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Ultrasound-guided management of reversible diaphragmatic dysfunction after extubation in an infant with transient pectus excavatum: a case report

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Case Report

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Abstract

Background: Diaphragmatic dysfunction is a clinically relevant complication of invasive mechanical ventilation (IMV) in infants, associated with respiratory biomechanical immaturity and reduced muscle activation related to sedation and prolonged ventilatory support. Diaphragmatic ultrasonography has emerged as a noninvasive bedside tool for real-time functional assessment and may support clinical decision-making during ventilator weaning and rehabilitation.

Case presentation: We report the case of a previously healthy 1-month-old infant admitted with respiratory syncytial virus bronchiolitis complicated by pneumonia, requiring IMV for 7 days. Following extubation to high-flow nasal cannula (HFNC), the patient developed persistent moderate-to-severe inspiratory effort, requiring noninvasive ventilation (NIV) for 6 days. After withdrawal of positive pressure support, progressive pectus excavatum, subcostal and intercostal retractions, axial hypotonia, a globular abdomen, and radiographic hypoventilation were observed. Diaphragmatic ultrasonography demonstrated reduced inspiratory thickness (13.5 mm) and a low diaphragmatic thickening fraction (DTF, 17%), consistent with diaphragmatic weakness. An individualized physiotherapy program was initiated, including sensorimotor stimulation, abdominal muscle strengthening, and the use of an abdominal support band, while HFNC was maintained. After 72 hours, repeat ultrasonography showed improvement (DTF 33%, thickness 16 mm), accompanied by better thoracoabdominal synchrony, regression of chest wall deformity, and improved lung aeration. HFNC was subsequently discontinued, and the patient was discharged with clinical improvement.

Conclusions: Diaphragmatic ultrasonography enabled early identification of diaphragmatic dysfunction, differentiation from inspiratory overload, and avoidance of unnecessary reintroduction of positive pressure support. Serial assessment supported targeted rehabilitation and demonstrated short-term reversibility of diaphragmatic dysfunction, highlighting its potential role in pediatric critical care.

Clinical trial number: not applicable

INTRODUCTION

Diaphragmatic dysfunction is a recognized complication of invasive mechanical ventilation (IMV) in pediatric patients, particularly when associated with prolonged ventilation, use of neuromuscular blocking agents, and systemic corticosteroids [1–3]. Furthermore, anatomical and physiological features of respiratory mechanics in infants and children—such as a highly compliant chest wall, a biomechanically disadvantaged diaphragm, and underdeveloped accessory muscles—render this population especially vulnerable to the adverse effects of IMV [1–4].

To date, there are no definitive data on the incidence of IMV-associated diaphragmatic dysfunction in pediatric populations, nor are there well-established reference values for diaphragmatic thickness. Consequently, serial assessment of diaphragmatic parameters has been recommended for real-time monitoring [5]. Loss of muscle trophism in peripheral muscles may begin within 48 hours of mechanical

ventilation and persist until sedation is withdrawn [2, 4], whereas diaphragmatic atrophy can develop as early as 18 hours after IMV initiation and may progressively worsen, potentially prolonging ventilation and negatively impacting clinical outcomes [6, 7].

To our knowledge, reports describing reversible pectus excavatum associated with diaphragmatic dysfunction following mechanical ventilation in infants are scarce. In this context, diaphragmatic ultrasonography has emerged as a noninvasive and radiation-free tool for evaluating diaphragm function. It enables measurement of muscle thickness and excursion throughout the respiratory cycle, providing diagnostic and prognostic information that may support clinical decision-making and guide physiotherapeutic interventions aimed at respiratory muscle strengthening and ventilator weaning [1, 2, 5]. Therefore, this study aims to report a case of diaphragmatic muscle weakness following orotracheal extubation in a young infant with acute viral bronchiolitis and to describe how ultrasound findings guided therapeutic decision-making..

