Med. J. Cairo Univ., Vol. 86, No. 6, September: 3093-3098, 2018
www.medicaljournalofcairouniversity.net

Role of Pulmonary Sonography in Evaluation of Artificially Ventilated Neonates

AHMED H. SHEHATA, M.Sc.; ABD EL-RAHMAN M. EL-MASHAD, M.D.;
MOHAMMED A. EL-TOMY, M.D. and MOHAMMED A. NASSAR, M.D.

The Department of Pediatrics, Faculty of Medicine, Tanta University

Abstract

Background: Several neonatal chest conditions require Invasive mechanical ventilation, which is lifesaving for the critically ill neonates. Limiting the duration of airway intubation and mechanical ventilator support is crucial. Weaning from mechanical ventilation induces significant changes in lung aeration which can be easily detected by lung sonography.

Aim of the Work: Is to identify the role of pulmonary sonography in evaluation of the artificially ventilated neonates.

Patients and Methods: The study included 40 neonates suffering from peripheral diseases requiring mechanical ventilation. All patients had chest ultrasound studies after clinical assessment. Chest ultrasound was performed during the different modes of mechanical ventilation including Assisted Controlled Ventilation (AC), Synchronized Intermittent Mechanical Ventilation (SIMV) and before extubation, follow-up the patients for 48 hours postextubation to assess if its failure occurred. Lung ultrasound was done using a standardized evaluation of lung aeration, i.e. Lung Ultrasound Score (LUS). Other traditional investigations including blood gases and chest X-ray were performed as well.

Results: LUS was significantly higher in the 10 patients with post extubation failure. A cut off value of LUS of >13 was highly sensitive and specific for failure of switching from AC to SIMV mode and >6 prior to extubation was indicative of post extubation failure.

Conclusion: Chest ultrasound provides a rapid, non invasive, objective and reliable tool for guiding the mechanical ventilation weaning process in neonates through the LUS with high confidence even when compared to other traditional indices as blood gases and respiratory mechanics. A cut off value of LUS of >13 was highly sensitive and specific for failure of switching from AC to SIMV mode and >6 prior to extubation was indicative of post extubation failure.

Key Words: *Lung ultrasound – Mechanical ventilation – AC mode – SIMV mode – Extubation.*

Introduction

THE incidence of pulmonary complications related to mechanical ventilation is an important issue among critically ill patient. Reducing the duration of respiratory support is essential for minimizing these complications. The extubation of a patient marks the end of the weaning process. Unfortunately, even after a successful spontaneous breathing trial (SBT), approximately 30% of patients develop respiratory distress within 48h hours of extubation; this results in extubation failure and requires either therapeutic non-invasive ventilation or reintubation [1]. The loss of pulmonary aeration following extubation is a hallmark of extubation failure, leading to impaired gas exchange, prolonged mechanical ventilation, and increased morbidity and mortality [2].

The amount of lung aeration loss can be quantified via lung ultrasound during different clinical conditions including the weaning process. It is a non-invasive and radiation-free procedure, which can be performed quickly at the bedside and enables a dynamic assessment of lung aeration changes depending on ventilation conditions, as opposed to a chest X-ray. For many years, lungs were not considered accessible by ultrasound waves. However, the artifacts produced at the interface between lungs and fluids can be easily indentified by lung ultrasound [3].

Although chest radiography is routinely performed, it has limited diagnostic performance, and lung computed tomography (CT) remains the reference methods. Ultrasonography can be used at the bedside and gained widespread acceptance even in unexpected situations such as tracheal intubation [4].

Lung aeration loss can be estimated by using a validated score called the Lung Ultrasound Score (LUS). As previously recommended, all of the intercostal spaces of the anterior, lateral and posterior regions of both lungs (6 regions per side) are evaluated [5].

Correspondence to: Dr. Ahmed H. Shehata, The Department of Pediatrics, Faculty of Medicine, Tanta University

Aim of the work: Is to identify the role of pulmonary sonography in evaluation of the artificially ventilated neonates.

Patients and Methods

This observational study was carried out on a randomly selected 40 neonates on mechanical ventilation suffering from peripheral respiratory disease in the neonatal care unit of Tanta University Hospital during the period from June 2016 to December 2016.

All patients were subjected to:

A- Full history taking and thorough clinical examination.

B- Investigations: Complete blood count, C reactive protein (CRP), capillary blood gases, serum electrolytes (Na, K).

