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Management Of Acute Asthma Exacerbations:

Optimizing The Approach To ED And Hospitalized Patients

Lauren Maskin, MD
Pediatric Hospital Medicine
CNEB Asthma Pathway Physician Champion
Medical Director of Clinical Effectiveness

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OBJECTIVES

- Discuss goals for treatment of asthma exacerbations in the Emergency Room
- Review modalities for delivering medications
- Present benefits of a standardized approach for ED and Inpatient exacerbation management

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ABOUT US

- Children's Asthma Pathway Development Team formed in 2012 with the goal of standardizing care from Emergency Room visit through Inpatient Discharge
- Standardized dosing for albuterol, ipratropium bromide and steroids
- Provided guidelines for when and how to reassess patients
- Established criteria for additional therapeutic interventions
- Set expectation for screening and categorizing underlying disease
- Established admission and discharge criteria
- Reduced unnecessary testing

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ED GOALS

STEROIDS

Give within first 60 minutes

BRONCHO-DILATORS

Manage aggressively early

First and Second Line agents

SUPPORTIVE THERAPY

Assess for need for chronic therapy or specialist referral

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Pathophysiology

A chronic inflammatory disorder of the airways, associated with variable airflow obstruction

4 Key Components

1. Bronchial constriction
2. Inflammation
3. Bronchial hyper-responsiveness
4. Airway remodeling

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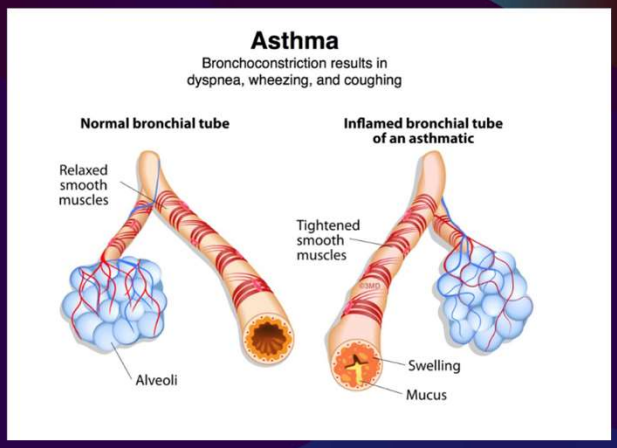
Bronchoconstriction

- Predominant physiologic event --> symptoms
- Stimulus-> bronchial smooth muscle contraction -> acute narrowing of bronchi
- Allergen-induced: IgE-dependent release of mediators (histamine, tryptase, leukotrienes and prostaglandins) from mast cells -> direct contract airway smooth muscle
- Aspirin + NSAIDs: non-IgE-dependent response
- Other irritants (exercise, cold air, etc): mechanisms less well defined, intensity related to underlying inflammation



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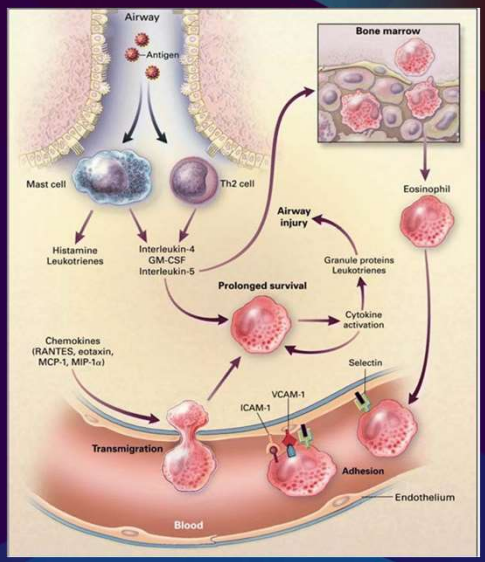
Inflammation

- Inflammatory cell infiltration contributes to airway hyperresponsiveness, airflow limitations, symptoms and disease chronicity – patterns may differ which has implications for phenotypic differences
  - Neutrophils (esp in sudden-onset, fatal exacerbations; occupational asthma, and tobacco smoke exposure)
  - Eosinophils
  - Lymphocytes
  - Mast cell activation
  - Resident cells
  - Epithelial cell injury
- Mucus hypersecretion, inspissated mucus plugs and edema of airways
- Persistent inflammation in some patients will lead to structural changes, including sub-basement fibrosis, mucous hypersecretion, injury to epithelial cells, smooth muscle hypertrophy, and angiogenesis, i.e. airway remodeling



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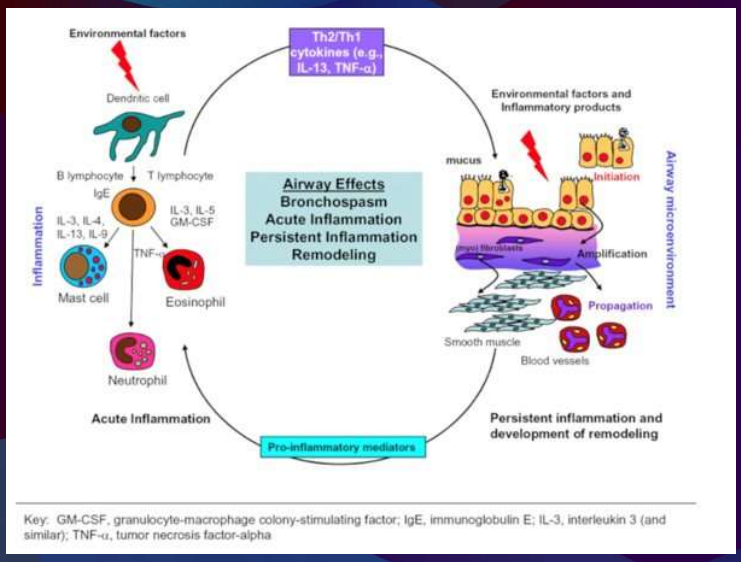

Hyperresponsiveness

- Exaggerated bronchoconstrictor response to a wide variety of stimuli
- Mechanisms: inflammation, dysfunctio nal neuroregulation and structural changes

Airway Remodeling:

- Permanent structural changes can occur associated with loss of lung function
- Thickening of subbasement membrane, subepithelial fibrosis, airway smooth muscle hypertrophy and hyperplasia, blood vessel proliferation and dilation, and mucus gland hyperplasia and hypersecretion

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STEROIDS

ED Goal: Steroids within 60 minutes to reduce admissions

- Oral steroid administration within one hour of presentation is associated with reduced hospitalization, need for ED visit and duration of symptoms
- Initial effects at ~2hrs, typically takes 4-6 hours to take full effect to reduce airway inflammation by suppressing activation of inflammatory cells and production of immune modulators
- Methylprednisolone has less mineralocorticoid effect; reserve for critical exacerbations or when oral doing is not tolerated due to vomitingNo evidence that IV methylprednisolone is superior to oral options

Leung JS. Paediatrics: how to manage acute asthma exacerbations. Drugs Context. 2021 May 26;10:2020-12-7. doi: 10.7573/dic.2020-12-7. PMID: 34113386; PMCID: PMC8166724.

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WHY DEX?

- Cheaper $$
- Palatability (kids like it more)
- 5-6 x more potent, half-life 36-72hrs -> Improved compliance with less dosing
- Fewer side effects such as vomiting

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WHAT'S THE PROOF?
DEX VS PRED

- Qureshi 2001: prospective non-blinded RCT no significant different in relapse rate (6.9 v 7.4%), no difference in admission rate when stratified by asthma severity (12 v. 11%), total time spent in ED, or severity score on discharge
  - Pred: more vomiting, less compliance, More missed > 2 days of school
- Andrews 2012: More cost effective, especially if doses provided by ED
- Keeny 2014: No difference in asthma scores during ED visit, # Alb treatments needed, rates of hospitalization, or relapse visits
- Cronin 2016: mean pediatric respiratory assessment measures (PRAM), beta-agonist use, admissions, admission LOS, unscheduled return visits within 14 days, quality of life indicators not significantly different; did see difference in use of further steroids and study did not include "severe" exacerbations
- Watnick 2016: Relative risk reduction of 35% for relapse visit in a retrospective analysis
- Paniagua 2017: no difference in persistence of symptoms, quality of life, admissions, ED returns or vomiting at day 7; greater adherence with Dex
- PECARN 2022: no difference in rate of return visits for continued or worsening symptoms between 1 and 2 doses of dexamethasone
- Hoefgen 2022: initial steroid choice not associated with 30 day re-utilization after hospitalization

