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CLINICAL CASE REPORT

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Bilateral Diaphragmatic Paralysis in a Patient With Critical Illness Polyneuropathy

A Case Report

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Abstract: Bilateral diaphragmatic paralysis (BDP) manifests as respiratory muscle weakness, and its association with critical illness polyneuropathy (CIP) was rarely reported. Here, we present a patient with BDP related to CIP, who successfully avoided tracheostomy after diagnosis and management.

A 71-year-old male presented with acute respiratory failure after sepsis adequately treated. Repeated intubation occurred because of carbon dioxide retention after each extubation. After eliminating possible factors, septic shock-induced respiratory muscle weakness was suspected. Physical examination, a nerve conduction study, and chest ultrasound confirmed our impression.

Pulmonary rehabilitation and reconditioning exercises were arranged, and the patient was discharged with a diagnosis of BDP.

The diagnosis of BDP is usually delayed, and there are only sporadic reports on its association with polyneuropathy, especially in patients with preserved limb muscle function. Therefore, when physicians encounter patients that are difficult to wean from mechanical ventilation, CIP associated with BDP should be considered in the differential diagnosis.

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Abbreviations: BDP = bilateral diaphragmatic paralysis, BiPAP = bilevel positive airway pressure, CIP = critical illness polyneuropathy, CMAP = compound muscle action potential, EPAP = expiratory positive airway pressure, IPAP = inspiratory positive airway pressure, MIP = maximal inspiratory pressure.

INTRODUCTION

Bilateral diaphragmatic paralysis (BDP) manifests as respiratory muscle weakness, and prompt evaluation and management are important. However, in some cases, the diaphragm is the initial or the only muscle involved. It can be myopathic or neuropathic in origin, although some cases are considered idiopathic, occurring in association with the following conditions: spinal cord injury,[1] motor neuron disease,[2,3] infectious diseases such as herpes zoster,[4] human immunodeficiency virus infection, pneumonia, noninfectious polyneuropathy,[5] cardiac surgery,[6,7] lung transplantation,[6,8] postsurgical neuralgic amyotrophy,[9] mediastinal tumors,[10] neurosarcoidosis,[11] chronic inflammatory demyelinating polyradiculoneuropathy,[12] peripheral neuropathy,[12] multiple sclerosis,[13] anterior horn cell disease,[14] Charcot–Marie–Tooth syndrome,[15–17] POEMS syndrome (polyneuropathy, organomegaly, endocrinopathy, M-protein spike, and skin changes),[18,19] and critical illness polyneuropathy (CIP).[20]

The symptoms of diaphragmatic paralysis depend on whether it is unilateral or bilateral, how rapidly it develops, and the presence of underlying pulmonary disease.[21] Patients with unilateral diaphragmatic paralysis are usually asymptomatic and may spontaneously recover with compensatory mechanisms, especially if there is no underlying pulmonary or neurological disease.[22] In contrast, BDP usually goes unrecognized, especially in patients who are ventilator dependent, until cor pulmonale or cardiorespiratory failure presents with it. Therefore, the early diagnosis of BDP is clinically challenging and requires a thorough understanding of medical history, laboratory data, and clinical experience.

Patients with BDP usually present with a restrictive pulmonary disorder, and have marked reduction in functional residual capacity and residual volume because of decreased lung compliance secondary to atelectasis. Vital capacity falls by approximately 50% with abdominal paradoxical breathing patterns.[23] Here, we report a case of BDP resulting from CIP secondary to sepsis.

PATIENT INFORMATION

The case report was not reviewed by an institutional review board because a case report does not meet the definition of ''research'' in Chang Gung Medical Foundation Institutional Review Board. Written informed consent was obtained from the patient for publication of this case report.

