Acute Asthma Exacerbation Treatment and Impact in a Pediatric Emergency Department

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Acute Asthma Exacerbation Treatment and Impact in a Pediatric Emergency Department

Paige Barber and Sarah Jindoyan

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NSG 602 DNP Project Practicum

February 16, 2021
Introduction

Background and Significance

Asthma exacerbations can range from mild to severe and can eventually lead to respiratory arrest. According to the Centers for Disease Control and Prevention (2017), over 19 million people live with asthma in the United States; 5.5 million of those affected are under 18. Pediatric asthma exacerbations account for more than 1.8 million Emergency Department (ED) visits annually, and it is the leading cause for hospitalization in this patient population (Dexheimer et al., 2013). While children have a higher risk for morbidity and mortality, children who reside in urban areas, regardless of economic status or race, are at much greater risk for having a diagnosis of asthma (Aligne et al., 1999). Increased risk for asthma development in this population includes genetics, atopy, microbial exposure, and environmental factors (Ferrante & La Grutta, 2018). While asthma mortality is considered low throughout the life span, asthma mortality in children is strongly associated with the frequency of symptoms and hospital admissions (Ferrante & La Grutta, 2018). According to the American Academy of Pediatrics, in-hospital processes are also likely to contribute to disparities. Children from low socioeconomic status, with or without ethnic minority backgrounds, may have an increased risk of in-hospital mortality (McKay & Parente, 2019). Pediatric asthma has been labeled a global epidemic as the prevalence, morbidity, and mortality have significantly increased over the past forty years. While asthma is recognized as the most common chronic disease in children, issues of under-diagnosis and undertreatment persist (Serebrisky & Wiznia, 2019). Because of the severity of this issue, it is important to examine the current process in place and what steps can be taken to improve this process. This project will study adopting a new and highly intensive emergency department (ED)
asthma algorithm and determine its impact on hospitalization rates, ED length of stay (LOS), and discharge rates among pediatric patients.

Acquired knowledge on the research topic is based on objective findings from Ann and Robert H. Lurie Children's Hospital of Chicago's Emergency Department. According to the retrieved metrics, the ED LOS increased while hospitalizations of this patient population decreased. The asthma algorithm process affects the work system, including a more extended stay in the ED because of increased tasks and treatment required at the ED bedside. It needs to be explored further to determine how the asthma algorithm process has changed the work system and outcomes. For this reason, this project utilizes all of these platforms. It aims to understand the core goal by gathering data through electronic medical records to understand how the algorithm has impacted the emergency department, the hospital overall, and patient outcomes.

The Lurie Children's Asthma Algorithm guides providers and nurses on asthma treatment, as illustrated in Figure 1. The Lurie Children's Asthma Score (LCAS) is meant to provide consistency in assessments and communication among clinicians to be applied to the algorithm, which then guides nurses, physicians, etc., on the course of treatment. It helps guide clinicians' asthma treatment based on each patient's severity and can decrease unwarranted variation among clinicians. The previous algorithm had the LCAS, but it was not used as consistently. The LCAS was revised based on multidisciplinary, inter-department feedback and incorporated into the new algorithm. As illustrated in Figure 2 of the Emergency Department Asthma Algorithm, patient scoring is based on respiratory rate, oxygen requirement, aeration and auscultation, and work of breathing (Ann and Robert H. Lurie Children's Hospital of Chicago, 2019a). The severity of symptoms is scored in the range of 0-12, subsequently categorizing the
Ann and Robert H. Lurie Children's Hospital of Chicago is an urban, academic 360 tertiary care hospital with approximately 56,000 ED visits annually. Quality improvement is embedded in the culture, led by a dedicated multidisciplinary interdepartment team and guided by the organizational mission and vision known as Vision 2025. This vision has five pillars, one of which is Caring for More Children and Providing the Best Care and Experience (Ann and Robert H. Lurie Children's Hospital of Chicago, 2019a). This project aligns with the 2025 vision, in caring for more children and utilizing evidence-based care. By improving asthma care efficiency through more intensive treatment in the ED, reduced inpatient admissions, and reduced LOS, the mission of caring for more children, has the potential to be better.

**Problem Statement**

Overcrowding and ‘throughput,’ the act of transitioning patients from ED to inpatient admission, has been a significant concern in the department for the last several years; therefore, evaluation of changes made to the asthma algorithm that may affect ED and inpatient LOS and admission rates is of great importance. This study aims to determine if the new asthma algorithm affects admission rates, ED length of stay, and discharge rates.

