The Role of Airway Fluoroscopy in the Evaluation of Children With Stridor

Objective: To determine the sensitivity and specificity of airway fluoroscopy in the diagnosis of pediatric laryngotracheal abnormalities.

Design: Retrospective chart review.

Setting: Tertiary care children’s hospital.

Patients: Thirty-nine children, with a mean age of 18 months at the time of evaluation, were evaluated for stridor.

Main Outcome Measures: Diagnoses made by airway fluoroscopy and endoscopy. The medical records of patients who had undergone both airway fluoroscopy and airway endoscopy for the evaluation of stridor over a 5-year period were reviewed. The sensitivity, specificity, and positive and negative predictive values of airway fluoroscopy in the diagnosis of laryngomalacia, tracheomalacia, airway stenosis at any level, and airway mass lesions were determined using endoscopic evaluation as the “gold standard.”

Results: Twenty-three of 39 patients (59%) received a different diagnosis by airway endoscopy than by airway fluoroscopy. The sensitivity of airway fluoroscopy in the diagnosis of laryngomalacia, tracheomalacia, airway stenosis, and an airway mass was 27%, 20%, 69%, and 43%, respectively. The specificity for the same diagnoses was 100%, 94%, 100%, and 100%, respectively.

Conclusions: Airway fluoroscopy appears to be reliable in the diagnosis of laryngomalacia, tracheomalacia, airway stenosis, and airway masses because of its high specificity. However, its sensitivity in detecting these common causes of stridor is poor. Negative fluoroscopic study results require further diagnostic evaluation if the clinical indication exists; therefore, the value of fluoroscopy as a screening tool remains uncertain.


Approximately 10% of patients who present to a pediatric emergency department have a breathing complaint. One of the most common symptoms in these children is a high-pitched breathing sound called stridor. Stridor can be an alarming symptom to patients and parents, and its evaluation can pose a significant diagnostic dilemma to physicians. The differential diagnosis may include a wide array of supraglottic, glottic, and subglottic abnormalities. Clinical distinction among such diagnoses poses a challenge to physicians.

The “gold standard” for diagnosing the cause of stridor is flexible laryngoscopy in conjunction with direct laryngoscopy and bronchoscopy, providing direct visualization of the entire supraglottic and subglottic airway as well as of both fixed and dynamic airway lesions. Each component of this evaluation works synergistically to increase the diagnostic power of the whole, but not without individual drawbacks. Direct laryngoscopy and bronchoscopy allow visualization of the subglottic airway but involve considerable operating room expenses as well as the risk of anesthesia. Flexible fiberoptic laryngoscopy permits more thorough assessment of laryngeal dynamics, facilitating detection of laryngomalacia and vocal cord paralysis. It provides a cheaper alternative to direct laryngoscopy and can be performed at the bedside without the risks of general anesthesia; however, it visualizes only the supraglottic airway and is therefore limited in its diagnostic capacity. Appropriate choice of diagnostic modalities requires careful consideration of the risks and benefits of each procedure in conjunction with the clinical scenario.

Airway fluoroscopy is a minimally invasive radiographic means of evaluating the upper airway structures; however, its sensitivity and specificity in identifying the cause of stridor remain uncertain. Many authors have suggested that the most helpful study to determine the utility of airway fluoroscopy would be one in which all patients with stridor are prospectively evaluated with both airway fluoroscopy and direct laryngoscopy and bronchoscopy. However, performing endoscopy on all children would produce unjustifi-
and airway mass lesions were calculated using traditional staryngomalacia, tracheomalacia, airway stenosis (at any level), predictive values of airway fluoroscopy in the diagnosis of latlon), and the sensitivity, specificity, and positive and negative predictive values of airway fluoroscopy in the diagnosis of laryngomalacia, tracheomalacia, airway stenosis (at any level), and airway mass lesions were calculated using traditional statistical methods.

### METHODS

A retrospective review of patient records was completed after study approval was obtained from the institutional review board. All subjects were patients at a tertiary care children's hospital that is affiliated with our academic institution. Three searches, spanning a 5-year time period, were conducted: (1) a search for all patients who underwent airway fluoroscopy; (2) a search for all patients who underwent airway endoscopy (either flexible fiberoptic laryngoscopy or direct laryngoscopy and bronchoscopy), and (3) a search for several diagnostic codes that identify a variety of laryngotracheal abnormalities. Also, the principle investigator's operative log for the period of interest was reviewed. All search results were cross-referenced, and all collected charts were thoroughly examined. Patients who had undergone both airway fluoroscopy and airway endoscopy during the previous 5-year period were included. Each patient's age at evaluation, date of evaluation, sex, and ultimate diagnosis made by each diagnostic modality were recorded.

