Received: 6 January 2020 | Revised: 22 April 2020 | Accepted: 28 April 2020

DOI: 10.1002/emp2.12103

JACEP OPEN
JOURNAL OF THE AMERICAN COLLEGE OF EMERGENCY PHYSICIANS OPEN
A GLOBAL JOURNAL OF EMERGENCY MEDICINE
Open Access
WILEY

ORIGINAL RESEARCH

Pediatrics

Pediatric respiratory distress: California out-of-hospital protocols and evidence-based recommendations

Tabitha Cheng MD[1] | Jennifer Farah MD[1] | Nicholas Aldridge MD[1] | Sharon Tamir[2,3] | J. Joelle Donofrio-Odmann DO[1,2,3]

[1]Department of Emergency Medicine, University of California San Diego (UCSD), San Diego, California, USA

[2]Department of Pediatrics, UCSD, San Diego, California, USA

[3]Rady Children's Hospital of San Diego, San Diego, California, USA

Correspondence
Tabitha Cheng, MD, Department of Emergency Medicine, UCSD, San Diego, USA.
Email: tabitha.cheng@gmail.com

Meeting presented at the 2018 National Emergency Medical Services Physicians (NAEMSP) Annual Conference, San Diego, California.

Funding and support: By *JACEP Open* policy, all authors are required to disclose any and all commercial, financial, and other relationships in any way related to the subject of this article as per ICMJE conflict of interest guidelines (see www.icmje.org). The authors have stated that no such relationships exist.

Abstract

Objectives: Prehospital protocols vary across local emergency medical service (EMS) agencies in California. We sought to develop evidence-based recommendations for the out-of-hospital evaluation and treatment of pediatric respiratory distress, and we evaluated the protocols for pediatric respiratory distress used by the 33 California local EMS agencies.

Methods: Evidence-based recommendations were developed through an extensive literature review of the current evidence regarding out-of-hospital treatment of pediatric patients with respiratory distress. The authors compared the pediatric respiratory distress protocols of each of the 33 California local EMS agencies with the evidence-based recommendations. Our focus was on the treatment of 3 main pediatric respiratory complaints by presentation: stridor (croup), wheezing < 24 months (bronchiolitis), and wheezing > 24 months (asthma).

Results: Protocols across the 33 California local EMS agencies varied widely. Stridor (croup) had the highest protocol variability of the 3 presentations we evaluated, with no treatment having uniform use among all agencies. Only 3 (9.1%) of the local EMS agencies differentiated wheezing in children < 24 months of age, referencing this as possible bronchiolitis. All local EMS agencies included albuterol and epinephrine (intravenous/intramuscular) in their pediatric wheezing (asthma) treatment protocols. The least common treatments for wheezing (asthma) included nebulized epinephrine (3/33) and magnesium (2/33). No agencies included steroids in their treatment protocols (0/33).

Conclusion: Protocols for pediatric respiratory distress vary widely across the state of California, especially among those for stridor (croup) and wheezing in < 24 months (bronchiolitis). The evidence-based recommendations that we present for the prehos-

Supervising Editor: Angela Lumba-Brown, MD.

pital treatment of these conditions may be useful for EMS medical directors tasked with creating and revising these protocols.

KEYWORDS
California, emergency medical services, evidence-based, pediatric, prehospital, protocols, Respiratory distress, stridor, wheezing

1 | INTRODUCTION

Respiratory distress is the one of the most frequently encountered pediatric out-of-hospital medical complaints and is the top complaint in children < 1 year of age.[1–3] Prompt identification and treatment of the appropriate underlying cause of pediatric respiratory distress is a challenge for most emergency medical service (EMS) professionals. This is likely because pediatric respiratory distress differs significantly from adult respiratory distress.[4] In 2014, the American Academy of Pediatrics (AAP) made significant changes to bronchiolitis guidelines and the National Association of State EMS Officials (NASEMSO) 2019 National Model EMS Clinical Guidelines include a bronchiolitis pediatric-specific guideline. With bronchiolitis being the leading cause of hospitalization in children < 2 years old and asthma the most common chronic childhood disease, affecting 334 million people worldwide, it is important for out-of-hospital professionals to stay up to date with current guidelines to be able to optimally manage exacerbations in these illnesses.[5,6]

Adults and children have significant differences in airway anatomy and physiology, particularly in infants < 1 year of age.[4] Airway diameter in a pediatric patient is considerably smaller than in an adult, thus any narrowing heightens concern for obstruction.[4] Upper airway causes of pediatric respiratory distress produce noise during inspiration, called stertor or stridor, depending on the location of the problem.[4,7] Stridor results from sounds originating from the larynx and trachea. Causes of stridor on pediatric patients may include croup, anaphylaxis, or foreign body aspiration.[7] Croup or laryngotracheobronchitis is the most common cause of acute stridor in childhood, responsible for 15% of pediatric respiratory visits to the emergency department (ED).[8] It is caused by inflammation in the upper airways usually caused by viruses, occurring most frequently in the fall and winter. In addition to stridor, a classic "barking cough" can also be appreciated in croup, particularly in infants and small children.[7]

Lower airway causes of pediatric respiratory distress produce noises during expiration, called wheezes, rhonchi, or rales, depending on the location and type of problem.[5,9] Children have more smooth muscle throughout their airways, making them more sensitive to inflammation caused by foreign substances and infections.[4] Wheezing in children has multiple etiologies including bronchiolitis (in children < 24 months), asthma, cardiac conditions, and foreign body aspiration, the first 2 being the most common.[9] Bronchiolitis is a seasonal illness, occurring mostly in the fall and winter months.[10] This is a lung condition typically caused by a viral infection, such as respiratory syncytial virus (RSV) or rhinovirus. It affects the lower, smaller portions of the airway known as bronchioles causing retractions and coarse lung sounds. Children often demonstrate upper airway symptoms, such as rhinorrhea, together with lower airway infection and inflammation, causing appreciable wheezes and/or crackles. This can lead to profound dehydration and respiratory failure.[10]

ED management of the most common pediatric respiratory distress presentations, such as stridor and wheezing, has evolved over time, but it is unknown if out-of-hospital protocol changes have progressed at the same pace. Out-of-hospital protocols and treatment recommendations for pediatric respiratory distress vary widely across California. This study focuses on the most common etiologies of stridor and wheezing. Our 2 objectives were first to develop evidence-based recommendations for the out-of-hospital treatment of 3 main pediatric respiratory complaints by symptom presentation: stridor (croup), wheezing in children < 24 months (bronchiolitis), and wheezing in children 2 years and older (asthma), and second to evaluate the current protocols for pediatric respiratory distress used by the 33 EMS agencies in California.

