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Original Article

Paediatrics Section

Comparing the Results of Chest X-ray with Chest Ultrasound in Neonates Admitted in Neonatal Intensive Care Unit

ELHAM ZAREI, VAHID ALIZADEH

ABSTRACT

Introduction: Chest X-ray (CXR) is the potential method for the diagnosis of pulmonary disorders. It has been using in respiratory distress syndrome detection in neonates.

Aim: To compare the diagnostic accuracy of lung sonography against the CXR in Acute Respiratory Distress Syndrome (ARDS) in newborn babies admitted in Neonatal Intensive Care Unit (NICU).

Materials and Methods: This cross-sectional study was conducted on newborns admitted in NICU ward during July 2016 to April 2017. The recorded data includes gender, gestational age at birth and bedside trans-thoracic chest ultrasonography from the neonates, which were undergone anterior-posterior CXR by the clinical physician. The chest sonography was accomplished longitudinally from anterior and lateral chest. Two different expert radiologists performed the interpretation of CXR and sonography without knowledge about the results of other test.

Results: Total 134 newborns were enrolled in this study containing 75 males (55.9%). Seven cases had congenital abnormality including diaphragmatic hernia and situs inversus. Pneumothorax and pleural effusion were detected in eight and four cases, respectively. All these diagnoses were confirmed by both CXR and chest sonography. The most prevalent findings in CXR were haziness and consolidation. Chest sonography showed abnormal pleural line in 55 newborns (41%), more than three B-lines in 44 cases (32.8%), white lung in 31 newborns (23.1%) and consolidation in 38 patients (8.4%). Chest ultrasonography had 89.09% (95% CI, 81.72%-94.23%) sensitivity and 95% (95% CI, 75.13%-99.87%) specificity for diagnosis of chest abnormalities in NICU-admitted neonates.

Conclusion: Although, sonography has good potential for diagnosis of chest pathologies in newborns, it seems it is not the first step for assessing the newborns' chest, instead of CXR. However, chest sonography is so valuable for serial follow-ups and as a supplementary technique in suspicious CXRs.

Keywords: Acute respiratory distress syndrome, Neonate, Radiography, Thoracic sonography

INTRODUCTION

Chest imaging with X-ray (CXR) has high diagnostic potential in some disorders such as respiratory distress syndrome in neonates [1]. This technique has also the potential of assessing the treatment response and evaluating the complications following treatment. However, although CXR has great potential in diagnosis of respiratory problems, the ionising radiation to the neonates is not without risk and may have destructive effects [2,3].

Several studies have conducted about using of ultra-sonography in NICUs and have showed that sonography is beneficial in diagnosing neurological, cardiological and abdominal disorders. The merits of sonography include low cost, the lack of necessity to separate the neonate from incubator, repeatability, no ionising radiation and being fast. Of course, this technique has some limitations in pulmonary evaluations. High amount of air in these organs results in reduction in penetration of ultrasound beam and the images from normal lungs have artifacts. Moreover, ultrasonography has lately been used in some situations like emergency department and adult intensive care unit for diagnosis of pulmonary conditions e.g., pneumothorax, interstitial alveolar syndrome and pleural effusion [4,5], and also diagnosis of pneumonia [6,7] and differentiation of cardiogenic pulmonary oedema from exacerbation of chronic obstructive pulmonary disease [7].

Because of the thinning of thoracic walls in children in comparison to adults, the chest ultrasound is a suitable technique for evaluation of pleural and parenchymal disease in children.

Some researchers have recently indicated that trans-thoracic

sonography could be a valid technique for evaluating the critical pulmonary conditions in neonates such as Transient Tachypnoea of the Newborn (TTN) and Respiratory Distress Syndrome (RDS) [8-11]. There are studies on the supplemental role of diagnostic pulmonary sonography for newborns in NICU; however, these evaluations were limited to exceptional circumstances or the evaluated variables were just the result of sonography [12,13].

MATERIALS AND METHODS

Total 134 neonates admitted in NICU of Ali-Asghar Hospital, Tehran, Iran were enrolled in this retrospective study during July 2016 to April 2017. This study was approved by the ethical committee of Iran University of Medical Sciences, Tehran, Iran and held with accordance with deceleration of Helsinki. The informed consent was obtained from the parents of all the enrolled neonates prior to the study. All neonates who were less than 28 days and diagnosis with ARDS were included in the study. Cases of major congenital malformations or complex congenital heart disease and those who were transferred out of the NICU without treatment were not considered for the study.