Once all data were collected, the diagnoses made by airway endoscopy were viewed as definitive. The data were tabulated using Microsoft Excel (Microsoft Corp, Redmond, Washington), and the sensitivity, specificity, and positive and negative predictive values of airway fluoroscopy in the diagnosis of laryngomalacia, tracheomalacia, airway stenosis (at any level), and airway mass lesions were calculated using traditional statistical methods.

### RESULTS

A total of 39 patients (23 boys and 16 girls) who had undergone both airway fluoroscopy and airway endoscopy were identified. The average age at evaluation was 18 months. In addition to airway fluoroscopy, 29 patients underwent direct laryngoscopy with bronchoscopy, 1 patient underwent direct laryngoscopy alone, 4 patients underwent flexible fiberoptic laryngoscopy with bronchoscopy, and 2 patients underwent flexible fiberoptic laryngoscopy alone. Three patients underwent direct laryngoscopy and bronchoscopy and flexible fiberoptic laryngoscopy. In 37 of the 39 patients, airway fluoroscopy was conducted before endoscopic evaluation.

The most common diagnoses made by airway endoscopy were airway stenosis at any level (n=13), laryngomalacia (n=11), airway mass lesion (n=7), and tracheomalacia (n=5). Mass lesions included cysts (n=4), hemangiomas (n=2), and recurrent laryngeal papillomatosis (n=1). Other diagnoses included normal airway (n=3), adenoid hypertrophy (2), airway inflammation (n=2), arytenoid edema (n=1), vocal cord paralysis (n=1), abnormal laryngeal anatomy (n=1), and shortened aryepiglottic folds (n=1). The most common diagnoses made by airway fluoroscopy were normal airway (n=18), subglottic narrowing (n=10), airway mass lesion (n=3), laryngomalacia (n=3), tracheomalacia (n=3), subglottic asymmetry (n=3), and prominent arytenoids (n=1). Mass lesions included a “base of tongue mass” (n=1), “subglottic mass” (n=1), and a “soft tissue density at the aryepiglottic fold” (n=1) (Table 1).

In all, 23 of 39 patients (59%) received a different diagnosis endoscopically from the diagnosis made by airway fluoroscopy. Statistical evaluation was conducted for the utility of airway fluoroscopy in the diagnosis of the 4 most common abnormalities diagnosed by airway endoscopy: airway stenosis, laryngomalacia, airway mass lesions, and tracheomalacia. Of the 13 patients diagnosed as having airway stenosis, 9 were identified by airway fluoroscopy (sensitivity, 69%; specificity, 100%; negative predictive value, 87%; and positive predictive value, 100%). Of the 11 patients diagnosed as having laryngomalacia, 3 were identified by airway fluoroscopy (sensitivity, 27%; specificity, 100%; negative predictive value, 78%; and positive predictive value, 100%). Of the 7 patients diagnosed as having airway mass lesions, 3 were identified by airway fluoroscopy (sensitivity, 43%; specificity, 100%; negative predictive value, 89%; and positive predictive value, 100%). Of the 5 patients diagnosed as having tracheomalacia, 1 was identified by airway fluoroscopy (sensitivity, 27%; specificity, 100%; negative predictive value, 87%; and positive predictive value, 100%).

<table>
<thead>
<tr>
<th>Diagnosis</th>
<th>Airway Fluoroscopy</th>
<th>Direct Laryngoscopy and Bronchoscopy</th>
<th>Flexible Fiberoptic Laryngoscopy/Bronchoscopy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Airway stenosis</td>
<td>10</td>
<td>13</td>
<td>0</td>
</tr>
<tr>
<td>Laryngomalacia</td>
<td>3</td>
<td>10</td>
<td>3</td>
</tr>
<tr>
<td>Airway mass lesion</td>
<td>3</td>
<td>7</td>
<td>1</td>
</tr>
<tr>
<td>Tracheomalacia</td>
<td>3</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Normal airway</td>
<td>18</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Adenoid hypertrophy</td>
<td>1</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Airway inflammation</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Arytenoid edema</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Vocal cord paralysis</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Abnormal laryngeal anatomy</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Shortened aryepiglottic folds</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Subglottic asymmetry</td>
<td>3</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Table 1. Diagnoses Made by Each Modality

