Brazilian Journal of Anesthesiology 2024;74(1): 744348

Sociedade Brasileira de Anestesiologia

Brazilian Journal of ANESTHESIOLOGY

CASE REPORT

Ultrasound evaluation of diaphragm function in patients with cervical spinal cord injury: case report

Luisa María Charco-Roca [a], Elena Simón-Polo [b,*], Pablo Crispín Cuesta-Montero [a]

[a] *General University Hospital of Albacete, Anaesthesiology and Resuscitation Service, Albacete, Spain*
[b] *General Hospital of Albacete, Anaesthesaia, Reanimation and Pain Treatment, Albacete, Spain*

Received 16 August 2020; accepted 11 December 2021
Available online 25 December 2021

KEYWORDS
Lung ultrasound;
Spinal cord trauma;
Diaphragmatic paralysis;
Tracheostomy, case report

Abstract Ultrasound evaluation of diaphragm function allows the detection of diaphragm dysfunction and the adaptation of ventilatory support in patients admitted to intensive care units. The studied patient had a C3 spinal cord injury. Ultrasound evaluation of diaphragm mobility showed that the patient suffered diaphragm dysfunction. A tracheotomy was indicated, and early ventilatory support was initiated. Ultrasound evaluation of diaphragm function in patients with cervical spinal cord injury is a useful and simple technique. It provides fast and reliable data for the diagnosis of respiratory insufficiency of neuromuscular origin.

Introduction

Traumatic spinal cord injury requires the collaboration of a multidisciplinary team, both for the specialized treatment of the acute phase and for secondary complications. In respiratory management in the acute phase, an evaluation of respiratory function is a priority to anticipate the need for ventilatory support.

Ultrasound evaluation of diaphragm function allows the detection of diaphragm dysfunction in patients with cervical spinal cord injury and provides ventilatory support in anticipation of respiratory complications.[1]

We described the case of a polytraumatized patient with cervical spinal cord injury and the early ventilatory support provided in the intensive care unit, with the aim of analyzing the main evaluation key points and early ventilatory management.

Case report

Polytraumatized 65-year-old man with no medical history of interest, who was admitted to the intensive care unit after an accidental fall from three meters high. The patient presented a mild head trauma of 15 on the Glasgow Coma Scale (GCS) upon the arrival of the emergency service personnel to the scene of the accident. He also presented facial trauma with soft tissue edema in the facial region and active bleeding from the nasal and oral cavities.

A total body Computed Tomography (CT) scan was performed, showing subdural hematoma, subarachnoid hemorrhage, multiple complex facial fractures and complex C4 to C7 vertebral fractures. The injuries caused significant soft

* Corresponding author.
E-mail: elsimhz@hotmail.com (E. Simón-Polo).

https://doi.org/10.1016/j.bjane.2021.12.005

tissue oedema at the cervical level that displaced the airway to the right.

The patient presented neurological deficits consisting of paresis of the lower limbs with right lower limb hypoesthesia and paresis of the upper limbs with greater involvement of the right arm associated with ipsilateral hypoesthesia. The medullary reflexes were preserved. Given the findings of this clinical examination, an urgent cervical Magnetic Resonance Imaging (MRI) scan was performed. The MRI showed the presence of C6—C7 subluxation with disc protrusion and epidural hematoma anterior to the vertebral body of C6, along with a small rupture of the yellow and interspinous ligaments. The images showed minimal spinal deformity with small patchy areas of myelopathy and showed another area with strong myelopathy at the C3 vertebra (Fig. 1). Upon the radiological findings and the diagnosis of incomplete spinal cord injury (American Spinal Injury Association — ASIA C), the patient was intervened urgently by performing a discectomy and anterior cervical fixation of vertebral bodies C6—C7 using a plate.

After the intervention, the patient presented an adequate neurological state, showing good respiratory dynamics with ventilatory support in Continuous Positive Airway Pressure (CPAP) mode + 6 cmH_2O. The patient was extubated, remaining under clinical supervision. After ten minutes, the intercostal and abdominal musculature appeared to be used in all the respiratory cycles and the patient reported dyspnea. No decrease in Peripheral Oxygen Saturation (SpO^2) was observed on the pulse oximetry monitor. At this time, a diaphragm M-mode ultrasound was performed. It showed bilateral diaphragmatic thinning (Fig. 2).