The recorded data includes gender, gestational age at birth, and bedside trans-thoracic chest ultrasonography from the neonates which were undergone anterior-posterior CXR by the clinical physician. Evaluated parameters in CXRs were the condition of lung aeration, and also parenchymal findings such as haziness, consolidation, collapse and parahilar reticulation in addition to pleural abnormalities.

Bedside chest sonography was also accomplished in all cases upto 48 hours after CXR. The trans-thoracic sonography has done with sonosite apparatus with superficial probe (high-resolution, more than 7.5 Mega-Hertz frequency) and microconvex in supine position longitudinally from all area of anterior chest and also laterally along the side of posterior axillary line. The duration of chest sonography was at most 5 minutes. The evaluated indices in chest sonography were:-

1. Pleural line with concentration on increasing in its thickness, alteration of its regularity and its movement [Table/Fig-1].

2. Interstitial pattern by evaluating the B-Line and presence of white-lung [Table/Fig-1].

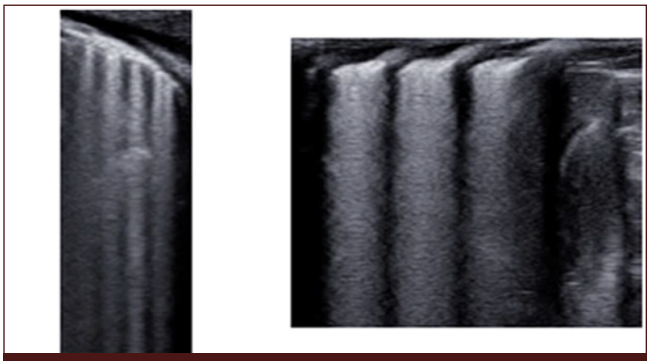
3. Consolidation as focal or sub-pulmonic and/or deep consolidation (sonographic air bronchogram) [Table/Fig-2].

The results of CXR and chest sonography were categorised into three groups:-

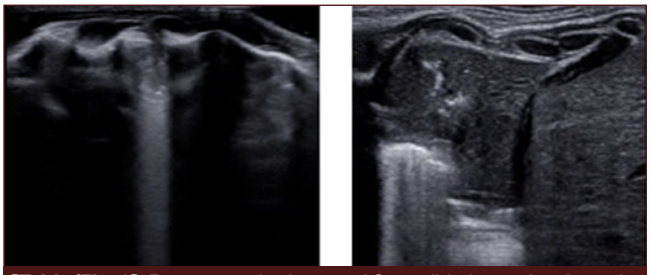
i) Neonates with congenital anomalies.

ii) Neonates with pleural abnormalities.

iii) Other neonates which their lung parenchymal findings were assessed.



[Table/Fig-1]: Repesennative image of Pleural line with concentration and alteration of its regularity and movement (Left) and Interstitial pattern by evaluating the B-Line and presence of white-lung (Right)



[Table/Fig-2]: Repesennative image of Consolidation as focal or sub-pulmonic and/or deep consolidation (sonographic air bronchogram)

STATISTICAL ANALYSIS

The recorded data are presented as mean±standard deviation (SD) and number (percent). The analyses have done using SPSS software version 22.0. The p-value less than 0.05 were considered as statistically significant.

RESULTS

Total 134 neonates were enrolled in this study with mean birth age of 33.52±3.71 weeks. 83 cases (61.9%) were premature and 51 cases (38.1%) were mature. Out of all 75 neonates (55.9%) were male and 59 neonates (44.1%) were female. The mean birth weight of neonates was 2151.89±846.19 grams (600 to 3800 grams) [Table/Fig-3]. The imaging results of this study were categorised into three groups:-

i) The neonates with congenital disorders.

ii) The neonates with pleural abnormalities.

iii) The other neonates in which all ultrasonography and CXR findings had recorded in a check list previously.

During the study seven cases of anomaly have been recorded. Six neonates had diaphragmatic hernia and one neonate had situs inversus all of which were detected in both ultrasonography and X-ray imaging. Twelve neonates had pleural abnormalities which eight cases had pneumothorax and four cases had pleural effusion. Seven cases with pneumothorax had been diagnosed

with X-ray which has been detected in sonography by absence of B-line and sliding in pleural line and also its confirmation in M mode by Barcode view. In one case the pneumothorax was not diagnosed in X-ray, but it was identified in ultrasonography.