A significant obstacle in caring for more children was the lack of bed availability for patients in need of pediatric specialty care. Improving asthma treatment algorithms can increase main hospital bed availability and allow for more specialty transfers that were denied in previous years. It was found that over 500 inpatient transfers from other hospitals were denied in 2016 due to this very issue, despite adding additional bed capacity within the Lurie Children’s institution (Ann and Robert H. Lurie Children's Hospital of Chicago, 2019b). A 2017 analysis
was done to determine hospital length of stay by diagnosis at Lurie Children's Hospital compared to other leading pediatric hospitals to further understand institutional areas for improvement. Asthma was a leading admitting diagnosis and therefore chosen for further review.

According to Ann and Robert H. Lurie Children's Hospital of Chicago (2018), asthmatic patients at Lurie Children's Hospital average LOS was 2.97 days compared to peer LOS of 1.96 days. An asthma diagnosis held the highest amount of dollars spent ($718,950). The overall goal of implementing a highly intensive algorithm for early and more aggressive treatment in the ED was hypothesized to decrease inpatient LOS and increase ED discharges, ultimately allowing for more available inpatient beds. The earlier and more aggressive treatment within the new algorithm identified patients as mild, moderate and severe. The severe track has one albuterol nebulizer followed by continuous nebulizer and magnesium administration. Treatment on this algorithm is deemed more aggressive by expediting the continuous nebulizer treatments and advocating for use of magnesium. The prior algorithm did not differentiate asthma severity in treatment and had all asthmatics start with three nebulizers before going to hour long continuous treatments. The purpose of these changes were to allow for more inpatient bed availability, to decrease LOS by 50%, and to increase the number of patients treated with evidence-based care, through universal communication in patient care throughout the hospital, by utilizing the LCAS.

**Study Aim and Purpose**

Previous research has stated that more aggressive asthma management care in the ED will decrease admission rates and reduce hospital (inpatient) length of stay. Therefore, the purpose of this study is to determine whether the implementation of the new asthma algorithm, based on LCAS, has a positive impact on decreasing the number of asthma exacerbation admissions and improving treatment effectiveness.
While there has always been a specific algorithm to treat pediatric asthma exacerbations, in June 2019, recent institution changes were made to the previous algorithm to better align with national guidelines. The newly adopted algorithm utilizes weight-based albuterol dosing. Previously, everyone was treated with the same dosage of albuterol, and now patients weighing equal to, or over, 20 kilograms receive double the albuterol dosage. Additionally, a switch from jet nebulizers to breath actualized nebulizers (BANs) were adopted based on the study by Sabato et al. (2011) that showed improved asthma scores, reduced respiratory rates, and reduced admission rates with the BAN. The department has aimed to treat these patients more aggressively in the ED to reduce asthma admission rates and allow for more external hospital specialty transfers. Therefore, research is required to determine if the recently implemented asthma algorithm changes create an evidence-based impact on patient management and improvement of proposed institution outcomes.

**Research Questions**

This study addresses the following research questions:

- How does the Emergency Department Asthma Algorithm and LCAS affect efficiency and effectiveness in asthma treatment and patient outcomes?
- How can the efficiency and effectiveness of the Emergency Department Asthma Algorithm be best evaluated?
- Can ED LOS and admission/discharges adequately reflect the algorithm's efficiency and effectiveness?

**Theoretical Framework**

This project's theoretical framework is the Systems Engineering Initiative for Patient Safety (SEIPS), written by Carayon et al. (2006). Within the ED setting, the Systems
Engineering Initiative for Patient Safety, figure 3, looks at a work system processes and outcomes, combining patient and organizational outcomes with the focused goal of improved patient safety and patient outcomes to deliver appropriate asthma treatment interventions.

According to Carayon et al. (2006), the SEIPS model looks at the interrelationships amongst the work system that includes the organization and the five components of the work system (person, tasks, tools and technologies, physical environment, organizational conditions) and how they interact with each other and influence each other. The interactions between the various components "produce" different outcomes: performance, safety and health, and working life quality. While this project focuses on the ED in specific, the SEIPS model philosophy supports a global view. With a focus on this project, asthma and hospital outcomes are viewed to understand better how to address the processes to improve patient and organizational outcomes.

For this project, "the processes" or asthma algorithm is affected by the external environment and each component of the work system that influences the asthma algorithm process. The aim is to identify the ED asthma algorithm's process by thoroughly acknowledging the algorithm and its complex effect on both the work system and outcomes. The implemented asthma algorithm then yields results in inpatient, employee, and organization outcomes. Results of each set of outcomes need to be analyzed to ensure improvement has been noted following the new algorithm's implementation. It is proposed that review of inpatient admissions, ED discharges, and ED LOS will understand whether these particular variables lead to a more efficient work system and improvement of patient and organizational outcomes.

