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Possibilities Of Comprehensive Ultrasonic Examination In The Diagnosis Of Larynx Stenosis In Children

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Abstract: Objective: To evaluate the diagnostic value of comprehensive ultrasound examination of the larynx, including B-mode imaging, Doppler study, and bronchophony assessment, in detecting and characterizing laryngeal stenosis in children of different age groups.

Materials and Methods: The study included 128 children aged from 1 month to 14 years (mean age 5.6 ± 2.8 years) diagnosed with laryngeal stenosis of various origins. All patients underwent a comprehensive ultrasound examination of the larynx to assess structural changes, blood flow parameters, vocal fold mobility, and bronchophony intensity.

Results: Echographic signs of stenosis of grades I–IV were identified in all cases. The mean anteroposterior dimension of the subglottic space decreased with the severity of stenosis: from 4.2 ± 0.5 mm at grade I to 0.9 ± 0.2 mm at grade IV ($p < 0.001$). A reduction in bronchophony amplitude directly correlated with the severity of respiratory insufficiency ($r = 0.71$). The sensitivity of the method was 91%, specificity — 88%, and overall diagnostic accuracy — 89%.

Conclusion: Comprehensive ultrasound examination with Doppler study and bronchophony assessment is a highly informative and safe method for diagnosing laryngeal stenosis in children. The technique allows accurate determination of airway narrowing, identification of inflammatory and cicatricial changes, and objective monitoring of treatment effectiveness.

Keywords: Laryngeal stenosis, ultrasound diagnostics, bronchophony, children, echography, Doppler imaging.

Introduction: Laryngeal stenosis in children is one of the most dangerous pathologies of the respiratory tract, accompanied by impaired patency of the upper airways and a high risk of respiratory failure. In childhood, the disease most often develops as a result of inflammatory processes, traumatic injuries, congenital anomalies, or following tracheal intubation. Early assessment of the degree of stenosis is crucial for selecting appropriate treatment strategies and preventing life-threatening complications. Traditional imaging methods, including laryngoscopy and computed tomography, have high diagnostic value; however, their use in children is limited due to invasiveness, the need for anesthesia, and radiation exposure. In this context, non-invasive methods such as ultrasound examination (US) are gaining increasing importance.

Modern ultrasound technologies—B-mode imaging, Doppler sonography, and compression elastography—make it possible to obtain not only anatomical but also functional information about the larynx, the degree of lumen narrowing, and the nature of pathological soft-

tissue changes. A comprehensive echographic approach enables dynamic follow-up, quantitative assessment of stenosis severity, and determination of the type of lesion (inflammatory, cicatricial, post-intubation). This contributes to timely diagnosis, identification of morphological changes, assessment of airway functional status, reduction in the number of invasive procedures, and preservation of respiratory and vocal function in children.

Aim of the Study

To evaluate the diagnostic value of comprehensive ultrasound examination (B-mode, Doppler sonography, bronchophony) in the detection, characterization, and dynamic monitoring of laryngeal stenosis in children of different age groups.

METHODS

The study included 128 children (74 boys and 54 girls) aged from 1 month to 14 years (mean age 5.6 ± 2.8 years). All patients were treated in an otorhinolaryngology department with an established diagnosis of laryngeal stenosis of various etiologies.

The etiological structure of the disease was as follows: in the majority of children (52%), stenosis was caused by viral infection; in 28%, it developed as a post-intubation complication; in 12%, it was congenital; and in 8%, it resulted from traumatic laryngeal injury.

Only patients with a reliably confirmed diagnosis of laryngeal stenosis were included in the study. Children with severe congenital anomalies of the trachea and bronchial tree that could affect interpretation of echographic findings were excluded.

Ultrasound examination was performed using a Canon Aplio 500 system with a high-frequency linear transducer (7–12 MHz). The examination was conducted with the patient in the supine position with moderate head extension, providing optimal visualization of the anterior neck surface and laryngeal structures. In selected cases, a silicone stand-off pad 5–10 mm thick was used to improve image quality.