Variables			Number or Mean± SD	Percent (%)
Demographic Features				
Gestational Age at Birth (week)			33.52± 3.71	-
Prematurity			83	61.9
Male			75	55.9
Birth-Weight (g)			2151.89± 846.19	-
Imaging Findings				
Chest X-ray Findings	Aeration	Normal-aeration	105	78.4
		Hyper-aeration	16	11.9
		Hypo-aeration	13	9.7
	Parenchymal Findings	Normal	26	19.4
		Reticulation	7	5.2
		Collapse	2	1.5
		Consolidation	12	8.9
		Haziness	77	57.5
		Haziness+ Collapse	3	2.2
		Haziness+ Consolidation	3	2.2
		Reticulation+ Pleural Space	1	0.7
		Reticulation+ Haziness	3	2.2
Chest USG Findings	Pleural Line	Normal	79	58.9
		Abnormal (irregular or thick)	55	41
	B-Line	Normal	59	44
		Positive-more than 3 lines	44	32.8
		Positive-White Lung	31	23.1
	Consolidation	Negative	96	71.6
		Focal or sub-pulmonic	26	19.4
		Deep (sonographic air bronchogram)	10	7.5
		Both	2	1.49

[Table/Fig-3]: Demographic data and imaging findings of enrolled neonates.

Then, further high-quality X-ray confirmed the diagnosis.

Presence of mild pleural effusion in four neonates was confirmed in ultrasonography that was difficult to diagnose in X-ray.

One case was a premature neonate (28 weeks) with diagnosis of RDS and surfactant shortage. He has been evaluated by sonography immediately after birth and so intubated and administrated by surfactant. The patient was followed-up by serial lung sonographies each hour for three hours and owing to lack of recovery, another dose of surfactant was administrated and the neonate was followed-up aging for three hours. Primary sonographic finding in NICU was white lung which had been changed into several B-lines after six hours.

In X-ray imaging, 11.9%, 9.7% and 78.4% of neonates had hyperaeration, hypoaeration and normal X-rays in terms of aeration, respectively. Parenchymal findings in chest-X-rays were including reticulation, collapse, consolidation and haziness. Lung ultrasonography findings revealed abnormal pleural line (irregular or thick), having more than three B-lines, white lung, focal or subpulmonic consolidation and deep consolidation (sonographic air bronchogram) [Table/Fig-3]. [Table/Fig-4] is presenting the cross-tabulation between cases with reticulation and haziness in CXRs across situation of B-line

Reticulation and /or Haziness in X-ray	B-Line in Lung Sonography			
	Normal	Positive-More than 3 Lines	Positive-White Lung	Total
Yes	25 (26.6%)	41 (43.6%)	28 (29.8%)	94
No	34 (85%)	3 (7.5%)	3 (7.5%)	40

[Table/Fig-4]: Cross-tabulation between cases with reticulation and haziness in chest X-rays across situation of B-line in lung sonography.

Collapse and/or Consolidation in X-ray	Consolidation in Lung Sonography				
	Negative	Focal or Sub pulmonic	Deep (Sono Air Broncho-gram)	Both	Total
Yes	4 (20%)	9 (45%)	6 (30%)	1 (5%)	20
No	92 (80.7%)	17 (14.9%)	4 (3.5%)	1 (0.9%)	114

[Table/Fig-5]: Cross-tabulation between cases with collapse and/or consolidation in chest X-ray across consolidation in lung sonograph.

Chest X-ray	Lung Sonography		
	Normal	Abnormal	Total
Normal	23 (95.8%)	1 (4.2%)	24
Abnormal	12 (10.9%)	98 (89.1%)	110
Total	35	99	134

[Table/Fig-6]: Diagnostic potential of lung sonography compared to chest X-ray (gold standard).

in lung sonography [Table/Fig-1]. The results showed that evaluation of lung with sonography had high power in detecting abnormalities as 69 cases (73.4%) with reticulation and /or haziness in CXR had positive B-line with more than three lines or white lung.

Moreover, the cross-tabulation between cases with collapse and/or consolidation in X-ray across consolidation in lung sonography [Table/Fig-5] revealed that lung sonography has also high potential in detection of consolidations [Table/Fig-2].

Generally, the calculation of power of lung sonography according to the CXR (as gold standard) showed that lung sonography had 89.09% (95% CI, 81.72%-94.23%) sensitivity and 95% (95% CI, 75.13%-99.87%) specificity for diagnosis of lung pathologies in neonates admitted in NICU. Furthermore, the positive likelihood ratio and negative likelihood ratio for lung sonography were 17.82 (95% CI, 2.63-120.5) and 0.11 (95% CI, 0.07-0.20), respectively. The calculated positive predictive value and negative predictive value were also 98.99% (95% CI, 93.54%-99.85%) and 61.29% (95% CI, 47.90%-73.16%), respectively [Table/Fig-6].

