Differentiation between lung congestion and lung infection using lung ultrasound in congenital heart diseases with significant left to right shunt

Elsaeed Rashad Fouda[1], Mahmoud Mohamed Ahmed Moawad[2 *] , Ghada Ahmed Sharabash[1], Basim Abdelfattah Elgazzar[1*].
[1]Department of Pediatrics- Faculty of Medicine - Menoufia University
[2]Department of Radiodiagnosis- Faculty of medicine- Menoufia University
***Corresponding author:** Ghada Ahmed Sharabash
Mobile: 01019635603
E-mail: ghadaahmedaser@gmail.com

ABSTRACT

Background: shunt lesions (left-to-right) consider the most popular congenital cardiac anomalies in pediatrics and they are the most common cause of high-cardiac-output heart failure. Lung ultrasound (LUS) is increasing in its popularity for the diagnosis of pulmonary complications with pediatric cardiovascular and congenital heart diseases lung ultrasound outperforms the diagnostic accuracy of the chest radiograph, with a low-cost, portable, real-time, radiation-free method.

Aim and objectives: to differentiate between lung congestion and lung infection using lung ultrasound in congenital heart diseases with significant left to right shunt and comparing the ultrasound findings with x-ray findings.

Subjects and methods: This observational case study that was conducted on children and adolescents with significant left to right shunt during the period from the first of December 2022 to the end of September 2023 from pediatric cardiology Unit, Menoufia University Hospitals. The study was involved 50 cases.

Results: There was a statistically significant difference between the studied population regarding Pearson's correlation coefficients (r) between Lung ultrasound findings and X-ray findings regarding lung congestion and between Lung ultrasound findings and X-ray findings regarding lung infection. There was no statistical difference between ASD,VSD and PDA regarding increased broncho vascular markings and lung infection.

Conclusion: Lung ultrasound (LUS) could be accurate, sensitive and efficient. It was used to differentiate between lung congestion and lung infection in congenital heart diseases with significant left to right shunt.

Keywords: lung congestion, lung infection, congenital heart diseases, left to right shunt

INTRODUCTION

Nowadayas, ultrasound has been used in widely extended cases for evaluation of non-seen body organs as heart,abdomen,CNS and extended to be used for studying pathophysiological changes of the lunges as simple,portable,bed side diagnostic tool without hazards of radiation and may help a lot for followup and control of our cases that is on anti-failure medication.

Lung ultrasound (LUS) is increasing in its popularity for the diagnosis of pulmonary complications with pediatric cardiovascular and congenital heart disease, lung ultrasound outperforms the diagnostic accuracy of the chest radiograph, with a low-cost, portable, real-time, radiation-free method. A “wet lung” detected by lung ultrasound predicts impending acute heart failure decompensation and may trigger lung decongestion therapy[1] .

Left to right shunt lesions consider the most common congenital cardiac anomalies in children, and are the most common cause of high output heart failure [2].

When there is an abnormal connection between the right and left side of the heart, left to right shunt lesions occurs as atrial septal defect [ASD], ventricular septal defect [VSD], patent ductus arteriosus [PDA], and complex endocardial cushion defects including the atrial and ventricular septa. Since pressures in left heart are generally more than pressures in right side, blood flows to the lower pressure to right side of the heart across defects (i.e., ASD, VSD, PDA). The combination of the excess flow from the left side of the heart plus normal venous return to the right side of the heart across the vena cava leads to overload the lungs with excess blood [3].

Newborn infants with significant left to right shunts are asymptomatic at birth due to high pulmonary vascular resistance. If left to right shunt is large, (for example, a large ventricular septal defect), usually symptoms develop by 1 to 2 months of age when the pulmonary vascular resistance normalizes [4].

Over a period of time, the pulmonary blood flow increases, this results symptoms as tachypnea, tachycardia, failure to thrive, and sweating with feedings [5].

One of the significant and problematic morbidities in children with CHD is infection. Patients with an acute infection, such as acute respiratory infection (ARI), will experience anorexia, malabsorption, or metabolic disorders. Changes in lung circulation may lead to structural abnormalities accompanied by impairment in local cellular immunity, rendering children to be more vulnerable to ARI [6].

