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Point of care diaphragm ultrasound in infants with bronchiolitis: A prospective study

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Abstract

Background: Bronchiolitis is the most common reason for hospitalization of children worldwide. Many scoring systems have been developed to quantify respiratory distress and predict outcome, but none of them have been validated. We hypothesized that the ultrasound evaluation of the diaphragm could quantify respiratory distress and therefore we correlated the ultrasound diaphragm parameters with outcome.

Methods: Prospective study of infants with bronchiolitis (1-12 months) evaluated in a pediatric emergency department. Ultrasonography examinations of the diaphragm was performed (diaphragm excursion [DE], inspiratory excursion [IS], inspiratory/expiratory relationship [I/E], and thickness at end-expiration [TEE] and at end-inspiration [TEI]; thickening fraction [TF]).

Results: We evaluated 61 infants, 50.8 % males. Mean TF was 47% (IQR 28.6-64.7), mean I/E 0.47 (± 0.15), mean DE 10.39 ± 4 mm. There was a linear correlation between TF and oxygen saturation at first evaluation ($P = 0.006$, $r = 0.392$). All children with lower values of TF required HFNC and one of them required CPAP. A higher IS was associated with the future need of respiratory support during admission ($P = 0.007$). IS correlated with the hours of oxygen delivery needed ($P = 0.032$, $r = 0.422$). TEI ($t = 3.701$, $P = 0.002$) was found to be main predictor of hours of oxygen delivery needed.

Conclusion: This study described ultrasound diaphragmatic values of previously healthy infants with bronchiolitis. DE, IS, and TEI correlated with outcome. If confirmed in larger studies, bedside ultrasound semiology of the diaphragm can be a new objective tool for the evaluation and outcome prediction of infants with bronchiolitis.

KEYWORDS

imaging, infant pulmonaryfunction, infections: pneumonia, TB, viral, non-invasive ventilation, respiratory and airway muscle

Abbreviation: DD, diaphragm dysfunction; DE, diaphragmatic excursion; ED, emergency department; I/E, inspiratory/expiratory relationship; IS, inspiratory slope; POCUS, point-of-care ultrasound; SD, standard deviation; TEE, thickness at end-expiration; TEI, thickness at end-inspiration; TF, thickening fraction; US, ultrasound three volte.

1 | INTRODUCTION

Bronchiolitis is a viral acute lower respiratory tract infection in infants presenting with coughing, wheeze and poor nutrition as the major symptoms.[1–3] Bronchiolitis is the most common reason for hospitalization and intensive care unit admissions of children worldwide, with wide consequences on economy, and human resources in pediatric departments.[4,5]

Attempts to find effective treatments have been frustrating[6] and none of the many published trials found a definitively effective pharmacological treatment, failing to support the effectiveness of bronchodilators,[7] adrenaline,[8] humidified oxygen,[9] anticholinergics,[10] corticosteroids,[11] and hypertonic solution.[3] Similarly, the different clinical scores published in current literature failed in predicting clinical outcome.[3,12–15]

Therefore, assessment of infants with bronchiolitis, including the physical examination, can be complicated by variability in the disease state, and may require serial observations over time to fully assess the child's status, which is obviously difficult in particular settings like ED.

Moreover, all these parameters are based on subjective clinical findings, which can vary between different assessing physicians. The possibility of evaluating objective parameters which are easy to measure allow the physician a better evaluation of each child. In this setting, point-of-care ultrasound (POCUS)[16] is having a growing interest. Nevertheless, POCUS has focused on lung parenchyma, while limited data are available on ultrasound (US) evaluation of respiratory muscles in emergency care settings especially in children.

In this scenario, considering that many scoring systems have been developed in the attempt to objectively quantify respiratory distress, we hypothesized that the direct evaluation of the main respiratory muscle—the diaphragm—could be a new helpful tool for the evaluation of an infant with bronchiolitis and to predict the outcome. This could be particularly feasible in the "new era" of the modern emergency room pediatrician with the increasing use of POCUS.

