Role of point-of-care ultrasound in the management of congenital diaphragmatic palsy

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SUMMARY

In newborns, brachial plexus injury is the most common peripheral nerve injury during the delivery. It may also lead to phrenic nerve injury causing diaphragmatic palsy. Conservative management remains the mainstay of treatment for congenital diaphragmatic palsies. Surgical plication is a potential management strategy for the persistent cases, but the timing and outcomes are not clear. Here, we present a case where diaphragmatic palsy was diagnosed and monitored using point-of-care ultrasound. The surgical intervention was avoided by serial monitoring of diaphragmatic excursion on ultrasound, which revealed improvement despite persistent requirement of respiratory support.

BACKGROUND

Brachial plexus injury is the most common peripheral nerve injury during delivery.[1] Phrenic nerve supplies the diaphragm. Its injury may, therefore, result in congenital diaphragmatic palsy (CDP).[2] This may lead to respiratory distress with persistent and prolonged requirement of respiratory support. Management of such cases includes symptomatic management with appropriate respiratory support and surgical plication in individual cases. Here, we present a case who presented with a history of obstructed labour, requiring resuscitation and persistent requirement of respiratory support.

CASE PRESENTATION

A term male baby with a birth weight of 2.7 kg presented to the emergency at day of life (DOL) 13 with complaints of respiratory distress, decreased right upper limb movement and decreased cry and activity since birth. He was born by vaginal delivery with breech presentation. There was a history of meconium-stained liquor, cephalo-pelvic disproportion and obstructed labour. Baby did not cry after birth and required positive pressure ventilation. Baby developed respiratory distress and was shifted to the neonatal intensive care unit (NICU) and put on continuous positive airway pressure (CPAP). The baby was lethargic with mild hypotonia. He had decreased movements of the right upper limb since birth. At 36 hours of life, in view of worsening respiratory distress, the baby was intubated and started on invasive ventilation. Epinephrine infusion was started in view of poor perfusion. Baby had cyclical movements of upper and lower limbs for which phenobarbitone and levetiracetam were sequentially added. Gradually, baby improved, inotropes weaned and stopped within the next 3 days. Feeds were gradually increased, and full feeds were attained by DOL 5. Baby was extubated after 7 days to CPAP. In view of positive septic screen (platelet count of 96×10^9/L, total leucocyte count of 23900/cumm), lumbar puncture was done, and cerebrospinal fluid (CSF) culture grew coagulase negative Staphylococci. MRI brain done was suggestive of hypoxic ischaemic encephalopathy (HIE) changes.

In view of the persistent requirement for respiratory support, the baby was referred to our hospital at DOL 13. At presentation, Downe's score was 3/10. Heated humidified high flow nasal cannula (HHHFNC) was started. Chest X-Ray (CXR) revealed bilateral clear lung fields and right diaphragm at a higher position (figure 1a). The baby had decreased right upper limb movements with no evidence of fracture and no gross deformity at the time of presentation. In view of obstructed labour, decreased movements of right upper limb and higher position of the right dome of the diaphragm on CXR—brachial plexus injury associated with right phrenic nerve injury causing right diaphragmatic palsy was suspected. Point of care ultrasound (POCUS) lung with the curvilinear probe of frequency 3–8 MHz at subxiphoid space directed upwards (figure 2) showed decreased movement of right hemi-diaphragm, compared with left hemi-diaphragm. M-mode ultrasonography showed decreased right-sided diaphragmatic excursion of 0.10 cm, compared with left side of 0.58 cm, which was suggestive of right hemi-diaphragm palsy (figure 3). Early intervention suspecting HIE and brachial plexus injury was started at the third week of life. Baby had repeated episodes of seizures, which required reloading with levetiracetam. Limb physiotherapy was continued for brachial plexus injury. Gradually, the activity of the baby improved. Slight improvement in the upper limb activity was observed at DOL 31. Baby had a

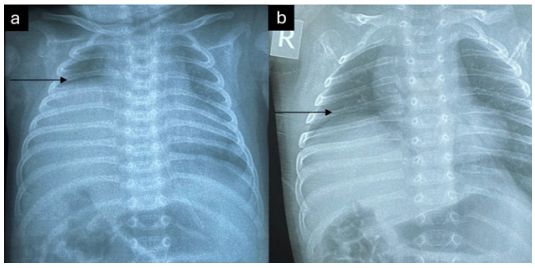

Figure 1 (a) Chest X-ray at admission showing right diaphragm at higher position. (b) Chest X-ray at discharge.

