Study of the accuracy and diagnostic yield of chest radiographs in children with cardiac diseases

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Introduction
The chest radiograph (CXR) still has an important role in the diagnosis of heart diseases. We aim by this study to evaluate the use of CXR in the Pediatric Cardiology Unit in Assiut University Children Hospital for children (4–10 years old) with suspected heart disease.

Patients and methods
This was a 6-month, case series clinical study undertaken in the inpatient Pediatric Cardiology Unit, Assiut University Hospital, Assiut City, Egypt, between the first of March 2017 and the 31st of August 2017.

Results
It was observed that the percentage frequency of cases with true chamber enlargement and/or hypertrophy among cases diagnosed as having computed tomography ratio of more than 50% in the CXR was 64%, and CXR sensitivities for cardiac chamber enlargement in comparison with the gold standard test (ECHO) were 93.9% for the right atrium, 87.5% for the left atrium, 68.4% for the right ventricle, and 68.4% for the left ventricle. The CXR specificities for cardiac chamber enlargement in comparison with ECHO were 71.4% for the right atrium, 88.2% for the left atrium, 90.3% for the right ventricle, and 87.1% for the left ventricle.

Conclusion
Auditing the guidelines of interpretation of the CXR for children aged 4–10 years that were used in the pediatric cardiology unit of Assiut University Hospital for Children, the following could be concluded: The sensitivities and specificities of CXR in diagnosing specific chamber enlargement are still inadequate; depending on echocardiography in such data is the most accurate; and chest roentgenogram is accurate in detecting cardiac site and situs.

Keywords:
chest radiography, congenital heart disease, echocardiography, electrocardiogram, rheumatic heart diseases

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Introduction

Chest radiograph (CXR) is an important tool in evaluating heart disease in children. It is easy to perform, economical, and provides important information including heart size, pulmonary blood flow, and any associated lung disease, and history of present illness coupled with physical examination provides the treating physician with a reasonable list of differential diagnoses, which can be further focused on with the aid of CXR and ECG, making it possible to select a management plan or make a decision to refer the child for further evaluation and treatment by a specialist [1].

CXR is a projection radiograph of the chest that uses ionizing radiation in the form of radiograph to generate images of the chest [2].

CXR obtained in two perpendicular views, anteroposterior and lateral, makes it possible to construct a three-dimensional image of the heart [3].

The CXR is the most common and simplest method of radiography to assess the cardiovascular system. The advantages of CXR is cost-effectiveness, being noninvasive, and ease of accessibility for patients. Therefore, it is suggested that this method be considered as a complementary tool in patients with a suspected cardiac lesion [4].

Aim

The aim of this study was to evaluate the accuracy of CXR in the diagnosis of cardiac diseases in children admitted to the Cardiology Unit of Assiut University Children Hospital in comparison with more advanced investigations.

Patients and methods

This was a 6-month, case series clinical study undertaken in the inpatient Pediatric Cardiology

Unit, Assiut University Hospital, Assiut City, Egypt, between the first of March 2017 and the 31st of August 2017. Ethical committee approval no 17100837.

The study included 50 cases (19 boys and 31 girls). All patients were recruited from the Pediatric Cardiology Unit. The diagnosis of pediatric heart diseases and assessments of all cases were established in Assiut University Children's hospital.

Inclusion criteria

Children aged 4–10 years old with suspected heart disease (congenital heart disease, rheumatic heart diseases) were enrolled in the study.

Exclusion criteria

Children with the following were excluded from the study:

(1) Primary lung disease.
(2) Bone deformity.
(3) Patients with inadequate criteria of the accuracy of the CXR.

Methodology

The investigated patients were evaluated according to the following protocol.

Detailed clinical history and physical examination

Investigations:

(1) CXR films:

All cases had CXR, posteroanterior view in the erect position.

The following points were reported:

(a) The view.
(b) Cardiac site.
(c) Cardiac size.
(d) Cardiac configuration.
(e) Cardiac chamber size.
(f) Thymus shadow.
(g) Pulmonary vasculature.
(h) Associated pulmonary diseases.

(2) Echocardiogram:

(a) Definite detection of cardiac site and visceroatrial situs.
(b) Accurate measurements of chamber diameters and wall thickness with the referral of these measurements to the standard for age.
(c) Detection of anatomical abnormalities within the heart or proximal parts of great vessels.
(d) Estimation of pulmonary pressure.
(e) Evaluation of the pericardium.
(f) Detection of the thymus gland and its size.

Measurements were taken according to standard methods described by the American Society of Echocardiography. They included the following (and they are):

(i) Right and left ventricular dimensions and thickness.
(ii) Left atrial dimension.
(iii) Ascending aorta dimension.
(iv) Main pulmonary artery diameter.

(3) ECG:

(a) Rhythm, rate, cardiac axis, *p* wave, QRS complex, and T-wave were evaluated for the detection of cardiac site and cardiac size.