2 | METHODS

EMS systems in California are divided into 33 local EMS agencies (local EMS agencies), each representing either a single county or multiple counties within a region. Each local EMS agency develops their own set of medical control policies to regulate the delivery of EMS within their region. These policies vary widely depending on the complaint. In an effort to improve the quality of EMS care in California, the EMS Medical Directors Association of California (EMDAC) has created evidence-based recommendations for EMS protocols.[11–13] These recommendations are aimed to assist local EMS agency medical directors to develop high-quality, evidence-based protocols.[11–13]

Three authors independently performed a literature review within PubMed. The search was limited to articles in the English language published in PubMed from 1983–2018. During the literature search, the following treatments were concentrated on: epinephrine (nebulized, intramuscular, or intravenous), humidified oxygen, and noninvasive positive pressure ventilation for stridor; suctioning, albuterol, and noninvasive positive pressure ventilation for bronchiolitis; and albuterol, ipratropium, epinephrine (intramuscular or intravenous), magnesium, steroids, and noninvasive positive pressure ventilation for asthma. We also included recommendations made by various

organizations, like the American Academy of Pediatrics (AAP), that have performed systematic reviews and meta-analyses regarding treatment interventions.[10] Given that no articles were found in PubMed searching for "prehospital and pediatric respiratory distress," our review was supplemented with more general search terms including many emergency department- and hospital-based studies. The broader literature search concluded in January 2019 and included search terms such as "croup treatment," "pediatric wheezing treatment," and "bronchiolitis management."

The grading of recommendations assessment, development and evaluation (GRADE) methodology was used to evaluate our literature. We assigned levels of evidence and categorized our recommendations based on the American College of Emergency Physicians (ACEP) process of creating clinical policies, with slight modification. Two authors reviewed studies and assigned levels of evidence based on the study design, including features such as data collection methods, randomization, blinding, outcome measures, and generalizability. Levels of evidence I consisted of randomized controlled trials, prospective cohort studies, meta-analysis of randomized trials or prospective studies or clinical guidelines or comprehensive reviews. Levels of evidence II consisted of nonrandomized trials and retrospective studies. Levels of evidence III consisted of case reports, case series, and expert consensus. Using the assigned levels of evidence of each study, recommendations were made using the following standards.

Level A recommendations

- Out-of-hospital recommendations with a strong degree of certainty based on 1 or more levels of evidence I studies or multiple levels of evidence II studies.

Level B recommendations

- Out-of-hospital recommendations with a moderate degree of certainty based on 1 or more levels of evidence II studies or multiple levels of evidence III studies.

Level C recommendations

- Out-of-hospital recommendations based on only poor quality or minimal levels of evidence III studies or based on consensus.

No recommendation

- No recommendation was given in those cases where only preliminary data or no published evidence exists, and we had no expert consensus.
- We also withheld recommendation when studies, no matter their levels of evidence, showed conflicting data.

In March 2016, 2 authors comparatively reviewed the current pediatric respiratory distress protocol from the 33 agencies (Table 1). The focus of this review was the management of the following categories of pediatric respiratory distress: stridor (croup), wheezing < 24 months (bronchiolitis), and wheezing (asthma). The protocols were then compared to the evidence-based tables, carefully examining the treatment versus its level of evidence, and thus, recommendation level (Table 2). Descriptive statistics were used to compare these protocols.

The Bottom Line

Emergency medical service protocols vary widely for the out-of-hospital management of stridor in the setting of croup and wheezing with bronchiolitis in young children. This variation is an opportunity for practice improvement to improve outcomes in young children with respiratory distress.

3 | RESULTS

3.1 | Evidence review and out-of-hospital treatment recommendations

3.1.1 | Pediatric respiratory distress: treatment of stridor (croup)

3.1.1.1 | *Clinical question*

How should EMS professionals treat pediatric respiratory distress with stridor (croup)?

3.1.1.2 | *Summary of current evidence*

Treatment for stridor in children includes supportive care, nebulized epinephrine, and steroids. Mist or humidified oxygen treatment for stridor is, however, not recommended. There are very few out-of-hospital studies specifically on the treatment of stridor in children, thus our review relies primarily on ED- and hospital-based studies.

Nebulized epinephrine should be administered to children in severe respiratory distress with stridor in the out-of-hospital setting. Based on the following systematic review meeting level I evidence (levels of evidence I), a level A recommendation was made. A Cochrane systematic review based on 8 randomized control trials with 225 pediatric patients with croup evaluating the use of nebulized racemic epinephrine in the ED and inpatient settings showed improvement in symptoms of croup 30 minutes post-treatment but no difference in return visits, length of hospital stay, or intubation rates.[5]

Use of out-of-hospital steroids in the treatment of croup was found to be a level A recommendation. A Cochrane systematic review of 43 randomized control trials with a total of 4565 children with croup showed that glucocorticoids reduced symptoms at 2 hours after treatment, shortened the length of hospital stay, and reduced return visits.[14] An out-of-hospital study involving a retrospective medical record review of 188 croup patients showed that when dexamethasone was administered out-of-hospital, the number of nebulized epinephrine doses decreased significantly.[15] Recommendations for optimal type, dose, and route of glucocorticoid are difficult as these are not as well studied.[14]

Mist or humidified oxygen therapy in patients with stridor is not recommended with level A recommendation against its use. One Cochrane systematic review with 3 ED studies with 135 patients total and 2 randomized controlled trials involving 71 and 140 patients found that mist

TABLE 1 California local EMS agencies' pediatric respiratory distress protocol treatments based on presentation