**Literature Review**

**Search Method**
A broad search on Pubmed, years 2010-2020, including clinical trials, randomized control trials, reviews, and systemic reviews, were selected using subject headings asthma, albuterol or salbutamol or ventolin or sultanol or provent, emergency or critical care or intensive care, pediatric or child, or childhood, and length of stay or discharge. Search results included 197,519 articles and needed to be narrowed down to the location of the study. Emergency department or emergency room since the entirety of our focus takes place in the emergency department and interventions applied in that setting. Further narrowing results with subject headings "asthma" AND "emergency department" OR "emergency room" AND pediatric or child* AND "length of stay" returned 2,090 results and further narrowed down to 594 articles that included these subjects in their abstract. Studies were focused on browsing that asthma interventions were done in a pediatric emergency department and variables measured from improving asthma treatment delivery and its effect on patient outcomes and efficiency. Literature was focused on asthma algorithm compliance, patient outcomes, asthma medications, and observational task methods.

Asthma Compliance to Algorithm

Several studies research varying aspects of asthma exacerbation and treatment in the ED. Gray et al.'s (2016) study examined quality improvement methods in the emergency department by utilizing asthma severity scores and high compliance rates to measure improvement in timely administration of SABA treatment. In this case, compliance was measured through a time series analysis, and the key drivers included knowledge, engagement, decision support, and workflow enhancement. Statistical process control charts were then used to process results. It was found that this implementation and compliance helped reduce the length of stay in the ED and reduce the rate of admission without increasing unplanned return admissions (Gray et al., 2016).
Another study focused on applying a computerized asthma detection system combined with a paper-based asthma care protocol to help standardize care and reduce time to dispose of decisions. The study's goal was to address guideline adherence inadequacy and increase clinician use of guidelines to decrease time to disposition (Dexheimer et al., 2013). Although clinicians were provided with a great deal of support and education from leadership, disposition time remained unchanged due to low adherence to the paper-based asthma protocol.

According to Rutman et al.'s (2016) study, patient care is optimized and ED flow improved when using standardized care for asthma patients. A retrospective study was done for quality improvement purposes. Statistics were pulled and analyzed from 15 months before and after the implementation of a modified asthma pathway. The study enabled providers to make earlier disposition decisions to significantly reduce the length of stay (Rutman et al., 2016). It was not, however, measured in this early disposition affected the rate of unplanned return admissions.

While it is known that algorithms, protocols, or guidelines are detrimental to help guide clinicians in the patient care that they provide, adherence to these guidelines is critical. In the implementation of a computerized asthma detection system, in conjunction with a paper-based asthma care protocol, it was found that there was no improvement in disposition time because of poor adherence. The study mentions that the paper-based protocol is an 8-page guideline, including asthma severity metrics and asthma care, including reassessment and treatment guidelines. This guideline was available at triage and in the ED's physical area (Dexheimer et al., 2013). This study's deficiency is that it is not streamlining the guideline and process by including a paper-based guide. Emergency medicine requires time-sensitive guidelines and treatment availability. Electronic medical records (EMR) have been created to contain protocols or
information that clinicians may need to access to treat decompensating patients urgently. For this reason, the protocols were not adhered to by these clinicians; therefore, the study was unable to find a decrease in time to patient disposition. Clear, documented guidelines must be in place to increase clinician adherence to provide best practices in care.

**Patient Outcomes**

While it is clear evidence-based asthma pathways and protocols effectively improve patient outcomes, it is not clear that including objective admission criteria early in the ED course will improve patient care. In the (Rutman et al., 2016) study, implementing standardized and objective admission criteria did reduce the length of stay by encouraging early disposition decisions; however, patient outcomes after discharge were not measured. Therefore, we cannot determine if patient outcomes were improved. Rebound admissions could have increased due to quicker admission decisions. Studying whether the patients with shorter lengths of stay in the ED had lower rebound encounters or shorter hospital stays would provide greater evidence that patient care had improved.

Johnson et al.’s (2017) study investigated pediatric asthma rebound patients and found socioeconomic status and environmental exposure were not predictive of rebound patients. This finding leaves the question up for investigating whether more aggressive treatment, such as increased albuterol dosage, could be a predictor of fewer rebound patients.