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Stridor results from turbulent airflow through the airway caused by narrowing and obstruction. There are 3 types of stridor: inspiratory, expiratory, and biphasic. By definition, inspiratory stridor occurs when the patient inhales, and expiratory stridor is heard when the patient exhales. Biphasic stridor is audible during both inspiration and exhalation. The cause of stridor is classified according to its anatomical site of origin: supraglottic, glottic, and subglottic. Supraglottic refers to the sites above the vocal cords, while glottic and subglottic refer to the sites at the level of and below the vocal cords, respectively. The differential diagnosis of stridor consists of a variety of both fixed and dynamic obstructions in each of these locations. In children, supraglottic disorders typically present with inspiratory stridor. In laryngomalacia, for instance, floppy or redundant supraglottic tissue collapses downward into the airway under the negative pressure of inspiration. Glottic disorders are usually caused by vocal cord paralysis or obstruction by an inflammatory, neoplastic, or vascular mass lesion. Subglottic disorders, localized to the trachea, often present with biphasic stridor. Fixed lesions in the subglottic airway cause stridor through turbulent airflow. More dynamic subglottic lesions, such as tracheomalacia and vascular compression, lead to expiratory stridor through airflow collapse under increasing outward flow and pressure from the lungs. Laryngotracheobronchitis (croup), congenital airway malformations, traumatic airway lesions, and iatrogenic obstructions such as foreign body aspiration, mass lesions, and airway stenoses may present with symptoms of obstruction at any level.

Regardless of its pathogenesis, stridor remains a distressing symptom, and diagnosing its underlying cause is a challenging problem for general pediatricians and otolaryngologists alike. Accurate history and physical examination are crucial to the evaluation. Complete endoscopic examination remains the optimal diagnostic study. Direct laryngoscopy and bronchoscopy allow examination of the entire airway. However, because of the associated invasiveness, expense ($500-$1200), and anesthesia risks (eg, nausea, vomiting, sore throat, blood pressure changes, pain, allergic reaction, or death), their routine use in the evaluation of all patients is unnecessary and unjustified. Another type of diagnostic study is flexible fiberoptic laryngoscopy. Because it can be performed at the bedside, with only topical anesthesia and a thin fiberoptic scope, it can provide a rapid and relatively inexpensive ($150-$200) means of airway evaluation and has particular value in the detection of dynamic airway lesions. Nevertheless, it is limited to examination of the supraglottic structures. Consequently, much attention has been paid to less invasive radiographic means of evaluation, including plain x-ray films and airway fluoroscopy.

Airway fluoroscopy has been used in the evaluation of obstructive sleep apnea, foreign body obstruction, and vocal cord dysfunction syndrome, among others. However, its true role in the evaluation of children with stridor remains poorly defined. A prospective study by Rudman et al sought to evaluate the role of airway fluoroscopy in comparison with other diagnostic studies in determining the site of airway obstruction in children with stridor. The comparison was between direct laryngoscopy and bronchoscopy, flexible fiberoptic laryngoscopy, and plain x-ray films. The authors concluded that airway fluoroscopy is a valuable adjunct to flexible fiberoptic laryngoscopy, particularly in the evaluation of lower airway lesions and dynamic lesions such as laryngomalacia. However, this conclusion is in conflict with that of a study by Gibson et al that found that the sensitivity of airway fluoroscopy was higher in identifying supraglottic lesions than it was in identifying subglottic lesions. This controversy remains unresolved.

Airway stenosis, laryngomalacia, airway mass lesions, and tracheomalacia are known to be common causes of stridor in children, consistent with the endoscopic diagnoses observed in this study. Following endoscopic evaluation, however, the diagnoses made by airway fluoroscopy were rarely found to be correct. In fact, with 59% of patients receiving a different diagnosis after endoscopic evaluation from the diagnosis made by airway fluoroscopy, our findings call into question the reliability of diagnoses made by airway fluoroscopy. In particular, 16 of 18 “normal” airways on airway fluoroscopy were found to have some abnormality on endoscopy. The importance of this finding cannot be underestimated, especially as the majority of these patients did not undergo complete airway evaluation with direct laryngoscopy and tracheobronchoscopy with flexible fiberoptic laryngoscopy. Anywhere from 10% to 50% of children with stridor are found to have multiple airway lesions on endoscopic evaluation, and we suggest that additional lesions may be found if complete endoscopic evaluation is conducted on all patients. Furthermore, the promise of airway fluoroscopy as a screening study remains uncertain, with poor sensitivity in all of the evaluated di-