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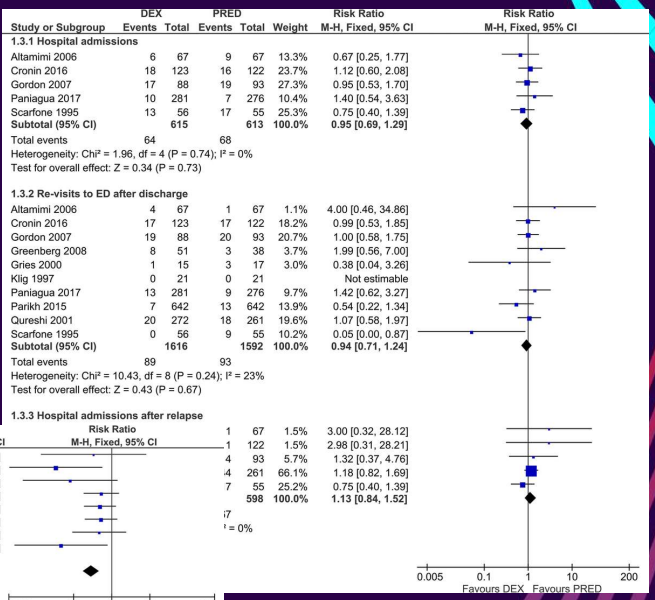
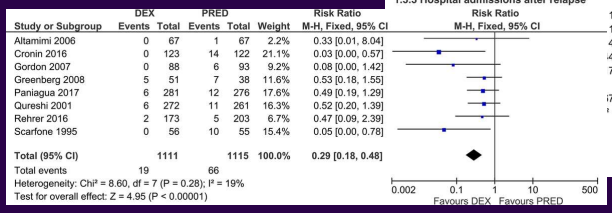
Cai 2021:

Dex Single Or 2-dose Regimens Viable Alternative To 5 Day Pred

Meta-analysis Showed No Difference In Rate Of Hospitalization, ED Revisit Or Relapse After Discharge



Vomiting



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BRONCHODILATORS

Albuterol

Activate beta-2-receptors in medium and large airways → increases cAMP → inhibits calcium release from intracellular stores → inhibits smooth muscle contraction/reverses bronchospasm

Higher doses cause greater bronchodilation until receptor saturation. Dosing limited by side effects: tachycardia, hypokalemia, and diastolic hypotension. Other side effects include tremors and nausea. Prolonged use can lead to arrhythmias/ST segment changes and elevated troponins.

Ipratropium Bromide

Short-acting anticholinergic, serves as an adjunctive bronchodilator. Blocks interaction of acetycholine with muscarinic receptors on bronchial smooth muscle cells while decreasing edema and secretions. Slower onset but may specifically relieve cholinergic broncho-motor tone. Does not cross mucous membranes, so central anticholinergic effects are minimal.

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IPRATROPIUM BROMIDE

- Qureshi 1998: double blinded RCT adding 500mcg IB with 2nd and 3rd albuterol doses
  - Absolute reduction in admissions by 15% for severe pts
  - Significant reduction in asthma scores and reduced oxygen need in severe patients
- Griffiths 2013: Adding IB to albuterol in the ED setting significantly reduces the odds of hospital admission
  - Use of 750-1000mcg given in 1-3 divided doses in the ED setting leads to greater improvement in lung function (PFTs, clinical scores, need for oxygen, need for additional SABAs) and fewer side effects (nausea and tremor)
- Wyatt 2015: Adding IB not significantly associated with reduced admissions rates; increases side effects, therefore reserve for more severe exacerbations
- Beneficial effects appear to decline with additional dosing (Qureshi 1998, Craven 2001, Griffiths 2013)

Qureshi, F., Pestian, J., Davis, P., & Zaritsky, A. (1998). Effect of nebulized ipratropium on the hospitalization rates of children with asthma. *New England Journal of Medicine*, *339*(15), 1030-1035.
Griffiths B, Ducharme FM. Combined inhaled anticholinergics and short-acting beta2-agonists for initial treatment of acute asthma in children. Cochrane Database Syst Rev. 2013 Aug 21;(8):CD000060. doi: 10.1002/14651858.CD000060.pub2. PMID: 23966133
Wyatt, E. L., Borland, M. L., Doyle, S. K., & Geelhoed, G. C. (2015). Metered-dose inhaler ipratropium bromide in moderate acute asthma in children: a single-blinded randomised controlled trial. *Journal of paediatrics and child health*, *51*(2), 192-198.

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SUPPORTIVE THERAPIES

Magnesium – off label use

- Mg^{2+} ions compete with voltage-gated calcium channels
- Improves peak expiratory flow rates and forced expiratory volume in one second
- Reduces hospital admission when combined with beta-agonists
- Dose-dependent effect on bronchodilation with improved clinical outcomes when serum concentration rises above 4mg/dL
  - 20mg/kg has not shown to reliably achieve supraphysiologic level
  - doses above 50mg/kg have not shown to have superior clinical benefits
- 50mg/kg administered *after fluid bolus* (to increase preload) administered over 20 minutes with serial blood pressure measurements (faster rates increase the risk of hypotension)
- Can repeat every 6 hours based on half-life (2.7 hrs) and return-to-baseline concentrations (4-6 hrs)
- Do not use in patients with Creatinine Clearance <30mL/min, neuromuscular diagnoses, AV block or myocardial conditions

Terbutaline

- Early administration associated with reduced need for NIV
- Side effects: hypotension, hypokalemia, elevated troponins
- Bolus followed by infusion; restricted to ICU use

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MODALITY MATTERS

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AEROSOL DEPOSITION

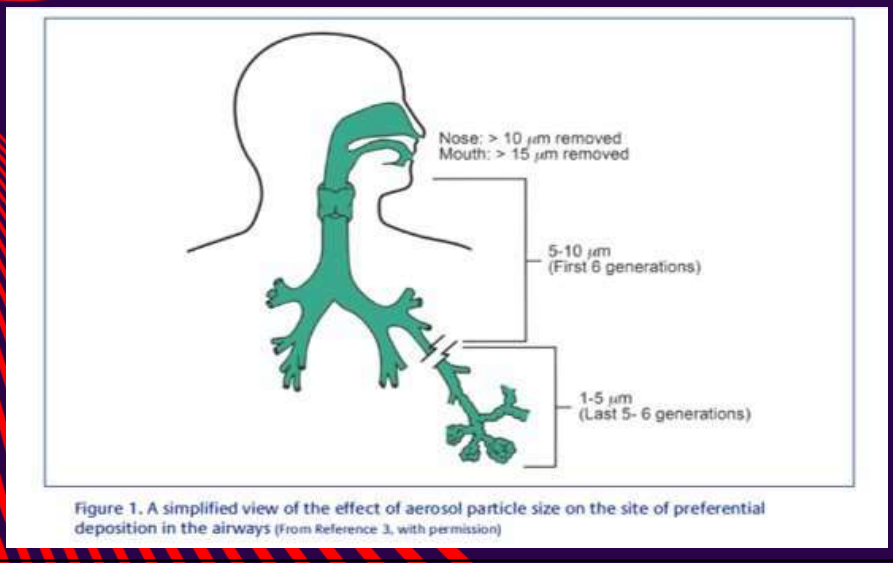

Figure 1. A simplified view of the effect of aerosol particle size on the site of preferential deposition in the airways (From Reference 3, with permission)