2 | MATERIALS AND METHODS

We conducted a prospective study from January 1st 2017 to April 30th 2017. The study was approved by the Ethics Committee of our Institution (number 1444_OPBG_2017), and fully informed consent from the parents of each participant was obtained before the study.

There is no uniform definition of bronchiolitis, and no definite age limitation. Children with a clinical diagnosis of bronchiolitis according to AAP guidelines ("a constellation of clinical symptoms and signs including a viral upper respiratory prodrome followed by increased respiratory effort and wheezing in children less than 2 years of age") were evaluated.[17]

Only infants from 1 to 12 months of age were included, in order to reduce biases of selection.[18–21]

Infants with life threatening disease requiring immediate intervention, preterm, with cardiac diseases or co morbidities or genetic disorders or disability were excluded.

All patients underwent a routine clinical evaluation in the emergency room. A grading of disease severity was obtained according to current scales[22]:

A. Mild bronchiolitis: score 1-4
B. Moderate bronchiolitis: score 5-8
C. Severe bronchiolitis: score 9-12
D. Healthy infant: score 0

Body weight, height or body length, head circumference, were measured.

We used the following admission criteria:

1. Moderate/severe respiratory distress (patients with respiratory score 9-12 after suctioning; Consider admission case-by-case for those with respiratory score 5-8).
2. Hypoxemia (O2 saturation <90% awake, 88% asleep).
3. Apnea
4. Dehydration requiring ongoing IV fluids.

Admission was considered in case of the following risk factors: lack of reliable caregiver at home, inability to follow recommended care plan, risk for loss to follow-up.

ICU consult for apnea with bradycardia and cyanosis, toxic appearance, respiratory failure; consider for.

We used the following criteria for beginning high flow nasal cannulae (HFNC):

1. PaCO2 >50 mmHg or PaO2 ≤60 mmHg
2. Persisting SatO2 <90% despite low flow oxygen administration or persisting score >9

We used the following criteria for beginning continuous positive airway pressure (CPAP):

1. No clinical improvement after 36 h of HFNC (no reduction in respiratory rate nor heart rate, no improvement in SatO2, PaCO2, PaO2, clinical score)

To complete and widen the clinical evaluation, chest ultrasound scans were acquired by two experienced pediatrician in chest ultrasound.

We used a portable Doppler ultrasound machine (SonoSite M-Turbo) with a 10-12-MHz linear transducer.

Ultrasonography examinations were performed following the methodology previously described by Copetti et al.[23–25]

Both longitudinal and transversal sections were collected on the anterior, lateral, and posterior chest wall. Lung ultrasound (Figure 1) data were classified according to a previously proposed echographic score[26]:

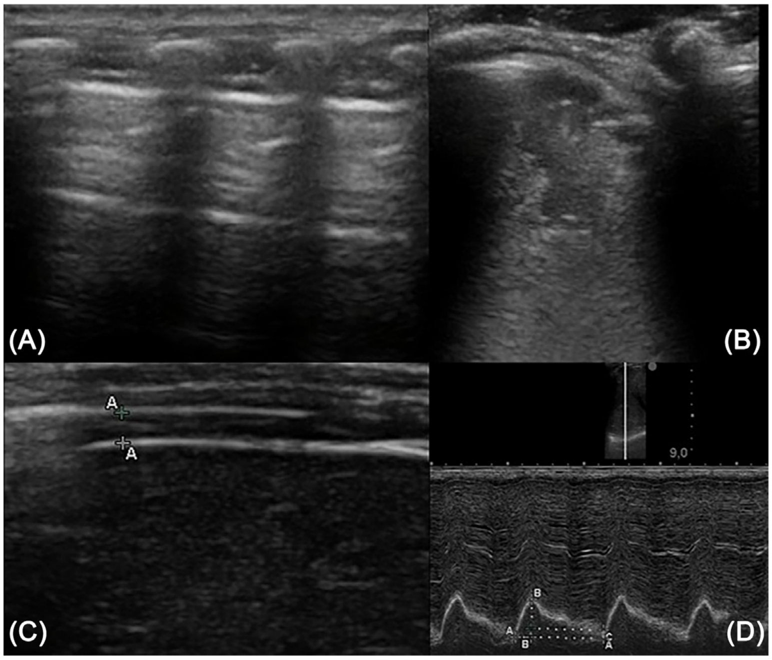

FIGURE 1 (A) normal chest ultrasound; (B) subpleural consolidation; (C) right emidiaphragm evidenced by the two hyperechoic lines; (D) diaphragm movement evaluated in M-mode: A-A all respiratory cicle, B-B diaphragm excursion, B-C expiratory phase, A-B inspiratory phase

A. Mild bronchiolitis: score 1-3
B. Moderate bronchiolitis: score 4-6
C. Severe bronchiolitis: score 7-8
D. Normal lung ultrasound pattern: score 0

The patients have been studied in the semi-recumbent position throughout the study. The sonographic examinations were performed when the infants looked calm, excluding therefore crying moments or ongoing cough. We used pacifiers or distraction techniques to calm infants when they looked uncooperative during the examinations, and waited until they fell asleep or became calm.

Ultrasound recordings of diaphragm thickness were performed as previously reported.[27,28]

The diaphragm was located by placing the transducer in the ninth or tenth intercostal space near the midaxillary line and angled perpendicular to the chest wall (Figure 1). The zone of apposition was assessed at 0.5-2 cm below the costophrenic sinus.

The diaphragm thickness was recorded in time motion mode. The sweep speed was adjusted as slow as possible to obtain a minimum of three cycles on the same image. The diaphragm was outlined by the two clear bright parallel lines of the pleural and peritoneal membranes (Figure 1C).

Several images were recorded and images were deemed invalid if the two clear bright parallel lines of the pleural and peritoneal membranes were not plainly identified at each moment of the respiratory cycle. Ultrasonographic recordings were stored on compact disks.

The measurements included diaphragm thickness at end-expiration (TEE) and at end-inspiration (TEI).

During M-mode imaging, the normally functioning diaphragm is represented as an echogenic line that moves freely during inspiration and expiration. Inspiration is identified on the sonographic tracing as upward flexion; expiration is identified as downward flexion. Estimation of diaphragmatic excursion was conducted by measuring the vertical distance between the upper border of the liver at the end of expiration to the upper border of the liver at the end of inspiration. This vertical distance represents right/ diaphragmatic excursion (Figure 1D).[29,30]

Examinations of numerous respiratory cycles were done and recorded on cine movies, and we counted the average of three cycles, as suggested by literature.[31]

Measurements were averaged out of three or more consecutive breaths on the last valid image recorded at the end of each period.

Following these guidelines, the diaphragmatic excursion (DE, displacement, cm), the speed of diaphragmatic contraction (inspiratory slope [IS], cm/s), the duration of the cycle (Ttot, in second), the inspiratory/expiratory relationship (I/E) have been measured (Figure 1).

The thickening fraction (TF) was calculated as (TEI-TEE)/TEE and expressed as a percentage.

2.1 | Primary outcome

1. Description of diaphragmatic us findings in otherwise healthy infants with bronchiolitis
2. Correlation of ultrasound findings with hours of respiratory support.

2.2 | Secondary outcome

Furthermore, the ultrasound lung score was obtained and correlated with the clinical data to estimate the agreement between clinical and echographic diagnosis and with admission, length of stay, respiratory support.

2.3 | Statistical analysis

Statistical analysis was performed using the SPSS software (IBM SPSS Statistics, version 24.0, Chicago, IL). The normality of the data distribution was assessed by the Kolmogorov-Smirnov test. Values were expressed as arithmetic means ± standard deviation (SD) for continuous variables, median, and interquartile range (IQR) for non-parametric data, or number and percentage (%) for categorical variable. The Mann-Whitney test, Student's *t* test and one-way analysis of variance (ANOVA) were used to compare non-parametric and normal data respectively while the χ^2 was used to compare categorical variables. The Pearson (normal data) or Spearman (non-parametric data) tests were used for correlation analysis between variables. A multiple linear regression analysis (stepwise method) was performed with oxygen use time as the dependent variable and oxygen saturation at admission, echographic and clinical score and ecographic parameters as independent variables. A *P* value <0.05 was considered statistically significant.