To perform the ultrasound examination, a high-frequency linear ultrasound probe (10—12 Hz) was used, placing it perpendicular over de 9^{th}—10^{th} intercostal space in the anterior axillary line, to observe part of the area of apposition of the diaphragm with the rib cage (apposition zone). In this area, the diaphragm is seen as 3 layers of different densities arranged in parallel (pleura, diaphragm, and peritoneum).[2,3]

Provided these clinical signs and considering the ultrasound findings and spinal cord injuries shown in the MRI, it was decided to perform a surgical tracheotomy in anticipation of respiratory failure in the patient. Subsequently, the patient remained with ventilatory support as needed.

Discussion

The location and degree of cervical spinal cord injury affects both the onset of mechanical ventilation and the successful weaning of the respirator. Injuries above C5 and ASIA A are among the factors with the highest risk for developing respiratory failure. After the ultrasound examination, it was found a diaphragmatic thickness below 1.5 mm.

One of the ways to measure the diaphragmatic function is the diaphragmatic thickness, using the M mode. This depends on muscle mass and is correlated with forced vital capacity. The decrease in diaphragmatic thickness is associated with a decrease in amplitude assessed by electromyography and may indicate the presence of atrophy or disfunction. The normal diaphragmatic thickness in ventilated patients is 2.4 $\pm$ 0.8 mm, indicating atrophy values below 2 mm. Ratios of 1.8 are considered normal values, accepting ratios of 1.2 as the lower limit.[3]

The presence of respiratory complications are also good predictors. The duration of mechanical ventilation is also determined by age (over 45 years), concomitant lung diseases, smoking, low level of consciousness (GCS less than 9), comorbidities and an injury Severity Score less than or equal to 16.[4]

In C1—C2 injuries, there is no effective respiratory musculature. The diaphragm is innervated by the phrenic nerve, which is composed of the C3, C4, and C5 cervical nerves. Therefore, patients with complete motor injury above C5 will almost invariably need ventilatory support.[1] Injuries below C5 result in paralysis of the intercostal and abdominal musculature; therefore, some patients will require respiratory support.

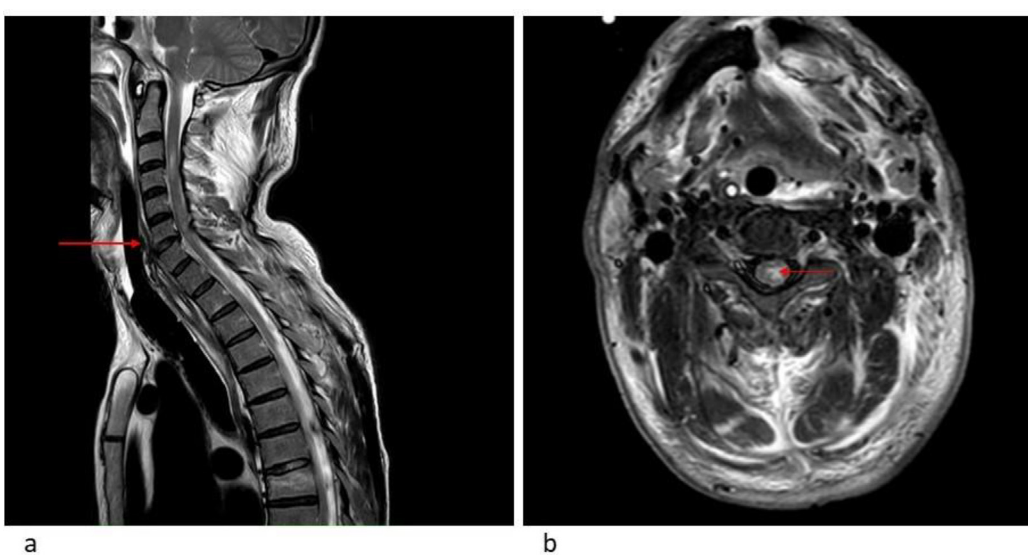

Figure 1 Cervical nuclear magnetic resonance. (a) Sagittal section with anterior ligament injury image at the level of C5 to C7 vertebral bodies. (b) Cross section at the level of the C3 vertebral body showing alteration of the signal suggestive of myelopathy.

