

Bedside sonographic evaluation of the diaphragm in ventilator dependent patients with Amyotrophic Lateral Sclerosis. A report of two cases

Shrestha GS^{1,2}

Department of Anaesthesiology, ¹Tribhuvan University Teaching Hospital, Institute of Medicine, Kathmandu, Nepal, ²Alka Hospital Pvt. Ltd., Jawalakhel, Lalitpur, Nepal

Corresponding author: Dr. Gentle Sunder Shrestha, MBBS, MD Anaesthesiology, Fellow in Adult Critical Care, Lecturer, Department of Anaesthesiology, Institute Of Medicine, Tribhuvan University Teaching Hospital, Maharajgunj, Kathmandu, Nepal; e-mail: gentlesunder@hotmail.com

ABSTRACT

Amyotrophic lateral sclerosis (ALS) is a neurodegenerative disease with progressive and inexorable loss of bulbar and limb functions. Respiratory muscle weakness and failure is a common complication late in the course of disease. Bedside ultrasonography of the diaphragm was done in two ventilator dependent patients with ALS. Thickness of the diaphragm was markedly reduced during both end expiration and end of deep inspiration. The degree of diaphragmatic thickening was also significantly reduced. The diaphragmatic excursion during deep inspiration was sub-optimal. The findings were consistent with diaphragmatic atrophy and paralysis. Sonography of the diaphragm can be a useful non-invasive bedside tool for the diagnosis and follow up of diaphragmatic involvement in patients with amyotrophic lateral sclerosis.

Keywords: Amyotrophic lateral sclerosis, diaphragmatic paralysis, ultrasonography, ventilator dependent.

Amyotrophic lateral sclerosis (ALS) is the most common form of progressive motor neuron disease.¹ The clinical course is inexorably progressive and over 60% of patients die within three years of presentation. Respiratory muscle weakness and failure is an important cause of morbidity and mortality in these patients.² Ultrasonography of the diaphragm can help in prompt identification and follow up of patients with diaphragmatic dysfunction and paralysis.³ Here, I report bedside sonography of the diaphragm of two ventilator dependent patient with ALS, which revealed diaphragmatic atrophy and paralysis.

FIRST CASE

A 51 years old male patient presented with the history of gradually progressive weakness of the extremities for five months duration. It started in bilateral lower limbs, which was followed by the weakness of upper extremities for two months duration. Later in the course of disease, he had involvement of respiratory muscles manifested as progressive shortness of breath, to the point that he required mechanical ventilatory support. All four extremities were flaccid with preserved deep tendon reflexes. There was marked atrophy of thenar and hypothenar muscles. There was no bowel and bladder involvement. Gag reflex was absent. A panel of investigations was done including antinuclear antibody, serum ceruloplasmin level, serum protein electrophoresis, MRI of brain and cervical spine, nerve conduction study, needle electromyography, muscle

biopsy and nerve biopsy. The reports were suggestive of ALS. He was tracheostomized following prolonged mechanical ventilation. He was started on tablet Riluzole 50 mg twice daily. Attempts to wean from mechanical ventilation were unsuccessful and the patient remained ventilator dependent.

Bedside ultrasonography of the diaphragm was done as described by Sarwal A et al,⁴ using curvilinear transducer C60X (frequency range of 5 to 2 MHz) and linear array transducer HFL38X (frequency range of 6 to 13 MHz) (MicroMaxx®; SonoSite, USA). Patient was placed in supine position with the tracheostomy tube attached to T-piece with oxygen supplementation at 8 litres per minute. Thickness of the diaphragm was assessed at the zone of apposition by placing the linear array transducer at the anterior axillary line to obtain an intercostal view. The transducer was positioned to obtain a sagittal image of the diaphragm between eighth and ninth ribs in both sides. Two dimensional B-mode ultrasonography was used to measure the diaphragm thickness at end expiration (at functional residual capacity) and at end of deep inspiration (at total lung capacity).

