SD) age was 7 (4.2) years, 42% (12,328) were female, 77% (22,630) were non-Hispanic black, and 76% (22,350) had public insurance. A total of 4,957 (16.9%) of patient visits resulted in hospitalization The AUCs for each model were 1) decision tree, 0.72 (95% confidence interval [CI] = 0.66–0.77); 2) logistic regression, 0.83 (95% CI = 0.82–0.83); 3) random forests, 0.82 (95% CI = 0.81–	**Level of Evidence:** II **Strengths:** Large data set **Weaknesses:** Single center study; retrospective study means data limited to EHR. **Conclusion:** The gradient boosting machines model was the most accurate at predicting need for admission

AP-Asthma protocol; AUC-Area under the receiver operating characteristic curve; β-agonist- Beta agonist; BD- Bronchodilators; CI-Confidence interval; CS-Corticosteroids; CXR-Chest radiograph; DB-double blind; DV- Dependent variable; Dx- Diagnosis; EBP-Evidence based practice; ED-Emergency Department; EHR-Electronic health record; EMS-Emergency Medical Services; GEE- Generalized estimating equations; IB-Ipratropium bromide; ICD-9-International Classification of Diseases, 9th Revision; ITS-Interrupted time series; ICU-Intensive care unit; IV: Independent variable; LASSO- Least absolute shrinkage and selection operator; LOS- Length of stay; LR-Logistic regression; n- Sample size; MA-Meta analysis; MD- Mean difference; MLA- Machine learning approach; MPI-Modified Pulmonary Index; n-Sample size; NIH-National Institutes of Health; OCS-Oral corticosteroids; OR-odds ratio; PAS- Pediatric Asthma Score; PIV-Peripheral intravenous; Pox-Peripheral oxygen; Pre-k-preschoolers; QI-Quality improvement; RCS-Respiratory Clinical Score; RCT-Randomized clinical trial; RR-Risk ratios; SD-Standard deviation; SS-Statistically significant; YOA-Years of age

Citation	Conceptual/ Theoretical Framework	Study Design/ Method	Sample/Setting	Major Variables and Definitions	Measurement of Variables	Data Analysis	Findings/Results	Decision for Use
			with a single children's hospital between 1/1/12, and 12/31/15 that had received one or more doses of a β-agonist and CS. **Exclusion Criteria:** Patients who received diphenhydramine to avoid inclusion allergic reaction or anaphylaxis.		admissions versus expected admissions for each decile of predicted risk.	normalizing coefficients were then applied to the training data set.	0.83); and 4) gradient boosting machines, 0.84 (95% CI = 0.83–0.85)	
Rutman et al., (2016) Modification of an Established AP Improves Care **Country:** United States **Funding:** Not stated **Bias:** None	Health Belief Model or Transtheoretical Model inferred	**Design:** Time series design, QI **Purpose:** To determine the impact of a modified AP and order sets on the percentage of patients receiving evidence-based care and on the	n=5584 **Setting:** Tertiary, university-affiliated, 323-bed pediatric hospital with a dedicated pediatric ED (43,000 annual visits) **Inclusion criteria:**	**IV:** Implementation of modified AP (using RCS, renaming order sets) **DV1:** LOS **DV2**: Cost	Monitored the percentage of eligible asthma patients each month with an asthma order set activated. LOS <30minutes Cost data obtained from	For outcome measures (LOS and cost), ITS analysis was conducted by using segmented linear regression models	A statistically significant difference was found in the intercept for costs among those discharged from the ED ($59; *P* = .04) In this analysis of costs, the post-period slope had a *P* value of 0.08, which may	**Level of Evidence:** III **Strengths:** Analysis included 4yr of data, and results sustained for 2yr in post modification period. **Weaknesses:** Used RCS, rather than more widely used clinical tools which