Muchão et al.’s (2016) study showed a higher dose of albuterol in a meter-dosed inhaler did not reduce the length of stay in the ED; however, the nebulization albuterol dose was not investigated.

**Algorithm Medication**
Another study focused on early treatment with oral corticosteroid therapy and its impact on the length of stay. A retrospective chart review was used to collect data on corticosteroid administration and length of stay. Data was collected on subjects who received dexamethasone or prednisolone within 60 minutes of triage and those who received one of these two therapies later than 60 minutes of triage. Results revealed that early administration of oral corticosteroid therapy was directly associated with a decreased length of stay. Although corticosteroid therapy's choice may also affect the length of stay, this was not measured (Davis et al., 2012). In Davis et al.'s study (2012), both dexamethasone and prednisolone were administered. The study failed to measure each medication separately, which leads to an unknown variable. A deficiency in this study is that it is unknown if both medications were equally effective in decreasing length of stay or if one was more effective than the other.

In Wilkinson et al.'s (2018) study, breath-enhanced albuterol nebulizer treatments were compared to continuous albuterol treatments regarding the length of stay in the ED. There was no significance in the length of stay between the two different treatments; however, albuterol dosage was not investigated.

While the data collected by these studies are useful and applicable to practice, some deficiencies have been found. While studies measuring timely administration of the first short-acting beta-agonist (SABA) treatment, most commonly albuterol, there is no mention of the concentration of the treatment given. The study's focus is the timeliness of the treatment and how it impacted care and length of stay times, but it does not disclose the type of SABA and dose of the treatment given.

Deficiencies in past studies
While extensive research has examined acute asthma exacerbations in pediatric populations, there is limited research focusing on the dosing effects in albuterol treatments. Research proves that pathways, adherence to pathways, and timeliness of treatment are all strong contributors to better patient outcomes; few studies found that focus on the effects of a more intensive asthma algorithm on pediatric patient ED length of stay, admission, and discharge rates. Organizational efficiency, improved patient outcomes, and reducing rising healthcare costs for asthma needs further exploration.

**Methods**

**Study Design**

A retrospective chart review has been utilized for secondary analysis. The length of time in the ED, dependent variable, is quantified from when the nurse documents the patient in the electronic chart management system until the patient is discharged or admitted to inpatient from the ED. The independent variable is the new asthma algorithm in comparison to the old algorithm.

The best way to analyze the algorithm's results is to retrospectively look at the data from the old algorithm and compare it to the data from the new algorithm. Because the nebulizers changed from jet nebulizers to BAN nebulizers and albuterol dosing was doubled for those over 20 kilograms in June 2019, a retrospective study gives us the ability to compare the current to previous algorithm.

**Instrument Validity and Reliability**

Utilizing eight months of chart data from the old algorithm and eight months of data from the new algorithm demonstrates the effect the new algorithm has had on the hospital system through asthma admissions, ED discharges, and ED LOS. Taking eight months, July 2018-
February 2019 and July 2019-February 2020, of data from each pathway allows for equal comparisons and accounts for some of the variability that can occur in seasons. Some asthma case variations occur with winter because of increases in virus spreading and in spring and fall with seasonal allergies. Additionally, the coronavirus (COVID-19) pandemic changed the new algorithm in March 2020 to reduce high-risk aerosolizing procedures and presents an augmentation to the algorithm that may or may not be permanently adopted; therefore, we ended our chart review before the algorithm changed due to COVID-19.

Population

Patients that present to the ED are assigned an acuity level 1, 2, 3, 4, or 5, and subsequently admitted or discharged home. Acuity levels are based on the Emergency Severity Index (ESI), a five-level emergency triage algorithm maintained by the Agency for Healthcare Research and Quality (AHRQ). The ESI triage is based on the acuity of patients' health care problems and the number of resources their care is anticipated to require (ahrq.gov, 2020). An acuity of 1 will require the greatest number of resources emergently, while an acuity of 5 does not anticipate requiring any resources. All patients that are seen and treated in the pediatric emergency department for an asthma exacerbation are included in the study except patients with acuity levels 1 and 5 because they either need emergent lifesaving interventions or require no intervention. Patients of all ethnicities, races, and comorbidities were included in the data.

Setting

The setting is the pediatric emergency department of Ann and Robert H. Lurie Children's Hospital in Chicago. The study design included a retrospective chart review in which data will be collected from July 2018-February 2019 and from July 2019-February 2020, comparing the previous asthma algorithm to the more intensive asthma algorithm.
Inclusion Criteria

The sample studied includes patients who present to the ED for acute asthma exacerbation, are assigned an acuity level of 2, 3, or 4, and subsequently admitted or discharged home. Acuity 1 and 5 were excluded from this research study.