Case presentation

A previously healthy 1-month-old infant diagnosed with respiratory syncytial virus (RSV) bronchiolitis associated with pneumonia required invasive mechanical ventilation (IMV) for 7 days. During this period, the patient received midazolam, fentanyl, dexmedetomidine, lorazepam, methadone, and antibiotic therapy. After a successful spontaneous breathing trial, the patient was extubated on May 13 to high-flow nasal cannula (HFNC). However, moderate-to-severe respiratory effort developed within the first hours after extubation, requiring initiation of noninvasive ventilation (NIV).

The patient remained on NIV until May 19, when support was transitioned back to HFNC. Following NIV withdrawal, progressive pectus excavatum (Fig. 1A) was observed, accompanied by subcostal and intercostal retractions. Despite the absence of tachypnea or tachycardia, chest radiography demonstrated hypoventilation (Fig. 2A). On May 22, diaphragmatic ultrasonography revealed a diaphragmatic thickening fraction (DTF) of 17% and inspiratory thickness of 13.5 mm, consistent with diaphragmatic dysfunction. The patient also presented marked axial hypotonia, with a globular and hypotonic abdomen, and delayed motor milestones.

In the absence of clinical signs of respiratory distress warranting reintroduction of positive pressure, a physiotherapy program was initiated, including age-appropriate motor stimulation, targeted strengthening of the abdominal complex, and use of an abdominal support band (Fig. 3), while HFNC was maintained for metabolic support. After 72 hours, repeat ultrasonography under HFNC showed improvement, with DTF increasing to 33% and inspiratory thickness to 16 mm (Table 1), accompanied by regression of pectus excavatum and resolution of retractions (Fig. 1B). The treatment was maintained for an additional 72 hours, after which HFNC was discontinued.

On May 28, ultrasound evaluation on room air confirmed sustained ventilatory comfort, with further improvement in thoracoabdominal dynamics and motor milestones. Chest radiography demonstrated

adequate lung expansion (Fig. 2B). The patient was discharged on May 30 with recommendations for home physiotherapy and outpatient follow-up.

Table 1
Mean values of diaphragmatic assessment by ultrasonography at three time points: pre-intervention, 3 days after intervention, and 6 days after intervention.

Date of evaluation	Inspiratory thickness	Expiratory thickness	DTF	Contraction speed	Diaphragmatic mobility
22/05	13,5 mm	11,5 mm	17%	2,2	85 mm
25/05	16 mm	12 mm	33%	2,3	96 mm
28/05	16 mm	12 mm	33%	3,1	134 mm

DISCUSSION

Muscle weakness and atrophy are common in pediatric patients requiring ventilatory support, even for short durations. These changes are largely driven by reduced muscle activation and diminished voluntary postural adjustments against gravity, both of which are essential for maintaining thoracoabdominal synchrony during spontaneous breathing [1, 2, 4]. In mechanically ventilated infants and children, multiple factors contribute to progressive muscle weakness, including reduced chest wall stability due to highly compliant ribs and sternum, the effects of gravity in the supine position, exposure to sedatives, neuromuscular blocking agents and/or corticosteroids, and prolonged immobilization [2, 3]. In the present case, despite the absence of neuromuscular blocking agents, diaphragmatic thinning was documented in real time and interpreted in light of reference values from healthy neonates [10, 11].

Despite its clinical relevance, the temporal progression of muscle weakness in relation to ventilation duration remains poorly characterized, as do the associated structural and functional musculoskeletal changes [2]. Pectus excavatum, the most common chest wall deformity in childhood, has an uncertain etiology but is generally attributed to abnormalities in costal cartilage growth and structure [12, 13]. From a biomechanical perspective, it may represent either a primary or secondary alteration. Importantly, it can be transient and responsive to therapeutic intervention, as observed in this case, underscoring the importance of early rehabilitation strategies [4].

Although a direct association between mechanical ventilation and pectus excavatum has not been established, this deformity may result in clinically relevant functional consequences, including ventilatory restriction and hypoventilation, as observed in this patient. It may also lead to secondary alterations in scapulothoracic and abdominal mechanics, as well as compensatory muscle recruitment patterns during growth, potentially resulting in long-term functional impairment if not addressed early [12, 13].