3 | RESULTS

3.1 | Study population (clinical findings)

We evaluated 61 previously healthy infants (median age 2.84 [2,25-6.20], 50,8 % males). Bronchiolitis clinical score was mild in 43.1%, moderate in 48.3%, severe in 8.6% cases. 19.7 % children were discharged, 80.3 % were admitted for a median length of 4 days (2-6.5). Respiratory Syncitial Virus was the most common etiological agent (47.4% cases). Twenty-seven children required no respiratory support, HFNC were started in 25 cases, among these 7 required CPAP, of these 2 required mechanical ventilation. Table 1 shows the general and clinical characteristics for the study population according to respiratory support.

3.2 | Study population (POCUS findings)

Table 2 shows M-mode sonographic findings of right diaphragmatic excursion (DE) and thickness, inspiratory slope (IS), TF, lung US score in the groups. Mean TF was 47% (IQR 28.6-64.7), mean I/E was 0.47 (± 0.15), mean DE was 10.39 ± 4 mm.

Table 3 shows the effect of diaphragmatic and lung findings on respiratory support and its changes with clinical and ecographic score.

3.3 | Diaphragm POCUS and clinical scores: correlations

Infants with severe bronchiolitis had lower TF than those with moderate and mild clinical score, though there was no statistically significant difference.

All children with lower values of TF required high-flow nasal cannulae and one of them required continuous positive airway pressure. There was a linear correlation between TF and oxygen saturation at first evaluation (*P* = 0.006, *r* = 0.392).

Children with moderate eco score had lower DE compared with those with mild (7.45 ± 2.76 vs 11.31 ± 4.01, *P* = 0.045) and normal eco score (7.45 ± 2.76 mm vs 10.94 ± 3.81 mm, *P* = 0.023) while statistically significant differences were not reached between mild and normal eco score. Significant differences emerged in IS according to ecographic score (*P* = 0.008) (Figure 2) and those who needed respiratory support during admission had a higher IS at first evaluation (*P* = 0.007) (Figure 3). Furthermore the IS correlated with the hours of oxygen delivery needed (*P* = 0.032, *r* = 0.422). The Table 4 shows the percentiles of right DE and IS in our study population.

All US diaphragmatic findings were compared with respiratory rate and no statistically significant correlations were found.

3.4 | Lung POCUS and clinical scores: correlations

Lung ecographic score was associated with higher hours of oxygen delivery (*P* = 0.002) and length of admission (*P* = 0.001). There was a positive correlation between the clinical score and the ecographic score (*P* = 0.006, *r* = 0.364).

3.5 | Clinical score and outcome

Clinical score severity increased with the length of hospitalization (*P* = 0.001) and hours of oxygen delivery (*P* = 0.001). The ventilation support hours correlated with length of hospitalization (*P* = 0.001, *r* = 0.845) and negatively correlated with the oxygen saturation at first evaluation (*P* = 0.038, *r* = −0.301).

3.6 | Multiple linear regression analysis

The multiple linear regression analysis (step-wise) with hours of oxygen delivery values as a dependent variable and oxygen saturation at admission, echographic and clinical score, echographic parameters (TEI, TEE, DE, IS), age, symptoms onset, and weight as independent variables yielded a single variable model ($r = 0.637$, $r^2 = 0{,}405$). This model included the end inspiration thickness ($t = 3.089$, $P = 0.008$; $R = 0.637$ $R2 = 0.405$).

4 | DISCUSSION

This is the first study evaluating diaphragmatic function through POCUS in previously healthy children with bronchiolitis. We found different respiratory parameters (DE, IS, TEI, TF, and ecographic score) that correlated with length of stay, hours of oxygen delivered and the need for respiratory support, giving a new tool to help the emergency pediatrician to guide his evaluation for children with bronchiolitis.