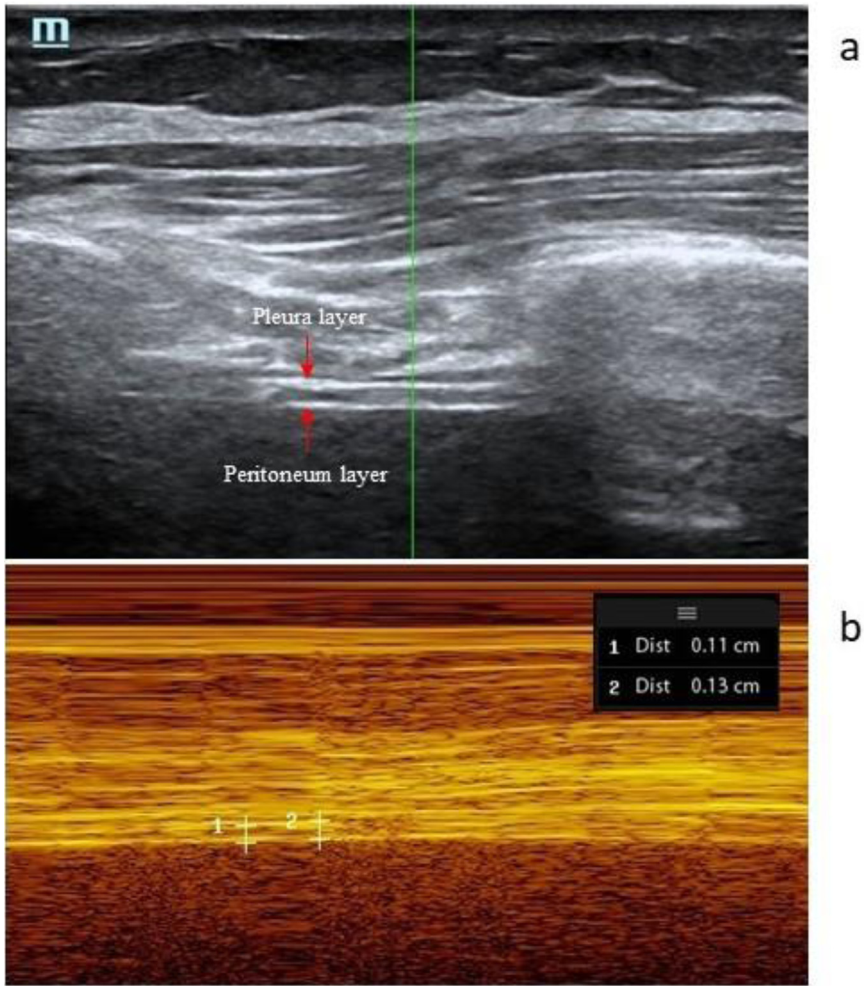

Figure 2 Ultrasound images. Right diaphragm exploration. (a) 2D mode. (b) M-mode ultrasound of the diaphragm. Measurement of diaphragm thickness using M-mode at the level of the right hemidiaphragm. Is visualized as 3 parallel lines. Number 1 represents the inspiratory thickness and number 2, the expiratory thickness.

It is unknown whether invasive mechanical ventilation should be performed preventatively in all patients or selectively based on signs of acute respiratory failure, but there is evidence to support that in patients with injuries above C5 and complete quadriplegia, intubation should be performed routinely and early because delays can cause preventable morbidity.[5]

In this case, the ligament injuries that caused instability of the vertebral bodies were located in C5 to C7, but the nuclear magnetic resonance showed that the extension of the spinal cord injury was from C3 to C7. These lesions are consistent with the injury incident, a fall that caused severe facial trauma and could have caused spinal distraction due to hyperextension of the neck.

Although radiological tests support the diagnosis, only a comprehensive clinical and neurological assessment can confirm the severity of acute spinal cord injuries. The loss of respiratory capacity in patients with cervical spinal cord injury occurs due to exhaustion of the musculature involved in the ventilatory process, hemorrhage or ascending spinal oedema, accumulation of secretions, atelectasis, other associated traumas, or other conditions of the patient.

Tracheotomy is required in 11−35% of patients with cervical spinal cord injury for the treatment of pulmonary complications and pulmonary hygiene.[1] Tracheotomy reduces the duration of respiratory cycles, improves lung capacity to mobilize secretions and reduces resistance of the respiratory tract. As a result, the weaning of the ventilator becomes easier and reduces the mechanical ventilation duration.[4] There is evidence that early tracheotomy reduces the incidence of pneumonia, shortens the duration of mechanical ventilation, reduces the stay in the ICU and reduces the rates of serious complications associated with orotracheal intubation, such as tracheal stenosis. Tracheotomy does not appear to have deleterious effects when performed shortly after cervical fixation surgery and does not promote cross infection despite the proximity of the incisions.[1]

For the patient presented in this article, tracheotomy was indicated to anticipate any signs of exhaustion as an immediate respiratory complication. If this technique was not available, the patient would have required ventilatory support in the short term. In that case, the option of noninvasive mechanical ventilation would have been considered, which, upon presenting multiple facial fractures, could have been difficult.