	Management protocols																		
	Stridor						Wheezing												
							<24 months (bronchiolitis)						≥24 months or age not specified (asthma)						
Local EMS agency	Nebulized Epi	IM or IV Epi	Steroids	Suctioning	Humidified O_2/mist	NIPPV	Suctioning	Albuterol	Nebulized HTS	Nebulized Epi	Steroids	NIPPV	Albuterol	Ipratropium	Nebulized Epi	IM or IV Epi	Steroids	Mg	NIPPV
Alameda	N	N	N	N	N	N	[a]	[a]	[a]	[a]	[a]	[a]	Y	Y	N	Y	N	N	Y
Central California	Y	Y	N	N	N	Y	N	Y	N	N	N	Y	Y	N	N	Y	N	N[b]	Y
Coastal valleys	Y	N	N	N	N	Y	[a]	[a]	[a]	[a]	[a]	[a]	Y	Y	N	Y	N	N	Y
Contra Costa	N	Y	N	N	N	Y	[a]	[a]	[a]	[a]	[a]	[a]	Y	N	N	Y	N	N	Y
El Dorado	Y	Y	N	N	N	Y	[a]	[a]	[a]	[a]	[a]	[a]	Y	Y	N	Y	N	N	Y
Imperial	Y	N	N	N	Y	Y	[a]	[a]	[a]	[a]	[a]	[a]	Y	N	N	Y	N	N	Y
Inland counties	N	Y	N	N	Y	Y	[a]	[a]	[a]	[a]	[a]	[a]	Y	Y	N	Y	N	N	Y
Kern	Y	Y	N	N	N	Y	[a]	[a]	[a]	[a]	[a]	[a]	Y	Y	N	Y	N	Y	Y
Los Angeles	Y	N	N	N	N	Y	[a]	[a]	[a]	[a]	[a]	[a]	Y	N	N	Y	N	N	Y
Marin	Y	N	N	N	Y	Y	[a]	[a]	[a]	[a]	[a]	[a]	Y	Y	N	Y	N	N	Y
Merced	Y	N	N	N	N	Y	[a]	[a]	[a]	[a]	[a]	[a]	Y	N	N	Y	N	N[b]	Y
Monterey	N	Y	N	N	N	N	[a]	[a]	[a]	[a]	[a]	[a]	Y	Y	N	Y	N	N	N
Mountain valley	N	Y	N	N	Y	Y	N	Y	N	N	N	Y	Y	N	N	Y	N	N	Y
Napa	N	N	N	N	N	Y	[a]	[a]	[a]	[a]	[a]	[a]	Y	Y	N	Y	N	N	Y
North Coast	Y	Y	N	N	N	Y	[a]	[a]	[a]	[a]	[a]	[a]	Y	Y	N	Y	N	Y	Y
Northern California	N	Y	N	N	Y	Y	[a]	[a]	[a]	[a]	[a]	[a]	Y	N	N	Y	N	N	Y
Orange	N	N	N	N	Y	Y	[a]	[a]	[a]	[a]	[a]	[a]	Y	N	N	Y	N	N	Y
Riverside	N	Y	N	N	N	N	[a]	[a]	[a]	[a]	[a]	[a]	Y	Y	N	Y	N	N	Y
Sacramento	N	Y	N	N	Y	Y	[a]	[a]	[a]	[a]	[a]	[a]	Y	N	N	Y	N	N	Y
San Benito	N	Y	N	N	Y	Y	[a]	[a]	[a]	[a]	[a]	[a]	Y	N	N	Y	N	N	Y
San Diego	Y	Y	N	N	Y	Y	[a]	[a]	[a]	[a]	[a]	[a]	Y	Y	N	Y	N	N	Y
San Francisco	N	Y	N	N	N	Y	[a]	[a]	[a]	[a]	[a]	[a]	Y	N	N	Y	N	N	Y
San Joaquin	N	N	N	Y	Y	Y	[a]	[a]	[a]	[a]	[a]	[a]	Y	Y	N	Y	N	N	Y
San Luis Obispo	N	Y	N	N	N	Y	[a]	[a]	[a]	[a]	[a]	[a]	Y	N	Y	Y	N	N	Y
San Mateo	N	Y	N	Y	Y	Y	[a]	[a]	[a]	[a]	[a]	[a]	Y	N	N	Y	N	N	Y

(Continues)

TABLE 1 (Continued)

Local EMS agency	Management protocols: Stridor: Nebulized Epi	IM or IV Epi	Steroids	Suctioning	Humidified O_2/mist	NIPPV	Wheezing: <24 months (bronchiolitis): Suctioning	Albuterol	Nebulized HTS	Nebulized Epi	Steroids	NIPPV	≥24 months or age not specified (asthma): Albuterol	Ipratropium	Nebulized Epi	IM or IV Epi	Steroids	Mg	NIPPV
Santa Barbara	N	Y	N	N	Y	Y	a	a	a	a	a	a	Y	N	N	Y	N	N	Y
Santa Clara	N	Y	N	N	Y	Y	a	a	a	a	a	a	Y	N	N	Y	N	N	Y
Santa Cruz	N	Y	N	N	Y	N	a	a	a	a	a	a	Y	N	N	Y	N	N	Y
Sierra-Sacramento	Y	Y	N	N	Y	Y	a	a	a	a	a	a	Y	Y	N	Y	N	N	Y
Solano	N	Y	N	N	N	Y	a	a	a	a	a	a	Y	N	N	Y	N	N	Y
Tuolumne	N	Y	N	Y	Y	Y	N	Y	N	N	N	Y	Y	Y	N	Y	N	N[b]	Y
Ventura	N	Y	N	N	Y	Y	a	a	a	a	a	a	Y	N	Y	Y	N	N	Y
Yolo	Y	Y	N	Y	Y	Y	a	a	a	a	a	a	Y	Y	Y	Y	N	N	Y

Epi, epinephrine; IM, intramuscular; IV, intravenous; Mg, magnesium; NIPPV, noninvasive positive pressure ventilation; HTS, hypertonic saline; O_2, oxygen.
Y refers to "Yes," the number of local emergency medical services agencies who include this treatment in their protocols, versus N for "No".
[a]Specific wheezing protocols for bronchiolitis or < 24 months do not exist.
[b]This local EMS agency has Mg protocols for Adult respiratory distress, but no specific guidelines for pediatrics.

therapy is ineffective for improving respiratory distress in pediatric patients with croup.[16–18]

No studies were found specifically examining parenteral (intravenous or intramuscular) epinephrine use in pediatric patients with stridor or croup. In regard to treatment with noninvasive positive pressure ventilation, 1 small nonrandomized trial focusing on children with chronic stridor from laryngomalacia identified that noninvasive positive pressure ventilation was well tolerated and improved work of breathing.[19] Given this population is unique compared to the general out-of-hospital population with acute stridor, conclusions cannot be made from this study on whether noninvasive positive pressure ventilation would help in all cases of acute stridor.

