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Diagnostics

Diaphragmatic excursion measurement in emergency patients with acute dyspnea: toward a new diagnostic tool?

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ABSTRACT

Introduction: During acute dyspnea (AD), respiratory exhaustion is mainly due to diaphragm fatigue. The primary objective was to validate interobserver reproducibility of diaphragmatic excursion (DE) in emergency department (ED) patients admitted for AD. The secondary objectives were to assess the feasibility of DE measurement and intraobserver reproducibility. Finally, we examined whether the DE value was associated with a need for noninvasive ventilation (NIV).

Materials: This was a monocentric, prospective, technical reproducibility study. Adult patients in spontaneous ventilation admitted for AD were included. Two operators carried out 2 consecutive diaphragm excursion measurements each on the right and left hemidiaphragms.

Results: Twenty-four patients were analyzed. The feasibility was 96% on the right and 67% on the left. The interobserver concordance between the 2 measures was 0.80 (95% confidence interval [CI], 0.59-0.91) (average difference, −0.07 ± 0.48 cm) on the right and 0.59 (95% CI, 0.19-0.82) (average difference, 0.30 ± 0.91 cm) on the left. For right DE values inferior to 2.3 cm, the interobserver concordance between measures was 0.92 (95% CI, 0.78-0.97). The intraobserver concordance was 0.89 (95% CI, 0.81-0.94) (average difference, 0.02 ± 0.35 cm) on the right and 0.90 (95% CI, 0.82-0.95) (average difference,−0.06 ± 0.45 cm) on the left. When the DE was greater than 2 cm, no patient required NIV.

Conclusion: Diaphragmatic excursion measurement of the right diaphragm is feasible, with good interobserver and intraobserver reproducibility in ED patients admitted for AD. When the DE value is greater than 2 cm at admission, no subsequent NIV is required.

1. Introduction

The emergency physician's role is to provide appropriate initial therapy and direct patients to specialized departments according to their pathology and its severity. Admissions for acute dyspnea (AD) are common in emergency departments (EDs) and may have many etiologies [1,2]. Acute dyspnea admissions are mainly related to acute heart failure [3], acute exacerbation of chronic obstructive pulmonary disease (COPD), and severe pneumonia [1,2]. In patients with AD, respiratory exhaustion is mainly due to fatigue of the main breathing muscle, the diaphragm [4]. The emergency physician's care involves correction of hypoxemia and/or hypercapnia and adapt treatment according to the diagnosis. Independent of the diagnosis, the use of invasive (MV) or noninvasive (NIV) mechanical ventilation is based on clinical and biological criteria. Noninvasive ventilation is frequently used in EDs [5] and is recommended in the management of acute exacerbation of COPD and acute heart failure [6–8]. This allows, among others things, to reduce breathing work and respiratory exhaustion [9]. In contrast, patients with respiratory exhaustion will always need ventilation support. Late diagnosis of respiratory exhaustion is probably damaging to patients.

Emergency clinical ultrasonography (US) is increasingly used in EDs as a tool to diagnose or evaluate the effectiveness of initial care [10]. In the intensive care unit, decrease of diaphragmatic excursion (DE) among ventilated patients is defined as diaphragmatic dysfunction [11–13]. Diaphragmatic excursion analysis by M-mode US can predict an extended or a difficult MV [13] weaning [11]. Among unventilated patients, this measure is useful to evaluate diaphragmatic fatigability

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[14–16]. The feasibility and reproducibility of DE have been validated in healthy people [17]. This measure could be very useful as a diagnostic for respiratory exhaustion and as an instrument for prognosis evaluation. Some diaphragmatic electromyographic studies suggest that respiratory distress chronology begins with diaphragmatic fatigue, with increase in respiratory rate followed by alternate thoracoabdominal breathing and paradoxical abdominal breathing and, finally, an increase in $Paco_2$ associated with a decrease in minute ventilation and worsening of respiratory acidosis [4].

To date and to the best of our knowledge, no study has focused on DE analysis among AD patients admitted in ED. Diaphragmatic excursion measurement could be useful when it allows a fast and simple evaluation of diaphragmatic fatigue that is predictive of the need for mechanical ventilation. The primary objective of this study was to validate interobserver reproducibility of DE measurements. The secondary objectives were to assess the feasibility of DE measurement and intraobserver reproducibility. We also looked at whether the DE value was associated with a need for NIV during the first 4 hours.

2. Materials and methods

2.1. Materials

This single-center, prospective, technical reproducibility study was conducted from August 2013 to January 2014. The study population comprised patients attending the ED of University Hospital of Nîmes. The study protocol was approved by the Committee on Human Research South Mediterranean III (CPP-2012.09.08 bis), and written informed consent was obtained from all patients. The protocol was registered at ClinicalTrial.gov (NCT 01743105).