Ventilatory failure in patients with cervical spinal cord injury occurs more frequently after the fourth day of the injury, which is relevant for the monitoring and consideration of maintaining the intubation after early surgical intervention, especially those from cervical surgical procedures. If it is not necessary to initially secure the airway or ventilatory support, the need for intubation through PCO_2 (capnography and arterial blood gas) and spirometry with monitoring of the vital capacity (which has an excellent correlation with other pulmonary function tests) and Maximum Inspiratory Pressure (PImax) should be considered. This supposes a simple, global evaluation of the strength of the inspiratory musculature, which is a good indicator available at the bedside. In general terms, the PImax estimates the strength of the inspiratory muscles (diaphragm) and is achieved at residual volume and with the greatest inspiratory effort. The evaluation of diaphragm function is carried out through medical history, physical examination, nerve conduction studies and Electromyography (EMG). Nerve conduction and EMG studies are uncomfortable and can sometimes cause complications such as pneumothorax.[6]

Imaging techniques can be used as an approach for the evaluation of diaphragm dysfunction. Paresis or diaphragm paralysis is usually presented as an elevation on simple chest radiography.

Functional imaging with fluoroscopy is a simple and effective method to diagnose diaphragm dysfunction, being classified as paralysis, weakness or eventration. Diaphragm paralysis can be observed as an absence of orthographic excursion of the diaphragm in the respiratory cycles, usually presenting a paradoxical movement with inspiration.[7]

There is no consensus on the best ultrasound assessment method. The measurement of diaphragm shortening, which is the variation of thickness during inspiration/expiration, measured in the apposition zone, provides a simple way to diagnose paralysis or diaphragm dysfunction both unilaterally and bilaterally. Current recommendations on diaphragmatic evaluation by ultrasound is the use of diaphragmatic shortening, over other parameters, such as excursion.[7,8]

Diaphragmatic ultrasound in critically ill patients is a technique that can be performed at the patient's bedside (point of care ultrasound), easily reproductible and is event of adverse effects derived from ionizing radiation.

However, one of the limitations of this clinical case presents are the technical skills and ultrasound management that each one present, as well as the interobserver variability that exists when it is a dynamic test. Furthermore, due to the anatomy of the patient (such as subcutaneous emphysema, rib injuries at the place where the technique was performed, the presence of chest tubes, etc.) may lead to difficulty or impossibility of its performance.

Conclusions

Respiratory failure and pulmonary complications are the main factors that contribute to the morbidity and mortality of patients with cervical or high thoracic spinal cord injury.

This study considers that ultrasound evaluation of diaphragm function as an indicator of respiratory failure in patients with cervical spinal cord injury is a useful, simple, minimally invasive, and inexpensive technique. This technique provides reliable data to establish a prognosis regarding the initial needs for ventilatory support. This evaluation of respiratory function on observing adequate diaphragm mobility can also be applied to patients in the weaning phase of mechanical ventilation.

Conflicts of interest

The authors declare no conflicts of interest.

Supplementary materials

Supplementary material associated with this article can be found in the online version at doi:10.1016/j.bjane.2021.12.005.

References

1. Velmahos GC, Toutouzas K, Chan L, et al. Intubation after cervical spinal cord injury: to be done selectively or routinely? Am Surg. 2003;69:891–4.
2. Gerscovich EO, Cronan M, McGahan JP, Jain K, Jones CD, McDonald C. Ultrasonographic evaluation of diaphragmatic motion. J Ultrasound Med. 2001;20:597–604.
3. Dot I, Pérez-Teran P, Samper MA, Masclans JR. Diaphragm dysfunction in mechanically ventilated patients. Arch Bronconeumol. 2017;53:150–6.
4. Menaker J, Kufera JA, Glaser J, Stein DM, Scalea TM. Admission ASIA motor score predicting the need for tracheostomy after cervical spinal cord injury. J Trauma Acute Care Surg. 2013;75:629–34.
5. Huang YH, Ou CY. Magnetic resonance imaging predictors for respiratory failure after cervical spinal cord injury. Clin Neurol Neurosurg. 2014;126:30–4.
6. Zambon M, Greco M, Bocchino S, Cabrini L, Beccaria PF, Zangrillo A. Assessment of diaphragmatic dysfunction in the critically ill patient with ultrasound: a systematic review. Intensive Care Med. 2017;43:29–38.
7. McCool FD, Tzelepis GE. Dysfunction of the diaphragm. N Engl J Med. 2012;366:932–42.
8. Goligher EC, Laghi F, Detsky ME, Farias P, Murray A, Brace D, et al. Measuring diaphragm thickness with ultrasound in mechanically ventilated patients: feasibility, reproducibility, and validity. Intensive Care Med. 2015;41:642–9.