A 71-year-old male who presented with fever and respiratory distress was admitted. The patient had been receiving a 10-day antibiotics for acute calculous cholecystitis. On admission, he was found to have respiratory failure, sepsis, and hypovolemic shock. He was intubated and placed on mechanical ventilatory support (inspiratory positive airway pressure/expiratory positive airway pressure [IPAP/EPAP]: 20/10 cm H_2O]. He was a smoker for 20 years, but at the time of admission, he had not smoked for >10 years. Past medical history included hypertension that was controlled by medication for 10 years, chronic renal insufficiency, immunoglobulin A

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nephropathy, gouty arthritis, osteoarthritis of both knees, and benign prostatic hypertrophy. Five weeks before the present admission, the patient underwent percutaneous transluminal coronary angioplasty and stent placement for triple vessel coronary heart disease.

CLINICAL FINDINGS

On physical examination, there were diminished breath sounds at both lung bases with contraction of accessory muscles. On neurological examination, the patient was able to freely move all 4 limbs in bed. However, weakness of the right deltoid muscles, bilateral elbow extensors, and hip flexors as well as bilateral atrophy of the hypothenar, adductor pollicis, and first interosseous muscles were noted. Bilateral biceps, brachiradialis, and patellar deep tendon reflexes were reduced.

Diagnostic Assessment

A chest radiograph revealed no definite lung lesions. Bilateral diaphragmatic elevation was noted during deep inspiration (Figure 1). Initial arterial blood gas values were as follows: pH 7.305, $PaCO_2$ 101.2 mm Hg, PaO_2 87.6 mm Hg, HCO_3 49.2 mm/L, and O_2 saturation 95.1% on room air. Echocardiography showed hypertensive cardiovascular disease with an ejection fraction of 68% and 2:1 atrioventricular block with atrial flutter. Cerebrovascular, immunological, and thyroid disorders were excluded, along with respiratory, cardiac, infectious, and electrolyte imbalance complications. The patient was extubated, but it was difficult to wean him from the ventilator, and he was subsequently reintubated. After stabilization of his respiratory pattern and general condition, including hemodynamic status, extubation was attempted again. However, extubation and reintubation were performed 4 times because the patient developed marked hypercapnia after each extubation.

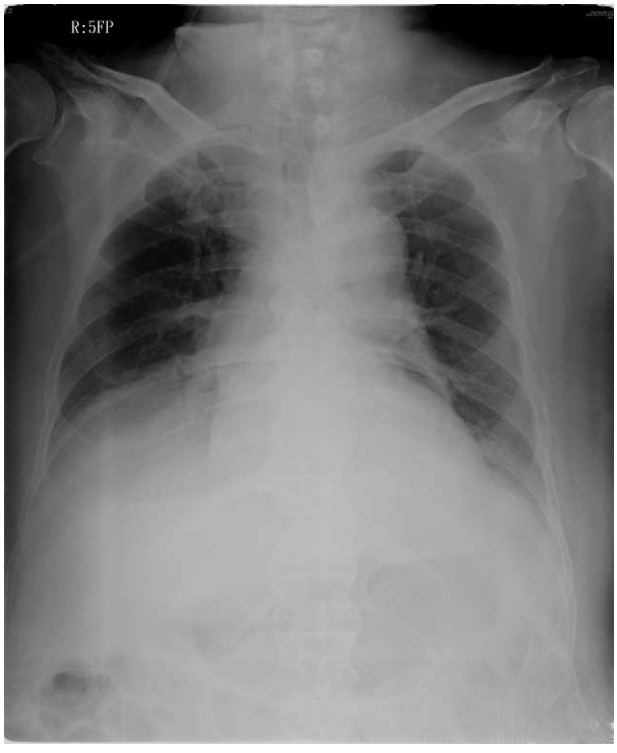

FIGURE 1. Chest radiograph before discharge showed no active lung lesions and bilateral diaphragmatic elevation during deep inspiration.

