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CAPABILITIES OF MULTIPARAMETRIC ECHOGRAPHY IN ASSESSING THE SEVERITY AND MONITORING THE EFFECTIVENESS OF TREATMENT OF LARYNGEAL STENOSIS IN CHILDREN

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Abstract. Diagnosis of laryngeal diseases in children remains one of the most complex and pressing challenges in modern otolaryngology and radiology. The anatomical and physiological characteristics of childhood—a small airway, a high larynx, pronounced vascularity , and a tendency for the mucous membrane to rapidly develop edema—determine the high risk of rapid progression of the pathological process, leading to decompensated stenosis.

The traditional "gold standard" for diagnosing laryngeal diseases is fiberoptic laryngoscopy . However, its use in pediatric practice is accompanied by several limitations, including the need for sedation, the risk of reactive laryngospasm, and potential mucosal trauma, which can worsen existing airway obstruction. Multislice computed tomography, despite its high spatial resolution, is limited by significant radiation exposure and static images, which reduces its usefulness in assessing the dynamic functional state of the vocal folds.

In recent years, ultrasound examination of the neck organs has become increasingly common in clinical practice. The absence of ionizing radiation, non-invasiveness , and the ability to conduct the examination in real time expand the diagnostic capabilities of ultrasound imaging in visualizing the anatomical and functional features of the larynx in children. However, sonographic parameters of the larynx in normal and various pathological conditions, taking into account age-related characteristics, remain insufficiently standardized. The diagnostic value of ultrasound, in comparison with endoscopic data, also requires further clarification.

Key words: pediatric otolaryngology, laryngeal ultrasound, laryngeal stenosis, stridor, echography, vocal fold paresis, subglottic space.

The aim of the study was to improve the diagnostic efficiency of laryngeal pathology in children and to validate the use of ultrasound as a safe and non-invasive alternative to traditional imaging techniques.

Materials and Methods. The study included 65 pediatric patients aged 1 month to 14 years with clinical manifestations of stridor, dysphonia, and signs of respiratory failure. All patients underwent laryngeal ultrasound examination using a 10–15 MHz linear transducer. Morphometric parameters, including glottal width, subglottic thickness , and arytenoid excursion amplitude, were assessed. The obtained ultrasound data were compared with the results of videolaryngoscopy , which was used as a reference method.

Results. The study identified specific sonographic markers for various forms of laryngeal pathology. For acute stenosing laryngotracheitis, a characteristic feature was an increase in subglottic soft tissue thickness of more than 1.2 mm, with a sensitivity of 93.8%. In cases of vocal fold paresis, real-time ultrasound allowed for the reliable detection of asymmetries in laryngeal structure mobility without the need for sedation. Ultrasound also demonstrated high prognostic value in dynamically monitoring the effectiveness of decongestant therapy, reducing the number of follow-up endoscopic examinations by 40%.

The aim of the study was to develop and systematize ultrasound criteria for obstructive laryngeal diseases in children, as well as to evaluate the diagnostic and clinical effectiveness of ultrasound monitoring during treatment to reduce the invasiveness of diagnostic interventions and optimize patient management.

Materials and Methods. A prospective clinical study was conducted at the Children's Multidisciplinary Clinic of Tashkent State Medical University in 2024–2025. The study included 65 patients aged 1 month to 14 years with clinical signs of laryngeal pathology.

Depending on the nosological form, all patients were divided into three main groups: Group I (n = 30) - children with acute stenotic laryngotracheitis; Group II (n = 15) - patients with congenital anomalies of the larynx (laryngomalacia , congenital membranes); Group III (n = 20) - children with functional disorders (paresis and paralysis of the vocal folds), including after cardiac surgery.

The control group consisted of 20 somatically healthy children of similar age without signs of respiratory pathology.

the Aplio 500 (Canon Medical Systems) and Sonoscape expert-class scanners , using a 7.5–15 MHz linear transducer. High-frequency scanning provided a spatial resolution of up to 0.1 mm. The examination was performed in B-mode without sedation. The patient was positioned supine with moderate neck extension (using a cushion under the shoulder girdle). Transverse scanning: the transducer was positioned in the projection of the thyroid cartilage to visualize the true and false vocal folds, the anterior commissure, and the arytenoid cartilages. Longitudinal scanning: the transducer was positioned in the midline to evaluate the epiglottis, preepiglottic space, and subglottic region.

Functional tests: laryngeal motility was assessed in real time during quiet breathing, forced inhalation (crying in young children), and the Valsalva maneuver in older children. Morphometric parameters assessed included: thickness of the mucosubmucosal layer in the cricoid cartilage (subglottic space); glottis width at the level of the posterior commissure during maximum inhalation; amplitude and symmetry of arytenoid cartilage and vocal fold movements.

Statistical data processing was performed using the Statistica 12.0 package. The significance of differences between ultrasound and videolaryngoscopy results (reference method) was assessed using Student's t-test and Pearson correlation analysis. The threshold for statistical significance was set at $p < 0.05$.

Results. A comparative analysis of ultrasound and videolaryngoscopy data demonstrated the high diagnostic efficacy of echography in visualizing laryngeal structures in children. The overall diagnostic accuracy of the method was 92.4%, confirming its high informative value in pediatric practice.