AP-Asthma protocol; AUC-Area under the receiver operating characteristic curve; β-agonist- Beta agonist; BD- Bronchodilators; CI-Confidence interval; CS-Corticosteroids; CXR-Chest radiograph; DB-double blind; DV- Dependent variable; Dx- Diagnosis; EBP-Evidence based practice; ED-Emergency Department; EHR-Electronic health record; EMS-Emergency Medical Services; GEE- Generalized estimating equations; IB-Ipratropium bromide; ICD-9-International Classification of Diseases, 9th Revision; ITS-Interrupted time series; ICU-Intensive care unit; IV: Independent variable; LASSO- Least absolute shrinkage and selection operator; LOS- Length of stay; LR-Logistic regression; n- Sample size; MA-Meta analysis; MD- Mean difference; MLA- Machine learning approach; MPI-Modified Pulmonary Index; n-Sample size; NIH-National Institutes of Health; OCS-Oral corticosteroids; OR-odds ratio; PAS- Pediatric Asthma Score; PIV-Peripheral intravenous; Pox-Peripheral oxygen; Pre-k-preschoolers; QI-Quality improvement; RCS-Respiratory Clinical Score; RCT-Randomized clinical trial; RR-Risk ratios; SD-Standard deviation; SS-Statistically significant; YOA-Years of age

Citation	Conceptual/ Theoretical Framework	Study Design/ Method	Sample/Setting	Major Variables and Definitions	Measurement of Variables	Data Analysis	Findings/Results	Decision for Use
		efficiency of care provided.	children who presented to ED with asthma exacerbation from 9/1/09, to 10/1/13, aged 1-18 YOA, and eligible for the AP. Eligibility for AP use included having a primary ICD-9 dx code. **Exclusion criteria:** acute illness: pneumonia, bronchiolitis, or croup; chronic conditions such as cystic fibrosis and restrictive lung disease; congenital and acquired heart disease; airway issues such as vocal cord paralysis, tracheomalacia, and tracheostomy dependence; immune		administrative records.		suggest a marginal increase in costs for ED-only patients	may limit generalizability. Requirement for ICD-9 dx code could have excluded patient is incorrectly coded. **Conclusions:** Modification of a well-established AP and electronic order set for ED and inpatient management of asthma led to immediate and sustained improvements in provision of evidence-based care and efficiency without significantly affecting costs.

AP-Asthma protocol; AUC-Area under the receiver operating characteristic curve; β-agonist- Beta agonist; BD- Bronchodilators; CI-Confidence interval; CS-Corticosteroids; CXR-Chest radiograph; DB-double blind; DV- Dependent variable; Dx- Diagnosis; EBP-Evidence based practice; ED-Emergency Department; EHR-Electronic health record; EMS-Emergency Medical Services; GEE- Generalized estimating equations; IB-Ipratropium bromide; ICD-9-International Classification of Diseases, 9th Revision; ITS-Interrupted time series; ICU-Intensive care unit; IV: Independent variable; LASSO- Least absolute shrinkage and selection operator; LOS- Length of stay; LR-Logistic regression; n- Sample size; MA-Meta analysis; MD- Mean difference; MLA- Machine learning approach; MPI-Modified Pulmonary Index; n-Sample size; NIH-National Institutes of Health; OCS-Oral corticosteroids; OR-odds ratio; PAS- Pediatric Asthma Score; PIV-Peripheral intravenous; Pox-Peripheral oxygen; Pre-k-preschoolers; QI-Quality improvement; RCS-Respiratory Clinical Score; RCT-Randomized clinical trial; RR-Risk ratios; SD-Standard deviation; SS-Statistically significant; YOA-Years of age

Citation	Conceptual/ Theoretical Framework	Study Design/ Method	Sample/Setting	Major Variables and Definitions	Measurement of Variables	Data Analysis	Findings/Results	Decision for Use
			disorders; sickle cell anemia; and medically complex children					
Walls, et al., (2017) Improving Pediatric Asthma Outcomes in a Community ED **Country:** United States **Funding:** No external funding **Bias:** None	Health Belief Model	**Design:** Time series design, pre and post intervention, QI **Purpose:** To improve the care of their pediatric asthma patients by introducing an asthma score, increasing the proportion of patients receiving CS, decreasing time to CS administration, and decreasing the proportion of patients who needed transfer for additional care.	n=724 289 Baseline 435 post intervention **Setting:** ED that sees ~55 000 patients per year, of whom 20% are <18 years old. The community hospital does not have pediatric inpatient beds or pediatric specialists. **Inclusion Criteria:** if the provider documented a clinical impression of "wheezing,"	**IV:** Asthma score **DV1:** Transfers out for higher level of care	**Process measures:** Proportion of children who has asthma score recorded, the proportion who received steroids, and for those who received steroids, the time from triage arrival to steroid administration. **Outcome measures:** Proportion of children needing transfer or additional care. **Balancing measure:** Return ED visits within 7 days	Control limits set at 3 SD from the mean. To analyze return visits; proportions were compared before and after the intervention by using the χ^2 test. Our secondary analyses included calculation of odds ratios (ORs) and *P* values based on the χ^2 test for proportions and *P* values based on the 2-tailed *t* test for time analyses. A *P* value of	Mean time to steroids decreased significantly, from 196 to 105 minutes ($P < .001$). Significantly fewer patients needed transfer after guideline implementation (10% compared with 14% during the baseline period) (odds ratio 0.63; 95% confidence interval, 0.40–0.99).	**Level of Evidence:** IV **Strengths:** First study to document a QI collaborative between a tertiary care pediatric ED and a community ED in the United States. **Weaknesses:** Only 64% of patients had an asthma score recorded during the implementation period. Majority of patients who were assigned an asthma score had mild to moderate asthma (score of <4).