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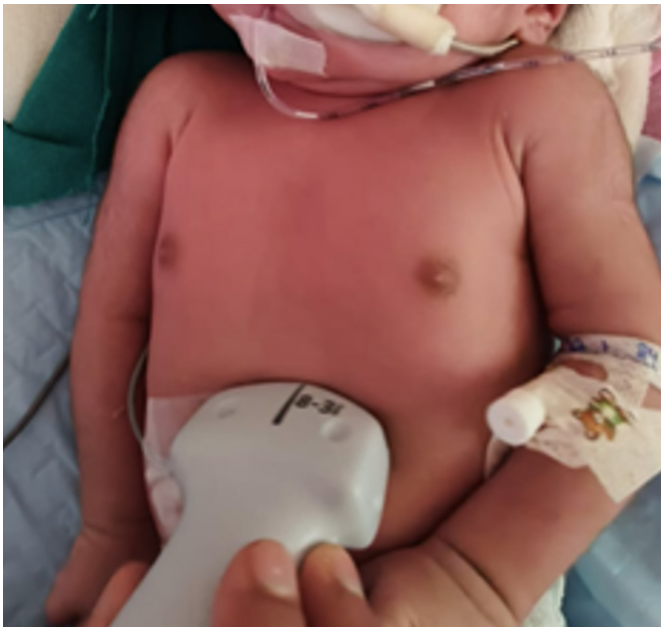

Figure 2 Probe position during POCUS for the assessment of diaphragmatic palsy.

persistent requirement for respiratory support (HHHFNC). Repeat POCUS lung was done to assess the diaphragmatic excursions. Ultrasound lung also suggested collapse/consolidation, for which oral azithromycin was added and nebulisation along with chest physiotherapy started. In view of the requirement for persistent respiratory support, diaphragmatic plication was planned. But repeat POCUS lung on DOL 45 showed improving right diaphragmatic movement with excursions of 0.15 cm on M- mode (figure 4a), hence surgery was withheld. Baby was monitored with serial POCUS to monitor the improving right hemi-diaphragmatic excursions. Gradually, respiratory distress improved. At DOL 58, a room air trial was given, which the baby tolerated well. Baby got discharged at DOL 71. At the time of discharge, upper limb movement against gravity was attained. CXR showed right hemi-diaphragm at lower position as compared with that at admission (figure 1b). POCUS at discharge showed improved right hemi-diaphragmatic excursions of 0.35 cm (table 1) (figure 4b).

TREATMENT

Supportive management with respiratory support (HHHFNC) and chest physiotherapy was given for the respiratory distress.

OUTCOME AND FOLLOW-UP

Patient was regularly followed up in out-patient department. At 6 months, the baby had attained normal movements of the right upper limb. There was no respiratory distress. POCUS lung done was suggestive of normal diaphragmatic excursion (0.96 cm) (figure 5). However, the baby had developmental delay in all the domains.

DISCUSSION

The incidence of birth injuries has decreased steadily over time, yet they constitute a significant health burden in resource-limited settings. They range from minor skin and soft injuries to long bone fractures, bleeds like cephalohaematoma, sub-galeal haematoma, intracranial haemorrhage and nerve injuries. Peripheral nerve injuries are commonly seen in newborns, out of which brachial nerve injuries are most common.[3] The global incidence of newborn brachial plexus palsy is reported to be between 1–4 cases per 1000 live births, with rates varying depending on study setting and availability of foetal and maternal care.[4] Less common nerve injury includes phrenic nerve injury, which is usually associated with brachial plexus injury and can lead to diaphragmatic palsy. Other common cause of neonatal phrenic nerve injury is iatrogenic due to cardiorespiratory surgery or intercostal catheter placement.[5]

In infancy, normal diaphragmatic function is essential for adequate ventilation due to the underdeveloped intercostal muscles.[6] As a result, diaphragmatic paralysis is poorly tolerated in infants and children, making them highly vulnerable to atelectasis, pneumonia and respiratory failure, even in cases of unilateral paralysis. Due to its varied and often nonspecific presentation, diaphragmatic paralysis is frequently underdiagnosed. Clinical signs that may raise suspicion include difficulty weaning from respiratory support, a persistently elevated hemidiaphragm on chest radiographs, unexplained respiratory distress or recurrent pneumonia/unilateral lung collapse.[7] Early diagnosis is crucial, as prolonged respiratory support may be necessary in such cases.