During the examination, the following parameters were recorded:

- echostructure of the laryngeal soft tissues and subglottic space;
- anteroposterior and transverse dimensions of the subglottic region at the level of the cricoid cartilage;
- mobility of the vocal folds at rest and during phonation;
- blood flow characteristics assessed by color and power Doppler mapping with calculation of the resistive index (RI) and pulsatility index (PI);
- acoustic parameters of bronchophony.

To assess bronchophony, an acoustic sensor was placed on the anterior surface of the neck in the projection of the cricoid cartilage. Recording was performed while the child pronounced simple syllables (“pa-pa” or “ta-ta”) during expiration. The obtained signals were analyzed in terms of vibration amplitude and frequency characteristics, allowing objective evaluation of sound conduction impairment and vibratory activity of the vocal cords.

The degree of stenosis was assessed according to the Cotton–Myer classification, which includes four levels of laryngeal lumen narrowing.

To verify the accuracy of ultrasound diagnostics, echographic findings were compared with fiberoptic laryngoscopy data, considered the “gold standard.” Comparative analysis was performed in 42 patients for whom endoscopy was not contraindicated.

Statistical analysis was performed using methods of variation statistics. Mean values (M), standard deviation (SD), and correlation coefficients (r) between echographic parameters and clinical stenosis grade were calculated. Student’s t-test was used to assess the significance of differences. Statistical significance was set at $p < 0.05$.

The study was approved by the local ethics committee. Written informed consent was obtained from the parents or legal guardians of all participants.

RESULTS

Echographic signs of laryngeal stenosis were identified in all 128 examined children. Distribution according to the Cotton–Myer classification was as follows: grade I stenosis was diagnosed in 38 patients (29.7%), grade II in 49 (38.3%), grade III in 32 (25.0%), and grade IV in 9 (7.0%). Thus, children with moderate and severe stenosis accounted for more than two-thirds of cases (70.3%), indicating a high prevalence of significant airway involvement in pediatric practice.

The dimensions of the subglottic space showed a pronounced dependence on stenosis severity. Mean anteroposterior diameters were: 4.2 ± 0.5 mm for grade I, 2.9 ± 0.4 mm for grade II, 1.8 ± 0.3 mm for grade III, and 0.9 ± 0.2 mm for grade IV ($p < 0.001$). A clear trend toward progressive lumen narrowing with increasing severity was observed, confirming a direct correlation between stenosis grade and anatomical constriction of the subglottic region.

In children with grade II–IV stenosis, characteristic echostructural changes were noted: thickening of the mucosal–submucosal layer in the region of the cricoid cartilage (mean 2.3 ± 0.6 mm), reduced clarity of cartilaginous contours, and the appearance of hypoechoic areas corresponding to edema or

granulation tissue. In prolonged disease, hyperechoic inclusions indicative of cicatricial changes were visualized.

Color and power Doppler mapping revealed specific features of laryngeal blood supply. In 56% of patients with chronic stenosis, increased vascularization was observed in areas of granulation tissue and thickened mucosa. In acute inflammation, blood flow was moderately increased, whereas cicatricial forms were characterized by reduced perfusion and the presence of avascular areas.

Bronchophony analysis demonstrated a marked reduction in vibration signal amplitude in 87% of patients with grade II–IV stenosis. In mild disease (grade I), parameters remained within physiological limits; however, progressive weakening of sound signal oscillations was noted with increasing laryngeal narrowing. Correlation analysis revealed a significant association between decreased bronchophony amplitude and the severity of respiratory failure ($r = 0.71$), confirming the high diagnostic value of this parameter in functional airway assessment.

Comparison of echographic findings with fiberoptic laryngoscopy results demonstrated high diagnostic performance of ultrasound examination:

- Sensitivity: 91%
- Specificity: 88%
- Overall diagnostic accuracy: 89%

The analysis showed that ultrasound examination allows not only determination of stenosis severity but also clarification of the morphological structure of the lesion, including the presence of edema, granulation tissue, or cicatricial changes. Additional use of Doppler and acoustic techniques (bronchophony assessment) expands the diagnostic capabilities of ultrasound, providing a comprehensive evaluation of the morphofunctional state of the larynx.