C- Plain chest X-ray: Chest X-ray was performed after admission with the patient in supine position as anteroposterior view using portable X-ray device.

D- Chest ultrasound: It was performed by a single expert who was blind to the clinical and radiological diagnosis. Lung ultrasound was done using the portable ultrasound device (SIEMENS ACUSON X300) using 12-MHz resolution and linear ultrasound transducer.

The lung ultrasound was done three times maximum using lung ultrasound score (LUS). Firstly, at the time of intubation, then before switching from pressure controlled ventilation (PCV) mode to synchronized intermittent mechanical ventilation (SIMV) mode, lastly, before extubation. Follow-up of the patient was done for 48 hours after extubation to assess post extubation failure.

Lung ultrasound was done using a standardized evaluation of lung aeration (lung ultrasound score) by assessing the aeration for each hemi-thorax as follow:

Upper and lower parts of anterior, lateral and posterior area of the lung (12 areas). For a given region of interest, each intercostal space was scanned and a number of points was allocated according to the most severe abnormality: Normal aeration (lung sliding with A-lines or less than two isolated B-lines; 0 point), moderate loss of aeration (3 or more separated B-lines; 1 point), severe loss of aeration (coalescent B-lines/curtain sign; 2 points), and lung consolidation (3 points). The LUS was calculated as the sum of points and ranged between 0 and 36 points. This score is similar for full term and preterm neonates and can be applied for both.

Results

Table (1) shows that lung ultrasound score during A/C mode reveals significantly lower score in the success group compared to the failed group (p=0.007). LUS in success group was ranging from 9 to 36 with mean 24.1 ±8.88 and the (LUS) lung ultrasound score in failed group was ranging from 21 to 36 with mean 32.89±5.28.

Table (1): Comparison between the LUS in success and failed extubation according to assisted controlled ventilation.

	Total (n=29)	Success extubation (n=20)	Failed extubation (n=9)	U	*p*
AC mode:					
Min. – Max.	9.0–36.0	9.0–36.0	21.0–36.0		
Mean ± SD.	26.83±8.86	24.10±8.88	32.89±5.28	34.00*	0.007*
Median	30.0	26.0	36.0		

Table (2) show that the lung ultrasound score during AC mode was significantly higher in left lung than the right one (p=0.005).

Table (2): Comparison between total lung ultrasound score in right and left lung according to assisted controlled ventilation.

AC	Right	Left	Z	*p*
AU:				
Min. – Max.	0.0–3.0	1.0–3.0	2.601*	0.009*
Mean ± SD.	1.76±1.15	2.31±0.76		
Median	2.0	2.0		
AL:				
Min. – Max.	0.0–3.0	1.0–3.0	2.392*	0.017*
Mean ± SD.	1.79±1.05	2.17±0.89		
Median	2.0	2.0		
LU:				
Min. – Max.	0.0–3.0	0.0–3.0	1.155	0.248
Mean ± SD.	2.34±0.90	2.17±1.20		
Median	3.0	3.0		
LL:				
Min. – Max.	0.0–3.0	0.0–r3.0	0.378	0.705
Mean ± SD.	2.24±0.99	2.28±1.03		
Median	3.0	3.0		
PU:				
Min. – Max.	0.0–3.0	1.0–3.0	2.126*	0.003*
Mean ± SD.	2.28±1.07	2.62±0.68		
Median	3.0	3.0		
PL:				
Min. – Max.	0.0–3.0	1.0–3.0	1.933	0.053
Mean ± SD.	2.28±1.07	2.59±0.73		
Median	3.0	3.0		
Total:				
Min. – Max.	5.0–18.0	4.0–18.0	2.802*	0.005*
Mean ± SD.	12.69±4.78	14.14±4.41		
Median	14.0	16.0		

Table (3) shows that lung ultrasound score during SIMV mode reveals significantly lower score in the success group compared to the failed group (p<0.001). LUS in success group was ranging from 5 to 16 with mean 7.57 ±3.5 and the LUS in failed group was ranging from 13 to 20 with mean 16.7±2.26.

Table (3): Comparison between the LUS in success and failed extubation according to SIMV mode.

	Total (n=40)	Success extubation (n=30)	Failed extubation (n=10)	U	*p*
SIMV mode:					
Min. – Max.	5.0–20.0	5.0–16.0	13.0–20.0		
Mean ± SD.	9.85±5.13	7.57±3.50	16.70±2.26	15.50*	<0.001*
Median	7.50	6.0	16.0		

Table (4) show that there is significant difference in lung ultrasound score between right and left lung during SIMV mode.

