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Paramedic Assessment and Treatment of Upper Airway Obstruction in Pediatric Patients: an Exploratory Analysis by the CSI-EMS

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1. Introduction

Croup, asthma, and anaphylaxis are potentially life-threatening pediatric emergencies. These medical conditions have distinct yet effective treatments. Croup causes upper airway obstruction through virally mediated edema of the upper airway. Nebulized epinephrine, via its alpha-1 effect of vasoconstriction, is a highly effective treatment for upper airway obstruction caused by croup.^{1–5} Asthma causes lower airway obstruction and is treated with albuterol whose beta-2 mechanism causes relaxation of the lower airways.⁶ Albuterol does not have significant alpha-1 effect making it ineffective for croup. In addition, its beta effect could potentially cause vasodilation, and theoretically worsen upper airway edema. Croup is the etiology of upper airway obstruction in the vast majority of children; other causes include tracheitis, epiglottitis, and abscesses which are often identified after failure to respond to nebulized epinephrine.⁷

Differentiating upper and lower airway obstruction and understanding the actions of inhaled medications are fundamental clinical skills for providers who care for children. The diagnosis of croup is made on clinical grounds based on history and physical examination.⁴ In the hospital environment there is substantial variability in care for croup, asthma, and bronchiolitis and hospital and physician characteristics are associated with these variations.^{8–13} In addition, appropriate treatment for croup has been suggested as a benchmark for quality of Emergency Department care of children.¹³ There is some

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suggestion that use of epinephrine for anaphylaxis is low in the out-of-hospital environment.^{14,15} However, there are no published papers in the literature on out-of-hospital treatment of croup. EMS providers work in an environment where ambient noise, movement, and other challenges not found in the hospital may cause difficulty in correctly distinguishing upper and lower airway obstruction. Pediatric patients are also a small minority (7-13%) of EMS transports so EMS providers often have limited ongoing exposure to pediatric patients in practice which may increase the risk of patients with croup not receiving the correct treatment.¹⁶ The objective of this exploratory study is to determine the proportion of children being transported code-3 (running lights and sirens) that likely had croup and was correctly treated with inhaled epinephrine.

2. Methods

2.1. Study Design

This was an exploratory analysis of a retrospective out-of-hospital medical record review conducted in the large urban metropolitan area of Multnomah County, Oregon that has approximately 750,000 residents. The Institutional Review Board approved the study.

2.2. Chart review tool development

The Children's Safety Initiative-Emergency Medical Services (CSI-EMS) is a large mixed methods multi-phase national study funded by the National Institutes of Health (NICHD R01HD062478) investigating patient safety events in out-of-hospital pediatric care. The CSI-EMS reviewed charts of code 3 (running lights and sirens) pediatric transports in a large metropolitan area. This EMS system includes both public fire and private transport responses to all 911 calls with fire units having at least 1 paramedic and private transporting units having 2 paramedics. Response times are similar for both fire and transport groups. The protocols in this system direct providers to administer nebulized epinephrine when croup or other causes of upper airway obstruction are suspected and communication with medical control is not required.

We used a standardized chart abstraction tool which was adapted from the widely-cited Harvard Medical Practice Study and Utah-Colorado chart abstraction forms.^{17,18} The adapted tool was revised through several rounds of testing and pilot reviews. The tool was delivered to the reviewers online by SurveyMonkey Inc, Palo Alto, California.

Mirroring methods used in the Harvard Medical Practice Study and Utah-Colorado studies, we assembled a panel of 7 physicians and 13 paramedic reviewers who underwent a common training. A physician and paramedic independently reviewed each case and were blinded to other reviews. Physician reviewers were Emergency Medicine or Pediatric Emergency Medicine physicians who work in a tertiary care/trauma center that provides pediatric online medical control to several agencies. One of two Pediatric Emergency Physicians with experience in prehospital care conducted a third review to arbitrate differences in the two previous reviews. These two final reviewers achieved a kappa statistic of 0.62 on presence or absence of an error in any of the major domains after dual review of an initial sample of charts. The review tool was designed to identify errors in the following

domains: resuscitation; assessment, impression/diagnosis, and clinical decision making; airway/breathing; fluids and medication; procedures; equipment; environment; and system. The reviewers identified the dispatch complaint, clinical impression, procedures, whether or not an error occurred, the nature of the error, and the degree of potential harm to the patient. The degrees of harm were assessed by the chart review tool using the following scale: 1) no harm likely or a near miss, 2) mild or temporary harm, including additional treatment, and 3) permanent or severe harm including death.

2.3. Study population

We included all code 3 transports for patients less than 18 years of age in the four-year period from 2008-2011 in a large urban EMS system. We did not include routine code 1 transports in the analysis. We selected only code 3 transports for this exploratory analysis in order to identify a cohort of patients most likely to benefit from EMS intervention as the patient was assessed to be in critical condition. Transport priority (code-3 vs. code-1) in this system is based entirely on paramedic impression of the severity of illness for all patient populations and clinical presentations.

2.4. Variables and Analysis

We identified the subgroup of code 3 patients treated with either inhaled albuterol or epinephrine. Each case was then reviewed to determine if the chart review process identified an error in assessment of upper vs. lower airway obstruction, medical decision making, or medication administration. We performed qualitative analysis on the reviewer responses to identify themes of factors contributing to use of albuterol when epinephrine was most likely indicated. A trained research assistant experienced in qualitative analysis reviewed the responses and analyzed the data using a hierarchical framework verified by the larger study team. We performed descriptive statistics including mean and standard deviation in the groups with and without upper airway obstruction in the cohort and compared the age and initial respiratory rate using the Wilcoxon-Mann-Whitney test since the data were not normally distributed. We conducted comparative statistics for these selected items as they affected our interpretation of the outcome.