The systematic use of LUS in pediatric cardiology should be encouraged to reduce serial CXR examinations that are not only expensive but also expose children to potentially high doses of radiation [8].

This study aimed to differentiate between lung congestion and lung infection using lung ultrasound in congenital heart diseases with significant left to right shunt.

PATIENTS AND METHODS

This a case observational study that was conducted on children and adolescents with significant left to right shunt and was enrolled from pediatric cardiology Unit, Menoufia University Hospitals during the period from the first of December 2022 to the end of September 2023. The study was involved 50 cases, the least sample size calculated using statistcs and sample size pro program version 6 is 44.

Ethical consideration:

1. An informed oral and written was obtained from all parents of both patients and control groups before getting them involved in the study.

2. The researcher explained the stages, the aims, the potential benefits and hazards of the study to all parents of the patients and control groups.

3. The patients had the right to leave the study at any time.

4. Confidentially and privacy were respected.

5. Ethical approval was obtained from the ethics committee of the Pediatrics department at the faculty of medicine Menoufyia University.

6. No conflicts of interest are to be declared, as reported by the authors.

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Sample size estimation

Based on review of past literature (Moustafa, M. et al.2018), who found that thirty-five had A-profile .The least sample size calculated using Statistics and Sample size pro program version 6 is 44 subjects. The power of study is 80% and confidence level is 95%.

Sample size: 50 subjects

Inclusion criteria:

Children (both sexes) and diagnosed with significant (according to size and amount of blood flow through the shunt) left to right shunt eg: VSD, ASD, PDA**.**

Exclusion criteria:

children more than 12 years and Other causes of lung congestion and lung infection as (autoimmune diseases, drugs, Tumor, inherited disorders.. etc)

Study procedure:

All children and adolescent subjected to the following:

1- detailed history taking (Personal history, family history, detailed cardiac history, symptoms related to lung infection)

2-Through clinical examination including (general examination ,vital signs, anthropometric measurments and systemic examination including cardiological examination for detection of any signs related to congenital heart disease and exclusion other causes of any disease can interfere with our study).

3- diagnostic evaluation including (Echocardiography , lung ultrasound ,chest x-ray).

Statistical analysis:

The data collected were tabulated & analyzed by SPSS (statistical package for the social science software) statistical package version 26 on IBM compatible computer.
Two types of statistics were done:

I. Descriptive statistics: were expressed number and percentage (No & %) for qualitative data and mean& SD and range for quantitative data.
II. Analytic statistics:
- Pearson Chi-squared test ($\chi 2$): It is the test of significance used to study association between two qualitative variables.
- Fisher exact test (FE): It is the test of significance used to study association between two qualitative variables in 2*2 table if any of expected cells is less than five.
- Sensitivity is the proportion of patients with disease who test positive.
- Specificity is the proportion of patients without disease who test negative.
- Predictive value of a positive test is the proportion of patients with positive tests who have disease.
- Predictive value of a negative test is the proportion of patients with negative tests who do not have disease.
- P value <0.05 was considered to be statistically significant**.**

RESULTS

The present observational case study that was conducted on 50 cases of children and adolescents with significant left to right shunt from pediatric cardiology Unit, Menoufia University Hospitals. Age (Years) ranged from .1 to 12 with mean ± SD = 1.81 ± 2.67. Number of male patients in the study population was 28 (56%). Number of rural patients in the study population was 31 (62%). [Table 1]

Table (1) : Demographic characteristics among the study population

	Study population (n = 50)
Age	
Mean ± SD.	**1.81 ± 2.67**
Median (IQR)	**0.75 (0.42 - 2)**
Range (Min-Max)	**11.92 (0.08 - 12)**
Sex	
- Male	**28 (56%)**

- Female	22 (44%)
Residence	
- Rural	31 (62%)
- Urban	19 (38%)

Figure (1): Clinical symptoms among studied patients.