3.1.1.3 | Current out-of-hospital treatment recommendation

Level A recommendation

- Treatment with nebulized epinephrine should be initiated in children with stridor and respiratory distress.
- Treatment with steroids should be initiated in patients with suspected croup.
- Treatment with mist therapy does not show any benefit.

Level B recommendation

- Not given.

Level C recommendation

- Not given.

No recommendation

- Treatment with noninvasive positive pressure ventilation.
- Treatment with IV/IM epinephrine.

3.1.2 | Pediatric respiratory distress: treatment of wheezing < 24 month (bronchiolitis)

3.1.2.1 | Clinical question

What is the treatment indicated for pediatric respiratory distress with wheezing in children < 24 months old (bronchiolitis)?

3.1.2.2 | Summary of current evidence

Treatment for wheezing in children < 24 months (bronchiolitis) is mainly supportive care. For this population, literature for treatment with beta-agonists, noninvasive positive pressure ventilation, and suctioning was examined more closely. There are very few out-of-hospital studies specifically on the treatment of wheezing in children < 2 years of age, thus our review relies primarily on ED- and hospital-based studies.

Given that bronchiolitis is associated with upper airway symptoms, such as rhinorrhea and nasal congestion, and infants are obligate nasal breathers, nasal suctioning is often part of the supportive care.[10] The studies that examined this met level II and III evidence, thus a Level B recommendation is made for the use of nasal suctioning in children < 24 months with wheezing with excessive secretions. A retrospective cohort study with 740 infants from 2 to 12 months with bronchiolitis found that more frequent nasal suctioning was

TABLE 2 Comparison of California local EMS agency's pediatric respiratory distress protocol treatments and their level of evidence

Management protocols and their level of evidence								
	Stridor (Croup)							
	Nebulized Epi	Steroids	Humidified O_2/mist	NIPPV	IM or IV Epi			
LEMSA[a]	12 (36%)	0 (0%)	18 (55%)	29 (88%)	24 (73%)			
Level of evidence	I	I	I	None	None			
Recommendation level	A	A	A (not to give)	No recommendation	No recommendation			
	Wheezing							
	<24 months (bronchiolitis)				≥24 months or age not specified (asthma)			
	Specify bronchiolitis?	Suctioning	Albuterol	NIPPV	Albuterol	Ipratropium	IM or IV Epi	NIPPV
LEMSA [a]	3 (9%)	0 (0%)	3 (9%)	3 (9%)	33 (100%)	15 (45%)	33 (100%)	32 (97%)
Level of evidence	–	II	I	II	I	I	I	I
Recommendation level	–	B	A (not to give)	A	A	A	A	A

IM, intramuscular; IV, intravenous; Epi, epinephrine; NIPPV, noninvasive positive pressure ventilation; HTS, hypertonic saline; O_2, oxygen.
[a]LEMSA, Local Emergency Medical Services Agency.

associated with decreased length of hospital stay; however, deep suctioning increased length of hospital stay.[20] A survey-based study on physician members of the American Academy of Pediatrics Section of Emergency Medicine, found that 82% of respondents recommended use of suctioning for bronchiolitis.[21]

A Cochrane systematic review and 3 meta-analyses (levels of evidence I) showed that for beta-agonist use in children < 2 years of age with wheezing (bronchiolitis), although there were some improvements in clinical parameters, there were no differences in hospital admission rates, hospitalization duration, or time to symptom resolution.[22–25] Moreover, these meta-analyses and 1 retrospective study (levels of evidence II) also showed potential for harmful adverse effects (tremors and tachycardia) when using beta-agonists in this population.[22,23,26] According to our review, and in agreement with recent AAP guidelines,[10] there is a level A recommendation against the use of albuterol for bronchiolitis given that the incidence of adverse effects outweighs any potential benefits. Similarly, inhaled anticholinergics have not been shown to improve outcomes in wheezing children < 2 years of age.[22,27] An important caveat is that the AAP guideline "does not apply to children with immunodeficiencies…, children with recurrent history of wheezing, chronic neonatal lung disease (bronchopulmonary dysplasia), neuromuscular disease, cystic fibrosis, or those with hemodynamically significant congenital heart disease."[8] Thus, if a pediatric patient < 24 months is in respiratory distress with wheezing, and history is unknown or unobtainable under the emergency circumstances, treatment with a dose of a beta-agonist may not be contraindicated. A keynote for out-of-hospital education and protocols would be the need to document whether there was a response to the albuterol if used.

Based on studies meeting level I and II evidence (levels of evidence I and II), a level A recommendation was made for noninvasive positive pressure ventilation use in the treatment of bronchiolitis.[28–30] A randomized control trial with 29 infants < 1 year of age with bronchiolitis and elevated carbon dioxide capillary levels, were randomized and treated with continuous positive airway pressure (CPAP) verses standard therapy showing a statistically significant decrease in capillary carbon dioxide levels.[28] A prospective, observational study of 12 infants with a diagnosis of bronchiolitis placed on nasal CPAP showed a significant decrease in respiratory accessory muscle use and expiratory wheezing.[29] A retrospective study with 49 children of a median age of 1.9 months showed that CPAP was effective in improving respiratory rate.[30]

3.1.2.3 | *Current out-of-hospital treatment recommendation*

Level A recommendation

- Treatment with nebulized albuterol has not been proven beneficial in the previously healthy patient with bronchiolitis.
- Treatment with noninvasive positive pressure ventilation should be initiated.

Level B recommendation

- Treatment with suctioning should be initiated.

Level C recommendation

- Not given.

3.1.3 | Pediatric respiratory distress: treatment of wheezing (asthma)

3.1.3.1 | *Clinical question*

How should EMS professionals treat pediatric respiratory distress with wheezing (asthma)?