To our knowledge, no previous studies assessed these findings in this category of patients, representing the most frequent reason of ED admission during cold months, and no reference values are available.

TABLE 1 General and clinical characteristics for the study population

	Patients 61	Respiratory support (*N* 25)	No respiratory support 36	*P*
Males (%)	31 (50.8)	10 (40)	21 (58.3)	ns
Age, months	2.84 (2.25–6.20)	3.1 (2.3–6.16)	2.46 (1.7–6.0)	ns
Weight, kg	5.93 ± 1.67	5.94 ± 1.76	6.0 ± 1.70	ns
Height, cm	60.03 ± 6.6	60.50 ± 6.58	59.82 ± 7.14	ns
Time from onset to ED evaluation, days	2.0 (1.0–3.0)	2 (1.25-3)	2 (1-3)	ns
Heart Rate, per minute	148.66 ± 20.44	153.10 ± 22.57	144.30 ± 17.45	ns
Respiratory Rate, per minute	48.13 ± 12.59	50.09 ± 11.72	46 ± 13.93	ns
Mean SatO2 at first evaluation, %	97.86 ± 2.67	96.36 ± 3.14	99.0 ± 1.49	**0.003**
RSV +	29 (54.1)	16 (64)	12 (33.3)	**0.01**
RSV A	12 (42.9)	7 (43.8)	5 (41.7)	ns
Co infections	11 (22.3)	7 (28)	4 (11.2)	ns
Clinical score				
Mild	42.1%	5 (20)	20 (60.6)	0.002
Moderate	48.3%	15 (60)	13 (39.4)	ns
Severe	8.6%	5 (20)	0	0.007
Eco score				
Normal	23%	2 (8)	12 (33.3)	0.02
Mild	63.9%	17 (68)	22 (61.1)	ns
Moderate	13.1%	6 (24)	2 (5.6)	**0.03**
Length of oxygen delivery (hours)	96 (48-144)			
HFNC	25 (41)			
Helmet cpap	7 (11.5)			
Mechanical ventilation	2 (3.3)			
Days of admission	4.0 (2.0-6.5)	7 (4.5-9.5)	2 (0-4)	**0.001**

Variables are expressed as percentages, arithmetic means ± SD or median (interquartile range, IQR). SaO2, haemoglobin oxygen saturation; RSV, respiratory sincitial virus; HFNC, high flow nasal cannula.
Bold values signifies statistically significant results.

Until recently, the emergency physician could only count on clinical findings, but there is a growing interest in discovering easy to obtain, objective/measureable parameters to guide the physician in clinical decision.

In fact, the concept of prevention and treatment strategies that take individual variability into account (the so called "precision medicine") is emerging as a priority.[32]

Traditionally, genomic and proteomic concepts have been included in this individualized approach[33]; however, the concept of precision medicine can be easily applied to POCUS as suggested by a recent review by Kessler et al.[34,35] This is particularly true about pediatric patients since their anatomy and physiology vary widely across the age spectrum, and particularly true for the emergency pediatricians which face unpredictable situations and need to move beyond fix protocols, tailoring the practice to the acute needs of each ill or injured emergent patient.

Therefore, this approach may have several procedural and therapeutic implications and, among these, diaphragm bed-side US evaluation is having a growing interest among researchers.

The diaphragm is the most important respiratory muscle and its function can be impaired by several factors, such as mechanical ventilation, pulmonary pathologies and thoracic and abdominal surgery,[36,37] causing diaphragmatic dysfunction, that has itself diagnostic and outcome implications,[38,39] being associated with respiratory insufficiency, prolonged mechanical ventilation,[40] and prolonged intensive care unit length of stay.[41]

TABLE 2 Diaphragmatic parameters in the study population

Diaphragmatic parameters	Patients 61
IScm/s	0.31 ± 0.11
EET, mm	2.19 ± 0.62
EIT, mm	3.17 ± 0.72
RAD, cm/s	0.73 ± 0.26
TF, %	49.0 (28.57-64.77)
DE, mm	10.38 ± 4.0
I/E	0.46 ± 0.15

Variables are expressed as arithmetic means ± SD or median (interquartile range, IQR).