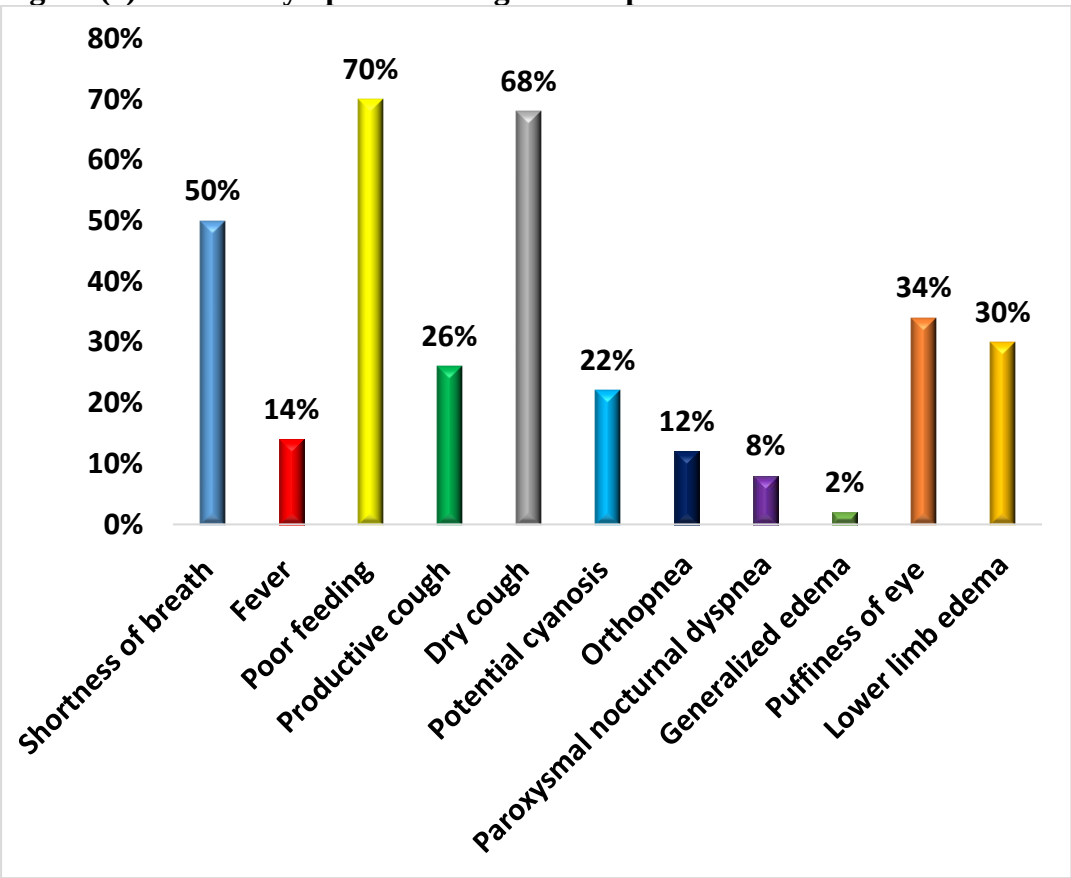

figure (1) showed Clinical presentation among the study population.

Table (2) : Echo findings among studied patients.

Variable	No. of studied patients=50	
	No.	%
Echo		
ASD	30	60
PDA	10	20
VSD	10	20
Right ventricular enlargement	29	58
Left ventricular enlargement	16	32
Pulmonary hypertension	4	8

Figure (2): Bar chart showing study population data regarding Echo findings.