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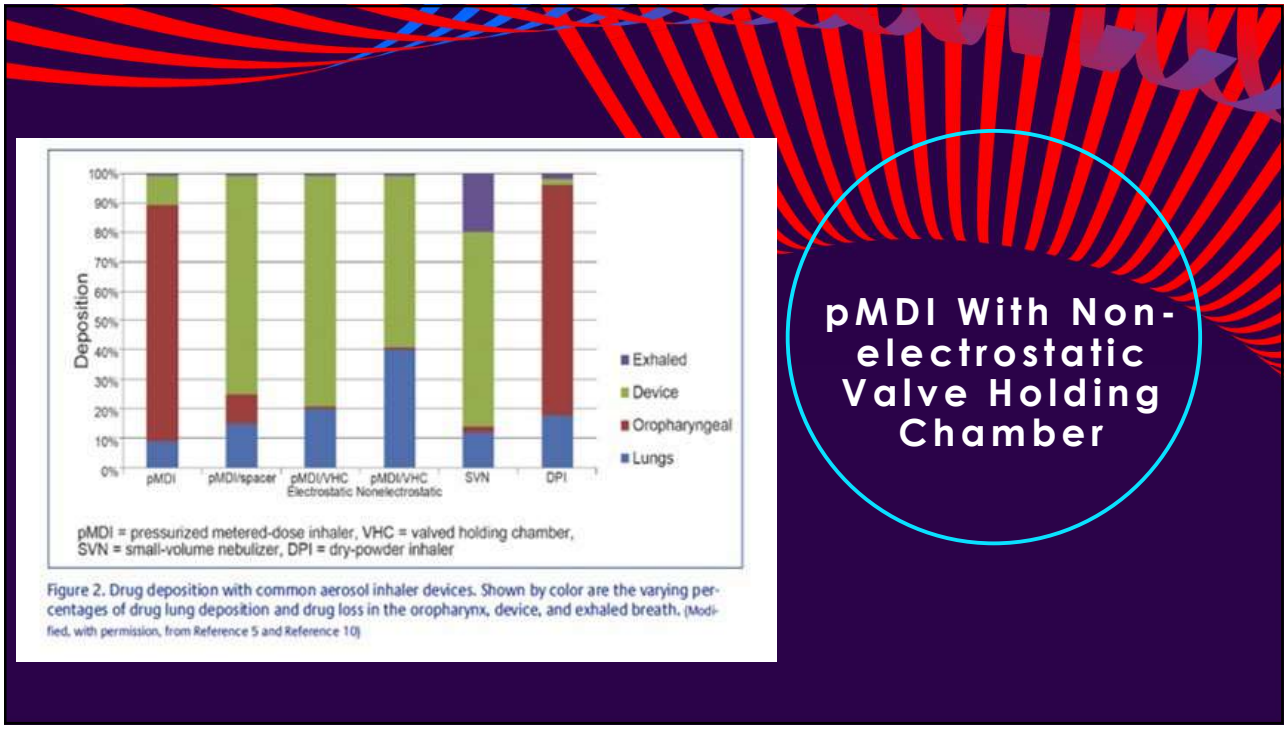

Figure 2. Drug deposition with common aerosol inhaler devices. Shown by color are the varying percentages of drug lung deposition and drug loss in the oropharynx, device, and exhaled breath. (Modified, with permission, from Reference 5 and Reference 10)

pMDI With Non-electrostatic Valve Holding Chamber

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DELIVERY OPTIONS

MDI w/spacer

Best for home use

Convenient

Focus on good technique

Jet Nebulizer

Current peds standard for ED and IP continuous albuterol

Use for very distressed patients

Dosing and drug combinations can be manipulated

Longer delivery times

Vibrating Mesh Neb

Improved drug delivery

Less well studied in pediatrics

May necessitate dosing adjustments

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AEROGEN ULTRA

- Evidence suggests delivers 5-6 fold greater aerosol compared to jet nebulizer
- Less volume used, less left behind
- 85% patients need only one treatment
- BUT one time use
- Dunne & Shortt: Prospective QI project. Total administered dose of albuterol in the VMN group was lower (no more than 5mg albuterol). The VMN was associated with fewer admissions to the hospital (28.1% vs 41.4%), shorter length of stay in the ED (37min reduction) and a reduction in albuterol dose. The device type was a predictor of discharge, disposition and amount of drug used.

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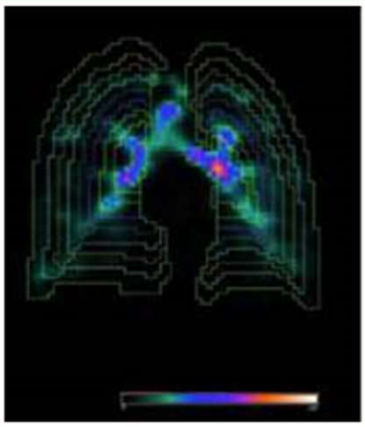
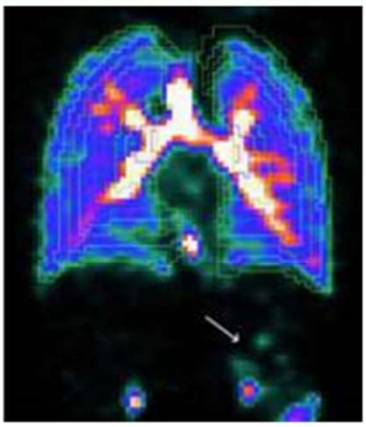
The Solution: Aerogen Ultra



Traditional Jet Nebulizer



Aerogen Ultra

- **6 Times more medication** delivered to the lungs with Ultra (**34.1%**) vs JN (**5.2 %**)[1]
- **Minimal medication** left in the Aerogen Solo (<0.1mL)[2]

Aerogen 1.Dugernier, J, et al. (2017) 2. Aerogen Solo Instruction Manual, 3. Dunne & Shortt (2018) 4. Avdeev, S. et al (2017) 5. Cushen, B. et ai (2016) 7

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DEVELOPING EVIDENCE

- Prospective chart review
- 3x less drug used in order to achieve D/C with VMN (3.72 vs. 11.23mg mean dose)
- 89 minute reduction in average ED LOS in VMN vs. JN group
- Admission rates were 41% lower in the VMN group vs. JN group
- Return to ED in 48-hour rates were 42% lower in VMN group vs. JN group

- Single blinded RCT, all treated until received mild assessment score and dispositioned
- Statistical significance in initial AS score with VMN group average at 9 and JN group average at 8
- 33% reduction in number of treatments needed (VMN 2 [1-3], JN 3 [2-5])
- 48% reduction in admission rates for severe AS in the VMN group vs. JN group
- Patients achieved symptom control 23 minutes faster in VMN group vs. JN group

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INPATIENT MANAGEMENT

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Steroids Again

- Hemani 2021: hospitalized children with mild-to-moderate exacerbations have significantly shorter LOS when starting Dex on admission opposed to Pred. Studied 1,410 children with difference found when steroids started *after* hospitalization. LOS did not differ when steroids started before admission. PICU transfers, ED revisits, and readmissions were uncommon.
- Tyler 2019: Using interrupted time series data, found no difference for LOS, total charges, or ICU transfers pre and post-implementation of dexamethasone protocol in ED. Slight trend in ICU transfers post.
- Cotter 2020: survey of hospitalist practices. Patient received dexamethasone in the ED, then inpatient care was variable – 44% of Hospitalists continued dex, 14% switched to pred, 2% give no additional steroids, and 40% tailors based on scenario. Hospitalists more likely to continue dex than pulmonologists (61 vs 15%, p <0.001). "Providers often revert to prednisone, especially in severe asthma exacerbations, possibly due to experience with prednisone and limited research on dexamethasone in the inpatient setting."
- Nelipovich 2022: survey hospitalist MDs and APPs in 2019 and 2021. Wide disagreement with using dex in both surveys, but self-reported increase in use in 2021. Moderate agreement with prescribing dex for poor tolerance or compliance. Moderate agreement with prescribing prednisone with higher severity of baseline asthma or current exacerbation.

Sunita Ali Hemani, Brianna Glover, Samantha Ball, Willi Rechler, Martha Wetzel, Nicole Hames, Elan Jenkins, Patricia Lantis, Anne Fitzpatrick, Sarah Varghese; Dexamethasone Versus Prednisone in Children Hospitalized for Acute Asthma Exacerbations. *Hosp Pediatr* November 2021; 11 (11): 1263–1272. https://doi.org/10.1542/hpeds.2020-004788
Amy Tyler, Jillian M. Cotter, Angela Moss, Irina Topoz, Amanda Dempsey, Jennifer Reese, Stanley Szefler, Heather Hoch; Outcomes for Pediatric Asthmatic Inpatients After Implementation of an Emergency Department Dexamethasone Treatment Protocol. *Hosp Pediatr* February 2019; 9 (2): 92–99. https://doi.org/10.1542/hpeds.2018-0099
Cotter JM, Tyler A, Reese J, Ziniel S, Federico MJ, Anderson Iii WC, Kupfer O, Szefler SJ, Kerby G, Hoch HE. Steroid variability in pediatric inpatient asthmatics: survey on provider preferences of dexamethasone versus prednisone. J Asthma. 2020 Sep;57(9):942-948. doi: 10.1080/02770903.2019.1622713. Epub 2019 Jun 12. PMID: 31113252; PMCID: PMC8086174.
Nelipovich S, Porada K, Vepraskas S, Soung P, Chou E. Current Practice and Rationale of Prescribing Dexamethasone for Pediatric Patients Hospitalized for Asthma. WMJ. 2022 Apr;121(1):30-35. PMID: 35442576.

