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ORIGINAL RESEARCH

# Factors predicting hospitalization of pediatric patients with croup presenting to the emergency department: a retrospective cross-sectional study

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## Abstract

Croup is the most common cause of acute, acquired upper airway obstruction in pediatric patients. Severe upper airway obstruction in children can quickly progress to respiratory failure; early and accurate diagnosis and treatment are essential. We examined the characteristics of pediatric patients with croup who visited our emergency department and required hospitalization even after appropriate treatment. We retrospectively studied patients who visited the pediatric emergency department of a tertiary hospital in Gyeonggi-do, Korea, from January 2018 to December 2021. After diagnosis and treatment using a defined protocol, all patients were divided into two groups: those who were hospitalized because they did not meet the criteria for discharge, and those who returned home. A multivariate logistic regression analysis was performed to identify factors associated with hospitalization. We studied 212 patients with an average age of 14 (12–16) months; 68 (32.0%) patients were female and 144 (67.9%) were male. In total, 47 (22.1%) patients were admitted for additional treatment. The multivariate logistic regression analysis revealed that tachycardia, tachypnea, decreased urine output and chest retraction were associated with hospitalization. A nomogram was constructed. Tachycardia, tachypnea, decreased urine volume and chest retraction in pediatric patients with croup showed a relationship with upper airway obstruction that persisted after treatment. If any of the above symptoms are observed in the emergency department, close observation is needed to determine whether respiratory failure is progressing; if so, prompt treatment is required.

## Keywords

Croup; Tachypnea; Tachycardia; Decreased urine output; Chest retraction

## 1. Introduction

Croup, the most common cause of acquired upper airway obstruction in children, is a self-limiting respiratory disease of the larynx, trachea and bronchi. Laryngeal tracheitis, tracheobronchitis and tracheobronchial pneumonia are all defined as croup. The condition affects about 3% of children aged 6 months to 3 years but can occur in those younger than 6 years, and atypically, younger than 6 months [1, 2]. Annually, croup accounts for 7% of hospitalizations for fever and acute respiratory illnesses in children younger than 5 years [3]. The diagnosis is primarily clinical; a sudden barking cough, inspiratory wheezing and hoarseness are characteristic. The respiratory rate usually increases and may be accompanied by tachycardia and a decrease in oxygen saturation. Chest retraction, nasal flaring, or cyanosis may suggest a severe condition [4–6]. Several scoring systems are available, but the modified Westley croup score (WCS) is most widely used in clinical practice and for research purposes. Still, clinical evaluation is more important than scoring [2, 7, 8]. Treatment seeks to alleviate the vascular edema and remove the upper airway obstruction and typically includes the administration of steroids or epinephrine, oxygen and advanced airway management [9–12]. Hospitalization is needed for patients with persistent respiratory signs and symptoms after treatment with epinephrine or worsening symptoms [3]. The symptoms tend to worsen at night; patients often visit the emergency department at that time [13]. Some such children require hospitalization or invasive respiratory support, but rapid treatment reduces the need for such interventions [14, 15]. Unlike adults, infants and young children have small and compliant airways; the development of upper airway obstruction can be rapid, and this can readily progress to respiratory failure because the respiratory reserve is smaller than in adults [16]. Rapid diagnosis of croup, classification of its severity, and emergency department treatment are important. Additionally, prompt identification of children who do not respond to initial treatment allows for early intervention and efficient allocation of resources. We


  

examined factors that predicted the hospitalization of patients with croup who visited the emergency department and did not respond to appropriate treatment. We evaluated the patients' history, vital signs upon arrival, complaints and results of the physical examination.

## 2. Materials and methods

### 2.1 Study design and setting

This retrospective study enrolled pediatric patients who visited a pediatric emergency department staffed by 2 pediatric specialists and 10 emergency medicine specialists at a tertiary hospital in Gyeonggi-do, Korea, from January 2018 to December 2021. All children were otherwise healthy, aged between 1 month and 6 years, and diagnosed with croup in the emergency department. Those with a history of foreign body aspiration, loss of consciousness, cyanosis or other diseases such as pneumonia and whose medical records were incomplete were excluded.