Respiratory muscle weakness induced by critical illness and septic shock, secondary to the previous history of cholecystitis and sepsis, was then suspected. A nerve conduction study revealed decreased amplitude of compound muscle action potentials (CMAPs) in the bilateral median, peroneal, and tibial nerves as well as in the right ulnar nerve, in addition to decreased conduction velocities in bilateral median, ulnar, peroneal, and tibial nerves. F-latencies were prolonged in bilateral median, ulnar, and tibial nerves as well as in the right peroneal nerve. F-waves were not recorded in the left peroneal nerve. H-latencies were prolonged in bilateral tibial nerves. On sensory nerve conduction studies, decreased conduction velocities were recorded in bilateral median and ulnar nerves across wrists. No CMAPs were detected in the right or left phrenic nerves. These results suggested the presence of a sensorimotor polyneuropathy (Table 1).

Therapeutic Intervention

On confirmation of the diagnosis of CIP with BDP, the patient was extubated and successfully placed on noninvasive mechanical ventilation using a bilevel positive airway pressure (BiPAP) mask. Bedside pulmonary rehabilitation was initiated, including postural drainage, free breathing exercise, respiratory muscle training such as sitting up in bed to decrease abdominal pressure, limb sensory and motor functional training, and reconditioning exercise. Chest ultrasound revealed no further deterioration, and he continued to receive continuous mask mechanical ventilation (IPAP/EPAP: 18/6 cm H_2O). When the patient could tolerate not using the mask for 10 to 20 minutes, he was discharged with a nasal mask BiPAP ventilator with pressure/volume control.

Follow-Up and Outcomes

Ten months later, the patient was readmitted with hypercapnic respiratory failure. He continued using a nasal mask during the daytime and a full facial mask at night (IPAP/EPAP: 20/5 cm H_2O) and was alert but bedridden. Chest ultrasound revealed poor movement and recruitment of bilateral diaphragms, especially on the right side, with a bilateral excursion of approximately 1 cm. A subsequent nerve conduction study revealed deterioration in the sensorimotor polyneuropathy compared with the previous study (Table 2). The patient was discharged with a nasal mask BiPAP ventilator and instructed to perform bedside exercise at home.

With regards to the progressive dyspnea and hypercapnia that occurred after each extubation and the repetitive weaning profile in spontaneous breathing, the patient had a low tidal volume and low maximal inspiratory pressure (MIP). Therefore, a diagnosis of critical illness septic shock-induced respiratory dysfunction complicated with CIP was confirmed. The serial changes in MIP and maximal expiratory pressure are shown in Figure 2.

Follow-up evaluation, 12 months after the onset of BDP, demonstrated a slow but progressive improvement in the patient's respiratory function, together with improvement in the neuropathy. Timeline of his clinical course was shown in Figure 3.

DISCUSSION

For a patient with BDP, chest radiography commonly shows elevation of both sides of the diaphragm with volume loss and/or atelectasis at the lung bases.[21] In most cases, severe bilateral diaphragmatic weakness can be diagnosed from

TABLE 1. Nerve Conduction Study on November 8, 2007

			Amplitude, mV		Latency, ms		Conduction Velocity, m/s		F-Wave Latency, ms		H-Waves Latency, ms	
Nerve	**Stimulation Site**	**Recording Site**	**RT**	**LT**	**RT**	**LT**	**RT**	**LT**	**RT**	**LT**	**RT**	**LT**
Median, m	Wirst	APB	1.8	2.9	7.4	6.2	45	45	34.1	31.3		
	Antecubital fossa	APB	1.7	2.5	13.2	11.8						
Ulnar nerve, m	Wrist	ADM	4.1	6.1	4.2	3.3	45	43	31.7	30.8		
	Below elbow	ADM	3.7	5.1	10.7	9.6						
Peroneal nerve, m	Ankle		1.1	0.9	4.7	38	38	61.2	NR			
	Below fibular head		0.6	0.6	15.5	14.3						
Tibial nerve, m	Ankle	AHB	1.8	3.5	6.2	37	37	61.3	57.9	35.5	34.8	
	Popliteal fossa	AHB	1.4	3.1	18.0	16.4						
Median, s	Mid palm	Index finger	33	2.0	2.0	66	61					
	Wrist		26	20	4.6	4.5	40	40				
Ulnar nerve, s	Wrist	Little finger	27	24	3.2	3.2	48	48				
Sural nerve, s	Calf	Posterior ankle	17	21		42	47					
Phrenic nerve	Supraclavicular fossa		No pick up, bilateral	NR	NR							