Thus, the study results confirm that comprehensive ultrasound examination of the larynx, combining B-mode imaging, Doppler sonography, and bronchophony analysis, is a highly informative, safe, and reproducible diagnostic tool for laryngeal stenosis in children. The main advantage of the method is the possibility of dynamic follow-up and objective assessment of treatment effectiveness without the need for invasive procedures.

Table 1. Distribution of laryngeal stenosis grades in children

Степень стеноза	Количество пациентов (n)	Процент (%)
I степень	38	29,7
II степень	49	38,3
III степень	32	25,0
IV степень	9	7,0

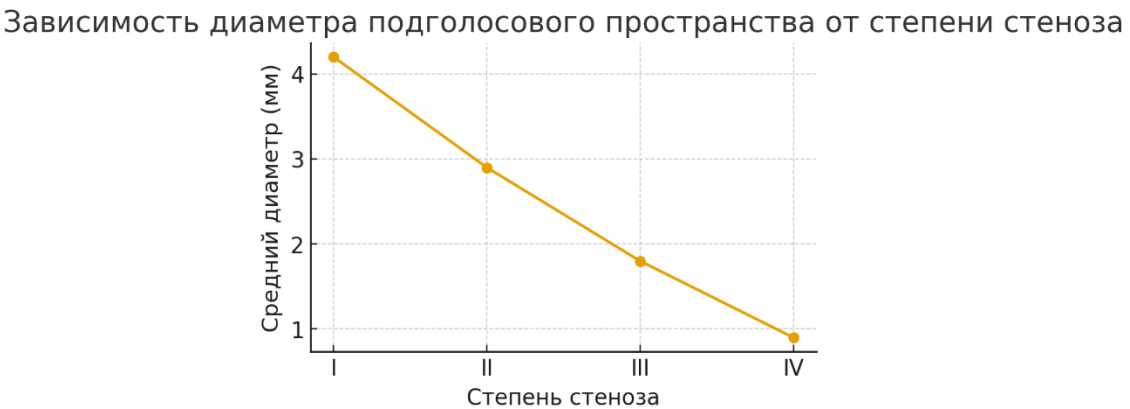

Figure 1. Changes in the mean diameter of the subglottic space depending on the degree of laryngeal stenosis

DISCUSSION

The obtained data convincingly demonstrate the high diagnostic value of a comprehensive ultrasound approach in the diagnosis of laryngeal stenosis in children of various etiologies. The combined use of techniques—B-mode imaging, Doppler analysis, and acoustic assessment of bronchophony—made it possible not only to objectively determine the degree of laryngeal lumen narrowing but also to comprehensively characterize morphological changes of the mucosa, submucosal layer, and perichondrial structures. In addition, the study enabled analysis of local hemodynamics and functional assessment of the vocal apparatus.

In recent years, there has been growing interest in ultrasound visualization of the upper airways in children. This is associated both with technological advances and the introduction of high-frequency transducers, as well as with the possibility of performing examinations without anesthesia or sedation. Echography is a non-invasive, safe, and reproducible method, which is particularly important in pediatric practice, where the use of endoscopic techniques may be limited by the child's age, respiratory insufficiency, or pronounced mucosal edema.

The results of the present study confirm that B-mode echography is a reliable tool for assessing the anatomical structure of the larynx. It allows visualization of the subglottic space, vocal folds, and cricoid cartilage, and enables identification of characteristic echostructural changes. Hypoechoic areas correspond to edematous and inflammatory changes, whereas hyperechoic inclusions indicate the presence of cicatricial or fibrotic tissue. During dynamic follow-up, gradual restoration of normal echostructure was observed as inflammatory changes regressed, making the method valuable not only for diagnosis but also for monitoring treatment effectiveness.

Doppler sonography significantly expands the diagnostic capabilities of ultrasound evaluation of the larynx. Changes in vascular patterns and resistive index (RI) reflect inflammatory activity and the degree of tissue vascularization. In patients with acute inflammation, increased blood flow and elevated RI were observed, whereas chronic stenosis was characterized by reduced perfusion, corresponding to fibrotic and sclerotic changes. These patterns are consistent with findings reported in domestic and international studies investigating inflammatory airway diseases in children. Therefore, Doppler sonography can be regarded as a reliable criterion for assessing the stage and activity of the pathological process.