Sample Size

The retrospective chart review includes all asthmatic exacerbation patients seen within the two years assigned an acuity 2, 3, or 4.

Statistical Analysis

The instruments utilized were Power BI, a Microsoft tool that provides excel file storage and analysis of the asthma data through the hospital's intranet. Data analysis was conducted utilizing Intellectus Statistics. The tools provide information regarding acuity level, treatments given, ED LOS, LCAS, admits, and discharges.

Human Subjects Protections

The patient record information storage is kept secure in the hospital system share point intranet and coded by medical record number.

Results

In the 16 months of asthma patients, assigned acuity level 2-4, 2593 patients were included. Between July 2018- February 2019, 1230 patients were treated with the old algorithm, and in July 2019-February 2020, 1363 patients were treated with the new algorithm. The acuity level and LCAS scores between the old and new algorithm were not significantly different, based on an alpha value of 0.05, indicating the patient populations had comparable asthma severity between the years (Table 1-2), with significantly similar asthma patient encounters between the
two eight-month samples allowed for a fair comparison between the algorithms. Admissions, discharges, bounce backs, and ED length of stay (in hours), were analyzed.

Table 1.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Old Algorithm</th>
<th>New Algorithm</th>
<th>t</th>
<th>p</th>
<th>d</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acuity</td>
<td>2.31</td>
<td>2.29</td>
<td>0.50</td>
<td>.617</td>
<td>0.02</td>
</tr>
</tbody>
</table>

P=0.05, N = 2593. Degrees of Freedom for the t-statistic = 2591. d represents Cohen's d.

Table 2.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Old Algorithm</th>
<th>New Algorithm</th>
<th>t</th>
<th>p</th>
<th>d</th>
</tr>
</thead>
<tbody>
<tr>
<td>LCAS_Score</td>
<td>4.48</td>
<td>4.61</td>
<td>-1.09</td>
<td>.277</td>
<td>0.05</td>
</tr>
</tbody>
</table>

P=0.05, N = 1990. Degrees of Freedom for the t-statistic = 1879.97. d represents Cohen's d.

ED length of stay was slightly longer with the new algorithm, 3.63 hours compared to 3.51 hours with the old algorithm. However, it was not statistically significant, as illustrated in Table 3. Despite education to utilize LCAS and new algorithm adherence, our results are similar to Dexheimer et al.'s (2013) study that hypothesized adherence reduces LOS in the ED; however, a reduction did not occur in their investigation. Muchão et al. (2016) and Davis et al. s's (2012) study showed a higher dose of albuterol (Muchão) and earlier doses of steroids (Davis) did not reduce the length of stay in the ED, which aligns with our findings. Rutman et al.'s (2016) study reduced ED LOS by adhering to an asthma algorithm; however, their comparative earlier sample had no asthma algorithm established, making a much more significant implementation impact than our comparison of a previous algorithm versus a newer, intensive algorithm. As seen in Table 3, our two-tailed t-test and Mann-Whitney U test were not significant based on an alpha value of 0.05. The two-tailed Mann-Whitney two-sample rank-sum test is an alternative to the independent samples t-test when the algorithm groups are not normally distributed and do not share the same assumptions (Conover & Iman, 1981).

Table 3
Two-Tailed Independent Samples t-Test for ED Hours by Old Algorithm vs. New Algorithm

<table>
<thead>
<tr>
<th>Variable</th>
<th>Old Algorithm</th>
<th>New Algorithm</th>
<th>t</th>
<th>p</th>
<th>d</th>
</tr>
</thead>
<tbody>
<tr>
<td>ED_HOURS</td>
<td>3.51</td>
<td>3.63</td>
<td>-1.72</td>
<td>.085</td>
<td>0.07</td>
</tr>
</tbody>
</table>

Note. N = 2378. Degrees of Freedom for the t-statistic = 2375.37. d represents Cohen's d.

Two-Tailed Mann-Whitney Test for ED HOURS by Old Algorithm vs. New Algorithm

<table>
<thead>
<tr>
<th>Variable</th>
<th>Old Algorithm</th>
<th>New Algorithm</th>
<th>U</th>
<th>z</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>ED_HOURS</td>
<td>1172.08</td>
<td>1205.35</td>
<td>685554.50</td>
<td>-1.18</td>
<td>.238</td>
</tr>
</tbody>
</table>

More bounce back patients 2.8% (37 patients) with the new, more intensive algorithm compared to the old algorithms 1.3% (16 patients). More aggressive treatment, such as weight-based albuterol dosage and greater magnesium administration frequency in the new algorithm, did not produce fewer rebound patients as predicted. There were fewer admissions with the new algorithm (41%) than with the old algorithm (43%); however, this was not statistically significant (p=0.220), as illustrated in Table 4.