AP-Asthma protocol; AUC-Area under the receiver operating characteristic curve; β-agonist- Beta agonist; BD- Bronchodilators; CI-Confidence interval; CS-Corticosteroids; CXR-Chest radiograph; DB-double blind; DV- Dependent variable; Dx- Diagnosis; EBP-Evidence based practice; ED-Emergency Department; EHR-Electronic health record; EMS-Emergency Medical Services; GEE- Generalized estimating equations; IB-Ipratropium bromide; ICD-9-International Classification of Diseases, 9th Revision; ITS-Interrupted time series; ICU-Intensive care unit; IV: Independent variable; LASSO- Least absolute shrinkage and selection operator; LOS- Length of stay; LR-Logistic regression; n- Sample size; MA-Meta analysis; MD- Mean difference; MLA- Machine learning approach; MPI-Modified Pulmonary Index; n-Sample size; NIH-National Institutes of Health; OCS-Oral corticosteroids; OR-odds ratio; PAS- Pediatric Asthma Score; PIV-Peripheral intravenous; Pox-Peripheral oxygen; Pre-k-preschoolers; QI-Quality improvement; RCS-Respiratory Clinical Score; RCT-Randomized clinical trial; RR-Risk ratios; SD-Standard deviation; SS-Statistically significant; YOA-Years of age

Citation	Conceptual/ Theoretical Framework	Study Design/ Method	Sample/Setting	Major Variables and Definitions	Measurement of Variables	Data Analysis	Findings/Results	Decision for Use
			"asthma," or "bronchospasm.		from initial visit.	<.05 was considered significant.		Reports on benchmarks for the emergency care of children with asthma emphasize care of children with moderate to severe asthma. **Conclusions:** Utilizations of an asthma severity score streamlines care.

AP-Asthma protocol; AUC-Area under the receiver operating characteristic curve; β-agonist- Beta agonist; BD- Bronchodilators; CI-Confidence interval; CS-Corticosteroids; CXR-Chest radiograph; DB-double blind; DV- Dependent variable; Dx- Diagnosis; EBP-Evidence based practice; ED-Emergency Department; EHR-Electronic health record; EMS-Emergency Medical Services; GEE- Generalized estimating equations; IB-Ipratropium bromide; ICD-9-International Classification of Diseases, 9th Revision; ITS-Interrupted time series; ICU-Intensive care unit; IV: Independent variable; LASSO- Least absolute shrinkage and selection operator; LOS- Length of stay; LR-Logistic regression; n- Sample size; MA-Meta analysis; MD- Mean difference; MLA- Machine learning approach; MPI-Modified Pulmonary Index; n-Sample size; NIH-National Institutes of Health; OCS-Oral corticosteroids; OR-odds ratio; PAS- Pediatric Asthma Score; PIV-Peripheral intravenous; Pox-Peripheral oxygen; Pre-k-preschoolers; QI-Quality improvement; RCS-Respiratory Clinical Score; RCT-Randomized clinical trial; RR-Risk ratios; SD-Standard deviation; SS-Statistically significant; YOA-Years of age