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Bronchodilators

- Albuterol
  - Continuous – greater bronchodilation effect at higher dosages with increases in side effects
    - Older age and higher albuterol dose associated with tachycardia
    - Diastolic hypotension associated with age, albuterol dose, Mg use and intubation
    - Elevated troponins assoc'd with diastolic hypotension, Mg use and larger volume boluses
    - Fluid bolus administration decreases odds of diastolic hypotension
    - Hypokalemia not significantly different between continuous and intermittent dosing
    - More likely to need prolonged therapy if: >5yo, GERD or food allergy diagnosis, higher age-standardized HR upon admission
    - Standardized dosing range 0.5-1mg/kg/hr rounded to closest 2.5mg
- Ipratropium Bromide
  - Little evidence to use routinely inpatient
  - Consider as adjunctive therapy in more severe cases
- Magnesium

1. Fergeson JE, Patel SS, Lockey RF. Acute asthma, prognosis, and treatment. J Allergy Clin Immunol. 2016.
2. Pardue Jones B, Fleming GM, Otillio JK, Asokan I, Arnold DH. Pediatric acute asthma exacerbations: Evaluation and management from emergency department to intensive care unit. J Asthma. 2016;53(6):607-617.
3. Phumeetham S, Bahk TJ, Abd-Allah S, Mathur M. Effect of high-dose continuous albuterol nebulization on clinical variables in children with status asthmaticus. Pediatr Crit Care Med. 2015;16(2):e41-6.
4. Kenyon CC, Fieldston ES, Luan X, Keren R, Zorc JJ. Safety and effectiveness of continuous aerosolized albuterol in the non-intensive care setting. Pediatrics. 2014;134(4):e976-82.
5. Wilkinson M, Bulloch B, Garcia-Filion P, Keahey L. Efficacy of racemic albuterol versus levalbuterol used as a continuous nebulization for the treatment of acute asthma exacerbations: A randomized, double-blind, clinical trial. J Asthma. 2011;48(2):188-193.
6. Andrews T, McGintee E, Mittal MK, et al. High-dose continuous nebulized levalbuterol for pediatric status asthmaticus: A randomized trial. J Pediatr. 2009;155(2):205-10.e1.
7. Fagbuyi DB, Venkataraman S, Ralphe JC, et al. Diastolic hypotension, troponin elevation, and electrocardiographic changes associated with the management of moderate to severe asthma in children. Acad Emerg Med. 2016;23(7):816-822.
8. Wisecup S, Eades S, Hashmi SS, Samuels C, Mosquera RA. Diastolic hypotension in pediatric patients with asthma receiving continuous albuterol. J Asthma. 2015;52(7):693-698.
9. Sarnaik SM, Saladino RA, Manole M, et al. Diastolic hypotension is an unrecognized risk factor for beta-agonist-associated myocardial injury in children with asthma. Pediatr Crit Care Med. 2013;14(6):e273-9.
10. Carroll CL, Coro M, Cowl A, Sala KA, Schramm CM. Transient occult cardiotoxicity in children receiving continuous beta-agonist therapy. World J Pediatr. 2014;10(4):324-329.

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How do we make an impact?

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QI 101

FORM A TEAM

Respiratory Therapy
Nursing
Pharmacy
Clinicians
Educators
Administrators

DEVELOP PROJECT PLAN

Create a clear problem statement
Define scope

IDENTIFY YOUR TOOLS & RESOURCES

Staffing
Approval Committees
Dissemination
Standardization

WORK TOWARD SMART METRICS

Specific
Measurable
Achievable
Relevant
Timebound

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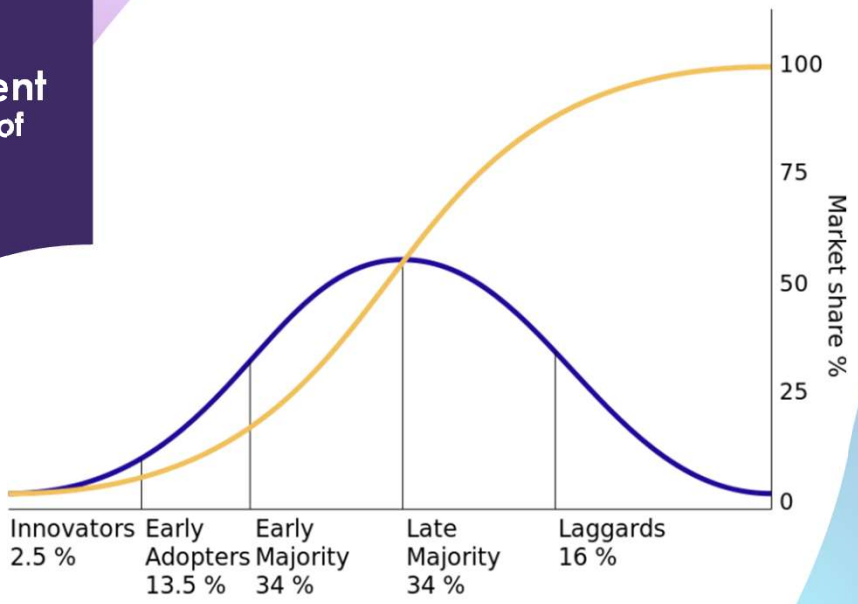
Change Management – Psychology of Change



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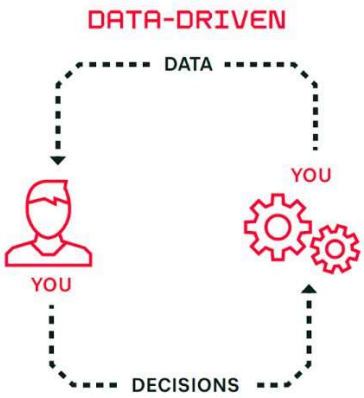
Utilizing Data



Build a team that brings a mix of experience, perspectives, and affability for change

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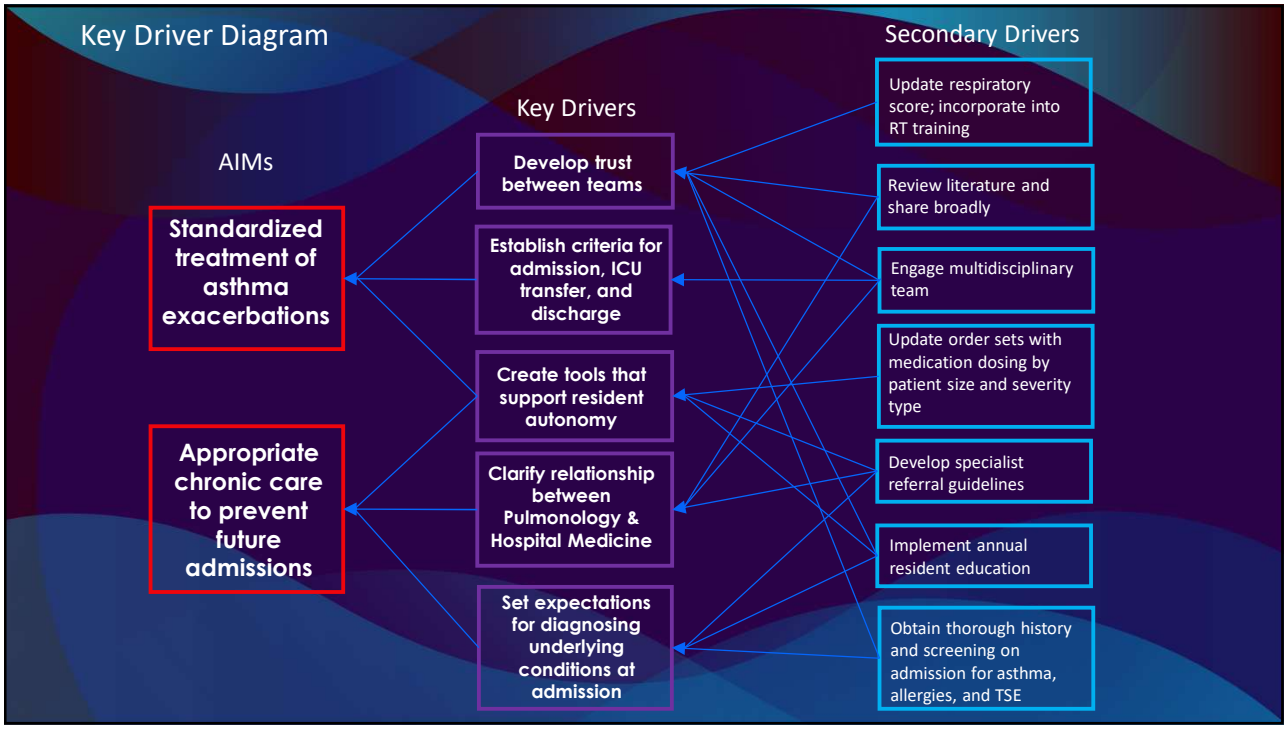
Key Driver Diagram
AIMs
Standardized treatment of asthma exacerbations
Appropriate chronic care to prevent future admissions
Key Drivers
Develop trust between teams
Establish criteria for admission, ICU transfer, and discharge
Create tools that support resident autonomy
Clarify relationship between Pulmonology & Hospital Medicine
Set expectations for diagnosing underlying conditions at admission
Secondary Drivers
Update respiratory score; incorporate into RT training
Review literature and share broadly
Engage multidisciplinary team
Update order sets with medication dosing by patient size and severity type
Develop specialist referral guidelines
Implement annual resident education
Obtain thorough history and screening on admission for asthma, allergies, and TSE

