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Sonographic evaluation of the diaphragm in patients with unilateral diaphragmatic paralysis

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Evaluation of diaphragm function is challenging because no single test has a high diagnostic yield. We describe ultrasound findings in three cases with acquired unilateral diaphragmatic elevation. These cases confirm that sonographic evaluation is a valid tool for identifying diaphragm dysfunction. In addition, ultrasound measurements of diaphragm thickness and the contractility can be used to determine if a diaphragm is paralyzed and suggest the duration of paralysis (i.e., acute or chronic).

Key words: Ultrasonography; Diaphragm; Paralysis

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Diagnosing unilateral diaphragm dysfunction is challenging because the clinical manifestations are subtle and no single test has a high diagnostic yield. Tests such as chest radiographs, fluoroscopy, phrenic nerve conduction studies (NCSs), needle electromyography of the diaphragm, and pulmonary function tests are available, but some are insensitive, uncomfortable, or invasive. Ultrasonography is a noninvasive technique that has proved to be an accurate, safe, easy-to-use, bedside modality that overcomes many of the limitations of other diagnostic techniques for diaphragm evaluation. We evaluated three patients with acquired unilateral diaphragmatic elevation with ultrasound and describe the ultrasound findings.

CASE

Three patients were referred for evaluations of suspected diaphragmatic paralysis because unilateral diaphragm elevation was noted in chest X-rays. The left hemidiaphragm is higher than the right suggests left diaphragm palsy and the right is higher than the left by more than 3 cm suggests right diaphragm palsy. Because the patients had had serial

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X-ray studies done in our hospital, the time of onset could be determined as sometime between the last normal chest X-ray and the first with unilateral diaphragmatic elevation. To evaluate diaphragm function, we performed phrenic NCS and diaphragm ultrasound. High-resolution ultrasound scans were obtained using a Philips iU22 scanner (Philips Medical Systems; Bothell, WA, USA) with a 12 MHz linear array transducer, as previously described.[1] The diaphragm thickness was measured at resting end expiration and at maximal inspiration (Fig. 1). Then the diaphragm thickening fraction (DTF) was calculated as a percentage using the formula DTF = (thickness at maximal inspiration – thickness at resting end expiration) / thickness at resting end expiration. Table 1 summarizes the NCS and ultrasound findings of the three patients.

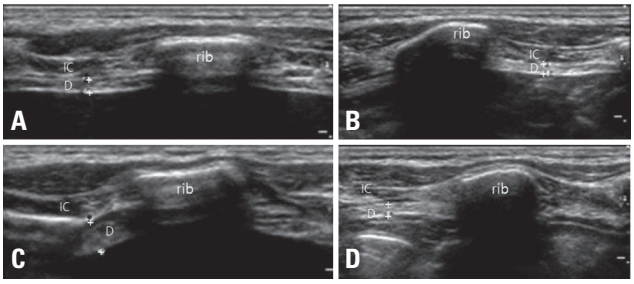

Fig. 1. Ultrasound of the right (A and C) and left (B and D) diaphragm of patient 2. The distance between the two markings (+) is the diaphragm thickness. (A, B) At the end of quiet expiration, the diaphragm is seen as a hypoechoic structure between two layers of hyperechoic fascia. (C) At maximal inspiration, the right diaphragm is seen 'peeling away' from the chest wall and thickens markedly. (D) At maximal inspiration, the left diaphragm slightly thickens. D, diaphragm; IC, intercostal muscle.

Patient 1 was a 58-year-old man with an approximately 10-year history of left diaphragm elevation. His medical history was unremarkable, except for well-controlled hypertension. He was a social drinker and an ex-smoker. He did not complain of any respiratory symptoms. Phrenic NCS showed abnormal results bilaterally. According to ultrasound analyses, the thickness of the left diaphragm was 56% that of the right side (normal limit, > 62%) and the DTF on the left side was also abnormally low. Chest computed tomography (CT) and laboratory tests were performed to assess the etiology of the diaphragm dysfunction and the results were unremarkable.