Table A2

Synthesis Table

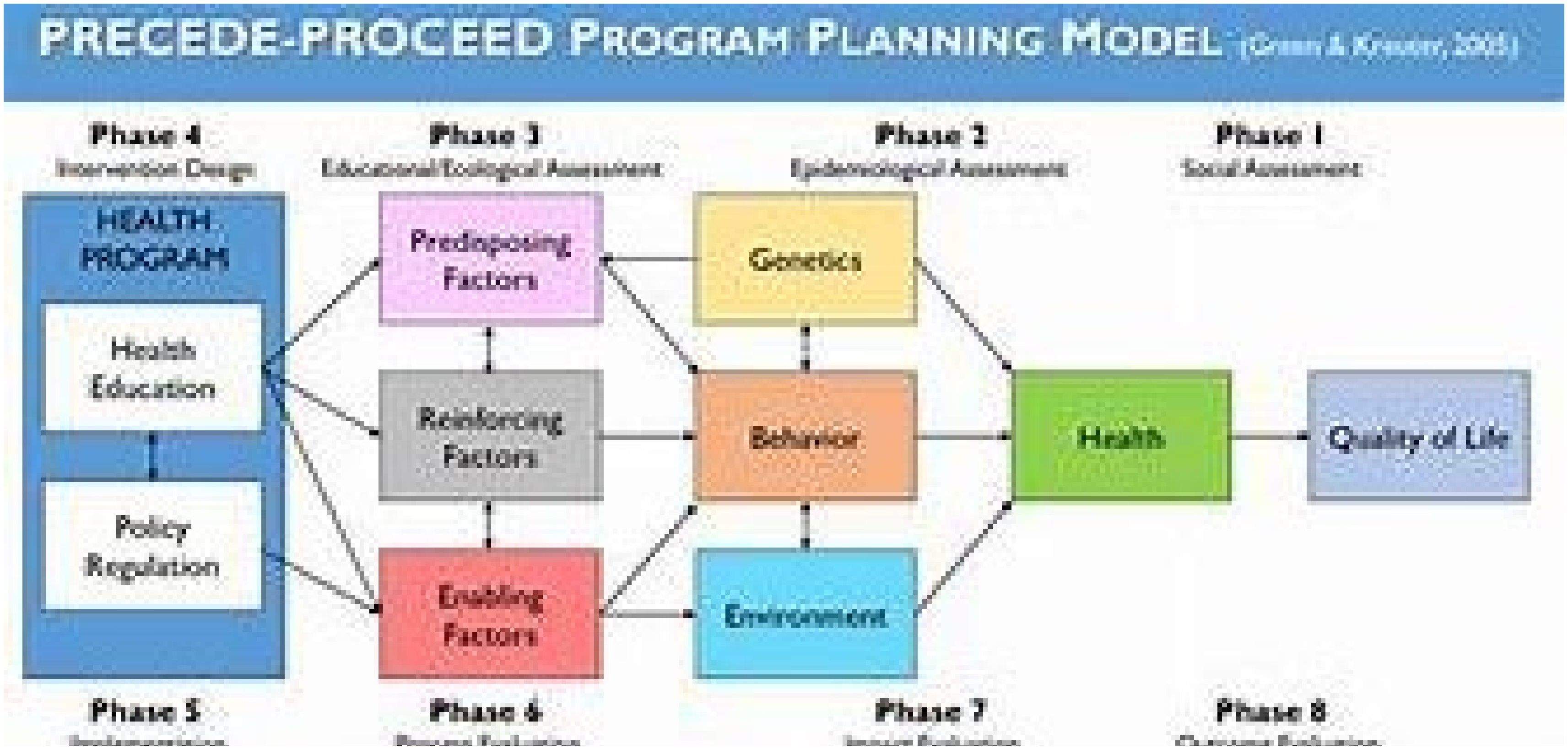
Author	Bekmezian et al.	Castro-Rodriguez et al.	Dondi et al.	Fishe et al.	Kaiser et al.	McIver et al.	Miller et al.	Patel et al.	Rutman et al.	Walls et al.
Year	2015	2016	2017	2018	2018	2017	2015	2018	2016	2017
Design/LOE	Prospective cohort study/IV	Systematic review with MA/I	Retrospective analysis/IV	Retrospective observational cohort study/II	Retrospective multicenter cohort study/II	Time series design, QI/II	Retrospective pre/post protocol cohort design/II	Retrospective analysis/II	Time series design, QI/III	Time series design, pre/post intervention, QI/IV
Study Characteristics										
Age range (YOA)	<21	<6	0-14	2-18	2-17	2-18	2-17	2-18	1-18	<18
Setting										
Tertiary Care/University Hospital	x	(systematic review)	x		Multi center analysis of 42 hospitals	x	x – inferred, not clearly stated	x	x	
Community Hospital										x
Prehospital				x						
Sample Size	1249	11 studies	603	3812	189331	582	261	29392	5684	724
Measurement Tools	Univariate and multivariate LR models	MD (inverse variance method) or Mantel–Haenszel RR	STATA 7.0	Multivariate LR models	GEEs	Statistical process control chart (unspecified)	Graph pad software		Segmented LR models	χ^2 test
IV - Interventions										
PAS					x	x				x
AP	x				x		x		x	
Nurse initiated protocol – CS in triage		x					x			
Prehospital CS administration				x						
Age of patient			x							
MLA								x		
DV – Outcomes Measured										

