

Subject: Role of Impulse Oscillometry in Children with Airway Narrowing After Bronchoscopic Stent Implantation, a Pilot Observational Study

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To the Editor,

We would like to address the critical issue of congenital airway anomalies, encompassing tracheal stenosis, tracheomalacia, and tracheo-bronchomalacia, which pose life-threatening challenges. Patients afflicted with these conditions frequently exhibit respiratory distress, such as tachypnea, dyspnea, chest tightness, chronic cough, exercise intolerance, and audible breathing sounds. The risk of recurring pulmonary infections is associated with inadequate airway clearance, culminating in irreversible lung damage over time.

Bronchoscopic airway stent placement emerges as an efficacious strategy for alleviating tracheo-bronchial obstructions. It demonstrates notable success in mitigating breathlessness, elevating quality of life, and enhancing survival rates, especially among adults with malignancies. However, the extension of this technique to pediatric populations remains underexplored, primarily due to concerns regarding potential complications, including hypoxia, laryngospasm, hemorrhage, and air-leak syndromes. Despite its clinical safety, the absence of established consensus or guidelines for bronchoscopy and airway stent implantation in infants and children persists (1).

Nevertheless, evaluation of pulmonary function after airway stent implantation by spirometry might be challenging in pediatric population due to weak respiratory efforts, inadequate cooperation, and poor comprehension. This is where Impulse Oscillometry (IOS) comes into play. Grounded in the forced oscillation technique, IOS passively assesses airway resistance and alveolar reactance during tidal breathing. IOS is able to differentiate resistance of peripheral (small) airways from central (large) airways, thus aiding treatment planning for obstructive lung diseases. It encompasses parameters like respiratory impedance (Z), respiratory resistance (R), and respiratory reactance (X), which together provide a comprehensive analysis of airway function, assisting in the assessment of obstructive and restrictive lung diseases.

Material & Methods

Detailing our single-center experience, this study delves into the implantation of tracheobronchial stents in four pediatric patients with intricate airway obstructions. From January 2019 to October 2022, patients aged 2 to 18 who underwent stent implantation at China Medical University Children’s Hospital were enrolled. We performed spirometry, impulse oscillometry, and bronchodilator tests before and two weeks after stent intervention. Our choice of stent was Bonastent (Standard SciTech Inc.), a self-expanding silicon-covered stent. Impulse oscillometry was conducted to gauge respiratory parameters, including airway resistance at 5 Hz (R5), airway resistance at 20 Hz (R20), R5-R20, alveolar reactance at 5 Hz (X5), and resonance frequency. The application of impulse oscillometry offers a window into obstructive lung disease assessment via resistance measurements. A difference greater than 0.07 kPaA/(L/s) between R5 and R20 hints at small airway dysfunction (SAD). Further, R5 exceeding 150% of the reference value signifies obstructive lung disease. A reduction of 30% of R5 value 15 minutes after 200 mcg of albuterol inhalation would be considered as positive evidence of airway reversibility. (2). Medcalc 20.118b was used as statistic software for data analysis.

Results

Among the four cases, ages ranging from 8 to 17(Table 1), airway stent implantation was a commonality. Notably, the patients exhibited significant improvements in R5-R20 post-stent intervention ($-0.37 \pm 0.21\text{kPaA/L/s}$, $P=0.04$), experiencing relief in respiratory symptoms and enhanced airway diameters, affirmed by bronchoscopy and chest X-ray findings. All subjects met criteria for severe obstructive lung disease, supported by their positive bronchodilator response in impulse oscillometry. An immediate spike in airway dimensions, validated through images, underscored the positive impact of stent implantation. Following the procedure, patients were treated with inhaled long-acting beta-2 agonists and inhaled corticosteroids (ICS-LABA). Our study demonstrated that airway stent implantation improved small airway functions of patients with congenital airway anomalies. In the meantime, we also showed feasibility of using impulse oscillometry for assess respiratory function after stent implantation.

Discussion

. In the ATLANTIS study, Kraft et al found a strong correlation between IOS-defined small airway dysfunction and asthma exacerbations(3). Clinical symptoms of asthma and other obstructive lung diseases may be attributed to long-term inflammation, increased resistance, narrowing, and remodeling of small airways. Patients with congenital airway anomalies exhibited elevated airway resistance with small airway dysfunction as well. Airway stent implantation emerges as a promising intervention, breaking the cycle of airway inflammation and enhancing ventilation by counteracting dynamic airway collapse. Regular use of inhaled corticosteroids may furthermore enhance small airway function after stent implementation.

In our study, while limited by sample size, stent type, and follow-up duration, offers evidence that airway stents can effectively address respiratory symptoms and improve small airway function in congenital airway anomalies. We have showcased the potential of impulse oscillometry as a valuable post-stent implantation monitoring tool, while also acknowledging the need for broader research endeavors.

Table 1. Demographic features of four patients with BONA stent implantation

| Case | 1 | 2 | 3 | 4 | Average (Mean±SD) |
|---|----------------|----------------|-------------|----------------|----------------------|
| Age (y/o) | 13 | 17 | 8 | 11 | 12.25 ± 1.88 |
| Sex (M) | F | M | F | F | |
| Height (cm) | 149.0 | 164.8 | 133 | 135.5 | 145.58 ± 14.62 |
| Weight (kg) | 36.0 | 77.3 | 36 | 21.2 | 42.63 ± 24.15 |
| Diagnosis | T-E fistula * | LMB ** | Tracheal | T-E Fistula * | |
| | Tracheomalacia | Bronchomalacia | Stenosis | Tracheomalacia | |
| Stent site | Lower trachea | LMB** | Mid-trachea | Lower trachea | |
| Stent size (mm) (Diameter*Length) | 14*20 | 12*30 | 12*30 | 12*40 | |

Table 2. Change of airway resistance before and after stent implantation

| Parameters (Mean ± SD) | Before Stent N=4 (Mean±SD) | After Stent N=4 (Mean±SD) | Reduction | P value |
|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|
| R5 (% of reference) | | | | |
| Pre-BD | 288.75 ± 85.78 | 223.75 ± 61.68 | -35.0 ± 49.0 | 0.07 |
| Post-BD | 220.75 ± 91.85 | 204.00 ± 44.74 | -16.8 ± 82.6 | 0.71 |
| R20 (% of reference) | R20 (% of reference) | R20 (% of reference) | R20 (% of reference) | R20 (% of reference) |
| Pre-BD | 159.25 ± 40.11 | 156.25 ± 42.13 | -4.25 ± 45.11 | 0.82 |
| Post-BD | 151.00 ± 63.89 | 153.00 ± 37.68 | 4.0 ± 54.60 | 0.89 |
| R5-R20 (kPaA/(L/s)) | R5-R20 (kPaA/(L/s)) | R5-R20 (kPaA/(L/s)) | R5-R20 (kPaA/(L/s)) | R5-R20 (kPaA/(L/s)) |
| Pre-BD | 0.92 ± 0.36 | 0.56 ± 0.27 | -0.37 ± 0.21 | 0.04** |
| Post-BD | 0.54 ± 0.30 | 0.51 ± 0.47 | 0.0 ± 0.50 | 0.92 |

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