TABLE 3 Correlations between diaphragmatic parameters and outcome

	Respiratory support			Clin score				Eco score				Bonferroni post hoc test *P*		
	Yes	No	*P*	Mild	Moderate	Severe	*P*	Normal (1)	Mild (2)	Moderate (3)	*P*	1 vs 3	2 vs 3	1 vs 2
IS	**0.337 ± 0.18**	**0.243 ± 0.061**	**0.007**	0.32 ± 0.12	0.30 ± 0.10	0.33 ± 0.16	ns	**0.24 ± 0.08**	**0.27 ± 0.08**	**0.39 ± 0.11**	**0.008**	**0.016**	**0.017**	ns
EET	2.13 ± 0.38	2.17 ± 0.71	ns	2.13 ± 0.64	2.23 ± 0.65	2.3 ± 0.36	ns	2.02 ± 0.45	2.27 ± 0.70	2.13 ± 0.42	ns	ns	ns	ns
EIT	2.98 ± 0.45	3.25 ± 0.85	ns	3.08 ± 0.72	3.31 ± 0.74	2.88 ± 0.40	ns	3.09 ± 0.55	3.22 ± 0.83	3.03 ± 0.26	ns	ns	ns	ns
RAD	0.718 ± 0.261	0.711 ± 0.269	ns	0.71 ± 0.25	0.72 ± 0.27	0.80 ± 0.27	ns	0.79 ± 0.39	0.68 ± 0.23	0.81 ± 0.18	ns	ns	ns	ns
TF (%)	41.66 (22.91-62.82)	55.55 (35.35-71.42)	0.061	47.05 (31.25–64.70) bb	55.55 (33.33-65.00)	17.85 (13.75–44.62)	ns	62.5 (33.73-75.18)	47.05 (28.12-62.82)	46.0 (22.88-63.52)	ns	ns	ns	ns
I/E	0.50 ± 0.13	0.41 ± 0.16	0.067	0.50 ± 0.12	0.45 ± 0.16	0.43 ± 0.25	ns	0.43 ± 0.18	0.47 ± 0.16	0.48 ± 0.10	ns	ns	ns	ns
DE (mm)	10.00 ± 3.93	11.17 ± 4.01	ns	10.31 ± 4.50	10.18 ± 3.52	11.45 ± 3.67	ns	10.94 ± 3.81	11.31 ± 4.01	7.45 ± 2.76	0.065	**0.045**	**0.023**	ns

Variables are expressed as percentagesm arithmetic means ± SD or median, (interquartile range, IQR). Ns, non significant. EET, end expiratory thickness, mm; EIT, end expiratory thickness, mm; RAD, respiratory act duration; IS, nspiratory slope; TF, thickness fraction; DE, escursione diaframma mm.
Bold values signifies statistically significant results.

Other clinical effects of diaphragmatic dysfunction may include rapid shallow breathing, paradoxical inward movement of the abdomen on inspiration, recurrent pulmonary infection, restrictive pattern on lung function test, and hemidiaphragm elevation on chest radiography.[42,43] Moreover, diaphragmatic dysfunction is recognized as an important cause for increased respiratory load.[44–46] Its prompt recognition is important in order to diagnose impending respiratory failure when clinical symptoms are still borderline. Therefore, an accurate and rapid assessment of the diaphragm is a potentially useful tool for clinicians[46] especially in emergency settings. This is particularly useful if we consider the described subjectivity of the most used clinical parameters in the evaluation of bronchiolitis in the ED.[13–15] In fact, hospital admissions for infants with bronchiolitis have increased significantly in recent years while the admission rates to intensive care units remained mostly unchanged,[47] suggesting that the increasing admission rate may be related to a changing health services landscape and probably the so called defensive medicine, rather than an increase in the overall severity of bronchiolitis. In this regard, an instrumental and measurable numeric evaluation with clear medical documentation may help the clinician in more objective evaluation of the infant in the ED.