Table 4

Admissions and Discharges with the Old vs. New Algorithm

<table>
<thead>
<tr>
<th>Admission/Discharge</th>
<th>Old Algorithm</th>
<th>New Algorithm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discharged</td>
<td>699[714.38] 57%</td>
<td>807[791.62] 59%</td>
</tr>
<tr>
<td>Admitted</td>
<td>531[515.62] 43%</td>
<td>556[571.38] 41%</td>
</tr>
</tbody>
</table>

χ² 1.50 df 1 p .220

Note. Values formatted as Observed [Expected].
In summary, the new asthma algorithm patients had a slightly longer ED LOS, fewer admissions, and greater bounce-backs; however, none of these results were significant (p=0.05). The LCAS scoring and acuity levels between the old and new algorithm illustrated that the patient populations during the two eight-month time frames had comparable asthma exacerbations. The new algorithm's slightly longer ED LOS and increases in return rate negatively impact the patient and hospital/patient financially. The slightly fewer admissions with the new algorithm may be beneficial for the hospital's mission of creating more bed availability for treating more children and improve patients' outcomes.

**Discussion**

The new asthma algorithm was adopted to reduce hospital LOS by 50% and reduce the cost of asthma treatment in the hospital overall by treating more effectively; therefore, freeing inpatient beds to allow for more lucrative transfer patients (Ann, 2017). While it is difficult to determine the new algorithm's efficiency and effectiveness with these goals, a retrospective chart review comparing previous algorithm patient data to the new algorithm patient data is a logical first step in determining whether the algorithm aligns with these goals. The treatment efficiency is best measured with a retrospective chart review by looking at ED LOS and admission rate. The effectiveness of treatment is best measured within a retrospective chart review by comparing bounce-backs and discharges. Our results showed no significant difference between the old algorithm and the new algorithm related to ED LOS, admissions, discharges, bounce-backs, acuity, or LCAS scores.

While it is known from previous studies that standardizing care with algorithms improve patient outcomes and provider decision making, our comparison groups were two algorithms. The new algorithm better reflects evidence-based care and national guidelines and includes
higher dosages of albuterol for patients weighing equal to or greater than 20 kg, emphasizing magnesium administration with higher acuity patients, utilizing BANs and earlier continuous nebulizers, and administers an additional dose of Atrovent along with steroids in severe exacerbations. Because of the complexity of all these changes within the algorithm, it is difficult to measure which, if any, elements of the algorithm change may have had the most significant impact on our results; however, as mentioned previously, no significant improvement in ED LOS, admissions, discharges, or returned admissions to the ED within 72 hours or “bounce-backs” were noted.

Whether asthma algorithm efficiency is truly captured by ED LOS and admission rates and effectiveness through bounce-backs and discharges is difficult to determine; however, comparison of these measures amongst the algorithms was the most objective method available with a retrospective chart review. The logical, most objective measurement in efficiency and effectiveness of the asthma algorithms is the LCAS, which proved to be insignificantly different amongst the algorithms; however, this poses additional research opportunities in the future since LCAS scores were not consistently documented in the medical records. The clinicians caring for asthma patients were educated on the importance of LCAS scores with the new algorithm adoption; however, missing LCAS data in the medical records made this effectiveness variable unreliable.

The sample size of 2593 patients was a strength within the study and matching seasonality between the algorithm samples. Unfortunately, the initial study aimed to compare two full years of asthma patients, but because COVID-19 interrupted the applicability of the new algorithm, the data post COVID-19 was excluded. The algorithm changed to meter dose inhalers (MDIs) instead of nebulizers to reduce aerosol-generating procedures and prevent transmission
of COVID-19. It is unknown whether the asthma algorithm will remain with MDIs indefinitely for mild to moderate exacerbations in the ED; however, there is no clear evidence to conclude the hospital system's updated COVID-19 algorithm has produced changes in regards to ED LOS, bounce-backs, admissions, or discharges.