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STANDARDIZATION TOOLS
GUIDELINES
National
Statements that contain recommendations based on evidence from rigorous systematic review and synthesis of published literature
PATHWAYS
Local
Translation of guidelines, latest literature, specialty preferences and knowledge of resources into practice. Provides series of recommendations to the multidisciplinary team to reduce unnecessary variation in care.
PROTOCOLS
Role Specific
Set of assessments and interventions constrained by rules or algorithms that define the care of a specific patient condition by a delegate (RT, RN, etc) initiated by a provider order

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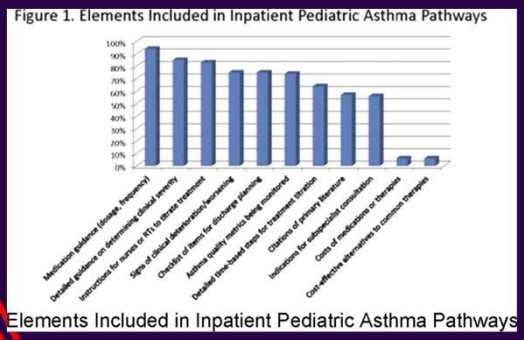
UTILIZATION & CHARACTERISTICS OF ASTHMA PATHWAYS



Sunitha V. Kaiser, Jonathan Rodean, Matt Hall, Samir Shah, Sanjay Mahant, Kavita Parikh, Rustin Morse, Arpi Bekmezian, Henry Puls, Michael Cabana; Utilization & Characteristics of Inpatient Pediatric Asthma Pathways in the United States. *Pediatrics* January 2018; 141 (1_MeetingAbstract): 445. 10.1542/peds.141.1MA5.445

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Reducing Variation In EDs

- ED pathway use significantly decreases time to corticosteroid administration (45 vs 29min to 20min year 2, *p <0.0001*) (Lucia 2020)
- Guidelines reduce ED LOS for treat-and-release patients (3.9 v. 3.3hrs), hospital LOS (1.5 v. 1.3 days), admission rates from ED (23.5% v. 18.8%), ICU admissions (23% v. 13.2%) and total charges ($4,457 v. $3,651) (Johnson 2018)
- Children in General EDs compared to Pediatric EDs
  - Less likely to receive corticosteroids in compliance with NIH guidelines (Miller 2015)
  - More likely to receive unnecessary testing and treatment (CXR and antibiotics)
  - Children's ED have higher compliance with all 3 goals (42% v. 31%) but overall only 34% of visits were concordant with guideline-based care (Hudgins 2021)
  - Guideline implementation increased utilization of steroids and decreased time to administration in community EDs (Walls 2017)

Miller AG, Breslin ME, Pineda LC, Fox JW. An Asthma Protocol Improved Adherence to Evidence-Based Guidelines for Pediatric Subjects With Status Asthmaticus in the Emergency Department. Respir Care. 2015 Dec;60(12):1759-64. doi: 10.4187/respcare.04011. Epub 2015 Jun 23. PMID: 26106203.
Hudgins JD, Neuman MI, Monuteaux MC, Porter J, Nelson KA. Provision of Guideline-Based Pediatric Asthma Care in US Emergency Departments. Pediatr Emerg Care. 2021 Oct 1;37(10):507-512. doi: 10.1097/PEC.0000000000001706. PMID: 30624420
Walls TA, Hughes NT, Mullan PC, Chamberlain JM, Brown K. Improving Pediatric Asthma Outcomes in a Community Emergency Department. Pediatrics. 2017 Jan;139(1):e20160088. doi: 10.1542/peds.2016-0088. Epub 2016 Dec 8. PMID: 27940506
Lucia D, Cain J, Porter A, Sagar M, Blazovic S, Finley L, Mallett L. Pediatric asthma pathway in the emergency room. Proc (Bayl Univ Med Cent). 2020 Aug 21;34(1):40-43. doi: 10.1080/08998280.2020.1801110. PMID: 33456142; PMCID: PMC7785189.
Johnson DP, Arnold DH, Gay JC, Grisso A, O'Connor MG, O'Kelley E, Moore PE. Implementation and Improvement of Pediatric Asthma Guideline Improves Hospital-Based Care. Pediatrics. 2018 Feb;141(2):e20171630. doi: 10.1542/peds.2017-1630. PMID: 29367203

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Reducing Variation In EDs

- Seattle Children's (Rutman 2016): retrospective study of QI initiative comparing pre and post asthma pathway implementation
  - Had Respiratory Clinical Score (CS) in place since 2002 with good interobserver agreement and pre-existing pathway
  - Noted 90% of patients with high score (9-12) after 1 hr were ultimately admitted yet had variable and prolonged LOS in the ED
  - Developed respiratory score-based admission criteria after 1 hr of treatment
  - Median ED LOS and time to bed request decreased by 30 mins without a change in % admissions, median inpatient LOS or PICU admissions

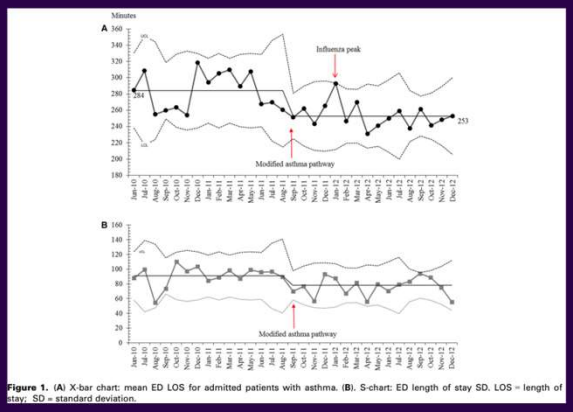

Figure 1. (**A**) X-bar chart: mean ED LOS for admitted patients with asthma. (**B**). S-chart: ED length of stay SD. LOS = length of stay; SD = standard deviation.

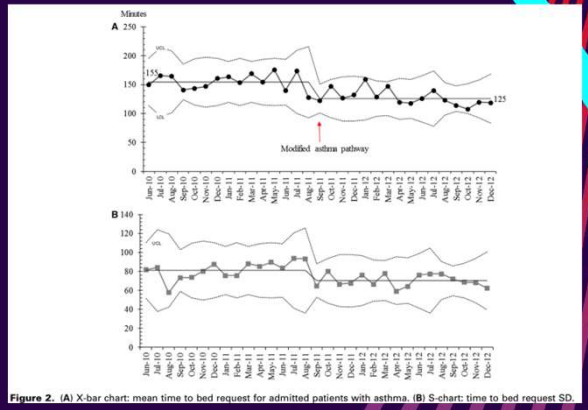

Figure 2. (**A**) X-bar chart: mean time to bed request for admitted patients with asthma. (**B**) S-chart: time to bed request SD.

Rutman L, Migita R, Spencer S, Kaplan R, Klein EJ. Standardized Asthma Admission Criteria Reduce Length of Stay in a Pediatric Emergency Department. Acad Emerg Med. 2016 Mar;23(3):289-96. doi: 10.1111/acem.12890. Epub 2016 Feb 13. PMID: 26728418.
Rutman L, Atkins RC, Migita R, Foti J, Spencer S, Lion KC, Wright DR, Leu MG, Zhou C, Mangione-Smith R. Modification of an Established Pediatric Asthma Pathway Improves Evidence-Based, Efficient Care. Pediatrics. 2016 Dec;138(6):e20161248. doi: 10.1542/peds.2016-1248. Epub 2016 Nov 2. PMID: 27940683.