Management of these patients has not been standardised. Diaphragmatic plication is a potential treatment modality for patients with diaphragmatic palsy, but its timing and outcomes are not clear.[2] This procedure flattens the diaphragm, preventing excessive cephalad movement during inspiration, thereby enhancing tidal volume and reducing work of breathing. Studies have shown that plication significantly improves pulmonary mechanics, decreases oxygen and ventilator dependency, and shortens NICU stay in affected neonates. However, the benefits of surgery and subsequent improvement should be weighed against the perioperative morbidity, and the fact that in most of the cases, distress improves with time.[8] Controversy in the

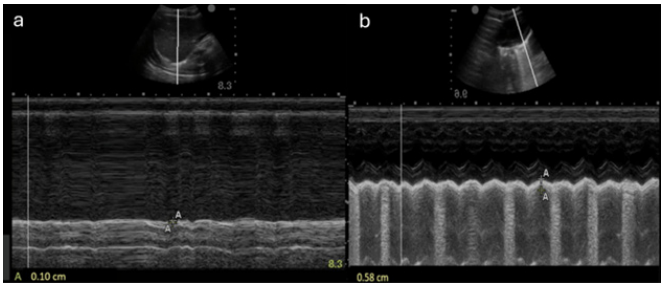

Figure 3 POCUS lung at admission. (a) Right hemi-diaphragmatic palsy characterised by decreased diaphragmatic excursion: 0.10 cm. (b) Left hemi-diaphragm with normal diaphragmatic excursion: 0.58 cm

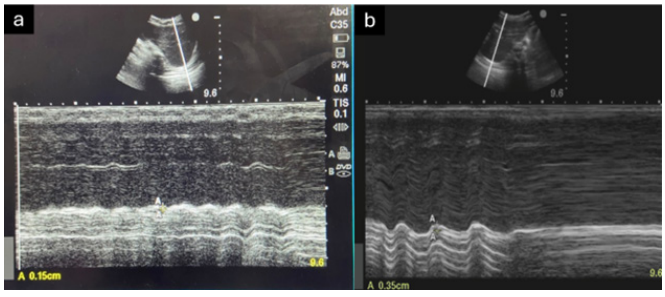

Figure 4 (a) Follow-up POCUS lung at day of life 45. Right hemi-diaphragmatic excursions of 0.15 cm. (b) At day of life 71 (at discharge),right hemi-diaphragmatic excursions of 0.35.

Table 1 Serial monitoring of diaphragmatic excursion on right side in M mode (lung POCUS)

Age	Right-sided diaphragmatic excursion
DOL 13	0.10 cm
DOL 45	0.15 cm
DOL 71	0.35 cm
6 months	0.96 cm

DOL, Day of Life; POCUS, Point of Care Ultrasound.

timing of the plication results from the fact that early plication can improve lung expansion and reduce ventilator dependency in cases where the time for spontaneous recovery is not certain.[8–10] Different authors have suggested different time periods when surgical intervention should be performed. Broadly, it has been classified as early (< 30 days) or late (> 30 days) plications.[2] In a case report by Reiter *et al*, thoracoscopic right diaphragm plication was done at DOL 33 in a case of diaphragmatic palsy in view of requirement of high-flow nasal cannula and not being able to wean over multiple weeks. Following which baby could be weaned to room air within 48 hours.[8] In a large case series of diaphragmatic palsy by De Vries *et al*, 12 out of 13 cases of plication were performed after 30 days of life. The authors advocated observation for the first 30 DOL to ensure no spontaneous recovery.[11] In other case reports and case series, authors have done plication before 30 DOL with good results.[12–14]

This variation in timing shows the need for a modality which can predict or monitor the resolution in cases of diaphragmatic palsy, which may prevent unnecessary operative intervention and associated morbidities. This case highlights the emerging role of POCUS lung for this very purpose. Ultrasonography offers several advantages over other imaging modalities (such as fluoroscopy), including no risk of radiation exposure, ease of use and the ability to perform bedside, especially in critically ill patients in intensive care units (ICU).[15] It allows both morphological and dynamic study of each hemi-diaphragm. It has also been utilised to measure diaphragmatic excursion and thickness, particularly before extubation, to help predict extubation success in both adults and neonates.[16 17] B-mode and M-mode have proven valuable in evaluating diaphragmatic function.[18]

M-mode sonography records successive positions of a structure over time, enabling the quantification of both