Inclusion of bronchophony assessment in the comprehensive echographic examination added a functional component to morphological diagnostics. Analysis of vibration signals during phonation provides valuable information on airway patency and vocal fold mobility. It was established that reduced or absent bronchophony amplitude is characteristic of severe stenosis and is directly associated with the severity of respiratory insufficiency ($r = 0.71$). As the clinical condition improves and the laryngeal lumen is restored, vibration amplitude increases, confirming the practical significance of this parameter for dynamic patient monitoring.

Thus, a comprehensive echographic approach incorporating B-mode imaging, Doppler sonography, and bronchophony provides a thorough assessment of the morphofunctional state of the larynx. The method allows determination not only of the degree and type of stenosis but also monitoring of reparative processes during treatment. It is particularly valuable in situations where endoscopy is contraindicated or technically difficult—for example, in neonates, in cases of severe inflammation, congenital anatomical anomalies, or when there is a high risk of anesthesia-related complications.

The practical significance of the present study lies in the possibility of implementing the proposed diagnostic algorithm into routine clinical practice of otorhinolaryngologists, pediatricians, and intensive care specialists. The use of echography enables timely detection of progressive stenosis, optimization of therapeutic strategies, reduction in the frequency of invasive interventions, and prevention of life-threatening complications. Future research directions include the development of quantitative ultrasound and Doppler criteria for stenosis severity, creation of standardized examination protocols, and integration of echographic monitoring into comprehensive diagnostic pathways for pediatric laryngeal diseases.

CONCLUSIONS

The results of this study convincingly confirm that comprehensive ultrasound examination of the larynx, including grayscale (B-mode) imaging, Doppler analysis, and bronchophony assessment, has high diagnostic value for detecting and grading laryngeal stenosis in children. This approach provides a multidimensional evaluation of the morphofunctional state of the larynx, allowing visualization not only of the degree of airway narrowing but also of the nature of structural changes in soft tissues, the submucosal layer, and cartilaginous elements.

B-mode imaging enables precise determination of lesion localization and extent, as well as differentiation

between acute inflammatory changes and chronic post-traumatic processes. Identification of edema, granulations, fibrotic, or cicatricial areas allows differential diagnosis of various stenosis forms and assessment of recovery dynamics following treatment.

Incorporation of Doppler techniques (color and power Doppler) significantly enhances ultrasound capabilities by providing information on local hemodynamic disturbances. Increased resistive index (RI) and enhanced vascular patterns indicate active inflammation, whereas reduced blood flow is characteristic of scarring and sclerosis stages. These parameters may serve as additional quantitative criteria for assessing disease severity and stage, as well as for monitoring treatment effectiveness.

Bronchophony assessment complements ultrasound findings with functional characteristics of the vocal apparatus and airways. Reduced vibration amplitude during phonation is closely associated with the severity of respiratory disorders (correlation coefficient r = 0.71), confirming the diagnostic value of this parameter. Repeated examinations during treatment allow objective monitoring of lumen restoration and laryngeal function, making the method particularly useful for dynamic follow-up.

The comprehensive ultrasound approach has clear advantages over traditional invasive diagnostic methods, as it minimizes the need for endoscopy under anesthesia. This is especially important for young children and patients with severe somatic conditions, in whom endoscopic examination may be difficult or contraindicated. According to comparative analysis, the proposed methodology demonstrated high effectiveness: sensitivity was 91%, specificity 88%, and overall diagnostic accuracy reached 89% compared with fiberoptic laryngoscopy, considered the “gold standard.” These data confirm the clinical reliability and reproducibility of the method.

Thus, inclusion of laryngeal ultrasound in the diagnostic algorithm for children with stenosis appears justified and promising. Application of this technique will improve diagnostic quality, enable timely detection of progressive airway narrowing, facilitate monitoring of treatment outcomes, and reduce the risk of complications. Implementation of a comprehensive echographic approach in pediatric otorhinolaryngology practice will expand early diagnostic capabilities and optimize the diagnostic and therapeutic process.

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