This study's clinical implications include determining whether the new algorithm was more effective in producing better patient outcomes by decreasing admission rate and bounce backs in the ED and increasing discharges to home, thereby increasing the number of inpatient beds available. More studies to validate our findings are needed to strengthen the evidence for the use of the new algorithm. Future studies could investigate whether the MDI algorithm is comparable to the previous two algorithms via ED LOS, bounce-backs, admissions, discharges, and other variables of interest, whether financially or for patient outcomes.

**Conclusion**

In summary, since asthma exacerbation is the leading cause of hospitalization in pediatric patients, this population needs study to navigate ways to improve the treatments provided and decrease admission rates to improve outcomes. The purpose of this study was to determine whether the implementation of the new asthma algorithm in the Lurie Children's Emergency Department has had a positive impact by decreasing the number of asthma exacerbation admissions and improving treatment effectiveness. While there were no significant findings between the two algorithms, additional studies in the future are recommended, as there were other variables, such as COVID-19, which may have impacted findings.
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effective, and higher doses are safe. *Pediatric Pulmonology* 51(11), 1122–1130. https://doi.org/10.1002/ppul.23469


Figure 2. Lurie Children's Asthma Score (LCAS)

Lurie Children's Asthma Score (LCAS)

<table>
<thead>
<tr>
<th>Score</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Respiratory Rate</td>
<td>No change</td>
<td>Mild change</td>
<td>Moderate change</td>
<td>Severe change</td>
</tr>
<tr>
<td>1-6 yrs</td>
<td>0 ≤ 20</td>
<td>21 ≤ 30</td>
<td>31 ≤ 40</td>
<td>&gt; 40</td>
</tr>
<tr>
<td>6-12 yrs</td>
<td>0 ≤ 25</td>
<td>26 ≤ 40</td>
<td>41 ≤ 50</td>
<td>&gt; 50</td>
</tr>
<tr>
<td>&gt; 12 yrs</td>
<td>0 ≤ 30</td>
<td>31 ≤ 50</td>
<td>51 ≤ 70</td>
<td>&gt; 70</td>
</tr>
<tr>
<td>Oxygen Requirement</td>
<td>Room Air</td>
<td>Low (10-20%)</td>
<td>Low (20-40%)</td>
<td>High (&gt;40%)</td>
</tr>
<tr>
<td>Atelectasis &amp; Auscultation</td>
<td>Good: Consolidation and clear breath sounds</td>
<td>Good: Whispered voice</td>
<td>Intermediate</td>
<td>Poor: Fine crackles/whistling</td>
</tr>
<tr>
<td>Work of Breathing</td>
<td>None</td>
<td>1 of the following: Stridor, intercostal, suprasternal, retraction, nasal flaring</td>
<td>2 of the following: Stridor, intercostal, suprasternal, retraction, nasal flaring</td>
<td>3 of the following: Stridor, intercostal, suprasternal, retraction, nasal flaring, use of accessory muscles</td>
</tr>
</tbody>
</table>

LCAS Reference Ranges:

- **Mild**
  - LCAS = 0 - 4
- **Moderate**
  - LCAS = 5 - 8
- **Severe**
  - LCAS = 9 - 12

**MEDICATION DOSING**

**Albuterol Intermittent Neb (BANS):**
- 20 kg < 5 mg
- 20 kg ≤ 2.5 mg

**Ipratropium Bromide (Atrovent) Nebs:**
- 0.5 mg

**Albuterol + Atrovent Nebs:**
- 20 kg = Albuterol 5 mg + Atrovent 0.5 mg
- 20 kg ≤ Albuterol 2.5 mg + Atrovent 0.5 mg

**Steroids:**
- Prednisolone (PO) 60 mg/dose
- Prednisolone (IV) Loading Dose: 2 mg/kg/dose (Max = 60 mg/dose)
- Maintenance Dose: 1 mg/kg/dose BID PO (Max = 60 mg/dose)
- **Alternative 0.6 mg/kg/dose s1 dose (Max = 16 mg/dose)**

**Epinephrine (1mg/ml) (IM):**
- 0.01 mg/kg/dose (Max = 0.5 mg)

**Levalbuterol (Xopenex) Nebs:**
- 1.25 mg (only used when taken at home or clinically indicated)
- (no differences in safety & efficacy of levalbuterol vs albuterol)

**Aminophylline (IV):**
- 6 mg/kg (do not give bolus if receiving aminophylline or theophylline at home)
- 0.11 to 1 mg/kg/hr (see order set for dosing recommendations)

**Terbutaline (IV):**
- 40 to 10 mcg/kg
- 0.2 to 0.4 mcg/kg/minute (titrate by 0.1 to 0.2 mcg/kg/min in increments as frequently as every 30 minutes based on patient response or toxicity) (Max = 5 mcg/kg/minute)

**Magnesium Sulfate (IV):**
- 20 mg/kg NS bolus (Max = 2 grams)
- 20 mg/kg IV over 60 minutes
- 10 mg/kg IV over 30 minutes

This clinical care guideline is meant as a guide for the healthcare provider, does not establish a standard of care in legal matters, and is not a substitute for medical judgment which should be applied based upon the individual circumstances and clinical condition of the patient.