### 2.2 Treatment

All patients were examined by a pediatric or emergency medicine specialist. Croup was diagnosed if any two of the following symptoms were evident: barking cough, hoarseness, or stridor during inspiration. The modified WCS at presentation was calculated. The clinical factors used to determine the WCS are stridor, chest retraction, air entry, cyanosis and level of consciousness. Our croup treatment protocol was as follows. Using the modified WCS, croup was classified as mild, moderate or severe. All patients with mild to severe croup received oral or intramuscular dexamethasone (0.6 mg/kg), and those with moderate to severe croup also received inhaled L-epinephrine (1:1000, 1 mL). When the oxygen saturation was <96%, oxygen was administered through a basic or high-flow nasal cannula or via endotracheal intubation. Patients who received inhaled L-epinephrine were observed for at least 2 h, and they were admitted if stridor persisted during inspiration at rest, cyanosis or loss of consciousness developed, the patient could not eat, or tracheal intubation was required [2, 17, 18].

### 2.3 Patients and data collection

An experienced pediatrician retrospectively reviewed the medical records of all 403 patients in terms of age, sex, medical history, vital signs, complaints and the physical examination and imaging findings. Age at diagnosis, sex, croup history, vital signs upon arrival (blood pressure, pulse, respiratory rate, oxygen saturation), complaints (fever, cough, barking cough, vomiting, hoarseness, dyspnea, loss of appetite, decreased urine output), physical examination findings (stridor during inspiration, chest retraction, air entry), imaging findings (subglottic narrowing), admission to the pediatric ward or intensive care unit, and duration of hospitalization were reviewed. All data except the duration of stay were collected immediately after arrival (before treatment). The age-specific definitions of tachycardia, tachypnea and hypotension used in this study were those established for sepsis and organ dysfunction of the 2002 International Pediatric Sepsis Consensus Conference [19]. Age was divided into four groups: 1 month to 1 year, 2 years to 5 years, 6 years to 12 years and 13 years to 18 years, and age-specific cutoffs for each criterion were chosen (Table 1) [19]. Hypoxia was defined as oxygen saturation <94% on room air [20].

**TABLE 1. Age-specific vital signs.**

| | Heart rate (beats/min) | Respiratory rate (breaths/min) | Systolic blood pressure (mmHg) |
|---|---|---|---|
| 1 mon–1 yr | >180 | >34 | <100 |
| 2–5 yr | >140 | >22 | <94 |
| 6–12 yr | >130 | >18 | <105 |

*The table shows the upper values for heart rate and respiratory rate for the 95th percentile and the lower values for systolic blood pressure for the 5th percentile.*

### 2.4 Statistical analysis

Categorical variables are expressed as absolute number (percentage) and were compared using Fisher's exact test or Pearson's chi-square test. The normality of the distribution of continuous variables was assessed using the Shapiro-Wilk test, but none of the variables were normally distributed; thus, all are expressed as median with interquartile range. The Mann-Whitney U-test was used to compare continuous variables. A $p$-value $< 0.05$ was considered statistically significant. Odds ratios (ORs) with 95% confidence intervals (CIs) were calculated *via* multivariate logistic regression; variables were selected in a stepwise manner. We calculated the areas under the receiver operating characteristic curves (AUROCs) and constructed a nomogram that predicted hospitalization. SPSS ver. 26.0 (IBM Corp., Armonk, NY, USA) and R ver. 4.2.1 (R Foundation for Statistical Computing, Vienna, Austria) software were used for all statistical analyses.