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Reducing Variation In EDs

Seattle Children's (Rutman, 2016):

- Impact of modifications in their pathway in 2011, including order set redesign and provider education, improved provider adherence to the pathway and subsequent delivery of care
- PDCA cycles can producing ongoing improvements
- Modification of pathways can be utilized to incorporate new evidence as it is produced

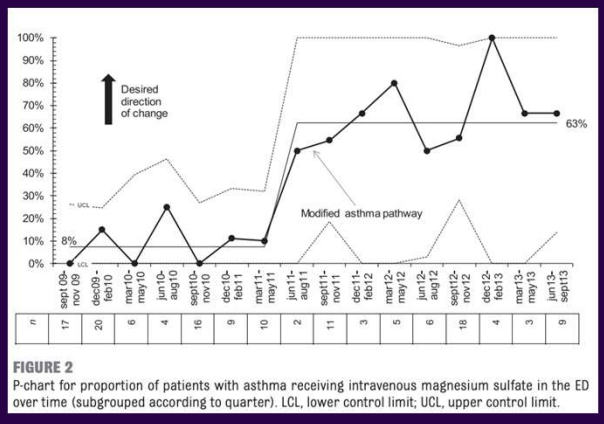

FIGURE 2
P-chart for proportion of patients with asthma receiving intravenous magnesium sulfate in the ED over time (subgrouped according to quarter). LCL, lower control limit; UCL, upper control limit.

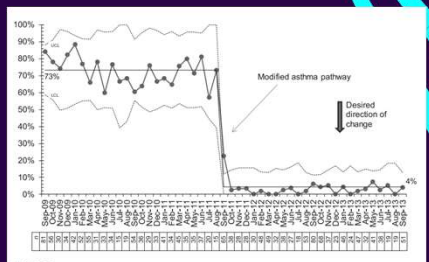

FIGURE 3
P-chart for proportion of patients with asthma receiving ipratropium bromide as an inpatient over time. LCL, lower control limit; UCL, upper control limit.

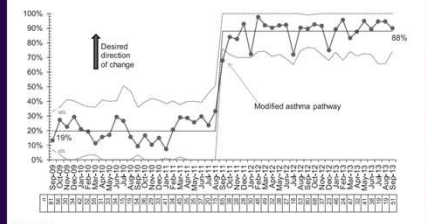

FIGURE 4
P-chart for proportion of admitted patients with asthma receiving the appropriate steroid prescription at hospital discharge. An appropriate prescription was defined as prednisone or prednisolone (2 mg/kg/d) for 5 to 10 days. LCL, lower control limit; UCL, upper control limit.

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INPATIENT PATHWAYS

Rainbow Babies and Children's Hospital, 1995-1996, Asthma Care Algorithm (ACA) used on c
- aLOS significantly shorter (2 v. 2.9d, p<0.001)
- ACA patients received fewer doses of beta-agonists but no difference in relapse rat
- >$700 saved per patient in hospital charges

NY Presbyterian-Weill Cornell Medical Center, 1994-1998 retrospective, non-randomized cor
- LOS decreased from 4.2 days to 2.7 days (P < 0.0001)
- Annual total charges for admissions decreased from $2M to $1.4M ($P$ < 0.005)
- Nursing and laboratory costs showed a statistically significant decrease
- Follow-up study at 8 months showed a readmission rate of 0.02%

Johns Hopkins, Randomized, controlled trial, 1995-1997 (Johnson, 2000):
- Included RN-driven protocol for weaning bronchodilators
- Intervention group had LOS 13h shorter than the control group and received less b increase in adverse outcomes or return visits to acute care

Children's Hospital of the King's Daughters, 1997, randomized with retrospective cohort cont
- LOS significantly less in the pathway group, 36h v. 71h (p<0.001)
- Total costs decreased $2,829 -> %1,685 ($p$<0.001)
- Pathway patients more likely to complete asthma teaching (65% v. 18%) (p<0.001), p<0.01), peak flow meter use (57% v. 23%, P<0.05), and with a spacer (100% v. 71%r

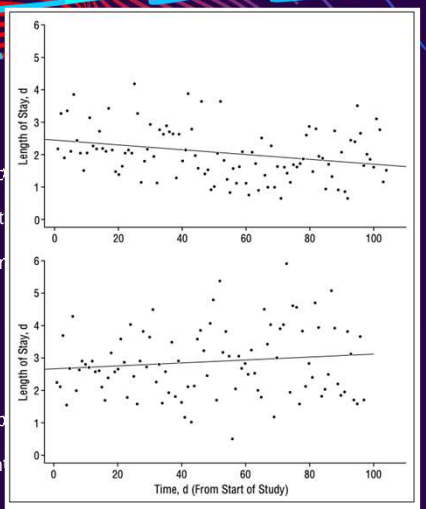

Figure 3. *Length of stay for asthma over the course of the study period. Top, Asthma care algorithm group (slope = 0.007, P = .003); bottom, control group (slope = 0.004, P = .26).*

Wazeka A, Valacer DJ, Cooper M, Caplan DW, DiMaio M. Impact of a pediatric asthma clinical pathway on hospital cost and length of stay. Pediatr Pulmonol. 2001 Sep;32(3):211-6. doi: 10.1002/ppul.1110. PMID: 11536450.
Johnson KB, Blaisdell CJ, Walker A, Eggleston P. Effectiveness of a clinical pathway for inpatient asthma management. Pediatrics 2000 Nov; 106(5): 1006-12.
Kelly CS, Andersen CL, Pestian JP, Wenger AD, Finch AB, Strope GL, Luckstead EF. Improved outcomes for hospitalized asthmatic children using a clinical pathway. Ann Allergy Asthma Immunol. 2000 May;84(5):509-16. doi: 10.1016/S1081-1206(10)62514-8. PMID: 10831004.
McDowell KM, Chatburn RL, Myers TR, O'Riordan MA, Kercsmar CM. A cost-saving algorithm for children hospitalized for status asthmaticus. Arch Pediatr Adolesc Med. 1998 Oct;152(10):977-84. doi: 10.1001/archpedi.152.10.977. PMID: 9790607.

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INPATIENT PATHWAYS

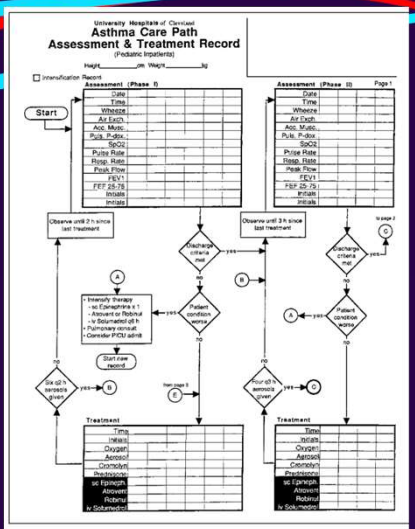

Figure 1. *Sample Algoform sheet, page 1 of 4. Top portion of form records chest assessment data, followed by algorithm cues, and then an area to record treatment given.*

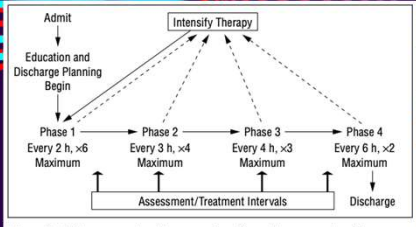

Figure 2. *Asthma care algorithm overview. The asthma care algorithm consists of 4 phases of decreasing frequency of assessment (eg, in phase 1, patients are assessed every 2 hours; phase 2, patients are assessed every 3 hours, and so on). Treatment occurs only when patients failed to meet specific discharge criteria at each assessment. Advancement to the next phase occurs as soon as discharge criteria are met or after 12 hours in phase. Intensified therapy may be given in any phase for clinical deterioration. Patients are discharged home when they require treatment no more often than every 6 hours.*

Table 1. Chest Assessment Measures*

Measure	Good	Fair	Poor
Wheezing	None or end-expiratory only	Inspiratory and expiratory	Breath sounds becoming inaudible
Air exchange	Equal in all lobes and not decreased	Decreased in some areas	Decreased throughout all lobes
Accessory muscle use	None	Intercostal or subcostal retractions	Same as fair with use of sternocleidomastoid muscles
Oxygen saturation (pulse oximetry), %	≥94	91-93	<90
Respiratory rate	Normal for age	Increased	Increased

**The frequency of assessment was determined by individual patient condition and results of previous assessment.*

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Inpatient Standardization

PATHWAYS FOR IMPROVING INPATIENT PEDIATRIC ASTHMA (PIPA)