Diaphragmatic function is most reliably assessed using ultrasonography, which allows relative isolation of diaphragmatic activity from other respiratory muscles and has gained increasing relevance in pediatric practice. The diaphragmatic thickening fraction (DTF) is a key parameter for the objective

assessment of inspiratory muscle activation, helping to distinguish between overload, weakness or atrophy, and normal function [1, 5, 6, 8, 9]. In the present case, although subcostal retractions associated with pectus excavatum might traditionally suggest inspiratory overload, ultrasonography demonstrated diaphragmatic weakness, as indicated by a low DTF (17%). This finding supported a targeted physiotherapeutic strategy focused on muscle strengthening and optimization of respiratory biomechanics, recognizing the diaphragm as the primary driver of ventilation.

The intervention was successful, avoiding the need for reintroduction of positive pressure and promoting rapid recovery of diaphragmatic function. DTF values returned to ranges consistent with ventilatory comfort, accompanied by clear improvement in respiratory pattern. This case highlights the importance of a physiology-based approach to respiratory care in infants following mechanical ventilation. The integration of diaphragmatic ultrasonography into routine clinical practice may facilitate early functional diagnosis, refine clinical reasoning, and support individualized rehabilitation strategies. Although limited by its single-case design, this case suggests that early ultrasound-based assessment of diaphragmatic function may help distinguish true muscle weakness from apparent inspiratory overload, thereby avoiding unnecessary escalation of ventilatory support and enabling targeted rehabilitation strategies.

FINAL CONSIDERATIONS

In this case, diaphragmatic ultrasonography enabled early identification of diaphragmatic muscle weakness and supported a targeted physiotherapy approach focused on muscle strengthening and optimization of respiratory mechanics. Within 72 hours of implementing an individualized rehabilitation strategy, diaphragmatic dysfunction was reversed, with documented improvement in thoracoabdominal dynamics, without the need to reintroduce positive pressure support. This approach was also associated with a shorter hospital stay and may contribute to reduced post-discharge morbidity.

The incorporation of diaphragmatic ultrasonography as a routine bedside tool requires appropriate training and increased awareness of the importance of early mobilization and rehabilitation strategies aimed at ventilator weaning. Further studies are needed to establish reference values and clinically relevant cut-off points for diaphragmatic function across different pediatric age groups, both under mechanical ventilation and during spontaneous breathing..

Abbreviations

IMV: Invasive Mechanical Ventilation; HFNC: High-Flow Nasal Cannula; NIV: Noninvasive Ventilation; DTF: Diaphragmatic Thickening Fraction; MV: Mechanical Ventilation; RSV: Respiratory Syncytial Virus.

Declarations

Ethics approval and consent to participate

Ethical approval for this case report was obtained from the Research Ethics Committee of the D'Or Institute for Education and Research, under opinion number 6.899.306. Free and informed written consent for participation in the study was obtained from the patient's legal guardians.

Consent for publication

Written informed consent for publication of clinical details, ultrasound findings, and associated images was obtained from the patient's legal guardians. A copy of the consent form is available for review by the Editor-in-Chief upon request.

Availability of data and materials

All data generated or analyzed during this study are included in this published article. Additional anonymized data are available from the corresponding author upon reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

da Silva CDA, Valentim M, Borges AF and Silveira DAP contributed to patient care in the pediatric intensive care unit, data collection, and manuscript drafting.

da Silva CDA and Terra, MA contributed to diaphragmatic ultrasound acquisition, interpretation of findings, and physiotherapeutic intervention.

da Silva CDA, Fernandes PV, Moorde DCBC and Gomes Junior SCS supervised the clinical management, contributed to critical revision of the manuscript, and provided intellectual guidance.

All authors read and approved the final manuscript.