## 3. Results

In total, 403 pediatric patients with croup were initially included, of whom 191 were excluded for the following reasons: incomplete medical records (n = 86), history of foreign body aspiration (n = 2), decreased consciousness (n = 3), cyanosis (n = 2), intubation (n = 2) and other diseases (n = 96). Patients with loss of consciousness, cyanosis or intubation were excluded because they were all hospitalized regardless of their treatment response. Additionally, 96 patients were excluded because of other diseases such as seizures, urinary tract infection, asthma, acute bronchiolitis and pneumonia. Ultimately, 212 patients were included, of whom 47 were admitted to the Department of Pediatrics for additional treatment (Fig. 1). Table 2 lists their general characteristics. The patients' average age was 14 (12–16) months; 68 (32.0%) patients were female and 144 (67.9%) were male. Nineteen (8.9%) had a history of croup. None of the patients had any congenital anomalies of the airway or a history of tracheal surgery. Upon arrival, no patient exhibited hypotension; tachycardia was noted in 47

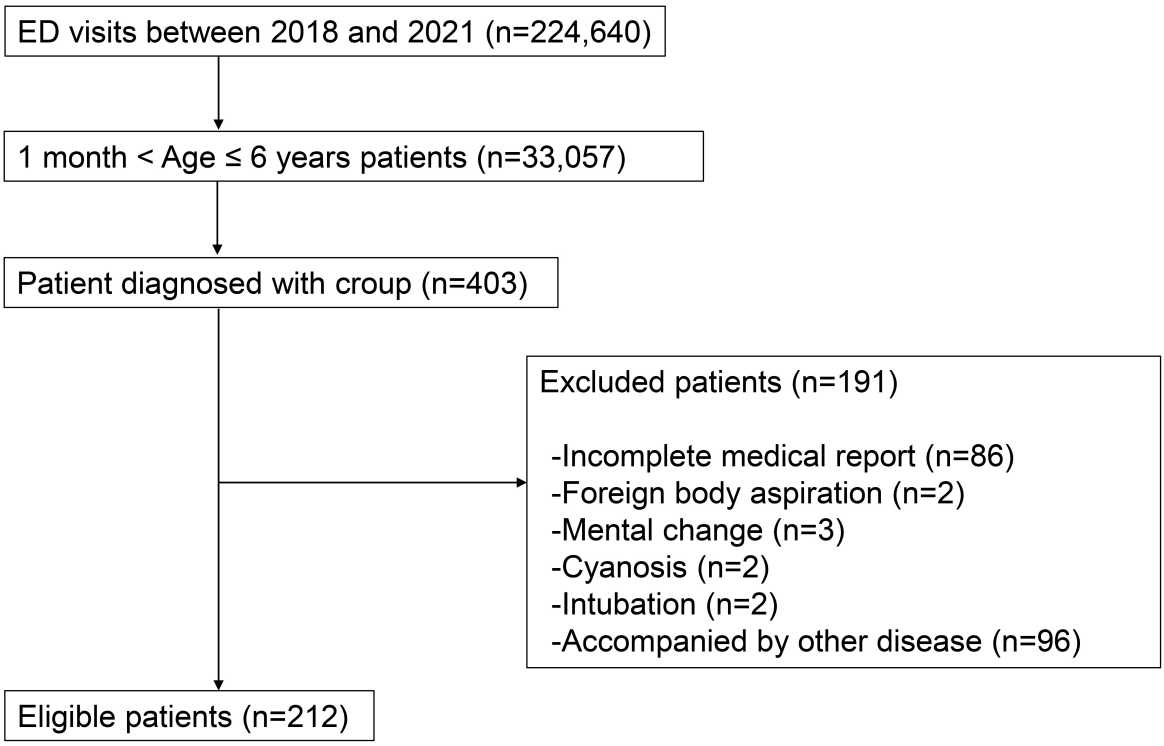


**FIGURE 1. Flow chart of patient selection.** ED, emergency department.

(22.1%) patients and tachypnea in 20 (9.4%). Imaging tests were performed on all patients to identify any other causes of fever, such as pneumonia and determine whether aspiration of a foreign body was present. Imaging showed that 121 (57.0%) patients had subglottic edema (the steeple sign). According to the WCS, 5 (2.3%) patients had severe croup (score >9), 16 (7.5%) had moderate croup (score of 5–9), and 191 (90.0%) had mild croup (score <5). They were treated according to the hospital protocol. A total of 47 (22.1%) patients were admitted to the Department of Pediatrics for further treatment. After admission, 31 (65.9%) received inhaled L-epinephrine (1:1000, 1 mL), 4 (8.5%) received supplemental oxygen, and 6 (12.7%) received both. The average hospital stay was 2.7 (2.0–3.5) days. No patients died. Table 3 compares the hospitalized and non-hospitalized groups. There were no significant between-group differences in mean age, sex, croup history, hypoxia status, complaints (cough, barking cough, hoarseness, dyspnea), imaging findings (steeple sign), treatment (nebulized epinephrine, steroid), or duration of hospitalization. However, hospitalization was more common for those with tachycardia (11.5% *vs.* 59.5%, $p < 0.001$), tachypnea (3.6% *vs.* 29.7%, $p < 0.001$), fever (43.0% *vs.* 61.7%, $p = 0.030$), vomiting (18.2% *vs.* 34.0%, $p = 0.027$), poor oral intake (48.5% *vs.* 70.2%, $p = 0.012$), decreased urine output (12.7% *vs.* 34.0%, $p = 0.001$), stridor during inspiration (40.6% *vs.