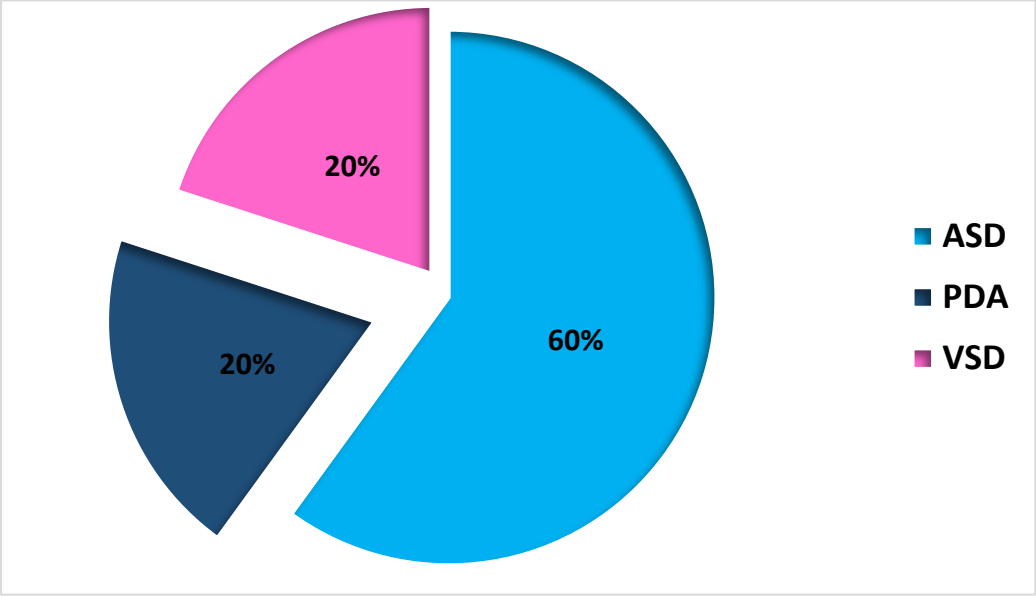

Table (3) : Lung ultrasound findings among the study population.

Variable	No. of studied patients=50	
	No.	%
A-lines (Dry lung)		
Present	27	54
Absent	23	46
B-lines (Wet lung)		
Absent	9	18
Mild	23	46
Moderate	13	26
Severe	5	10
Consolidation by ultrasound		
Present	16	32
Absent	34	68
Pleural effusion	4	8

In the study population, Number of patients with A-lines was 27 (54%). Number of patients with B-profile mild congestion in the study population was 23 (46%). Number of patients with B-profile moderate congestion in the study population was 13 (26%). Number of patients with B-profile sever congestion in the study

population was 5 (10%). Number of patients with consolidation by ultrasound in the study population was 16 (32%).patients with pleural effusion in the study population was 4 (8%). [Table 3]

Table (4): radiological findings among studied patients (n=50).

Variable	No. of studied patients=50	
	No.	%
Lobar consolidation	15	30
Increased broncho-vascular markings	34	68
Pleural effusion	3	6
Increased cardio thoracic ratio	15	30

Table (4) showed Chest x-ray findings among the study population. Number of patients with pleural effusion in the study population was 3 (6%). Number of patients with Lobar consolidation in the study population was 15 (30%). Number of patients with Increase broncho-vascular markings in the study population was 34 (68%).Number of patients with Increase cardio thoracic ratio in x ray in the study population was 15 (30%).

Table (5): Lung congestion by ultrasound in relation to x-rays in studied patients (n=50).

B line by US (Wet lung)	Increased broncho-vascular markings X-rays				Test of significance	p-value
	Present (n=34)		Absent (n=16)			
	No.	%	No.	%		
Present (n=41)	33	97.1	8	50	FE=16.32	<0.001 *
Absent (n=9)	1	2.9	8	50		

There was a statistically significant difference between lung ultrasound and X-rays regarding lung congestion (p-value <0.05). [Table 5]

Table (6) : Lung consolidation by ultrasound in relation to x-rays in studied patients (n=50).

C line by US (Consolidation)	Lobar consolidation by X-rays				Test of significance	p-value
	Present (n=15)		Absent (n=35)			
	No.	%	No.	%		
Present (n=16)	14	93.3	2	5.7	FE=37.05	<0.001*
Absent (n=34)	1	6.7	33	94.3		

There was a statistically significant difference between lung ultrasound and X-rays regarding lung consolidation (p-value <0.001). [Table 6]

Table (7) Pleural effusion by ultrasound in relation to x-rays in studied patients (n=50).