Sensory latencies are peak latencies, sensory conduction velocities are calculated using onset latencies, and F-wave latency: minimal F-wave latency. LT = left, NR = no response, RT = right.

physical examination, orthopnea disproportionate to the severity of underlying cardiopulmonary disease, measurements of vital capacity (<50% of predicted vital capacity in the upright position and a further reduction of ≥25% in the supine position), and a marked reduction in maximal respiratory pressure. In cases where the diagnosis is uncertain, measurements of transdiaphragmatic pressure, phrenic nerve conduction study, diaphragmatic electromyography (EMG), or chest ultrasound of the diaphragm may be performed.[21] Chest examination usually reveals limited excursion of the diaphragm, bilateral dullness on percussion over the lower chest, and absent breath sounds. In addition, the patient may be seen to use accessory muscles, have thoracoabdominal paradoxical respiration, and dyspnea and tachypnea at rest. The symptoms can worsen in the supine position[16] and may be misinterpreted as a sign of heart failure.

The early diagnosis of CIP with BDP is challenging and has only been sporadically reported. The diagnosis can be particularly delayed in patients without obvious limb or muscles weakness. Most studies in the reviewed literature have reported a median delay in the diagnosis of BDP of about 2 years, with a range of 6 weeks to 10 years.[24] In our case, by eliminating other possible differential diagnoses, the diagnosis of BDP related to

TABLE 2. Nerve Conduction Study on September 12, 2008

			Amplitude, mV		Latency, ms		Conduction Velocity, m/s		F-Wave Latency, ms		H-Waves Latency, ms	
Nerve	**Stimulation Site**	**Recording Site**	**RT**	**LT**	**RT**	**LT**	**RT**	**LT**	**RT**	**LT**	**RT**	**LT**
Median, m	Wirst	APB	0.7	0.5	5.8	6.7	49	34	NR	NR		
	Antecubital fossa	APB	0.5	0.5	11.3	13.5						
Ulnar nerve, m	Wrist	ADM	0.5	2.8	4.9	4.0	48	47	NR	31		
	Below elbow	ADM	0.4	2.6	14.6	9.8						
Peroneal nerve, m	Ankle		0.5	1.7	4.9	3.9	40	43	59.0	NR		
	Below fibular head		0.5	1.6	14.6	12.3						
Tibial nerve, m	Ankle	AHB	1.5	3.1	5.8	5.0	42	40	NR	56.2	36.8	34.2
	Popliteal fossa	AHB	1.2	1	14.9	14.5						
Median, s	Mid palm	Index finger	41	26	1.8	1.8	65	70				
	Wrist		28	34	4.0	4.0	45	44				
Ulnar nerve, s	Wrist	Little finger	33	16	2.7	3.1	57	46				
Sural nerve, s	Calf	Posterior ankle	15	14		41	47					

Sensory latencies are peak latencies, sensory conduction velocities are calculated using onset latencies, and F-wave latency: minimal F-wave latency. LT = left, NR = no response, RT = right.