3.1.3.2 | *Summary of the current evidence*

Recommendations based on current evidence supports the use of albuterol, ipratropium, magnesium, steroids, and noninvasive positive pressure ventilation in a child with an acute asthma exacerbation. There is strong evidence in the literature for albuterol use on pediatric patients in respiratory distress with known asthma in the ED[23,31–34]; however, the out-of-hospital literature is limited. Some out-of-hospital studies show improvement in dyspnea with the use of beta-agonists like albuterol.[35–37] One small study showed that basic life sup-

port (BLS) professionals could successfully administer nebulized beta-agonists in children.[37]

Multiple studies have shown that in severe asthma exacerbations in children, ipratropium use in the emergency setting reduced hospital admission rates and improved pulmonary function tests with no increase in adverse effects.[38–43] Studies on out-of-hospital use of ipratropium are limited to adults, with 1 small retrospective cohort study showing no differences before and after the addition of ipratropium to an out-of-hospital protocol.[44] Treatment with intravenous magnesium sulfate shows improvement in multiple randomized control trials when given intravenously during an acute asthma exacerbation.[45–49] A meta-analyses with a total of 859 pediatric patients given magnesium sulfate in the ED for acute bronchospasm showed some improved and no serious adverse events.[45] One Cochrane Review involving 665 patients (including 2 pediatric trials) who received magnesium sulfate in the ED for acute asthma found that for patients with severe asthma, peak flow rates improved and hospital admission rates were reduced.[46] Of note, inhaled magnesium sulfate has inconclusive results with a Cochrane Review of 6 trials showing no improvement in outcomes.[50]

Evidence for steroid administration in the ED for a pediatric patient during a moderate to severe asthma exacerbation is strong, and many studies suggest early administration for the best outcomes.[51–59] Current literature for out-of-hospital steroid administration in pediatric asthma exacerbations is limited; however, 1 small retrospective cohort study showed that after addition of out-of-hospital-administered oral dexamethasone to their asthma protocol, asthmatic children who received out-of-hospital steroids had shorter total hospital and total care times, decreased hospitalization rates, and less need for critical care.[60] Multiple studies showed that noninvasive positive pressure ventilation use in asthmatic children decreased work of breathing and improved oxygenation, reducing intubation rates.[61–65] Therefore, noninvasive positive pressure ventilation should be used prior to intubation in children with severe asthma exacerbations.

Intravenous and intramuscular epinephrine use in asthma is not well studied. Two randomized control trials showed no difference in clinical scores, pulmonary function, or admission rates between patients who received albuterol alone and patients who received subcutaneous epinephrine.[66,67] One retrospective chart review showed epinephrine used in acute life-threatening asthma was safe in patients 19–58 years of age.[68] Given the limited evidence, epinephrine is recommended for use, in addition to albuterol, only in asthmatic children with impending respiratory failure.

3.1.3.3 | *Current out-of-hospital treatment recommendation*

Level A recommendation

- Treatment with albuterol nebulized or by metered dose inhaler (MDI) should be initiated in all children in respiratory distress with signs of bronchospasm.
- Treatment with nebulized ipratropium should be initiated in moderate to severe asthma exacerbations.
- Treatment with intravenous magnesium should be initiated in severe asthma exacerbations.
- Treatment with steroids should be initiated early.
- Treatment with noninvasive positive pressure ventilation should be initiated in patients with severe asthma exacerbation.

Level B recommendation

- Not given.

Level C recommendation

- Treatment with intravenous or intramuscular epinephrine is indicated in addition to albuterol in acutely asthmatic children with impending respiratory failure only.

3.2 | Protocol review

Protocols from all 33 California local EMS agencies were reviewed for consistency and variability (Table 1). These were compared with recommendations for out-of-hospital respiratory distress management developed from the literature review (Table 2). Among the 33 California local EMS agencies, each had a protocol for pediatric stridor (or croup) as well as pediatric wheezing or asthma, but only 3 agencies differentiated wheezing in children < 24 months of age (bronchiolitis). Of the 3 presentations we evaluated, protocols for management of pediatric wheezing or asthma had the least variability, whereas protocols for the management of pediatric stridor had the highest variability.

3.2.1 | Pediatric stridor (croup) treatment

Stridor had the highest protocol variability of the 3 presentations we evaluated, with no treatment having uniform use among all agencies. The most common treatments included IV/IM epinephrine (24/33), noninvasive positive pressure ventilation (29/33), and humidified mist (18/33). The least common treatments were nebulized epinephrine (12/33) and suctioning (4/33). California local EMS agency protocols did not have stridor in the same categories. Some included stridor under "foreign body aspiration," others in "anaphylaxis" and some listed it as its own separate entity. Rarely was stridor listed under a specific "croup" protocol.

3.2.2 | Pediatric wheezing < 24 months (bronchiolitis) treatment

Three (9.1%) of the local EMSs agencies differentiated wheezing in children < 24 months of age, referencing this as possible bronchiolitis. All 3 included albuterol and noninvasive positive pressure ventilation as their recommended treatments. None of these included suctioning as part of their treatments.

3.2.3 | Pediatric wheezing (asthma) treatment

All local EMS included albuterol and epinephrine (intravenous/intramuscular) in their pediatric wheezing treatment protocols. The

least common treatments included nebulized epinephrine (3/33) and magnesium (2/33). Ipratropium is included in less than half of the California local EMS agency protocols (15/33). The majority include noninvasive positive pressure ventilation in their treatment protocol (32/33). No agencies included steroids in their treatment protocol (0/33). Only 2 of the 6 treatments, ipratropium (15/33) and nebulized epinephrine (3/33), had > 2 local EMS agencies with significant differences in recommended management.

4 | LIMITATIONS

These evidenced-based recommendations, as well as the protocol review, do not include all possible etiologies of stridor and wheezing in the pediatric patient, but instead they are focused on the most common diagnoses causing these symptoms. Only the protocols within the state of California were evaluated. This may limit the generalizability. The protocols were reviewed in 2016 and may have changed since this review. Additionally, the protocol review was limited to the pediatric respiratory protocols and did not examine the general pediatric protocol, if one was present, thus the number of local emergency medical services agencies with certain management and treatments may have been underestimated. Analyzing the available evidence and synthesizing it into recommendations always involves inherent biases. Specific prehospital research on treatment for pediatric respiratory distress was not often available for the evidence-based recommendations, thus research that was completed in an ED and hospital setting was extrapolated to the prehospital setting.