US	X-rays				Test of significance	p-value
	Present (n=3)		Absent (n=47)			
	No.	%	No.	%		
Present (n=8)	3	100	5	10.6	FE=16.75	**<0.001***
Absent (n=42)	0	0	42	89.4		

There was a statistically significant difference between lung ultrasound and X-rays regarding pleural effusion (p-value <0.001). [Table 7]

Table (8): Echo findings in relation to ultrasound findings in studied patients (n=50).

US findings	Echo findings						Test of significance	p-value
	ASD (n=30)		PDA (n=10)		VSD (n=10)			
	No.	%	No.	%	No.	%		
A lines (Dry lung)								
Present	17	56.7	4	40	6	60	$\chi2$=1.02	0.718
Absent	13	43.3	6	60	4	40		(NS)
B lines (Wet lung)								
Absent	7	23.3	2	20	0	0	$\chi2$=4.74	0.606
Mild	12	40	6	60	5	50		(NS)
Moderate	8	26.7	1	10	4	40		
Severe	3	10	1	10	1	10		
C lines (Consolidation)								
Present	11	36.7	3	30	2	20	$\chi2$=0.98	0.763
Absent	19	63.3	7	70	8	80		(NS)

there was no statistically significant difference between ASD,VSD and PDA regarding increased broncho vascular markings and lobar consolidation. [Table 7]

DISCUSSION

Lung ultrasound (LUS) is increasing in its popularity for the diagnosis of pulmonary complications with pediatric cardiovascular and congenital heart disease, lung ultrasound outperforms the diagnostic accuracy of the chest radiograph, with a low-cost, portable, real-time, radiation-free method. A “wet lung” detected by lung ultrasound predicts impending acute heart failure decompensating and may trigger lung decongestion therapy [8].

The main results were as followed:

In the study population, Age (Years) ranged from .1 to 12 with mean ± SD = 1.81 ± 2.67. Number of male patients in the study population was 28 (56%). Number of rural patients in the study population was 31 (62%).. Clinical presentation among the study population. Number of patients with Shortness of breath in the study population was 25 (50%). Number of patients with Fever in the study population was 14 (28%). Number of patients with Poor feeding in the study population was 35 (70%). Number of patients with Productive cough in the study population was 13 (26%). Number of patients with Dry cough in the study population was 34 (68%). Number of patients with Potential cyanosis in the study population was 11 (22%). Number of patients with Paroxysmal nocturnal dyspnea in the study population was 4 (8%).. Number of patients with Generalized edema in the study population was 1 (2%). Number of patients with Puffiness of eyes in the study population was 17 (34%). Number of patients with Lower limb edema in the study population was 15 (30%).

Our results supported with de Carvalho et al. who analyzed exams from 30 patients treated at the pediatric cardiology unit of a large highly complex hospital in Brazil. Twelve 12 (40 %) were younger than one year, one (3.3 %) was 1–2 years, seven (23.3 %) were 2–6 years, and 10 (33.4 %) were 6–10 years; 19 (63.4 %) were girls eleven (36.6 %) were boys. Due to sample size, it was not possible to divide them into age groups, type of cardiac alteration, or surgical indication [9].

The clinical symptoms in our patients were characteristic of the pathophysiology of left-to-right shunts. The high prevalence of shortness of breath, poor feeding, tachypnea, tachycardia, and dry cough can be attributed to the recirculation of already oxygenated pulmonary venous blood through the pulmonary vasculature. This excess pulmonary blood flow results directly or indirectly in almost all of the significant clinical features that characterize heart failure in infants and children[10].

The lung ultrasound findings provided valuable insights into the pulmonary status of our study participants. The presence of A-lines, indicating a dry lung, was observed in slightly more than half of the patients (54%). This suggests that a significant proportion of the cohort did not have significant pulmonary congestion or edema at the time of assessment. However, the remaining patients exhibited B-lines on lung ultrasound, which are indicative of pulmonary edema or congestion. Notably, almost half (46%) of the patients had mild congestion, while moderate and severe congestion were present in 26% and 10% of patients, respectively. These findings are consistent with the expected pathophysiology of left-to-right shunt lesions, which can lead to increased pulmonary blood flow and subsequent congestion [11] In pulmonary congestion, the ultrasound beam reflects off thickened interlobular septa, creating hyperechoic reverberation artifacts known as lung comets or B lines between the septa and overlying pleura, with more B lines indicating greater congestion and more severe symptoms [12].