Patients were included if they were admitted in ED for AD as defined by the association of 1 clinical criterion (respiratory rate >25/min and/or signs of respiratory distress) and hypoxia (SpO_2 <90%) or hypercapnia (pH < 7.35 and $Paco_2$ >45 mm Hg). All included patients were in spontaneous ventilation (absence of ventilation assistance) and were older than 18 years. Patients were not included if (1) they were suffering from a neurologic or neuromuscular disorder modifying diaphragm function without any decompensation, (2) they were admitted with AD requiring immediate mechanical ventilation (not allowing 2 US measures), or (3) they were admitted with current respiratory support therapy.

2.2. Aims

The primary objective of our study was to validate interobserver reproducibility of M-mode diaphragmatic US in patients with AD admitted in ED. Secondary aims were to evaluate the practicability of DE, the required time to perform the measures, and the intraobserver reproducibility of DE measurements. The exploratory objectives were to assess a potential association between DE values and the necessity, or futility, of NIV during the subsequent 4 hours and evaluate if some DE values seem to be associated with better interobserver reproducibility.

2.3. Measurements

Study participants had a diaphragmatic ultrasound in addition to usual care. The test was discontinued if the patient required respiratory support during this procedure. Two different operators, including the physician in charge of patient on admission in ED, carried out consecutive measurements for each study patient. The second operator performed the measures blinded from results of the first operator and the patient's records. Each operator carried out 2 consecutive diaphragm excursion measurements for both the right and left hemidiaphragms. Operators were timed in their measurements. *Feasibility* was defined as the ability to record a measure. All operators were trained as defined by an emergency clinical ultrasound university diploma. Moreover, they received a short specific training consisted of a lecture in PowerPoint format about DE measurement and practice: 1 measure on healthy volunteers and 1 on real patients with AD.

Ultrasound evaluation was performed using the technique described and validated as the anterior approach [17]. Patients were in a semisitting position. The operators placed the probe in the subcostal or lower intercostal region between the medioclavicular line and the anterior axillary line for the right diaphragm and between the midaxillary and anterior axillary lines for the left diaphragm. They used the liver or the spleen as a window for each right and left hemidiaphragms, respectively [17]. The probe was oriented in medial, cranial, and dorsal views [17]. Initial US evaluation used the 2-dimensional mode to select the best exploration line of each hemidiaphragm. Then, the operators switched to M-mode tracing when they managed to achieve an angle of more than 70° between the uppermost part of the diaphragm and the analysis axis in the most cranial part of the diaphragm. During inspiration, diaphragm movement toward the probe enabled M-mode tracing [12,17]. The image was stored when 6 measurements were recorded. *Diaphragmatic excursion* was defined as the measure in centimeters between the maximal inspiratory and expiratory position of the diaphragm. All tests were performed with the same ultrasound scanner (Vivid S6; GE Healthcare, Medical System Israel Ltd, Tirad Carmel, Israel) and the same phased array probe (1.3-3.3 MHz).

2.4. Sample size

In the absence of data on DE values in this specific population of patients with AD, we considered DE measurements to be equivalent to those from ventilated patients, both in magnitude and variability [11]. Twenty-two subjects were required to demonstrate a concordance correlation coefficient of 0.90 with a confidence interval (CI) of 95% and whose lower limit is superior than 0.80. To be conservative, we decided to include at least 25 subjects in this study.

Table
Patients' characteristics and care

Inclusion characteristics	Patients, n = 24
Female	13 (54%)
Age	80 (60-88)
BMI	26 (24-29)
Comorbidities	
COPD	6 (25%)
Asthma	3 (13%)
Heart failure	10 (42%)
Pulmonary embolism	3 (13%)
Clinical parameters	
SBP (mm Hg)	129 (109-139)
DBP (mm Hg)	71 (59-84)
HR (/min)	102 (88-120)
RR (/min)	29 (28-32)
SpO_2 (%)	89 (73-92)
Biological parameters	
pH	7.38 (7.29-7.43)
$Paco_2$ (KPa)	6.01 (5.02-7.12)
Pao_2 (KPa)	13.76 (7.89-19.33)
HCO_3- (mmol/L)	24.5 (21.3-27.0)
First final diagnosis	
Acute pulmonary edema	10 (42%)
Acute exacerbation of COPD	6 (25%)
Pneumonia	5 (21%)
Severe acute asthma	3 (13%)
Combined diagnosis	5 (21%)

Data are expressed as number (percentages) or median (25th-75th percentile). Combined diagnosis: at least 2 diagnoses.
Abbreviations: BMI, body mass index; SBP, systolic blood pressure; DBP, diastolic blood pressure; HR, heart rate; RR, respiratory rate.