In the right side, the thickness measured at end expiration was 0.11 cm (Fig. 1) and was 0.12cm (Fig. 2) at the end of deep inspiration. In the left side, it was 0.16 cm (Fig. 3) at end expiration and 0.18 cm (Fig. 4) at the end of deep inspiration. The degree of diaphragmatic thickening was measured using the formula: (thickness at end inspiration – thickness at end expiration) / thickness at

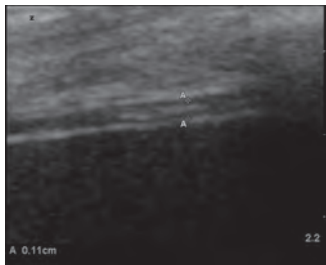


Fig. 1. End expiratory diaphragmatic thickness in right side (0.11 cm) at functional residual capacity.

end expiration. It was 9.09% in the right side and 12.50% in the left side. Diaphragmatic excursion was measured by placing the micro-convex transducer between the midclavicular and anterior axillary lines in the anterior subcostal region. The transducer was directed medially, cranially and dorsally. Right hemidiaphragm was visualized through hepatic window and left hemidiaphragm through splenic window. B-mode was used to visualize the diaphragm and then the imaging was changed to M-mode to measure the excursion during deep breathing (from end expiration to end of deep inspiration). It was 0.71 cm in right (Fig. 5) and 0.60 cm in left (Fig. 6).

SECOND CASE

A 60 years old gentleman, a military veteran, with no significant past medical history, presented with shortness of breath of two to three months duration. It was insidious in onset and gradually progressive. He



Fig. 3. End expiratory diaphragmatic thickness in left side (0.16 cm) at functional residual capacity

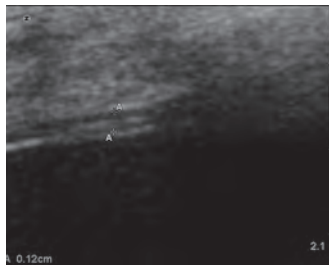


Fig. 2. End inspiratory diaphragmatic thickness in right side (0.12 cm) at total lung capacity.

also had generalized weakness of one to two months duration, involving all four limbs. Shortness of breath progressed to the point that he required endotracheal intubation to support oxygenation and ventilation. He had spastic extremities with muscle wasting and visible fasciculations. Sensory examination was normal. He had no involvement of extraocular muscles and never had diplopia or ptosis. Sphincter function and mentation was intact. He had a panel of investigations to reach the diagnosis. Complete blood count and electrolytes were normal. Calcium and phosphate levels were normal. Cerebrospinal fluid analysis was within normal limits. Erythrocyte sedimentation rate was normal. Thyroid function test and serum electrophoresis was normal. Acetylcholine receptor antibody in serum was negative. Creatine kinase level was within normal limit and deltoid muscle biopsy was negative for myopathy. Electromyography was suggestive of ALS. MRI of head and neck was normal. He continued to have gradual,

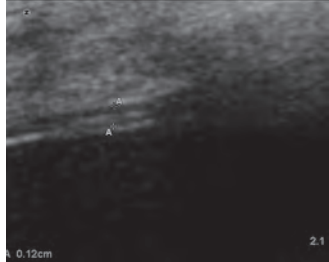


Fig. 4. End inspiratory diaphragmatic thickness in left side (0.18 cm) at total lung capacity.

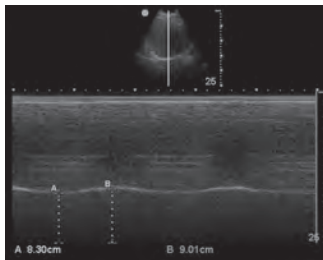


Fig. 5. Diaphragmatic excursion in right side (9.01 cm – 8.30 cm = 0.71 cm) during deep respiration.