* 89.3%, $p < 0.001$), chest retraction (11.5% *vs.* 65.9%, $p < 0.001$), and air entry (7.3% *vs.* 29.7%, $p < 0.001$). Table 4 shows the results of the multivariable logistic regression analysis. Tachycardia (OR, 3.515; 95% CI, 1.370–9.017; $p = 0.008$), tachypnea (OR, 4.317; 95% CI, 1.067–17.472; $p = 0.040$), decreased urine output (OR, 3.775; 95% CI, 1.235–11.540; $p = 0.019$), and chest retraction (OR, 6.413; 95% CI, 2.176–18.895; $p = 0.001$) were correlated with hospitalization. The AUROC of the model was 0.8968 (95% CI, 0.8454–0.9486; $p < 0.01$) (Fig. 2). The abovementioned variables were used to create a nomogram predicting hospitalization (Fig. 3). Chest retraction was the strongest predictor, followed by decreased urine output, tachycardia and tachypnea. The probability of hospitalization was determined by summing the scores for all variables. For example, if the chest retraction and tachypnea scores were 100 and 65, respectively, the total score would be 165 and the risk of hospitalization would be 65% (Fig. 3).

**TABLE 2. General characteristics of pediatric patients with croup.**

| | Total (n = 212) |
|---|---|
| Age at onset, mon | 14 (12–16) |
| Sex | |
| Female | 68 (32.0) |
| Male | 144 (67.9) |
| History of croup | 19 (8.9) |
| Vital signs | |
| Hypotension | 0 (0.0) |
| Tachycardia | 47 (22.1) |
| Tachypnea | 20 (9.4) |
| Hypoxia | 0 (0.0) |
| Steeple sign-positive | 121 (57.0) |
| Length of hospital stay, d | 2.7 (2.0–3.5) |

*Data are presented as n (%) or median (interquartile range).*

**TABLE 3. Baseline characteristics of patients admitted and discharged.**

| | Discharged (n = 165) | Admitted (n = 47) | *p*-value |
|---|---|---|---|
| Age at onset, mon | 14 (12–16) | 14 (12–15) | 0.428 |
| Sex | | | |
| Female | 53 (32.1) | 15 (31.9) | 0.980 |
| Male | 112 (67.9) | 32 (68.0) | |
| History of croup | 16 (9.7) | 3 (6.3) | 0.577 |
| Vital signs | | | |
| Hypotension | 0 (0.0) | 0 (0.0) | |
| Tachycardia | 19 (11.5) | 28 (59.5) | <0.001 |
| Tachypnea | 6 (3.6) | 14 (29.7) | <0.001 |
| Hypoxia | 0 (0.0) | 0 (0.0) | |
| Symptoms | | | |
| Fever | 71 (43.0) | 29 (61.7) | 0.030 |
| Cough | 155 (93.9) | 45 (95.7) | >0.999 |
| Barking cough | 126 (76.4) | 34 (72.3) | 0.569 |
| Vomiting | 30 (18.2) | 16 (34.0) | 0.027 |
| Hoarseness | 93 (56.4) | 30 (63.8) | 0.404 |
| Dyspnea | 33 (20.0) | 15 (31.9) | 0.112 |
| POI | 80 (48.5) | 33 (70.2) | 0.012 |
| DUO | 21 (12.7) | 16 (34.0) | 0.001 |
| Physical examination findings | | | |
| Stridor | 67 (40.6) | 42 (89.3) | <0.001 |
| Chest retraction | 19 (11.5) | 31 (65.9) | <0.001 |
| Air entry | 12 (7.3) | 14 (29.7) | <0.001 |
| Steeple sign-positive | 94 (57.0) | 27 (57.4) | >0.999 |
| Nebulized epinephrine | 15 (9.1) | 6 (12.7) | 0.421 |
| Steroid therapy | 165 (100.0) | 47 (100.0) | |