Diaphragmatic ultrasound has been proven to be a noninvasive, easily performed and learned with a short learning curve, and a reliable tool in assessing diaphragm function.[48–49] Most of the described studies have been performed in adult[50–67] patients in intensive care unit (either mechanically ventilated or post operative patients) and very few studies have been performed in children.[61,64–65,68]

In particular, a recent review by Zambon et al[48] found 17 studies on adult patients that evaluated diaphragm dysfunction (DD) or paralysis in critically ill patients[44]; DD to predict success/failure from mechanical ventilation[44,50–52]; and to assess the performance of DD measurements as indexes of respiratory effort in mechanically ventilated patients.[53–56]

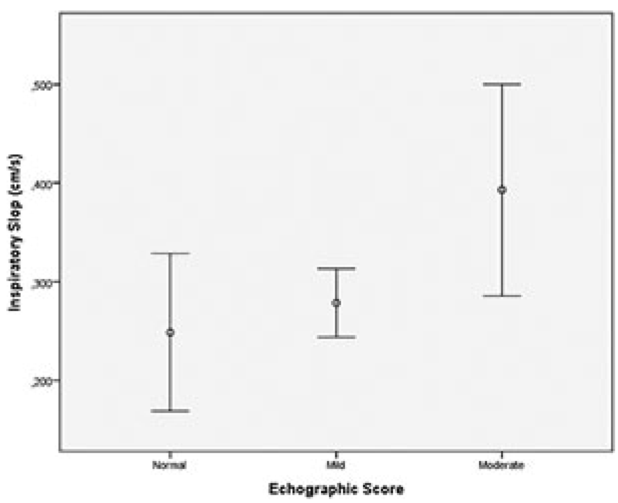

FIGURE 2 Difference in inspiratory slope (cm/s) between the different ecographic score groups

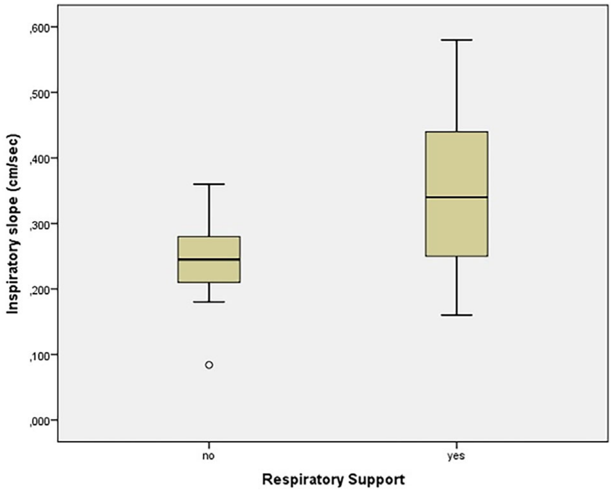

FIGURE 3 Difference in inspiratory slope (cm/s) according to the need for respiratory support

In particular, DD diagnosed with ultrasound was found in 29% of mechanically ventilated patients without history of diaphragmatic or neuromuscular disease.[44]

Either diaphragm excursion or thickening fraction measurements performed during a spontaneous breathing trial in intubated patients have shown good performance as weaning indexes. the thickening fraction has shown significant correlation, thus emerging as a new noninvasive tool to monitor respiratory workload during assisted mechanical ventilation.