- National QI project through the AAP's Value in Inpatient Pediatrics Network, now known as the Pediatric Acute & Critical Care (PACC) Quality Network, conducted in 2017
- Provided toolkit for implementing pathways and order sets
  - Guidance on dosing MDIs
  - Guidance on titration by RNs or RTs
  - Hospital discharge criteria
  - Reminders for Tobacco Smoke Exposure (TSE) screening and referrals
- *Set aims for all participating hospitals, ED:
  - Decrease overall usage of CXR to 15%
  - Achieve 90% documented compliance with assessing severity of exacerbations at triage
  - Increase proportion eligible children who receive systemic corticosteroids within 60 mins of arrival to 50%

Inpatient:

- Decrease inpatient LOS by 10%
- Increase early transition to administering bronchodilator via MDI by 50%
- Decrease prescription Abx at discharge to 10%
- Achieve 90% compliance with screening for secondhand smoke exposure
- Achieve a 50% increase in documentation of caregiver referral to smoking cessation resources

Sunitha V. Kaiser, Brittany Jennings, Jonathan Rodean, Michael D. Cabana, Matthew D. Garber, Shawn L. Ralston, Bernhard Fassl, Ricardo Quinonez, Joanne C. Mendoza, Charles E. McCulloch, Kavita Parikh; Pathways for Improving Inpatient Pediatric Asthma Care (PIPA): A Multicenter, National Study. *Pediatrics* June 2020; 145 (6): e20193026. 10.1542/peds.2019-3026
Gupta N, Cattamanchi A, Cabana MD, Jennings B, Parikh K, Kaiser SV. Implementing pediatric inpatient asthma pathways. J Asthma. 2021 Jul;58(7):893-902. doi: 10.1080/02770903.2020.1741612. Epub 2020 Mar 18. PMID: 32160068.
Kaiser SV, Lam R, Cabana MD, Bekmezian A, Bardach NS, Auerbach A, Rehm RS. Best practices in implementing inpatient pediatric asthma pathways: a qualitative study. J Asthma. 2019;1–11. doi:10.1080/02770903.2019.1606237.

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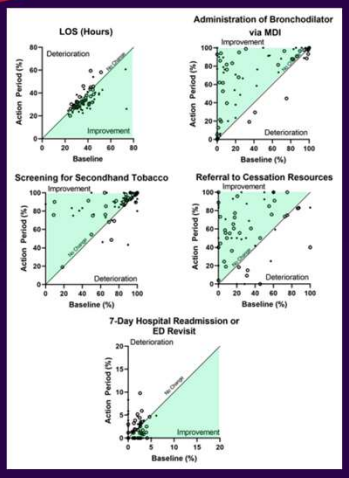
Inpatient Standardization

PATHWAYS FOR IMPROVING INPATIENT PEDIATRIC ASTHMA

- Kaiser 2020: Pathways were associated with increases in early administration of MDIs and referral to smoking cessation resources, but not other outcomes such as LOS. Most hospitals improved at least 1 outcome.
- Gupta 2021: 80% of hospitals completed implementation with overall high fidelity. Median time cost was 78h. Leaders reported improvements in care, enhanced interdisciplinary collaboration, and access to educational resources. Barriers = modifying EHRs.
- Kaiser 2019: QI methodology and data-driven approach helped overcome inertia. Committing to shared goals helped overcome disagreements. Integrating into EMR decreased some burden in implementation. Leveraging multi-disciplinary teams with protocols reduces variability in practice and expediates care. Engaging hospital leaders helps secure crucial resources.



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STANDARDIZING IN COMMUNITY SETTINGS

MCDANIELS 2019
Key determinants of pathway implementation in community hospitals includes

- Building implementation structure
- Engaging providers
- Addressing organizational and resource limitations
- Devising implementation solutions with external facilitators

JALADANKI 2022

High performing hospital qualities

- Dedicated local champions to provide consistent reminders of evidence-based practice and ongoing education
- Modify EMR tools
- Collaborative culture receptive to practice change and firm expectations to follow evidence-based practices

BARTLETT 2017
Combining tools via a pathway improves efficiency and outcomes

- Utilized standardized asthma score, RT driven albuterol protocol, order sets/EMR tools, and targeted education
- aLOS decreased from 2.9 to 2.3d
- Variable direct cost savings of $1,543 per case
- No increase in admissions

McDaniel CE, Jeske M, Sampayo EM, Liu P, Walls TA, Kaiser SV. Implementing Pediatric Asthma Pathways in Community Hospitals: A National Qualitative Study. J Hosp Med. 2020 Jan 1;15(1):35-41. doi: 10.12788/jhm.3296. Epub 2019 Sep 18. PMID: 31532746.
Jaladanki, Sravya et al. "Strategies for Sustaining High-Quality Pediatric Asthma Care in Community Hospitals." *Health services research : HSR.* 57.1 (2022): 125–136. Web.
Bartlett KW, Parente VM, Morales V, Hauser J, McLean HS. Improving the Efficiency of Care for Pediatric Patients Hospitalized With Asthma. Hosp Pediatr. 2017 Jan;7(1):31-38. doi: 10.1542/hpeds.2016-0108. Epub 2016 Dec 8. PMID: 27932381.

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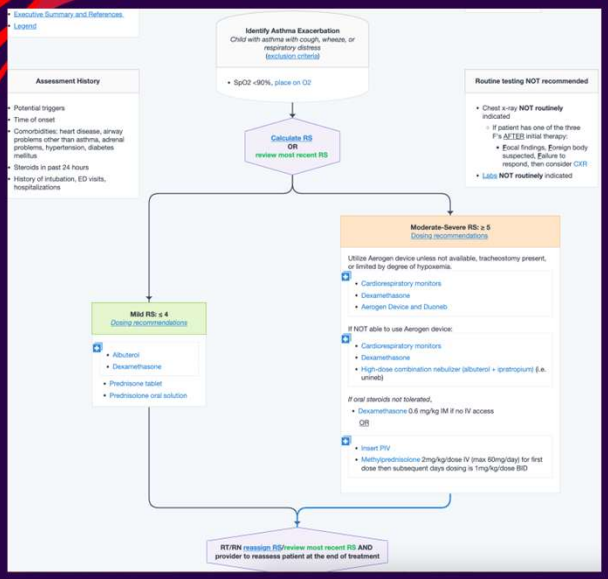
INITIAL ED MANAGEMENT



Dosing Guidelines for Moderate to Severe (RS 5 or above)

- Place on CR monitors
- Attempt dexamethasone PO once (max 16mg/day).

Patient weight	Dose (Number of 4mg tabs)
0 - 5 kg	2 mg (1/2 tab)
5 - 8 kg	4 mg (1 tab)
8 - 10 kg	6 mg (1.5 tab)
10 - 15 kg	8 mg (2 tab)
15 - 20 kg	10 mg (2.5 tab)
20 - 25 kg	12 mg (3 tab)
> 25 kg	16 mg (4 tab)

If not tolerated, give dexamethasone 0.6 mg/kg IM if no IV access OR methylprednisolone 2mg/kg/dose IV (max 60mg/day) for first dose then subsequent days dosing is 1mg/kg/dose BID

If Aerogen device used:

<10kg	>10kg
• 1 Duoneb ampule (3mL) ○ 2.5mg albuterol + 0.5mg ipratropium	• 2 Duoneb ampules (6 mL) ○ 5mg albuterol + 1mg ipratropium

If Aerogen device not used, start high-dose combination nebulizer treatment:

<10kg	>10kg
Albuterol nebulized 2.5mg x 3 AND ipratropium bromide 500mcg	Albuterol nebulized 5mg x 3 AND ipratropium bromide 1000mcg