3. Results

Figure 1 displays the patient flow diagram. A total of 490 charts were reviewed in total. We identified 32 cases where nebulized albuterol or epinephrine was used. Of these 32, 14 (44%) had symptoms consistent with upper airway obstruction and in all cases albuterol was given inappropriately as initial therapy. The other 18 patients (56%) had findings consistent with lower airway obstruction and were treated with albuterol. There was no improvement in any of the 14 patients with upper airway obstruction after albuterol treatment. One of the patients worsened after albuterol and developed increased respiratory distress. Subsequently this patient was treated correctly with nebulized epinephrine with improvement. Overall, 3 of the 14 patients (21%) were subsequently correctly treated with nebulized epinephrine after albuterol and all improved with the epinephrine treatment. The reviewers judged the potential harm caused by the errors to be mild or temporary harm in 7 of the 14 cases (50%) and severe harm in 7 of the 14 cases (50%).

Qualitative analysis

The qualitative analysis found that in 8 of the 14 (57%) upper airway obstruction cases, the paramedic used the words croup, stridor, or upper airway obstruction in the chart and administered albuterol as first-line therapy. In the other 6 (43%) cases, there were descriptors such as “barky cough” and “sudden onset noisy breathing” which indicated croup as the most likely etiology to the reviewer, but did not clearly indicate knowledge of the disease process. One of these 14 patients had an airway foreign body, one recent tracheal surgery, and another upper airway obstruction caused by anaphylaxis, with the remaining 11 cases presumed to be viral croup.

Table 1 displays characteristics of patients with upper airway obstruction transported code 3 and characteristics of those without upper airway obstruction group. They were similar in age, though those in the upper airway obstruction group had a higher initial respiratory rate. The vast majority of patients with upper airway obstruction were transported from home (79%) compared to 49% of all code 3 transports.

4. Discussion

This brief exploratory analysis is the first to describe treatment of pediatric upper airway obstruction in the EMS environment. We found that upper airway obstruction is frequently treated inappropriately with albuterol in children deemed critically ill by EMS providers and being transported code-3. The implications of incorrect treatment could include unnecessary worsening of illness in a critically ill patient causing avoidable suffering and potentially resulting in longer ED stays, increased need for hospitalization, or other additional interventions. Our results also allow us to hypothesize that the mechanisms responsible may include: 1) lack of recognition of upper airway obstruction on physical exam and 2) correct recognition of upper airway obstruction on exam and choosing inappropriate treatment. It is not surprising that upper airway obstruction would be treated inappropriately when it is not recognized on exam. In this scenario there are likely gaps in assessment skills with challenge in differentiating the sounds of stridor and wheezing that characterize upper and lower airway obstruction. The reason for incorrect treatment when upper airway obstruction is correctly identified is less clear. There may be lack of knowledge of the pharmacologic mechanisms of albuterol and epinephrine. Potential reluctance to use inhaled epinephrine could arise from undue concern for side effects since most experience with epinephrine is in adult cardiac arrest patients.

Difficulty recognizing upper airway obstruction has been demonstrated in a previous study among medical students and residents in Pediatrics and Emergency Medicine using videos of children in respiratory distress.¹⁹ These findings suggest diagnostic accuracy and treatment for common pediatric out-of-hospital emergencies is an area which could benefit from further study.

4.1 Limitations

This is an exploratory analysis with several important limitations to consider. First, this was a retrospective chart review based on what is documented in the chart by the treating

paramedic during routine care that may not accurately reflect the patient's condition. However, this most likely underestimates the number of true cases. Also, only "code 3" or "critical" transports were studied and many patients deemed non-critical may have been correctly treated, or were critically ill and not recognized as such. The inclusion of patients with code 3 transport priority also resulted in a small sample size which contributes to the exploratory nature of this study and its results. In addition, we did not have access to hospital records to clearly describe the outcomes of the patients. Lastly, this study was conducted in a single EMS system and has limited external validity.

4.2 Conclusions

This study found that children transported code-3 with respiratory distress from upper airway obstruction infrequently receive the correct treatment. Upper airway obstruction is caused by croup in the majority of cases, is an illness that is diagnosed on clinical grounds, and is a condition with highly effective treatment. EMS agencies could consider educational interventions on assessment and treatment of croup, or consider a decision support tool to aid in diagnosis and treatment.

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Figure 1.
Patient flow diagram

Table 1

Patient Characteristics

Characteristics	All Code 3 Transports (n = 490)		p-value
	No Upper Airway Obstruction (n = 476)	Upper Airway Obstruction (n = 14)	
Age (years)	6.92 (6.18)	5.07 (3.81)	0.58*
Age group			-
<1 year	83 (17.44)	1 (7.14)	
1-5 years	160 (33.61)	9 (64.29)	
>5 years	233 (48.95)	4 (28.57)	
Initial Respiratory Rate (breaths per minute)**	22.80 (13.96)	35.82 (10.52)	<0.005***
Diagnosis other than croup	476 (100)	3 (21.43)	-
Scene Location			-
Home	208 (43.70)	11 (78.57)	
Hospital/Clinic	108 (22.69)	2 (14.29)	
Other	160 (33.61)	1 (7.14)	
Fire Department Response	199 (41.81)	6 (42.86)	-

Values are presented as mean (standard deviation) for continuous variables and as number (percentage) for categorical variables.

* The Wilcoxon-Mann-Whitney test was used to compare age in years in patients with no upper airway obstruction and patients with upper airway obstruction.

** The initial respiratory rate was documented for 435 patients, including 424 patients with no upper airway obstruction and 11 patients with upper airway obstruction.

*** The Wilcoxon-Mann-Whitney test was used to compare initial respiratory rate in patients with no upper airway obstruction and patients with upper airway obstruction.