Table (4): Comparison between total lung ultrasound score in right and left lung according to SIMV mode.

AC	Right	Left	Z	*p*
AU:				
Min. – Max.	0.0–2.0	0.0–2.0	2.829	0.005*
Mean ± SD.	0.83±0.81	1.15±0.66		
Median	1.0	1.0		
AL:				
Min. – Max.	0.0–2.0	0.0–2.0	0.677	0.499
Mean ± SD.	1.05±0.81	1.13±0.65		
Median	1.0	1.0		
LU:				
Min. – Max.	0.0–1.0	0.0–2.0	1.000	0.317
Mean ± SD.	0.30±0.46	0.38±0.59		
Median	0.0	0.0		
LL:				
Min. – Max.	0.0–1.0	0.0–2.0	0.302	0.763
Mean ± SD.	0.35±0.48	0.38±0.54		
Median	0.0	0.0		
PU:				
Min. – Max.	0.0–2.0	0.0–1.0	2.486*	0.013*
Mean ± SD.	0.65±0.58	0.40±0.50		
Median	1.0	0.0		
PL:				
Min. – Max.	0.0–2.0	0.0–2.0	1.303	0.193
Mean ± SD.	0.58±0.59	0.43±0.55		
Median	1.0	0.0		
Total:				
Min. – Max.	0.0–8.0	0.0–8.0	0.3 89	0.697
Mean ± SD.	3.75±1.90	3.85±1.96		
Median	3.0	4.0		

Table (5) shows that lung ultrasound score before extubation reveals significantly lower score in the success group compared to the failed group (p<0.001). LUS in success group was ranging from 0 to 6 with mean 3.23±3.66 and the LUS in failed group was ranging from 7 to 13 with mean 8.7±2.54.

Table (5): Comparison between the LUS in success and failed extubation according to before extubation.

	Total (n=40)	Success (n=3 0)	Failed (n=10)	U	*p*
Before extubation:					
Min. = Max.	0.0–13.0	0.0–6.0	7.0–13.0	0.0*	<0.001*
Mean ± SD.	3.23±3.66	1.40±1.50	8.70±2.54		
Median	2.0	1.0	7.0		

Table (6) show that the lung ultrasound score before extubation is significantly higher in left lung than the right one (p=0.001).

Table (6): Comparison between total lung ultrasound score in right and left lung according to before extubation.

Before extubation	Right	Left	Z	*p*
AU:				
Min. = Max.	0.0–1.0	0.0–1.0	2.33 3*	0.020*
Mean ± SD.	0.23±0.42	0.05±0.22		
Median	0.0	0.0		
AL:				
Min. = Max.	0.0–1.0	0.0–0.0	3.000*	0.003*
Mean ± SD.	0.23±0.42	0.0±0.0		
Median	0.0	0.0		
LU:				
Min. = Max.	0.0–1.0	0.0–1.0	0.447	0.655
Mean ± SD.	0.10±0.30	0.08±0.27		
Median	0.0	0.0		
LL:				
Min. = Max.	0.0–2.0	0.0–1.0	1.000	0.317
Mean ± SD.	0.13±0.40	0.05±0.22		
Median	0.0	0.0		
PU:				
Min. = Max.	0.0–1.0	0.0–1.0	0.000	1.000
Mean ± SD.	0.05±0.22	0.05±0.22		
Median	0.0	0.0		
PL:				
Min. = Max.	0.0–1.0	0.0–1.0	1.414	0.157
Mean ± SD.	0.23±0.42	0.13±0.33		
Median	0.0	0.0		
Total:				
Min. = Max.	0.0–5.0	0.0–2.0	3.452	0.001
Mean ± SD.	0.95±1.18	0.35±0.58		
Median	1.0	0.0		

Table (7) shows the cut off points, sensitivity and specificity of lung ultrasound score in different mechanical ventilation modes to predict the failed extubation cases, on SIMV mode the cut off point is >13 with sensitivity 90% and specificity 86.67%, before extubation the cut off point is >6 with sensitivity and specificity up to 100%.

Table (7): Agreement (sensitivity, specificity) for different parameters to predict failed cases.