Pleural effusions, detected by lung ultrasound in 8% of patients, are also a known consequence of increased pulmonary pressure and congestion associated with left-to-right shunt lesions (Baren, 2008). These findings align with previous studies that have demonstrated the utility of lung ultrasound in detecting pleural effusions in pediatric populations [13]. Interestingly, a recent study found that lung ultrasound can detect effusions smaller than 10 mL in children[14].

The echocardiographic data revealed that ASDs were the most common congenital heart lesion in this cohort, followed by VSDs and PDA. The distribution of congenital heart defects in this study population is consistent with the expected prevalence patterns reported in the literature[15].

A key observation of this study was the strong correlation between the presence of B-lines on lung ultrasound, indicating pulmonary edema or congestion, and increased broncho vascular markings on chest X-ray, which are radiographic signs of pulmonary congestion. Importantly, lung ultrasound exhibited an impressive sensitivity of 97% in detecting lung congestion when compared to X-ray findings. This high sensitivity suggests that lung ultrasound is highly effective in correctly identifying patients with pulmonary congestion, minimizing the risk of false-negative results. However, the specificity was relatively lower at 50%, indicating a higher risk of false-positive results. The diagnostic accuracy metrics further reinforce our findings. The overall accuracy of lung ultrasound in detecting lung congestion was 82%, with a positive predictive value (PPV) of 80% and a negative predictive value (NPV) of 89%. These results align with previous studies that have underscored the high sensitivity of lung ultrasound in identifying pulmonary edema and congestion [16]

Notably, lung ultrasound exhibited excellent diagnostic accuracy for detecting lung consolidation in this study, with a sensitivity of 93%, specificity of 94%, and overall accuracy of 94% when compared to chest X-ray as the reference standard. The presence of lung consolidation on ultrasound showed a strong concordance with lobar consolidation patterns on X-ray. These findings corroborate the conclusions drawn by [17]

Lung ultrasound is a promising radiation-free modality that has shown increasing utility in diagnosing pulmonary complications in pediatric cardiology patients [18]

CONCLUSION

Lung ultrasound (LUS) could be accurate, sensitive and efficient it was used to differentiate between lung congestion and lung infection in congenital heart diseases with significant left to right shunt. It is a promising radiation-free modality that has shown increasing utility in diagnosing pulmonary complications in pediatric cardiology patients.

Limitations

1- This study was a single-center study with a relatively small sample size.
2- The enrolled children were selected to satisfy the inclusion criteria hence, the data of excluded children could not be analyzed.

Recommendations

1. Incorporate lung ultrasound as a routine diagnostic tool in the management of children with left-to-right shunt congenital heart diseases.
2. Develop standardized protocols and training programs for healthcare professionals to ensure proper utilization and interpretation of lung ultrasound findings.
3. Explore the use of lung ultrasound in monitoring disease progression and response to treatment in children with left-to-right shunt lesions.
4. Promote the integration of lung ultrasound into clinical decision-making algorithms for the management of pulmonary complications in children with congenital heart diseases.
5. Encourage the use of lung ultrasound as a radiation-free alternative to chest X-rays, especially in pediatric populations, to minimize exposure to ionizing radiation.
6. Establish guidelines and protocols for the systematic use of lung ultrasound in pediatric cardiology to reduce unnecessary chest X-ray examinations.

7. Investigate the cost-effectiveness and potential healthcare savings associated with the widespread implementation of lung ultrasound in the diagnosis and management of pulmonary complications in children with congenital heart diseases.
8. Conduct larger multicenter studies to further validate the diagnostic accuracy of lung ultrasound in various pulmonary conditions associated with congenital heart diseases.

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