*Data are presented as n (%) or median (interquartile range). POI, poor oral intake; DUO, decreased urine output.*

**TABLE 4. Multivariable logistic regression analyses of risk factors for admission of pediatric patients with croup.**

| | OR (95% CI) | *p*-value |
|---|---|---|
| Vital signs | | |
| Tachycardia | 3.515 (1.370–9.017) | 0.008 |
| Tachypnea | 4.317 (1.067–17.472) | 0.040 |
| Symptoms | | |
| Fever | 2.375 (0.962–5.864) | 0.060 |
| POI | 2.178 (0.769–6.162) | 0.142 |
| DUO | 3.775 (1.235–11.540) | 0.019 |
| Physical examination findings | | |
| Stridor | 2.546 (0.740–8.755) | 0.138 |
| Chest retraction | 6.413 (2.176–18.895) | 0.001 |

*OR, odds ratio; CI, confidence interval; POI, poor oral intake; DUO, decreased urine output.*

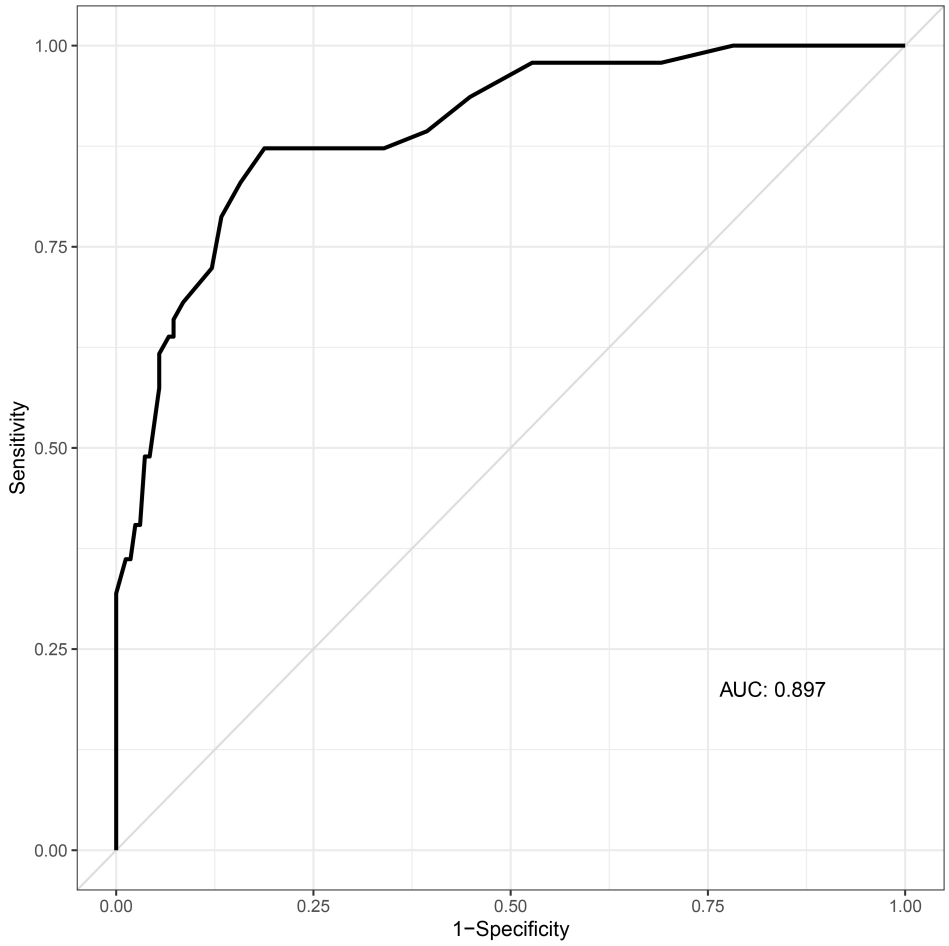


**FIGURE 2. Receiver operating characteristic curve of the multivariable logistic regression model predicting admission of children with croup.** AUC, area under the curve.

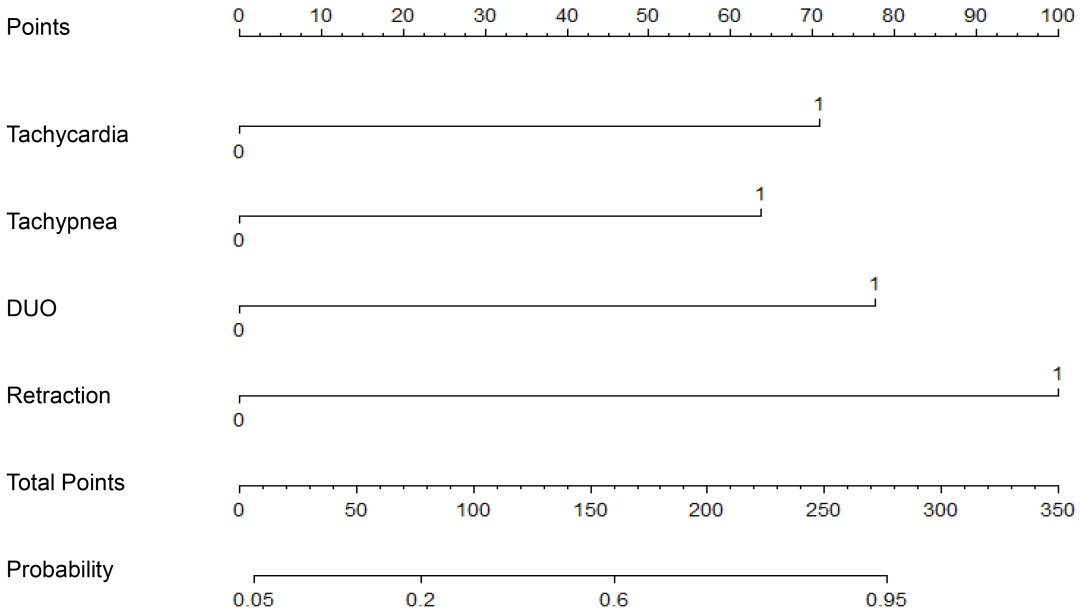


**FIGURE 3. Nomogram predicting admission of pediatric patients with croup who visited the pediatric emergency department.** Each factor was rated using the point scale (0–100) on the top, and the probability of admission was predicted by summing the scores. DUO, decreased urine output.

## 4. Discussion

It is important to assess patients with croup quickly because respiratory failure may develop rapidly. We report the associations between hospital admission and tachycardia, tachypnea, decreased urine output and chest retraction. These factors may warrant close observation in the emergency department because they are likely to require hospitalization; they may not respond to initial treatment. We created a nomogram using these risk factors to assist clinicians in making treatment decisions.