<table>
<thead>
<tr>
<th>Diagnosis</th>
<th>Sensitivity, %</th>
<th>Specificity, %</th>
<th>Positive</th>
<th>Negative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Airway stenosis (13)</td>
<td>69</td>
<td>100</td>
<td>100</td>
<td>87</td>
</tr>
<tr>
<td>Laryngomalacia (11)</td>
<td>27</td>
<td>100</td>
<td>100</td>
<td>78</td>
</tr>
<tr>
<td>Airway mass lesion (7)</td>
<td>43</td>
<td>100</td>
<td>100</td>
<td>89</td>
</tr>
<tr>
<td>Tracheomalacia (5)</td>
<td>20</td>
<td>94</td>
<td>33</td>
<td>89</td>
</tr>
</tbody>
</table>

Table 2. Sensitivity, Specificity, and Predictive Value of Airway Fluoroscopy
agnoses. Airway fluoroscopy was found to be most sensitive for the detection of airway stenosis, a fixed lesion. Our findings are contradictory to those of Rudman et al, 3 which suggest that airway fluoroscopy is more useful in the evaluation of dynamic airway lesions. Even in our study, however, a sensitivity of 69% is modest at best. Low negative predictive values suggest that even negative fluoroscopy study results will require further evaluation to rule out an underlying pathologic cause. Still, while the sensitivity of airway fluoroscopy was observed to be poor, diagnoses made by airway fluoroscopy were highly specific, ranging from 94% to 100% for all diagnoses. With the exception of tracheomalacia, positive predictive values were high. These data suggest that findings of airway stenosis, laryngomalacia, mass lesions, or tracheomalacia on airway fluoroscopy are reliable and may not require endoscopic confirmation.

The ideal study to define the utility of airway fluoroscopy in the evaluation of pediatric stridor would be a prospective design in which all subjects undergo both airway fluoroscopy and endoscopy. Unfortunately, the added risk and expense encountered through such a trial make it unreasonable, if not unethical, to conduct. Through a retrospective examination of patients who underwent both studies as part of their diagnostic workup, we attempted to simulate such a trial. Our study was limited by the fact that the physicians involved, both otolaryngologists and radiologists, were not blinded to the diagnoses that were made by previous radiographic or endoscopic evaluation. The impact of this limitation is minimal, however, as airway fluoroscopy was performed before endoscopy in 37 of 39 cases. As such, fluoroscopic diagnoses are presumed to be without outside influence. Our study was also limited by its relatively small total sample size, which in turn limits statistical power. The sample sizes within each diagnostic subgroup were even smaller (eg, there were only 5 patients in the tracheomalacia group), which may further reduce the strength of the conclusions that are drawn. The limited number of subjects is partly attributable to the elimination of those subjects who underwent only airway fluoroscopy; they were presumably treated based on the results of fluoroscopy alone. In essence, it could be said that this study included only those “difficult” cases in which further endoscopic evaluation was necessary to clarify the cause of the child’s stridor. Sensitivity may therefore be artificially decreased. Nevertheless, because of the high incidence of conflicting diagnoses, it is impossible to avoid the question of how many diagnoses may have changed in those subjects who underwent only airway fluoroscopy had they gone on to endoscopy. Without a true prospective study, the answer to this question will not be known.

Continued research is needed to further clarify the role of noninvasive radiographic imaging in the evaluation of pediatric stridor. Future research may also incorporate newer and more advanced imaging studies. Of particular interest is so-called virtual endoscopy, which can provide a noninvasive simulation of endoscopic evaluation. Research has shown that it has greater sensitivity in the detection of fixed airway lesions than of dynamic disorders; however, further evaluation is needed. 12 Other potentially useful modalities include spiral computed tomography and magnetic resonance imaging. With further study, each of these noninvasive modalities may acquire a more defined role in the diagnosis of pediatric stridor; however, currently available data clearly support endoscopy as the most accurate and thorough means of airway evaluation.

In conclusion, the symptom of stridor in a pediatric patient population poses a diagnostic dilemma to physicians who seek to balance effectiveness with a minimally invasive approach. Airway fluoroscopy is a minimally invasive and highly specific tool. Diagnoses made by airway fluoroscopy appear reliable; however, its sensitivity in detecting several common causes of stridor is poor. Negative fluoroscopic study results require further diagnostic evaluation if clinically indicated; therefore, the value of airway fluoroscopy as a screening tool remains uncertain.

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Author Contributions: Dr Sobol had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. Study concept and design: Berg, Naseri, and Sobol. Acquisition of data: Berg, Naseri, and Sobol. Analysis and interpretation of data: Berg and Sobol. Drafting of the manuscript: Berg and Sobol. Critical revision of the manuscript for important intellectual content: Naseri and Sobol. Statistical analysis: Berg. Administrative, technical, and material support: Naseri and Sobol. Study supervision: Sobol.

Financial Disclosure: None reported.

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REFERENCES