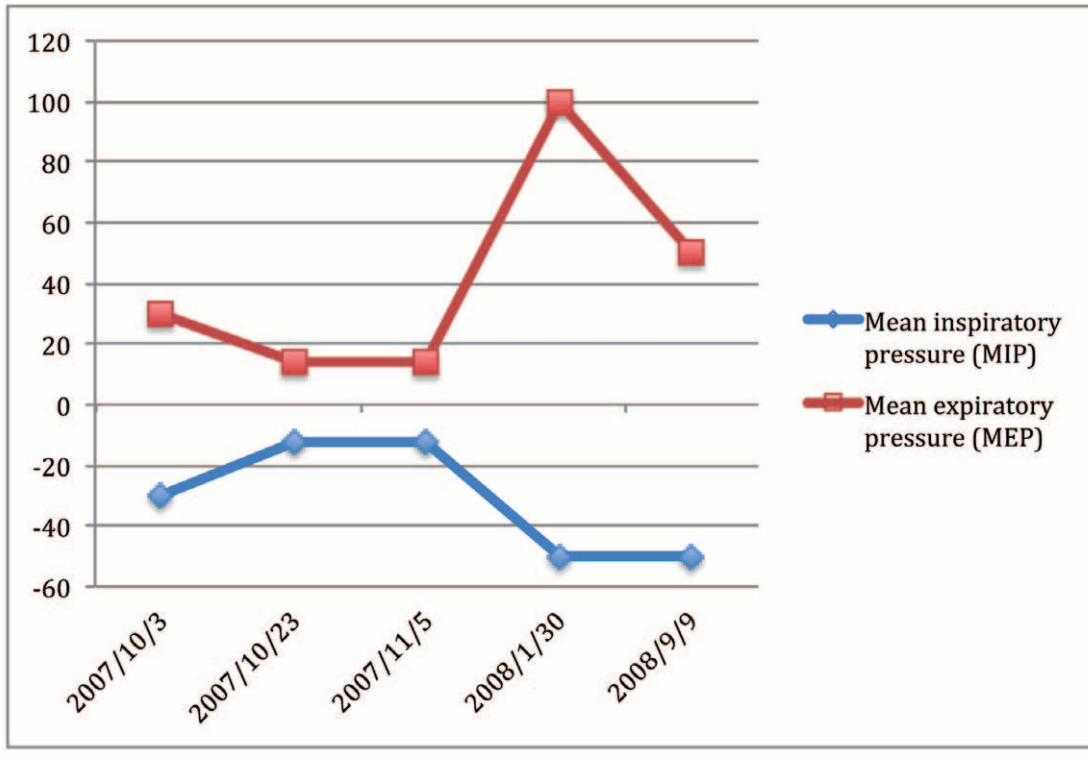

FIGURE 2. Serial changes in maximal inspiratory pressure and maximal expiratory pressure.

CIP was confirmed. We believed that the cause of BDP in our patient was related to CIP because of the previous history of infection; this has also been reported in other cases of diffuse neuropathy.[20] BDP can be secondary to a variety of pathological processes involving the peripheral nervous system, including abnormal antibody profiles, multifocal motor neuropathy with conduction block followed by diaphragmatic paralysis, and respiratory failure secondary to bilateral phrenic neuropathy.[25]

CIP is a sensorimotor polyneuropathy first described by Bolton et al in 1984.[26] BDP with polyneuropathy presents with progressive hypercapnia and hypoxemia because of atelectasis and ventilation-perfusion mismatching. Fluoroscopy with