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Clinical trial number: not applicable

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Figures



Figure 1A – Breathing pattern showing pectus excavatum and sub/intercostal retractions. Date: May 22



Figure 1B – Respiratory pattern showing improvement in pectus excavatum and absence of retractions. Date: May 25.

Figure 1

Respiratory pattern before and after 3 days of physiotherapy intervention aimed at muscle strengthening.

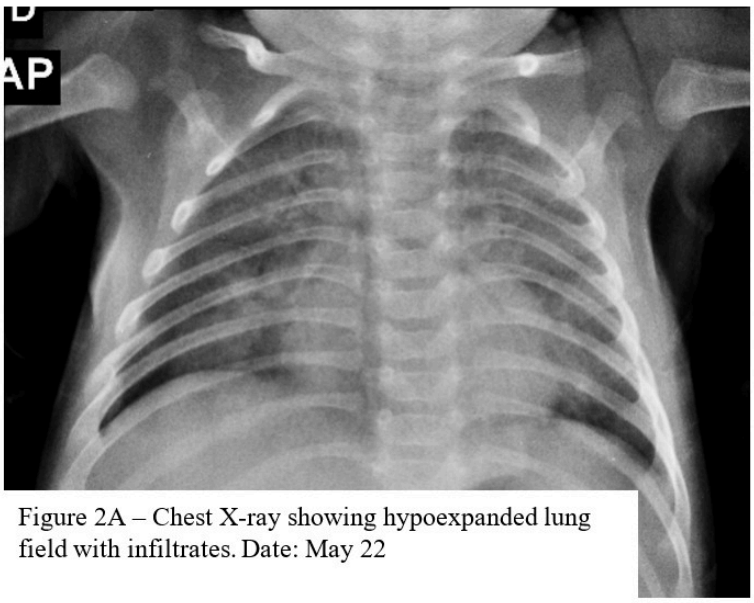


Figure 2A – Chest X-ray showing hypoexpanded lung field with infiltrates. Date: May 22

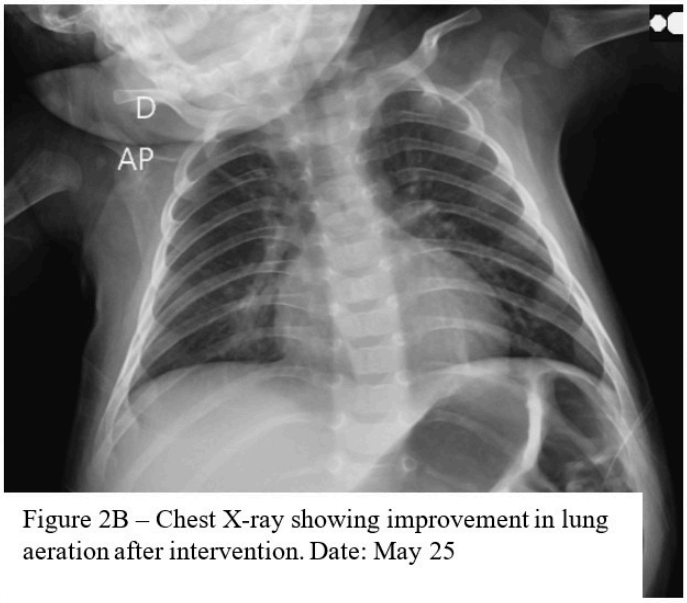


Figure 2B – Chest X-ray showing improvement in lung aeration after intervention. Date: May 25

Figure 2

Chest X-ray before and after the procedure.



Figure 3 – Targeted sensory-motor stimulation. 3A – Thoracoabdominal dynamics showing barrel chest, globular abdomen, and hypotonicity. 3B/C – Use of abdominal support band to improve diaphragmatic mechanics. 3D/E/F – Age-appropriate motor and respiratory strengthening stimuli. The stimuli were performed three times a day, with average periods of 30 minutes, in addition to guidance to caregivers for stimulation between physical therapy sessions.

Figure 3

Motor stimulation aimed at strengthening respiratory muscles and improving axial tone.