LOS		x		x	x	x			x	
Hospitalization		x		x		x		x		
CS administration	x	x			x	x	x			
Asthma triggers			x							
Discharges				x						
BD administration						x	x			
Adherence to national guidelines							x			
Cost					x				x	
Transfers										x

Appendix B

Figure B1

Precede- Proceed Framework



Green & Kreuter (2005).

Figure B2

PDSA Cycle

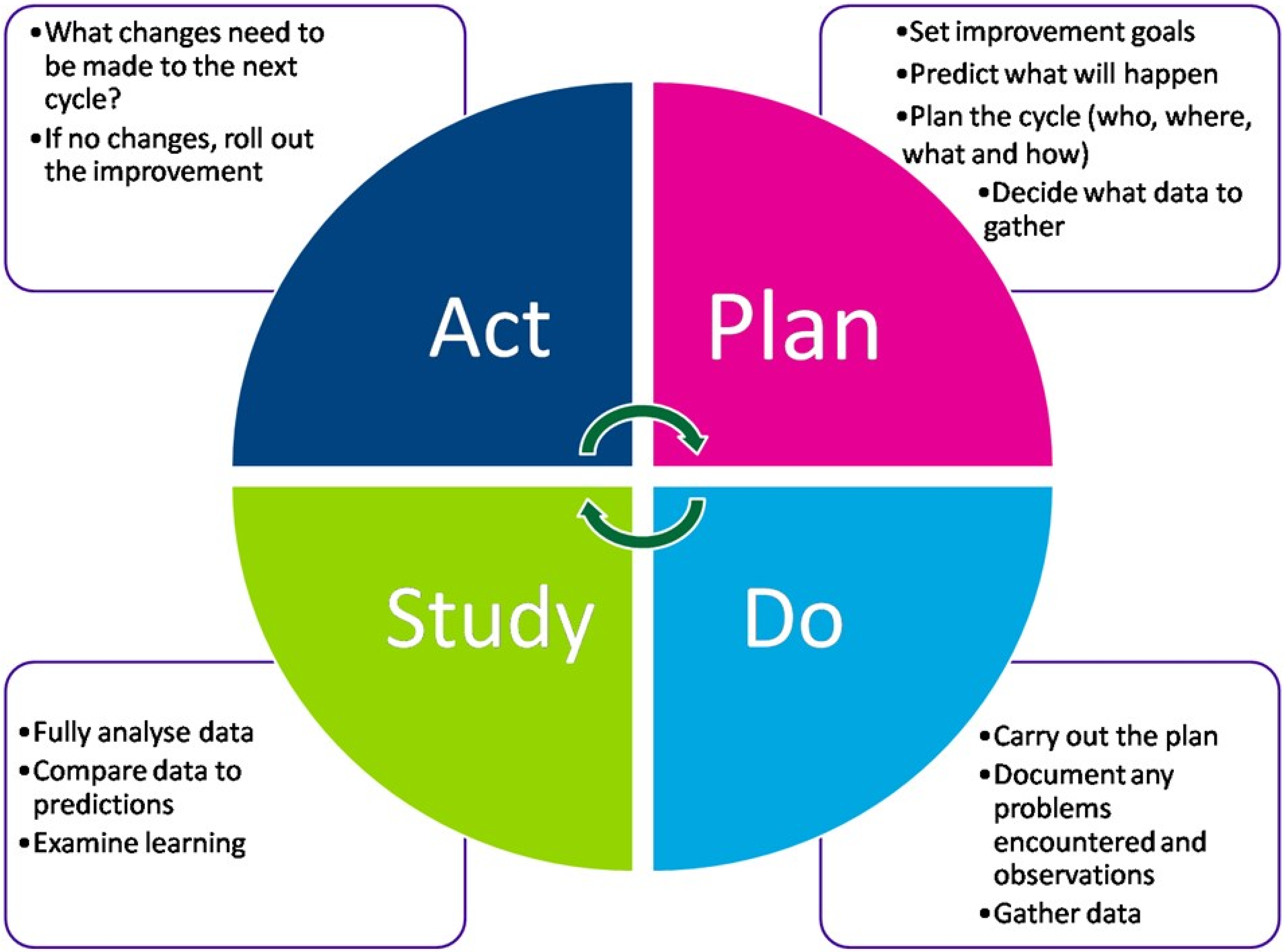


Figure 1. Nursing Administration of Dexamethasone in ED Triage to Pediatric Patients with Asthma

Goals: Decrease hospitalization rates in pediatric patients with asthma through early administration of corticosteroids (CS) in Emergency Department (ED) triage. **Objectives:** 1) Verify with ED physicians clear set of criteria for CS (dexamethasone) to be administered under standing orders by nurses in triage. 2) Discuss with pharmacy ability to stock CS in triage Omnicell. 3) Provide education to nurses at staff meetings on qualifying criteria, and benefits of CS in triage. 4) Analyze data provided by IT to determine how often standing orders were utilized and respective patient outcomes. 5) Present outcomes to staff; encourage sustainability. 5) Improve patient safety and outcomes while decreasing overall length of stay and hospitalization rates.

INPUTS	OUTPUTS		OUTCOMES		IMPACTS
	Activities	*Target*	*Short*	*Medium*	
<u>Key Staff</u> ED Nurses ED Physicians and Nurse Practitioners ED Pharmacy ED Manager IT Dept for EMR data collection <u>Clinical Partners</u> ED at Phoenix Children's Hospital <u>Funding Resources</u> None required at this time – considering IT time to gather data, Pharmacy tech time to stock Omnicell.	Meet with ED Physician to verify CS administration criteria. Meet with Pharmacy to discuss barrier to implementation and stocking CS in triage Omnicell. ED only has pills. Present education to nurses at staff meetings. Gather biweekly data and assess effectiveness and need for change in process.	