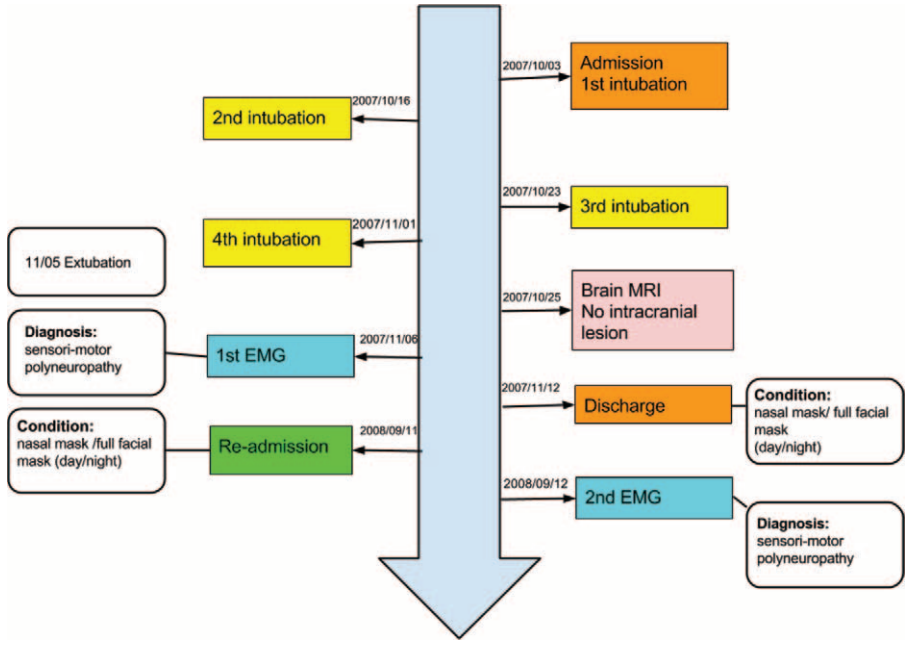

FIGURE 3. Timeline.

''sniff test'' can be used to diagnose unilateral diaphragmatic paralysis, but it is no longer considered useful in the diagnosis of BDP. Because of its easy availability and low invasiveness, chest ultrasound would be one of the methods of choice to diagnose and monitor recovery in BDP. EMG of the diaphragm is useful to distinguish between neuropathic or myopathic causes of BDP, and determine the severity and chronicity of the condition; however, the use of EMG is limited by technical issues, such as cross-contamination during examination, or the potential risk of pneumothorax.[27] Combining EMG with chest ultrasound can improve the safety and accuracy of the procedure by allowing visualization of the needles and adjacent tissues.[28]

In our case, the repetitive weaning profile in spontaneous breathing showed that the patient had a low tidal volume and MIP without ventilatory support. This led us to consider phrenic diaphragmatic dysfunction. For electrodiagnostic studies, recording electrodes were placed on the lower chest wall with the patient in the supine position, and the phrenic nerves were stimulated percutaneously using a bipolar stimulator in the supraclavicular fossa between the sternal and clavicular heads of the sternocleidomastoid muscle. We did not perform diaphragmatic needle EMG because of the risk of pneumothorax and hesitation on the patient's part. On chest ultrasound, poor diaphragmatic movement was evident without diaphragmatic thickening during deep and quiet breathing.

When recorded from surface electrodes on the chest wall, the conduction velocities of the phrenic nerves may be shortened because of coactivation of chest wall muscles innervated by the brachial plexus.[29] In our case, although we made every effort to obtain CMAPs of the phrenic nerves, we could not find any excursion of the diaphragm. Furthermore, on reviewing the patient's past medical history, his first chest x-ray already demonstrated bilateral elevation of the hemidiaphragm, small lung volumes, and atelectasis.

The diagnosis of BDP in our patient was first suspected after his fourth repetitive intubation, and he was treated with a BiPAP nasal mask, thereby avoiding tracheostomy. When it is difficult to wean a patient from mechanical ventilation resulting in repetitive endotracheal intubation, BDP should be considered as a diagnosis in order to avoid an unnecessary tracheostomy.

CONCLUSION

Our findings suggest that the cause of BDP in our patient was CIP secondary to a previous infection. The patient had bilateral phrenic neuropathy and sensorimotor polyneuropathy. Early diagnosis of CIP-induced BDP is not easy, although it can be diagnosed by various methods. One such method of choice is the chest ultrasound because of its convenience and real-time observations. However, combining chest ultrasound with EMG can be considered to improve the accuracy and safety of the procedure, and determine the severity and chronicity of diaphragmatic paralysis, whether the paralysis is neuropathic or myopathic, and the clinical course of the paralysis. When it is difficult to wean a patient from mechanical ventilation, CIP should be considered. Early diagnosis can prevent endotracheal intubation, unnecessary tracheostomy, and enable the introduction of early bedside rehabilitation as part of the treatment strategy.

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