	AUC	*p*	95% C.I	Cut off	Sensitivity	Specificity	PPV	NPV
SIMV mode	0.944	<0.001*	0.867–1.022	>13	90.0	86.67	69.0	96.3
Before extubation	1.000	<0.001*	1.0– 1.0	>6	100.0	100.0	100.0	100.0

Table (8) and Fig. (2) show that all neonates included were subjected to plain X-ray chest after admission. Chest X-ray findings were suggestive of RDS grade 2 in 13 (32.5%), RDS grade3 in 5 (12.5%), RDS grade 4 in 3 (7.5%), TTN in 15 (37.5%), meconium in 3 (7.5%) and pneumonia in 1 (2.5%).

Table (8): Distribution of the studied cases according to X-ray (n=40)

	No.	%
X-ray:		
RDS grade 2	13	32.5
RDS grade 3	5	12.5
RDS grade 4	3	7.5
TTN	15	37.5
Meconium	3	7.5
Pneumonia	1	2.5

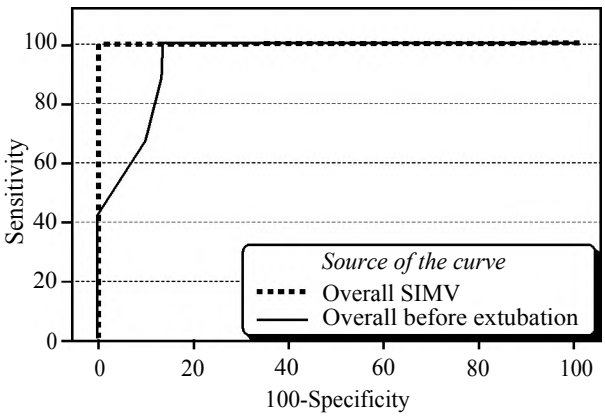

Fig. (1): ROC curve for different parameters to predict failed cases.

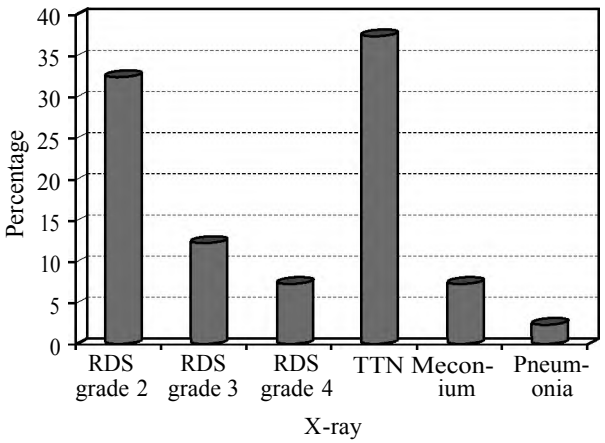

Fig. (2): Distribution of the studied cases according to X-ray (n=40).

Discussion

This study is an observational study evaluating the role of lung ultrasonography in weaning of mechanically ventilated neonates with peripheral respiratory diseases. It included 50 neonates 10 of them died and was discarded from the research due to failed weaning from the mechanical ventilation, the other 40 neonates were finally diagnosed as transient tachypnea of newborn (15 neonates), respiratory distress syndrome (21 neonates), meconium aspiration (3 neonates) and congenital pneumonia (1 neonates). All of them were subjected to chest ultrasound by a single expert.

In this study, LUS was significantly higher in failed group than in success group due to decreased lung aeration with mean±SD 24.1±8.88 in success group and mean±SD 32.89±5.28 in failed group, such values regarding patients on AC mode of mechanical ventilation. This is in agreement with Caltabeloti F et al who reported that failed extubation group showed high LUS on the contrary to the success extubation group that showed low LUS [6]. On SIMV mode of mechanical ventilation we found the same result as the success group showed statistically significant lower score than in failed group that is in accordance with Boles JM et al., who reported the same result in their study [1]. Jubran A et al., found high LUS in failed extubation and the need for reintubation for this group [7]. Lung ultrasound score in success group was ranging from 5 to 16 with mean±SD 7.57±3.5 and in failed group was ranging from 13 to 20 with mean 16.7±2.26.