5 | DISCUSSION

Pediatric stridor protocols had the highest variability of the 3 presentations we evaluated, with no treatment having uniform use among all agencies. Given that stridor was rarely listed under a specific "croup" protocol, this is possibly why the management of stridor varies greatly amongst local emergency medical services agencies. It may be beneficial to specify, and thus itemize, different management practices for all of the various causes of stridor. In the out-of-hospital setting, it can be very difficult to quickly identify the exact cause for audible stridor. However, designing a protocol that describes the specific features of a foreign body aspiration versus an allergic/inflammatory reaction (anaphylaxis) versus an infectious disease (croup and epiglottitis) could assist the out-of-hospital professional in selecting the most appropriate treatment. For example, treatment with racemic epinephrine would be indicated in both croup and anaphylaxis.

In most recent years, the AAP has adjusted its recommendations for treating bronchiolitis.[10] Currently, it is not advised to provide albuterol or steroids. Rather, treatment is more supportive in nature, promoting nasal suctioning, supplemental oxygen, and positive pressure ventilation when needed.[10] It is important for out-of-hospital professionals to be educated and trained on nasal suctioning for infants, as this supportive treatment can considerably improve the patient's respiratory distress. Many would agree that recognizing wheezing in young children as secondary to bronchiolitis and not to asthma, and thus treating them differently, is challenging. Thus, timely educational updates to out-of-hospital personnel informing them of these changes in guidelines are essential. Although albuterol is a very common medication, it is not without its own risks and side effects.[20,23,26] As well, the notion of tunnel-visioning on a single diagnosis, that is, asthma, in the presence of pediatric wheezing is also problematic, particularly when the professional's assumed treatment of choice (ie, albuterol) is not effective in managing the disease. It is important that if albuterol is chosen as a treatment modality, documenting its use and whether it changed the patient's respiratory status is helpful for the ED staff taking over care. Highlighting the uniqueness of bronchiolitis, in both pathology and treatment, could greatly benefit out-of-hospital care and ideally would be represented in each local EMS agency's respective protocols.

Generally, asthma (wheezing) treatment protocols aligned well with the current evidence found in our literature review. However, despite the evidence for use in pediatric asthma exacerbations, ipratropium use was in less than half of the local EMS agencies (15/33). This may be due to the narrow temperature storage window for ipratropium (36°F–77°F) and previous studies showing that many out-of-hospital medications show temperature-dependent degradation.[69,70] Magnesium and steroids were not included in any pediatric wheezing protocols. Magnesium use was included in 3 local EMS agency adult respiratory distress protocols but not in their pediatric protocols.

Although croup, bronchiolitis, and asthma are not exclusive causes of pediatric stridor, wheezing in < 24 months, and wheezing in ≥ 24 months, respectively, these are the most common diagnoses; thus, EMS pediatric protocols for these symptoms should reflect their specific treatments. EMS education, however, should still focus on differential diagnosis and a stepwise approach treatment of a child in respiratory distress. Pediatric respiratory distress protocols vary greatly in content and structure in California, especially among those for stridor (or croup) and wheezing in < 24 months (bronchiolitis). Pediatric stridor (or croup) not only had the highest protocol variability of the 3 presentations we evaluated, but it also had the most treatment deviations from the current evidence. Recent changes to treatment guidelines have likely created the discordance between current treatment practices and our evidence-based recommendations. Due to the limited number of out-of-hospital pediatric respiratory distress treatment studies, many ED-based studies facilitated the creation of these recommendations. The evidence-based recommendations presented in this study may be useful to EMS medical directors for the creation and revision of EMS protocols for the out-of-hospital treatment of pediatric respiratory distress.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

NA and JJD-O reviewed the California prehospital protocols. TC, NA, and ST completed the literature review for the evidence-based recommendations. TC and JF analyzed and interpreted the protocol

review data and the evidence-based recommendations from the literature review to write the manuscript. TC, JF, NA, ST, and JJD-O critically revised the manuscript. TC takes responsibility for the paper as a whole.