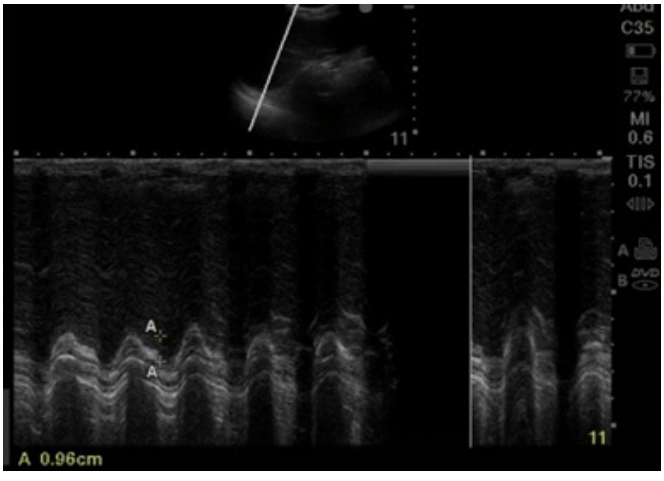

Figure 5 Normal diaphragmatic excursion on follow-up at 6 months age.

normal and abnormal diaphragmatic motion.[19] M-mode ultrasonography evaluates two key parameters: motion direction and excursion amplitude. Normal diaphragmatic motion occurs when the diaphragm moves toward the transducer during inspiration, with an excursion greater than 4 mm. Additionally, the difference in excursion between the two hemi-diaphragms should be less than 50%.[20] Decreased excursion is indicated when the amplitude is less than 4 mm or if the difference in amplitude between the hemi-diaphragms exceeds 50%. In our case, the right-side diaphragmatic excursion was only 1 mm initially, and the difference between the two sides was more than 80%. Absent motion is identified when the tracing appears as a flat line, while paradoxical motion occurs when the diaphragm moves away from the transducer during inspiration. Diaphragmatic paralysis is characterised by reduced, absent, or paradoxical diaphragmatic motion.[20] In neonates with high respiratory rates, evaluating the direction of diaphragmatic motion can be challenging. However, with skilled technique and adequate experience, it is often possible to determine the motion pattern on the affected side and compare it with the normal side. In our case, diaphragmatic excursions were diminished but not paradoxical. M-mode quantification is a more objective method, providing valuable insights for monitoring the progression or improvement of diaphragmatic function. Respiratory support may also alter the diaphragmatic motion direction and excursion amplitude.[21] Though the difference between the two sides will remain unaltered. When the baby is on positive pressure ventilation support, with no spontaneous breathing, the affected side may also appear normal. In our case, the baby was on HHHFNC and was spontaneously breathing. Minimal continuous pressure exerted through the HHHFNC should not change the excursion amplitude.

Many cases have been published showing the role of POCUS as a diagnostic modality for diaphragmatic palsy. Case report by Sehgal *et al*[22] was published in which ultrasound scan of the chest of newborn admitted with left-sided Erb's palsy was performed with the infant in the supine position, which noted no significant supra or infra diaphragmatic pathology. Movement of the left diaphragm was absent, with dampened amplitude on M-mode trace, whereas there was normal right-sided craniocaudal diaphragmatic excursion with normal M-mode. Over the subsequent weeks, the infant continued gradual weaning off respiratory support and no surgical intervention was needed. Zeng *et al*[23] published a case report in which a newborn having tachypnoea initially diagnosed with pneumonia but continued to exhibit tachypnea despite receiving appropriate antibiotic treatment. Chest radiography showed elevation of the right diaphragm. M-mode ultrasonography revealed reduced movement of the right diaphragm, leading to a diagnosis of diaphragmatic paralysis. After 4 weeks, the tachypnoea improved. A follow-up M-mode ultrasonography demonstrated a smaller difference in the movement of the bilateral diaphragms compared with the previous assessment.

To the best of our knowledge, ours is the first case report highlighting the potential use of POCUS in guiding the management of diaphragmatic palsy. With the progressive improvement in the diaphragmatic excursions on the M-mode, we could initially delay and ultimately avoid the surgical intervention and save the baby from the perioperative morbidities. It reinforces the role of POCUS as a

valuable, non-invasive tool in clinical decision-making for diaphragmatic dysfunction in neonates.

Learning points

- Diaphragmatic palsy should be suspected in cases of brachial plexus injury having respiratory distress.
- M-mode sonography (POCUS) can be used to diagnose and monitor progress in cases of diaphragmatic palsy.
- Surgical plication can be delayed or avoided in cases of improving diaphragmatic excursions in POCUS.
- Physiotherapy is the cornerstone of management in such cases.

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Case reports provide a valuable learning resource for the scientific community and can indicate areas of interest for future research. They should not be used in isolation to guide treatment choices or public health policy.

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