Several parameters have been studied to evaluate diaphragm function: 11 studies (51, 53, 57-79) measured diaphragmatic thickness, seven of them[48,51–53,55,56,60] assessing diaphragmatic contractility as thickening fraction. Five studies[44,56,61–63] measured respiratory excursion of the diaphragm in M-mode, five studies[54,63–66] measured diaphragm excursion in B-mode.[67]

To our knowledge, our study is the first one evaluating all the evaluable parameters in every single patients and the only one evaluating otherwise healthy pediatric patients with respiratory conditions. In fact, in current literature we found three studies[61,64,65] conducted on pediatric ill patients (either post operative or mechanically ventilated patients),[67] and only one study on pediatric healthy patients.[68] Using these last literature parameters and comparing them to our findings, we found that mean right DE was 10.38 ± 4 mm in our bronchiolitis patients compared to 6.4 ± 2.1 in healthy reference children. Similarly, when we compared those children with our patients according to weight, we found that healthy children had a median 5.8 mm excursion, about half excursion of our bronchiolitis children, suggesting a deeper DE in infants with respiratory distress. Interestingly, DE was one of the most important prognostic factors in our study, as well as IS and TEI, suggesting that higher inspiratory efforts where correlated with worse outcome. TEI, in fact, was strongly associated with the length of oxygen delivery and the future need of non invasive respiratory support during admission and with length of admission ($P < 0.05$). Another interesting finding was the lower TF in patients with severe bronchiolitis, indicating incipient diaphragm dysfunction in these infants, though there was no statistically significant difference when comparing between the all clinical score groups, probably due to the low number of patients with severe clinical score. One important consideration is that all these parameters are easy to measure and require a few minutes during routine clinical examination, allowing the emergency pediatrician to perform a really deep and respiratory system-focused examination of the patient. Moreover, the M-mode examination of diaphragm movements allow the physician to perform a "point-of-care spyrometry-like" evaluation of the child.

As described by Basile et al[26] our findings confirm the correlation between clinical and ecographic score. Moreover, in our study, ecographic score correlated with hours of oxygen delivery (and therefore to length of admission) and with DE and inspiratory slope, suggesting this tool might be another instrument for the emergency pediatrician to predict bronchiolitis outcome.

We acknowledge some limitations. First, it might be difficult to evaluate breath-by-breath variability in infants; however, we waited until we ensured quiet regular breathing, and we took an average of at least three respiratory cycles during our assessment. Secondly, our study had a relatively small sample size (mainly because we excluded all comorbidities in order to have a more homogeneous group and included only infants 1 to 12 month of age considering that in current literature there is no definitive agreement about age limitation.[18–20] Third, we did now included in this first study a control group.

Nevertheless, to our knowledge, no previous studies assessed sonographic measurements of so many diaphragmatic parameters in otherwise healthy infants with bronchiolitis, giving for the first time

TABLE 4 Percentiles of IS and DE in the study population

Percentiles	IS, cm/s	IS (no respiratory support), cm/s	IS (with respiratory support), cm/s	DE, mm
5th	0.16	0.084	0.16	5.27
10th	0.20	0.17	0.22	5.6
25th	0.22	0.20	0.24	7.22
50th	0.27	0.24	0.34	10.10
75th	0.35	0.28	0.44	13.80
90th	0.45	0.32	0.48	16.90
95th	0.49	0.36	0.57	17.50

IS, inspiratory slope; DE, diaphragm excursion.

reference values for this specific population and new prognostic elements to predict those children which may need respiratory support and, therefore, admission.

Bedside critical-care ultrasound semiology of the diaphragm, alongside with routine examination, can be easily performed (requiring a 1 to 3 min per evaluation) by a trained emergency pediatrician and may allow for the monitoring and evaluation of the respiratory function of infants with bronchiolitis and therefore guide further clinical management.[49,69] In our experience, this evaluation was performed during routine clinical examination during each rotation (morning, afternoon and night as part of a routine visit. Randomized, double blinded, placebo controlled studies may be needed to confirm our results and to better define the clinical utility of diaphragm ultrasound in managing infants with bronchiolitis and other respiratory diseases in the emergency room and during admission in different settings. Such an approach would give the emergency physician, for the first time, an objective, easy and quick to measure, parameter to quantify respiratory distress in infants with bronchiolitis and other respiratory disorders.

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CONFLICTS OF INTEREST

No conflict of interests to declare.

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