Tachypnea, tachycardia and chest retraction are important components of the pediatric early warning score (PEWS) used for early recognition and evaluation of clinical deterioration [21]. All three components are measured using various scoring systems when evaluating the severity of croup and the response to treatment [22]. Asmundsson *et al.* [15] found that children with tachypnea evident upon arrival at the emergency department required hospitalization even after treatment with basic racemic epinephrine (RE) as well as additional RE, helium-oxygen and transfer to the pediatric intensive care unit (PICU). Tachypnea develops because alveolar ventilation is reduced by upper airway obstruction, and the respiratory rate per minute thus increases to compensate; tachypnea reflects the extent of upper airway obstruction. We also found that tachypnea was related to the severity of croup and predicted hospitalization. Tachycardia is one of the most sensitive early symptoms of respiratory failure [23, 24]. In addition, an association between progressive tachycardia and acute respiratory distress syndrome has been reported in children [25]. We also found that tachycardia predicted hospitalization. However, Asmundsson *et al.* [15] found that when patients with croup presented with tachycardia, the need for further treatment such as additional RE, helium-oxygen and transfer to the PICU increased, but tachycardia per se was not independently associated with the need for such treatment.

Chest retraction is an item of the modified WCS used to assess croup severity, along with stridor, air entry, cyanosis and decreased consciousness [7, 26]. Of these, cyanosis and decreased consciousness are not useful early signs of upper airway obstruction, but chest retraction, stridor and air entry reflect the severity of such obstruction [7, 27, 28]. We investigated whether the latter three conditions were related to hospitalization; only chest retraction was so associated. Yang *et al.* [26] found that chest retraction and reduced air entry upon arrival at the emergency department correlated with the need for epinephrine inhalation and hospitalization because upper airway obstruction remained even after administration of 0.15 mg/kg dexamethasone. During normal breathing, contraction of the diaphragm and relaxation of the thoracic cavity generate negative pressure in that cavity; external air flows into the lungs *via* inhalation and alveolar ventilation is normal. Severe croup is associated with upper airway obstruction; even if negative pressure is generated, external air cannot flow into the lungs. The negative pressure increases, eventually causing chest wall inflow and chest retraction.

Hypoxia and hypotension do not sensitively reflect acute exacerbations of upper airway obstruction [15, 26]; both are late symptoms developing after the acute phase. None of our patients exhibited hypotension, and only two showed hypoxia; neither predicted hospitalization. We excluded patients with decreased consciousness and cyanosis; most evidenced hypoxia and hypotension.

Unlike several other studies that have predicted hospitalization for croup, we included vital signs and complaints in addition to the WCS itself [26, 29, 30]. Our data thus suggest that symptoms such as tachypnea, tachycardia and decreased urine output can be considered predictive of non-response to treatment in patients with croup.

Our work had several limitations. First, its retrospective nature creates a risk of selection bias. However, this was minimized by using the same examination and treatment protocols to evaluate and assist all patients. Second, we used an in-house protocol to determine the need for hospitalization. However, evaluations will differ depending on the experience and skill of the clinician reviewing the symptoms and conducting the physical examinations; only laboratory data are absolute. However, our institution employs specialists in the Departments of Pediatrics and Emergency Medicine. Third, our patients were not homogenous because of differences in the severity of croup and subsequent treatment. Fourth, our sample size was small. Future studies need to verify our findings with a larger sample size. Fifth, we did not consider whether patients had been treated or medicated at other hospitals before they visited us. Sixth, causative viruses were not identified; any effects of different viruses on the clinical symptoms were not considered. Further well-designed studies are needed.

## 5. Conclusions

In pediatric patients with croup who presented to our emergency department, tachycardia, tachypnea, decreased urine volume, and chest retraction were significantly associated with hospitalization because upper airway obstruction could persist after treatment. Therefore, if any of these are observed, monitoring for possible progression to respiratory failure is warranted.

### AVAILABILITY OF DATA AND MATERIALS

The data presented in this study are available on reasonable request from the corresponding author.

### AUTHOR CONTRIBUTIONS

MK—designed the study, wrote original draft, analyze the data. MS—designed the study, analyze the data, reviewed and edited. YL—designed the study, analyze the data, reviewed and edited. SH—designed the study, analyze the data, supervised, reviewed and edited. All authors read and approved the final manuscript.

### ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Soonchunhyang university Institutional Review Board (IRB) approved the study and waived the informed consent require-

ment (IRB file no. 2023-03-006-001). The study was conducted in compliance with the principles of the Declaration of Helsinki.

## ACKNOWLEDGMENT

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## CONFLICT OF INTEREST

The authors declare no conflict of interest.

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