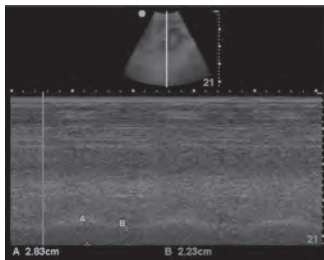


Fig. 6. Diaphragmatic excursion in left side (2.83 cm – 2.23 cm = 0.60 cm) during deep respiration.

but progressive worsening of muscle strength and attempts at weaning from mechanical ventilation were unsuccessful. He underwent tracheostomy after two weeks of intubation. He was started on tablet Riluzole 100 mg daily. He continued to be ventilator dependent. Noninvasive positive pressure ventilation was attempted, but was unsuccessful.

Beside ultrasonography of the diaphragm was performed as described in the first case. In the right side, the diaphragmatic thickness at end expiration was 0.12 cm and at end of deep inspiration was 0.14 cm. In the left side, the thickness at end expiration was 0.11 cm and was 0.13 cm at the end of deep inspiration. The degree of diaphragmatic thickening was 16.67% in right and 18.18% in left side. Diaphragmatic excursion was 0.34 cm in right side. The hemidiaphragm could not be visualized in left side due to poor sonographic window.

DISCUSSION

Patients with ALS present with progressive neurological deterioration involving the corticospinal tract, brainstem and anterior horn cells of the spinal cord.⁵ It is more common in men than in women, with the peak incidence between 50 to 75 years of age. The incidence being 2-3 people per 100,000 of the general population.² Majority of the patients present with limb symptoms. Respiratory onset disease, presenting with failure of respiratory muscle function, as in the second case, is seen in only 5% of patients with amyotrophic lateral sclerosis.^{6,7} Majority of the patients with ALS die from respiratory failure and the presence of respiratory muscle weakness is an independent predictor of quality of life.² Diaphragmatic dysfunction is common in patients with ALS.⁸

The diaphragm is the major respiratory muscle.

Ultrasonography is a non-invasive and portable method for assessing the diaphragm.⁴ Ultrasound has been shown to be similar in accuracy to most other imaging modalities for diaphragm assessment.^{9,10} Ultrasound measurement of thickness of the diaphragm and diaphragmatic thickening during inspiration was found to be helpful in diagnosing diaphragmatic paralysis¹¹ and to assess for potential functional recovery from diaphragmatic weakness or paralysis.¹² Average thickness of the diaphragm is 0.22 – 0.28 cm in healthy volunteers¹³ and 0.13 – 0.19 cm in paralyzed diaphragm. The thickness of less than 0.2 cm, measured at the end of expiration has been proposed as the cutoff to define diaphragm atrophy.⁴ In both patients, the thickness was below the cutoff value. In the first case it was 0.11 cm in right and 0.16 cm in left. In the second case it was 0.12 cm in right and 0.11 cm in left. Diaphragmatic thickening of less than 20% has been proposed to be consistent with diaphragmatic paralysis.¹² In the first case it was 9.09% in right and 12.50% in left. In the second case, it was 16.67% in right and 18.18% in left. The findings are similar to those reported in a case series of patients with ALS reported by Yoshioka *et al.*¹⁴

The normal range of diaphragmatic motion during deep breathing in adults is 1.9 – 9.0 cm.⁴ Diaphragmatic paralysis is indicated by the absence of excursion or paradoxical motion on sniffing and diaphragmatic weakness is indicated by less than normal amplitude of excursion. Excursion of more than 2.5 cm has been proposed as a cutoff for excluding severe diaphragmatic dysfunction.¹⁵ In the first case, it was 0.71 cm in right and 0.60 cm in left. In the second case, the excursion was only 0.34 cm in right side.

The patients discussed in this case report had atrophied and severely dysfunctional or paralyzed diaphragm.

Ultrasonographic findings correlate well with the clinical scenario of failure to wean from mechanical ventilation and prolonged ventilator dependence. Only a few studies have evaluated the role of ultrasonography in assessing diaphragmatic function in patients with ALS. Early identification of diaphragmatic involvement in ALS is crucial, since early application of non-invasive positive pressure ventilation improves the quality of life¹⁶ and prolongs survival.¹⁷ Bedside ultrasonography can be a valuable tool for the diagnosis and followup of diaphragmatic dysfunction, atrophy and paralysis in patients with ALS and other motor neuron diseases.

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