DISCUSSION

There are various studies about the usage of thoracic sonography in adults, which the diagnostic accuracy of sonography is comparable with Computed Tomography-scan (CT-scan) [14]. As the ultrasonography is operator dependent and also there is a growing availability of CT-scan over time, the application of ultrasonography has not expanded in practical guidelines yet.

Volpicelli G et al., showed the higher accuracy rate of thoracic sonography compare to CXR in detection of pleural effusion cases. They demonstrated that chest sonography in cases of small pleural effusion can be helpful more than CXR due to different shapes of lung area during different phases of respiration [4]. Our results in this study revealed that chest ultrasonography has comparable diagnostic potential with CXR. However, there was less usage of the CT-scan (as capability of CT-scan remain same, if proper protocol and motion reduction techniques were used) in neonates in contrast with adults, owing to more risks of X-ray and less accuracy of CT-scan in newborns [15].

In a study, 50 neonates with diagnosis of RDS and 50 controls were enrolled. All cases were undergone CXR and the findings of chest sonography including pleural line, A-line, B-Line, Lung consolidation, air bronchogram, bilateral white lung, interstitial syndrome and lung sliding were recorded. The results of sonography in this study showed concomitant presence of lung consolidation and abnormal changes of pleural line, absence of A-line and abnormal changes of pleural line and lung consolidation, and simultaneous presence of bilateral white lung and abnormality of pleural line. All patients with diagnosis of RDS have reports of bilateral white lung, abnormality of pleural line, absence of A-line and lung consolidation which the consolidations were usually in the sub plural areas. In this evaluation the presence of RDS was categorised into four groups based on CXR, which as the RDS severity increased, the deep consolidations and presence of air bronchogram augmented. In the authors' opinion, pleural line abnormality is not specific and it has seen in disorders such as TTN, pneumonia and bleeding. Thus, it has 100% sensitivity but 45% specificity. They also indicated that absence of A-line is not specific and recommended for overall usage of sonography findings for diagnosis of RDS [16]. The data of this study have been recorded 6 to 12 hours after child birth, so they cannot be extended to NICU-admitted newborns.

In another study by Coppetti R et al. a new sonographic view for diagnosis of TTN called "double lung point" has been introduced [10]. Total 32 newborns with diagnosis of TTN based on radiologic and clinical findings were undergone thoracic sonography one hour after birth. In addition, 60 newborns as control and 29 neonates with diagnosis of RDS were underwent chest sonography. The results of sonography in TTN newborns were the change of lung echogenicity from cranial into caudal. In the inferior lung areas of these neonates, very compact comet-tail artifact has been seen which has not been detected in superior areas. This view has been named double lung point. The results of this study indicated that double lung point view has 100% sensitivity and specificity for TTN. In our experiment after a few days passes from the neonatal admission in NICU, those typical findings mentioned in above article are not valuable. Because of further treatments and other superimposed complications such as aspiration and infectious pneumonia, the ultrasound and CXR findings become mixed.

LIMITATION

The parents concern and lack of co-operation, high cost of sonography versus CXRs, superimposed complications such as aspiration and infectious pneumonia were the limitations of our study. Also critical cases of RDS had to treat quickly which limited the diagnostic ultrasound application.

CONCLUSION

Overall, it seems that sonography is a good technique for evaluation of thoracic abnormalities, but it is not a substitute of CXR. On the other hand, the low-cost, fast bedside feature of chest sonography is suitable for serial follow-ups. Furthermore, chest sonography has higher accuracy in showing the pleural space pathologies. Nevertheless, larger field and recording of abdominal abnormalities is the merit of CXR over sonography. Therefore, we recommend follow-up sonography after taking baseline CXR from neonates in NICU. And if there would be changes in sonography findings, second CXR would be

performed. Moreover, sonography is a valuable modality in the case of suspicious CXRs.

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AUTHOR(S):

1. Dr. Elham Zarei
2. Dr. Vahid Alizadeh

PARTICULARS OF CONTRIBUTORS:

1. Faculty, Department of Radiology, Iran University of medical sciences, Ali Asghar hospital, Tehran, Iran.
2. Faculty, Department of Radiology, Iran University of medical sciences, Ali Asghar hospital, Tehran, Iran.

NAME, ADDRESS, E-MAIL ID OF THE CORRESPONDING AUTHOR:

Dr. Vahid Alizadeh,
Iran University of Medical Sciences,
Shahid Hemmat Highway,
Tehran,1449614535, Iran.
E-mail: vahid.ab1364@yahoo.com

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