Table 1. Clinical characteristics, NCS findings, and ultrasound findings of the three patients

	Patient 1		Patient 2		Patient 3	
Age	58		71		58	
Sex	Male		Male		Female	
Symptom	None		None		None	
Duration	About 10 years		1-4 months		2-10 months	
Chest X-ray						
Elevation side	Left		Left		Right	
Diaphragm ultrasound	Right	Left	Right	Left	Right	Left
Resting thickness (cm)	0.328	0.183	0.203	0.157	0.171	0.184
Side-to-side ratio[a]		**0.56**[d]		0.77		0.93
Maximal thickness (cm)	0.427	0.19	0.58	0.177	0.178	0.57
DTF[b] (%)	30	**4**[d]	186	**13**[d]	**4**[d]	210
NCS[c]	Right	Left	Right	Left	Right	Left
Latency (ms)	**12.6**[d]	**11.7**[d]	8.6	**14.2**[d]	**8.65**[d]	6.98
CMAP amplitude (mV)	**0.1**[d]	**0.1**[d]	**0.1**[d]	**0.1**[d]	0.4	1.2

DTF, diaphragm thickening fraction; NCS, nerve conduction study; CAMP, compound muscle action potential.

[a]Side-to-side ratio is a thickness ratio defined as the resting thickness of the side with the thinner expressed as a ratio of the larger, contralateral thickness (normal limit, > 0.62).

[b]The lower normal limit of DTF was 28% for right side and 17% for left side.

[c]The lower normal limit for latency is 8.62 ms, for amplitude it is 0.2 mV.

[d]Abnormal values are highlighted in bold.

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Patient 2 was a 76-year-old man with a 1- to 4-month history of left diaphragm elevation. He complained of respiratory difficulty while swimming. He had hypertension that was controlled well with medication. He was a non-smoker and a social drinker. Around the onset of diaphragm elevation, he was diagnosed with left optic neuritis and treated with oral steroids. However, brain and spine magnetic resonance imaging did not show any other abnormalities. Phrenic NCS showed delayed latency on the affected side, but the compound muscle action potential (CMAP) amplitude was abnormal bilaterally. In ultrasound analyses, the resting thickness of the diaphragm was normal bilaterally, but DTF was abnormal on the affected side. Chest CT showed a small thymoma (2.3 × 2.1 cm) in the anterior mediastinum that had persisted for several years without enlargement.

Patient 3 was a 58-year-old woman with a 2- to 10-month history of right diaphragm elevation. Her medical and social histories were unremarkable, except for hepatitis B. She did not complain of any respiratory symptoms. Phrenic NCS showed low CMAP amplitude on the affected side. In ultrasound analyses, the resting thickness of the diaphragm was normal bilaterally, but the DTF was abnormal on the affected side. Chest CT and laboratory tests were performed to assess the etiology of the diaphragm dysfunction and the results were unremarkable.

DISCUSSION

Phrenic NCS is commonly used for diaphragm evaluation and shows good sensitivity. However, it is nonspecific, technically challenging, mildly invasive, and shows large individual differences. The morphology of the CMAP is affected by the phase of respiration and can be difficult to determine in obese individuals.[2] Evaluation of the diaphragm with ultrasound imaging can provide useful information in addition to traditional techniques. Previously, we determined the normal reference values for diaphragm thickness and DTF in 80 healthy Koreans.[3] In that study, diaphragm atrophy was considered if the resting thickness was less than 0.11 cm or the side-to-side thickness ratio was less than 0.62. The lower normal limit of DTF was 28% for the right side and l7% for the left. Diaphragm thickness is significantly affected by demographic factors including sex, weight, height, and body mass index, and the normal limits for diaphragm thickness have varied across studies.[4-6] The normal limit of DTF is affected less by demographic factors and has shown similar results in several studies; a diaphragm thickening of < 20% is consistent with paralysis.[5,7]

In patient 1, who had had diaphragm paralysis for several years, ultrasound showed a reduced DTF with diaphragm atrophy present of the affected side. In patients 2 and 3, who had diaphragm paralysis for several months, ultrasound showed a reduced DTF without significant atrophy. Chronically paralyzed diaphragms are thin and do not thicken during inspiration. Therefore, in such cases, both parameters (i.e., thickness and thickening ratio) are useful. However, the thickness alone can be normal in an acutely paralyzed diaphragm. To identify acute diaphragm paralysis, the degree of diaphragm thickening is thought to be more sensitive than the thickness.

In summary, sonographic evaluation is a valid tool for identifying diaphragm dysfunction. Ultrasound measurements of diaphragm thickness and the DTF can be used to determine if a diaphragm is paralyzed and suggest the duration of paralysis (i.e., acute or chronic).

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