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Last update: 06.21.19 KH
Figure 3. Systems Engineering Initiative for Patient Safety (SEIPS)
<table>
<thead>
<tr>
<th>Author (Year)</th>
<th>Study Goals</th>
<th>Study design</th>
<th>Sample size and sample</th>
<th>Data Collecti</th>
<th>Summary of results/findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Davis, Burke, Hoga, &amp; Smith (2012)</td>
<td>Determine if early steroid use will have a decrease in length of stay in ED</td>
<td>Retrospective chart review</td>
<td>882 children ages 2-18</td>
<td>12 month period</td>
<td>Length of stay was significantly reduced (34 min average difference) in children who received steroids within 60 minutes compared to those that received steroids after 60 minutes (p&lt;0.0001)</td>
</tr>
<tr>
<td>Dexheimer, Abram, Arnold, Johnson, Shyr, Ye, Kang-Hsien, Patel, &amp; Aronsky, (2013)</td>
<td>Determine if implementing and adhering to asthma guidelines improves clinical outcomes (decreased length of stay)</td>
<td>Prospective, randomized control trial</td>
<td>704 patients ages 2-18</td>
<td>Three months</td>
<td>Adherence to guidelines was low despite efforts to educate, and length of stay did not change</td>
</tr>
<tr>
<td>Gray, Keeney, Grahl, Gorelick, &amp; Spahr (2016)</td>
<td>Determine if timely SABA administration and use of asthma scores improve patient outcomes</td>
<td>Retrospective chart review</td>
<td>5552 patients</td>
<td>31 months</td>
<td>Improved use of asthma scoring and time to SABA administration- 24% decrease in administration time sustained for 20 months, greater improvement was seen in less sick population- 29% reduction in SABA administration</td>
</tr>
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<tr>
<td>Muchão, Souza, Torres, Lalibera, Souza, Rodriguez, Schwartsm an, &amp; Filho, (2016)</td>
<td>Determine if higher dose MDI inhalers affect the length of stay in the ED, safety, and admission rates</td>
<td>Randomized controlled double-blind trial</td>
<td>119 patients ages 2-17 years</td>
<td>Two years</td>
<td>No difference in MDI dosage was seen in the length of stay, safety, admission rates</td>
</tr>
<tr>
<td>Rutman, Migita, Spencer, Kaplan, &amp; Klein, (2016)</td>
<td>Implementing asthma score admission criteria and its effects on length of stay in the ED, admits, inpatient length of stay, and ICU admissions</td>
<td>Retrospective chart review</td>
<td>3688 patients age 1-18</td>
<td>30 months</td>
<td>Admission rates and inpatient length of stay did not change; Improved efficiency: ED lengths of stay and time to bed request decreased by 30 minutes</td>
</tr>
<tr>
<td>Wilkinson, King, Iyer, Higginbotham, Wallace, Hovinga,</td>
<td>Breath-enhanced neb vs. jet nebulizer</td>
<td>Randomized control trial</td>
<td>50 patients Age 3-18 years</td>
<td>unknown</td>
<td>Moderate-severe asthmatics have similar results with breath-enhanced neb vs. jet neb.</td>
</tr>
<tr>
<td>&amp; Allen, (2018).</td>
<td>Westbrook, Creswick, Duffield, Li, &amp; Dunsmuir, (2012)</td>
<td>Demonstrate how WOMBAT technique can be utilized in different clinical settings</td>
<td>Systematic review</td>
<td>Eight articles that used the WOMBAT tool</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Westbrook, Duffield, Li, &amp; Creswick, (2011)</td>
<td>Determine time spent at bedside between different nursing wards and nursing educational levels</td>
<td>Prospective Observational study</td>
<td>191 hours observation, 57 nurses</td>
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<td></td>
<td></td>
<td></td>
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<td>41 months</td>
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<td>Nurses spent an average of 57% time completing tasks, 1/3 of their time with patients. Identifies few studies show how much time specific tasks take nurses.</td>
<td></td>
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</tbody>
</table>

WOMBAT is a standardized observational tool that allows comparisons across studies.