Lung ultrasound was done before extubation and lung ultrasound score (LUS) was calculated showing that there was statistically significant difference between both groups as there was a lower LUS in post extubation success group than the failed group, the range in success group was from 0 to 6 with mean±SD 1.4± 1.5 but in failed group the LUS was ranging from 7 to 13 with mean±SD 8.7±2.54. Soummer A et al., showed that the patient LUS increased indicating aeration loss and low LUS at the end of spontaneous breathing trials is a predictive of extubation success. On the other hand, high LUS is a predictive of post extubation distress and extubation failure [6]. Also, Caltabeloti et al., reported in their study that LUS

less than 13 is associated with extubation success but post extubation failure occurs with LUS more than 17 **[6]**.

In this study we found that the lung ultrasound score was significantly higher in left lung than right one and according to our best of knowledge we did not found any obvious or clear explanation, but according to the physiological and the anatomical bases it may be due to the narrow diameter and the orifice of the left main bronchus in comparison to the right one **[9]** which may affect the drainage of secretion from the left lung and subsequently affect its aeration. Another point of view explain that this is due to the position of the neonates in the incubators whose position were on left lateral position to prevent aspiration **[10]** this position may affect the good drainage of the secretion from the left lung and leads to bad aeration of the left lung.

According to different modes of mechanical ventilation (AC–SIMV) and before extubation we could predict the failed cases and we found that on AC mode the cut off point was >34 with sensitivity 66.67% and specificity 90%, on SIMV mode the cut off point >13 with sensitivity 90% and specificity 86.67%, and before extubation the cut off point >6 with sensitivity and specificity up to 100%.

Conclusion:

1- Lung ultrasound can be predict weaning success from the mechanical ventilation.
2- Cut off point to switch the mechanical ventilator mode from AC to SIMV is <13.
3- Cut off point to wean the patient from the mechanical ventilation is <6.

Acknowledgments: This research was carried out without funding.

Conflicts of interest: No conflicts of interest declared.

Authors' Contributions: All authors had equal role in design, work, statistical analysis and manuscript writing. All authors have approved the final article work.

References

1- BOLES J.M., BION J., CONNORS A., et al.: Weaning from mechanical ventilation. Eur. Respir. J., 29: 1033-1056, 2007.

2- PEÑUELAS O., FRUTOS-VIVAR F., FERNÁNDEZ C., et al.: Ventilation Group Characteristics and outcomes of ventilated patients according to time to liberation from mechanical ventilation. Am. J. Resp. Crit. Care. Med., 184 (4): 430-7, 2011.

3- FABIOLA C., PERBET S., BRISSON H., et al. (2016): Lung UltrasoundStudy Group. Ultrasound assessment of lung aeration loss during a successful weaning trial predicts postextubation distress. Crit. Care. Med., 40 (7): 2064-72, 2012.

4- COPETTI R. and CATTAROSSI L.: The 'double lung point': an ultrasound sign diagnostic of transient tachypnea of the newborn. Neonatology, 91, 203-209, 2007.

5- ROUBY J.J. and BROCHARD L.: Tidal recruitment and overinflation in acute respiratory distress syndrome: Yin and yang. Am. J. Repir. Crit. Care. Med., 15 (2): 104, 2007.

6- CALTABELOTI F., MONSEL A., ARBELOT C., et al.: Early fluid loading in acute respiratory distress syndrome with septic shock deteriorates lung aeration without impairing arterial oxygenation: A lung ultrasound observational study. Crit. Care., 18 (3): R91, 2014.

7- JUBRAN A., LAWM G., DUFFNER L.A., et al.: Post-traumatic stress disorder after weaning from prolonged mechanical ventilation. Intensive. Care. Med., 36: 2030-2037, 2010.

8- SOUMMER A., PERBET S., BRISSON H., et al.: The lung ultrasound study group: Ultrasound assessment of lung aeration loss during a successful weaning trial predicts postextubation distress. Crit. Care. Med., 40: 2064-72, 2012.

9- MONTAUDEN M., BERGER P., MARTHAN R., et al.: Assessment of airways with three-dimensional quantitative thin-section CT: In vitro and in vivo validation. Radiology, 242: 563-572, 2007.

10- DHILLON A.S. and EWER A.K.: Diagnosis and Management of gastroesophageal reflux in preterm infant in intensive care unit: Acta. Paediatr., 93: 88-93, 2004.