ORCID

Tabitha Cheng MD https://orcid.org/0000-0002-9976-2448

REFERENCES

1. Lerner EB, Dayan PS, Brown K, et al. Characteristics of the pediatric patients treated by the Pediatric Emergency Care Applied Research Network's affiliated EMS agencies. *Prehosp Emerg Care*. 2014;18(1):52-59.
2. Dieckmann RA, Brownstein D, Gausche-Hill M eds. *Pediatric Education for Prehospital Professionals: PEPP Textbook*. Sudbury, MA: Jones & Bartlett; 2000.
3. Shah MN, Cushman JT, Davis CO, Bazarian JJ, Auinger P, Friedman B. The epidemiology of emergency medical services use by children: an analysis of the National Hospital Ambulatory Medical Care Survey. *Prehosp Emerg Care*. 2008;12(3):269-276.
4. Mandal A, Kabra SK, Lodha R. Upper airway obstruction in children. *Indian J Pediatr*. 2015;82(8):737-744.
5. Asher I, Pearce N. Global burden of asthma among children. *Int J Tuberc Lung Dis*. 2014;18(11):1269-1278.
6. Pelletier AJ, Mansbach JM, Camargo CA. Direct medical costs of bronchiolitis hospitalizations in the United States. *Pediatrics*. 2006;118(6):2418-2423.
7. Bjornson C, Russell K, Vandermeer B, Klassen TP, Johnson DW. Nebulized epinephrine for croup in children. *Cochrane Database Syst Rev*. 2013(10):CD006619.
8. Zoorob R, Sidani M, Murray J. Croup: an overview. *Am Fam Physician*. 2011;83(9):1067-1073.
9. Simoneau T, Cloutier MM. Controversies in Pediatric Asthma. *Pediatr Ann*. 2019;48(3):e128-e134.
10. Ralston SL, Lieberthal AS, Meissner HC, et al. Clinical practice guideline: the diagnosis, management, and prevention of bronchiolitis. *Pediatrics*. 2014;134(5):e1474-e1502.
11. Glober NK, Sporer KA, Guluma KZ, et al. Acute stroke: current evidence-based recommendations for prehospital care. *West J Emerg Med*. 2016;17(2):104-128.
12. Sanello A, Gausche-Hill M, Mulkerin W, et al. Altered mental status: current evidence-based recommendations for prehospital care. *West J Emerg Med*. 2018;19(3):527-541.
13. Savino PB, Sporer KA, Barger JA, et al. Chest pain of suspected cardiac origin: current evidence-based recommendations for prehospital care. *West J Emerg Med*. 2015;16(7):983-995.
14. Gates A, Gates M, Vandermeer B, et al. Glucocorticoids for croup in children. *Cochrane Database Syst Rev*. 2018;8:CD001955.
15. Ali S, Moodley A, Bhattacharjee A, et al. Prehospital dexamethasone administration in children with croup: a medical record review. *Open Access Emerg Med*. 2018;10:141-147.
16. Moore M, Little P. Humidified air inhalation for treating croup. *Cochrane Database Syst Rev*. 2006(3):CD002870.
17. Scolnik D, Coates AL, Stephens D, Da Silva Z, Lavine E, Schuh S. Controlled delivery of high vs low humidity vs mist therapy for croup in emergency departments: a randomized controlled trial. *JAMA*. 2006;295(11):1274-1280.
18. Neto GM, Kentab O, Klassen TP, Osmond MH. A randomized controlled trial of mist in the acute treatment of moderate croup. *Acad Emerg Med*. 2002;9(9):873-879.
19. Fauroux B, Pigeot J, Polkey MI, et al. Chronic stridor caused by laryngomalacia in children: work of breathing and effects of noninvasive ventilatory assistance. *Am J Respir Crit Care Med*. 2001;164(10 pt 1):1874-1878.
20. Mussman GM, Parker MW, Statile A, Sucharew H, Brady PW. Suctioning and length of stay in infants hospitalized with bronchiolitis. *JAMA Pediatr*. 2013;167(5):414-421.
21. Mallory MD, Shay DK, Garrett J, Bordley WC. Bronchiolitis management preferences and the influence of pulse oximetry and respiratory rate on the decision to admit. *Pediatrics*. 2003;111(1):e45-e51.
22. Gadomski AM, Scribani MB. Bronchodilators for bronchiolitis. *Cochrane Database Syst Rev*. 2014(6):CD001266.
23. Camargo CA, Rachelefsky G, Schatz M. Managing asthma exacerbations in the emergency department: summary of the National Asthma Education and Prevention Program Expert Panel Report 3 guidelines for the management of asthma exacerbations. *J Emerg Med*. 2009;37(2 suppl):S6-S17.
24. Chavasse R, Seddon P, Bara A, McKean M. Short acting beta agonists for recurrent wheeze in children under 2 years of age. *Cochrane Database Syst Rev*. 2002(3):CD002873.
25. Zorc JJ, Hall CB. Bronchiolitis: recent evidence on diagnosis and management. *Pediatrics*. 2010;125(2):342-349.
26. Del Vecchio MT, Doerr LE, Gaughan JP. The use of albuterol in young infants hospitalized with acute RSV bronchiolitis. *Interdiscip Perspect Infect Dis*. 2012;2012:585901.
27. Everard ML, Bara A, Kurian M, Elliott TM, Ducharme F, Mayowe V. Anticholinergic drugs for wheeze in children under the age of two years. *Cochrane Database Syst Rev*. 2005(3):CD001279.
28. Thia LP, McKenzie SA, Blyth TP, Minasian CC, Kozlowska WJ, Carr SB. Randomised controlled trial of nasal continuous positive airways pressure (CPAP) in bronchiolitis. *Arch Dis Child*. 2008;93(1):45-47.
29. Cambonie G, Milési C, Jaber S, etal. Nasal continuous positive airway pressure decreases respiratory muscles overload in young infants with severe acute viral bronchiolitis. *Intensive Care Med*. 2008;34(10):1865-1872.
30. Pedersen MB, Vahlkvist S. Comparison of CPAP and HFNC in management of bronchiolitis in infants and young children. *Children (Basel)*. 2017;4(4).
31. Williams JR, Bothner JP, Swanton RD. Delivery of albuterol in a pediatric emergency department. *Pediatr Emerg Care*. 1996;12(4):263-267.
32. Hardasmalani MD, DeBari V, Bithoney WG, Gold N. Levalbuterol versus racemic albuterol in the treatment of acute exacerbation of asthma in children. *Pediatr Emerg Care*. 2005;21(7):415-419.
33. Qureshi F, Zaritsky A, Welch C, Meadows T, Burke BL. Clinical efficacy of racemic albuterol versus levalbuterol for the treatment of acute pediatric asthma. *Ann Emerg Med*. 2005;46(1):29-36.
34. Cates CJ, Welsh EJ, Rowe BH. Holding chambers (spacers) versus nebulisers for beta-agonist treatment of acute asthma. *Cochrane Database Syst Rev*. 2013(9):CD000052.
35. Thompson M, Wise S, Rodenberg H. A preliminary comparison of levalbuterol and albuterol in prehospital care. *J Emerg Med*. 2004;26(3):271-277.
36. Rodenberg H. Effect of levalbuterol on prehospital patient parameters. *Am J Emerg Med*. 2002;20(5):481-483.
37. Markenson D, Foltin G, Tunik M, Cooper A, Treiber M, Caravaglia K. Albuterol sulfate administration by EMT-basics: results of a demonstration project. *Prehosp Emerg Care*. 2004;8(1):34-40.
38. Iramain R, López-Herce J, Coronel J, Spitters C, Guggiari J, Bogado N. Inhaled salbutamol plus ipratropium in moderate and severe asthma crises in children. *J Asthma*. 2011;48(3):298-303.
39. Teoh L, Cates CJ, Hurwitz M, Acworth JP, vanAsperen P, Chang AB. Anticholinergic therapy for acute asthma in children. *Cochrane Database Syst Rev*. 2012(4):CD003797.
40. Qureshi F, Pestian J, Davis P, Zaritsky A. Effect of nebulized ipratropium on the hospitalization rates of children with asthma. *N Engl J Med*. 1998;339(15):1030-1035.