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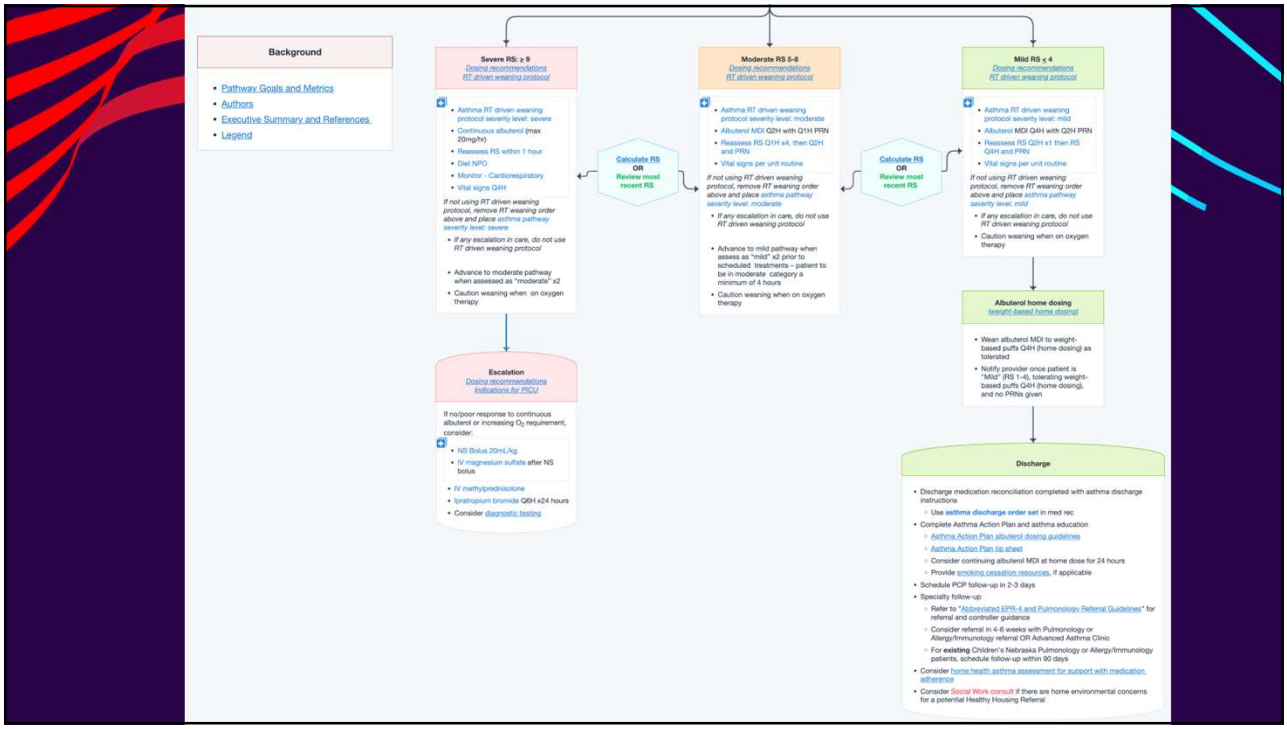
Background
Pathway Goals and Metrics
Authors
Executive Summary and References
Legend
Severe RS: ≥ 9
Dosing recommendations
RT driven weaning protocol
Asthma RT driven weaning protocol severity level: severe
Continuous albuterol (max 20mg/hr)
Reassess RS within 1 hour
Diet NPO
Monitor - Cardiorespiratory
Vital signs Q4H
If not using RT driven weaning protocol, remove RT weaning order above and place asthma pathway severity level: severe
If any escalation in care, do not use RT driven weaning protocol
Advance to moderate pathway when assessed as "moderate" x2
Caution weaning when on oxygen therapy
Calculate RS OR Review most recent RS
Moderate RS 5-8
Dosing recommendations
RT driven weaning protocol
Asthma RT driven weaning protocol severity level: moderate
Albuterol MDI Q2H with Q1H PRN
Reassess RS Q1H x4, then Q2H and PRN
Vital signs per unit routine
If not using RT driven weaning protocol, remove RT weaning order above and place asthma pathway severity level: moderate
If any escalation in care, do not use RT driven weaning protocol
Advance to mild pathway when assess as "mild" x2 prior to scheduled treatments – patient to be in moderate category a minimum of 4 hours
Caution weaning when on oxygen therapy
Calculate RS OR Review most recent RS
Mild RS ≤ 4
Dosing recommendations
RT driven weaning protocol
Asthma RT driven weaning protocol severity level: mild
Albuterol MDI Q4H with Q2H PRN
Reassess RS Q2H x1 then RS Q4H and PRN
Vital signs per unit routine
If not using RT driven weaning protocol, remove RT weaning order above and place asthma pathway severity level: mild
If any escalation in care, do not use RT driven weaning protocol
Caution weaning when on oxygen therapy
Albuterol home dosing
(weight-based home dosing)
Wean albuterol MDI to weight-based puffs Q4H (home dosing) as tolerated
Notify provider once patient is "Mild" (RS 1-4), tolerating weight-based puffs Q4H (home dosing), and no PRNs given
Escalation
Dosing recommendations
Indications for PICU
If no/poor response to continuous albuterol or increasing O2 requirement, consider:
NS Bolus 20mL/kg
IV magnesium sulfate after NS bolus
IV methylprednisolone
Ipratropium bromide Q6H x24 hours
Consider diagnostic testing
Discharge
Discharge medication reconciliation completed with asthma discharge instructions
Use asthma discharge order set in med rec
Complete Asthma Action Plan and asthma education
Asthma Action Plan albuterol dosing guidelines
Asthma Action Plan tip sheet
Consider continuing albuterol MDI at home dose for 24 hours
Provide smoking cessation resources, if applicable
Schedule PCP follow-up in 2-3 days
Specialty follow-up
Refer to "Abbreviated EPR-4 and Pulmonology Referral Guidelines" for referral and controller guidance
Consider referral in 4-6 weeks with Pulmonology or Allergy/Immunology referral OR Advanced Asthma Clinic
For existing Children's Nebraska Pulmonology or Allergy/Immunology patients, schedule follow-up within 90 days
Consider home health asthma assessment for support with medication adherence
Consider Social Work consult if there are home environmental concerns for a potential Healthy Housing Referral

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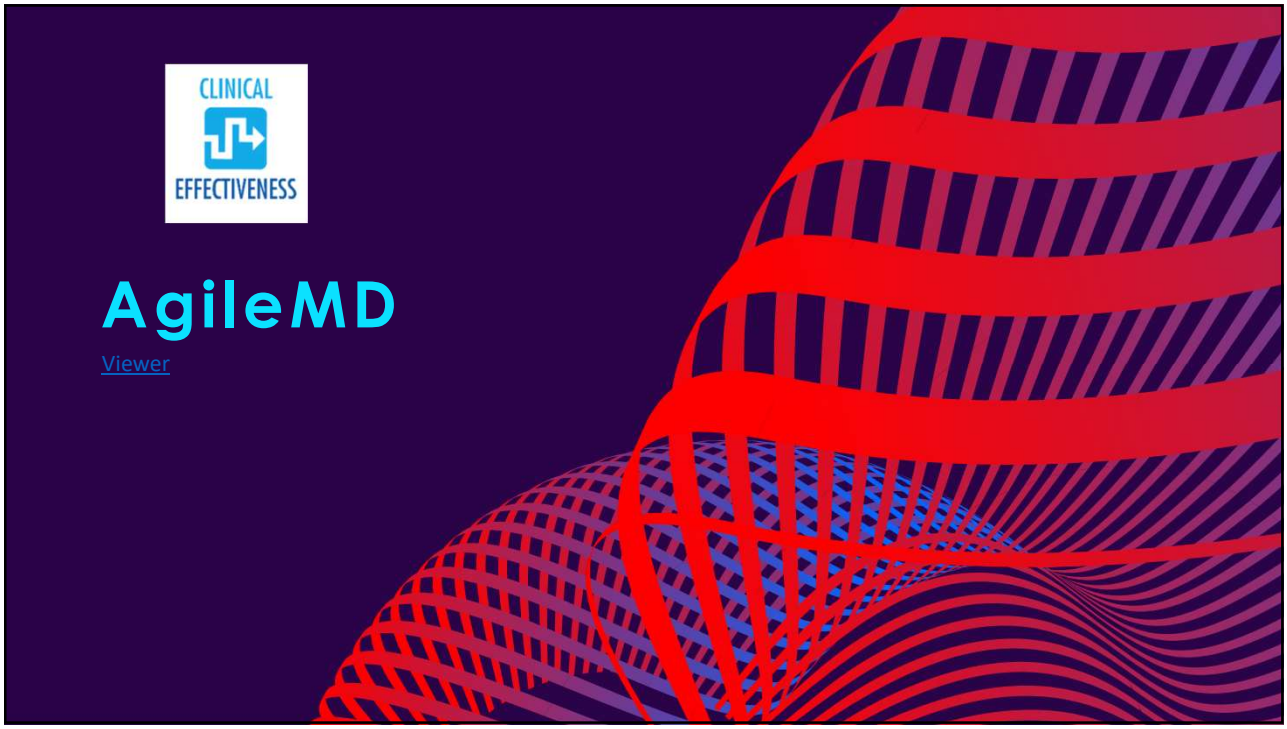
CLINICAL
EFFECTIVENESS
AgileMD
Viewer

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THANK YOU
Lauren Maskin
lmaskin@childrensnebraska.org
CNEB Pathways

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