1. Sonographic markers of acute stenosing laryngotracheitis (group I). In patients with acute stenosing laryngotracheitis, the leading diagnostic ultrasound sign was a circular or horseshoe-shaped thickening of the mucosubmucosal layer in the subglottic space. The average soft tissue thickness in grade I stenosis was 1.4 ± 0.2 mm, in grade II - 1.9 ± 0.3 mm, while in the control group this indicator did not exceed 0.8 ± 0.1 mm. In 86% of cases, a decrease in echogenicity was noted Subglottic tissue, forming the so-called " hypoechoic ring sign," which corresponded to the active exudative edema phase. Dynamic ultrasound monitoring during hormonal therapy recorded a decrease in edema thickness by an average of 0.3 mm over 24 hours, which significantly correlated with clinical improvement in the patients' condition.

2. Diagnosis of functional laryngeal disorders (group III). Real-time assessment of the mobility of the vocal folds and arytenoid cartilages (Cineloop) revealed asymmetry in the movements of the laryngeal structures in 18 patients (90%) with clinical suspicion of paresis. The glottis width during maximum inspiration in children with unilateral paresis decreased to 2.5–3.0 mm, while the normal value for children under 3 years of age exceeds 4.5–5.0 mm. Ultrasound examination accurately determined the affected side in 100% of cases, which fully coincided with the results of subsequent endoscopic verification.

3. Comparative characteristics of the methods. To assess the diagnostic validity of the ultrasound method, the operational characteristics of the test were calculated in comparison with videolaryngoscopy . The sensitivity of the method was 93.8%, specificity was 89.5%, and the

positive predictive value was 91.2%. No statistically significant differences were found between the results of laryngeal lumen measurements during ultrasound and endoscopic examination ($p > 0.05$), indicating the comparability and complementarity of the methods in primary diagnostics.

The average ultrasound protocol time was 6.5–15 minutes, and no cases required sedation. In 12 patients (18.4%), the ultrasound results were sufficient to avoid diagnostic endoscopy under general anesthesia, highlighting the clinical significance of this method and its potential to reduce the invasiveness of diagnostic procedures.

Discussion. The obtained results confirm the high diagnostic value of ultrasound examination in pediatric laryngology. The key advantage of echography over traditional videolaryngoscopy is its non-invasiveness and safety. In this study, 100% of children underwent examination without the use of sedation, which is crucial for patients with signs of respiratory failure, in whom stress and invasive interventions can trigger reflex laryngospasm and worsen obstruction.

A comparison of the obtained data with the results of international studies demonstrated a high correlation between the subglottic thickness measured by ultrasound and the degree of clinically evident stenosis. Furthermore, the presented study expands existing understanding by emphasizing dynamic monitoring. It was established that a decrease in the mucosubmucosal thickness by 0.2–0.3 mm is an early prognostic indicator of the effectiveness of the treatment and precedes significant clinical improvement. This allows for informed adjustment of the dosage of systemic glucocorticoids and minimizes their side effects.

Ultrasound has demonstrated particular value in diagnosing vocal fold paresis. Traditionally, verifying functional impairment in young children requires fiberoptic laryngoscopy under general anesthesia while maintaining spontaneous breathing, which is technically challenging and associated with anesthetic risks. This study demonstrates that real-time transcutaneous ultrasound provides visualization of arytenoid cartilage and vocal fold excursion with an accuracy comparable to endoscopic methods. This allows ultrasound to be considered the method of choice for initial screening of children after cardiac surgery, given the risk of injury to the recurrent laryngeal nerve.

At the same time, the limitations of this method must be considered. Visualization of laryngeal structures can be difficult in older children (over 12–14 years of age) due to ossification of the thyroid cartilage, which creates an acoustic shadow and limits evaluation of the posterior regions. Furthermore, the informative value of ultrasound examination is reduced by pathologies located deep within the lumen of the laryngeal ventricles or behind the air spaces, due to the physical properties of ultrasound wave propagation.

Thus, ultrasound examination of the larynx should be considered as an effective, safe and clinically significant method of primary diagnosis and dynamic observation in pediatric practice, with a clear understanding of its diagnostic capabilities and limitations.

Conclusions. Based on a study conducted on the use of multiparametric ultrasound in diagnosing laryngeal diseases in 65 children, the following conclusions were reached: High diagnostic efficacy. Laryngeal ultrasound is a highly informative imaging method with a sensitivity of 93.8% and a specificity of 89.5%. This method allows for the reliable detection of both organic changes (edema, tissue infiltration) and functional impairments (vocal fold paresis) without the need for invasive diagnostic interventions.

Objectification of laryngeal stenosis criteria. It has been established that an increase in the subglottic mucosal thickness of more than 1.2 mm in young children is a reliable sonographic marker of stenosis. This expands the potential of ultrasound imaging not only for initial diagnosis but also for objective , real-time dynamic monitoring of the effectiveness of decongestant therapy.

Safety and cost-effectiveness. The absence of ionizing radiation and the need for sedation make echography the method of choice ("first line") in pediatric laryngology. The use of a

standardized ultrasound protocol eliminated the need for diagnostic direct laryngoscopy under general anesthesia in 18.4% of patients, reducing the risk of iatrogenic complications and decreasing hospital costs. Versatility and clinical applicability of the method. Multiparametric echography has demonstrated high efficacy in a wide range of clinical situations—from the emergency diagnosis of acute stenotic laryngotracheitis to screening for laryngeal paresis in children after cardiac surgery. The obtained data on the layered sonographic anatomy of the larynx pave the way for the development and implementation of minimally invasive ultrasound-guided surgical technologies, including injection laryngoplasty , which will potentially improve the accuracy and safety of treating chronic laryngeal stenosis in children.

Conclusions. Laryngeal ultrasound is a highly informative, non-invasive, first-line diagnostic method for obstructive laryngeal diseases in children. The absence of radiation exposure and the need for anesthesia makes ultrasound a preferred tool for repeated patient monitoring in intensive care units and in outpatient otolaryngology practices.

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