دور الموجات فوق الصوتية على الرئة فى تقييم الأطفال حديثى الولادة على جهاز التنفس الصناعى

إن معدل حدوث المضاعفات الرئوية المتعلقة بالجهاز التنفس الصناعى له من الأمور الهامة بين مرضى الحالات الحرجة. كما أن تقليل مدة الدعم التنفسى مهم لتقليل مثل هذه المضاعفات لسوء الحظ ٣٠٪ من المرضى الذين يتم فصلهم من جهاز التنفس الصناعى رغم محاولات التنفس الذاتى يحدث لهم أضطرابات وصعوبات بالتنفس خلال ٤٨ ساعات عقب عملية الفصل مما قد ينتج عنه فشل عملية الفصل والحاجة إلى إعادة أتصال المريض مرة أخرى بجهاز التنفس الصناعى. إن ضعف التهوية الرئوية هى علامة هامة جداً بالنسبة لفشل الفصل من جهاز التنفس الصناعى مما قد يؤدى إلى خلل بتيادل الغازات بين الحويصلات الهوائية الدموية والشعيرات الدموية بالرئة بالأضافة إلى فترة الأتصال بجهاز التنفس الصناعى وزيادة نسبة الوفيات. يمكن للموجات فوق الصوتية على الرئة أن تحدد كمية نقص التهوية الرئوية فى مختلف الحالات الأكلينيكية بما فيها عملية الفصل من جهاز التنفس الصناعى وما يميز الموجات فوق الصوتية كونها آمنة لا ينتج عنها إشعاعات بجانب أنها سهلة وسريعة التطبيق ويمكن إستخدامها كفحص سريرى للمريض على عكس الأشعة السينية (أشعة إكس). عدة سنوات مضت لم تكن الرئة مكان جيد لمرور الموجات فوق الصوتية والآن وقد تم ملاحظة ظهور لعض العلامات فى السطح ما بين الرئة والسوائل بداخلها والتى أصبح من السهل رؤيتها بواسطة سونار الرئة. على الرغم من إستخدام الموجات فوق الصوتية على الرئة بشكل روتينى، إلا أن لها حدود فى الأداء التشخيصى مقارنة بالأشعة المقطعية لكن ما يميز الموجات فوق الصوتية هى إمكانية إستخدامها بجانب المريض بالإضافة آثناء تواجد المريض على جهاز التنفس الصناعى. يمكننا تقييم فقد التهوية الرئوية عن طريق سكور يدعى سكور السونار الرئوى.

الهدف من الدراسة: دور الموجات فوق الصوتية على الرئة فى تقييم الأطفال حديثى الولادة على جهاز التنفس الصناعى.

المرضى وطرق البحث: تم أجراء البحث على عدد ٤٠ طفلاً من حديثى الولادة المصابين بأعراض ضيق التنفس نتيجة ضيق النفس العابر، ميلازمة ضيق التنفس لدى الأطفال الخدع أو الألتهاب الرئوى الخلقى تكون أعراض تلك الأمراض على هيئة زيادة معدل التنفس عن ٦٠ دورة فى الدقيقة، تراجع جدار الصدر، الشخير والزرقة مع وجود بعض العلامات المسموعة على الصدر كأصوات الشخشخة، الفرقعة، نقص دخول الهواء على الرئتين أو صوت التنفس الشعبى.

النتائج: بخصوص الموجات فوق الصوتية على الصدر، لاحظنا أختلافاً ملحوظاً بين الأطفال الذين تم فصلهم من جهاز التنفس الصناعى مقارنة بالأطفال الذين فشل فصلهم، حيث لاحظنا زيادة سكور سونار الرئة فى الأطفال الذين تم فصلهم بنجاح وذلك خلال جميع الفحوصات بالموجات فوق الصوتية التى تم عملها أثناء الأنظمة المختلفة فى جهاز التنفس الصناعي بالأضافة إلى الفحص الذى تم عمله قبل الفصل مباشرة.

الأستنتاج: الموجات الفوق الصوتية على الرئة لها دور مهم فى الأطفال حديثى الولادة .

التوصيات: يوصى بعمل دراسات أخرى بنطاق أوسع وتشتمل على عدد أكبر من الأطفال حديثى الولادة. تدريب عدد مناسب من الأفراد خاصة بين الأطباء المعالجين على عمل الموجات الفوق الصوتية على الصدر لدى الأطفال حديثى الولادة وكذلك على كيفية قراءة العلامات الظاهرة بهذه الموجات. أهمية عمل الموجات الفوق الصوتية على الرئة للأ طفال حديثى الولادة على جهاز التنفس الصناعي قبل أتخاذ قرار الفصل من الجهاز.