41. Browne GJ, Trieu L, Van Asperen P. Randomized, double-blind, placebo-controlled trial of intravenous salbutamol and nebulized ipratropium bromide in early management of severe acute asthma in children presenting to an emergency department. *Crit Care Med*. 2002;30(2):448-453.
42. 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(8):CD000060.
43. Osmond MH, Klassen TP. Efficacy of ipratropium bromide in acute childhood asthma: a meta-analysis. *Acad Emerg Med*. 1995;2(7):651-656.
44. Davis DP, Wiesner C, Chan TC, Vilke GM. The efficacy of nebulized albuterol/ipratropium bromide versus albuterol alone in the prehospital treatment of suspected reactive airways disease. *Prehosp Emerg Care*. 2005;9(4):386-390.
45. Alter HJ, Koepsell TD, Hilty WM. Intravenous magnesium as an adjuvant in acute bronchospasm: a meta-analysis. *Ann Emerg Med*. 2000;36(3):191-197.
46. Rowe BH, Bretzlaff JA, Bourdon C, Bota GW, Camargo CA. Magnesium sulfate for treating exacerbations of acute asthma in the emergency department. *Cochrane Database Syst Rev*. 2000(2):CD001490.
47. Mohammed S, Goodacre S. Intravenous and nebulised magnesium sulphate for acute asthma: systematic review and meta-analysis. *Emerg Med J*. 2007;24(12):823-830.
48. Cheuk DK, Chau TC, Lee SL. A meta-analysis on intravenous magnesium sulphate for treating acute asthma. *Arch Dis Child*. 2005;90(1):74-77.
49. Torres S, Sticco N, Bosch JJ, etal. Effectiveness of magnesium sulfate as initial treatment of acute severe asthma in children, conducted in a tertiary-level university hospital: a randomized, controlled trial. *Arch Argent Pediatr*. 2012;110(4):291-296.
50. Blitz M, Blitz S, Beasely R, etal. Inhaled magnesium sulfate in the treatment of acute asthma. *Cochrane Database Syst Rev*. 2005(4):CD003898.
51. Rowe BH, Spooner CH, Ducharme FM, Bretzlaff JA, Bota GW. Corticosteroids for preventing relapse following acute exacerbations of asthma. *Cochrane Database Syst Rev*. 2001(1):CD000195.
52. Zemek R, Plint A, Osmond MH, etal. Triage nurse initiation of corticosteroids in pediatric asthma is associated with improved emergency department efficiency. *Pediatrics*. 2012;129(4):671-680.
53. Gray MP, Keeney GE, Grahl MJ, Gorelick MH, Spahr CD. Improving guideline-based care of acute asthma in a pediatric emergency department. *Pediatrics*. 2016;138(5).
54. Altamimi S, Robertson G, Jastaniah W, etal. Single-dose oral dexamethasone in the emergency management of children with exacerbations of mild to moderate asthma. *Pediatr Emerg Care*. 2006;22(12):786-793.
55. Cronin JJ, McCoy S, Kennedy U, etal. A randomized trial of single-dose oral dexamethasone versus multidose prednisolone for acute exacerbations of asthma in children who attend the emergency department. *Ann Emerg Med*. 2016;67(5):593-601.
56. Greenberg RA, Kerby G, Roosevelt GE. A comparison of oral dexamethasone with oral prednisone in pediatric asthma exacerbations treated in the emergency department. *Clin Pediatr (Phila)*. 2008;47(8):817-823.
57. Keeney GE, Gray MP, Morrison AK, etal. Dexamethasone for acute asthma exacerbations in children: a meta-analysis. *Pediatrics*. 2014;133(3):493-499.
58. Normansell R, Kew KM, Mansour G. Different oral corticosteroid regimens for acute asthma. *Cochrane Database Syst Rev*. 2016(5):CD011801.
59. Watnick CS, Fabbri D, Arnold DH. Single-dose oral dexamethasone is effective in preventing relapse after acute asthma exacerbations. *Ann Allergy Asthma Immunol*. 2016;116(2):171-172.
60. Nassif A, Ostermayer DG, Hoang KB, Claiborne MK, Camp EA, Shah MI. Implementation of a prehospital protocol change for asthmatic children. *Prehosp Emerg Care*. 2018;22(4):457-465.
61. Beers SL, Abramo TJ, Bracken A, Wiebe RA. Bilevel positive airway pressure in the treatment of status asthmaticus in pediatrics. *Am J Emerg Med*. 2007;25(1):6-9.
62. Carroll CL, Schramm CM. Noninvasive positive pressure ventilation for the treatment of status asthmaticus in children. *Ann Allergy Asthma Immunol*. 2006;96(3):454-459.
63. Warner GS. Evaluation of the effect of prehospital application of continuous positive airway pressure therapy in acute respiratory distress. *Prehosp Disaster Med*. 2010;25(1):87-91.
64. Basnet S, Mander G, Andoh J, Klaska H, Verhulst S, Koirala J. Safety, efficacy, and tolerability of early initiation of noninvasive positive pressure ventilation in pediatric patients admitted with status asthmaticus: a pilot study. *Pediatr Crit Care Med*. 2012;13(4):393-398.
65. Mayordomo-Colunga J, Medina A, Rey C, etal. Non-invasive ventilation in pediatric status asthmaticus: a prospective observational study. *Pediatr Pulmonol*. 2011;46(10):949-955.
66. Becker AB, Nelson NA, Simons FE. Inhaled salbutamol (albuterol) vs injected epinephrine in the treatment of acute asthma in children. *J Pediatr*. 1983;102(3):465-469.
67. Kornberg AE, Zuckerman S, Welliver JR, Mezzadri F, Aquino N. Effect of injected long-acting epinephrine in addition to aerosolized albuterol in the treatment of acute asthma in children. *Pediatr Emerg Care*. 1991;7(1):1-3.
68. Smith D, Riel J, Tilles I, Kino R, Lis J, Hoffman JR. Intravenous epinephrine in life-threatening asthma. *Ann Emerg Med*. 2003;41(5):706-711.
69. McMullan JT, Pinnawin A, Jones E, et al. The 60-day temperature-dependent degradation of midazolam and Lorazepam in the prehospital environment. *Prehosp Emerg Care*. 2013;17(1):1-7.
70. Gammon DL, Su S, Jordan J, et al. Alteration in prehospital drug concentration after thermal exposure. *Am J Emerg Med*. 2008;26(5):566-573.

How to cite this article: Cheng T, Farah J, Aldridge N, Tamir S, Donofrio-Odmann JJ. Pediatric respiratory distress: California out-of-hospital protocols and evidence-based recommendations. *JACEP Open*. 2020;1:955–964. https://doi.org/10.1002/emp2.12103