Patients (On receiving end of intervention.)	Patients presenting to ED who meet criteria for administering CS using standing orders.	Consistently receive CS from triage RN.	Decreased time to CS administration. Increased patient safety in the ED waiting room (decreased risk for deterioration). Decreased time to patient disposition. Decreased overall length of stay. Decreased hospitalization rates. Improved patient outcomes. Cost savings for organization.
				Improvement in symptoms while waiting.	
		ED RNs (Responsible for implementing intervention.	Provide education and increase RN knowledge on benefit/indications of CS in triage.	Improve rates of standing order initiation. Administer CS in triage when patients need to wait.	
				Perception of increased safety in WR, able to see the impact of CS administration in triage to sustain intervention.	
		Pharmacy (Will impact sustainability of intervention).	Stock Triage Omnicell with CS (dexamethasone)	Pharmacy to compound liquid to facilitate easier CS administration (compared to pills).	
				Demonstrate continuous ability to stock CS in triage to ensure sustainability of intervention.	

Assumptions: 1) There will be a large number of pediatric patients experiencing asthma exacerbation requiring corticosteroids in triage. 2) Pharmacy will stock the triage Omnicell with dexamethasone. 3) Pharmacy will compound oral liquid to facilitate ease of nurses administering dexamethasone in triage. 4) There are limited absolute contraindications to dexamethasone. 5) ED nurses will take the time to administer dexamethasone when triage is busy and patients must wait. 6) Timely administration of CS will lead to improvement in symptoms and decrease time to disposition after being seen by ED physician or Nurse Practitioner. 7) Utilization of standing orders for CS in triage will improve patient outcomes, decrease hospitalization rates.