ECG criteria of specific chamber enlargement were as follows:

(i) Right atrial hypertrophy: tall *p* waves (>3 mm) indicate – P pulmonale.
(ii) Left atrial hypertrophy: a widened and often notched P wave (with the P duration > 0.08 s in infants) is seen in – P mitrale.
(iii) Biatrial hypertrophy: a combination of increased amplitude and duration of the P wave is present.
(iv) Ventricular hypertrophy: produces abnormalities in one or more of the following (and they are) – the QRS axis, the QRS voltages, the R/S ratio, the T axis, and miscellaneous areas [5].

Data obtained from the CXR film were compared with those from clinical data, and ECG and echocardiography data, wherein the echocardiogram was considered the gold standard in diagnosing site, situs, anatomical configuration and size of the heart and its chambers, and was the most sensitive in detecting pulmonary pressure.

Results

According to CXR, clinical examination, ECG, and ECHO, all cases had normal cardiac situs (Tables 1–7).

In the echocardiogram, enlarged cardiac size was detected in 36 cases. A total of 31 (86.1%) cases of them had enlarged cardiac size on CXR.

In the echocardiogram, enlarged right atrium size was detected in 15 cases. Of those 13 cases, 86.6% had enlarged right atrium size on CXR.

In the echocardiogram, enlarged left atrium size was detected in 16 cases. A total of 14 (87.5%) cases from them had enlarged left atrium size on CXR.

In the echocardiogram, enlarged right ventricle size was detected in 19 cases. A total of 13 (68.4%) cases of them had enlarged right ventricle size on CXR.

Table 1 Data gained by the chest radiograph film in our studied cases

	n (%)
Normal cardiac site	50 (100)
Normal cardiac situs	50 (100)
C/T ratio >50%	32 (64)
Enlarged cardiac chamber	
Right atrium	22 (44)
Left atrium	18 (36)
Right ventricle	16 (32)
Left ventricle	17 (34)
Thymus shadow present	9 (18)
Pulmonary vasculature	
Normal	39 (78)
Pulmonary congestion	10 (20)
Pulmonary oligemia	1 (2)
Radiological evidence of pulmonary disease	4 (8)

Table 2 Data obtained from the echocardiography examination in our studied cases

Items	*n* (%)
Normal cardiac site	50 (100)
Normal cardiac situs	50 (100)
Dilated right atrium	15 (30)
Dilated left atrium	16 (32)
Dilated right ventricle	19 (38)
Dilated left ventricle	19 (38)
Increased pulmonary pressure	4 (8)

In the echocardiogram, enlarged left ventricle size was detected in 19 cases. A total of 13 (68.4%) cases of them had enlarged left ventricle size on CXR.

Discussion

As regards cardiac site, in all our cases, this item was diagnosed completely by the chest roentgenogram; cardiac site, in all of the cases, was normal. It could be concluded that the chest roentgenogram is accurate in excluding abnormal cardiac site.

The air bronchogram pattern is the most accurate method of diagnosis of visceroatrial situs; visceral (abdominal) situs is determined by the sidedness of the liver and stomach. All these signs are clear in chest roentgenogram, and, in turn, the situs of all our cases was diagnosed accurately by CXR film; cardiac situs of all cases were normal.

In this study, we prospectively evaluated the diagnostic performance characteristics of CXR to detect cardiac enlargement. We used ECHO as the gold standard.

It was observed that the percentage frequency of cases with true chamber enlargement and/or hypertrophy among cases diagnosed as having C/T ratio of more than 50% in the CXR was 86.8% (33 cases of 38 cases). In spite of the fallacies with regard to the use of C/T ratio in this age group, such as horizontal position of the heart, difficulty in obtaining midinspiratory film in this age group and the frequent presence of thymus [6], C/T proved to be of value in determining cardiac dilation and/or hypertrophy.

Table 3 Sensitivity and specificity of chest radiograph in the diagnosis of cardiomegaly in our studied cases

	Patients with cardiomegaly (as confirmed on echocardiology)		Test predictive value
	Condition positive	Condition negative	
Cardiomegaly by CXR			
Positive	True positive (TP)=31	False positive (FP)=3	Positive predictive value=TP/(TP+FP)=31/(31+3)=91.1%
Negative	False negative (FN)=5	True negative (TN)=11	Negative predictive value=TN/(FN+TN)=11/(5+11) ≈68.8%
	Sensitivity=TP/(TP+FN)=31/(31+5) =86.1%	Specificity=TN/(FP+TN)=11/(3+11) ≈78.6%	

CXR, chest radiograph.

Table 4 Sensitivity and specificity of chest radiograph in the diagnosis of right atrial enlargement in our studied cases

	Patients with enlarged RA (as confirmed on echocardiology)		Test predictive value
	Condition positive	Condition negative	
Enlarged RA by CXR			
Positive	True positive (TP)=13	False positive (FP)=10	Positive predictive value=TP/(TP+FP)=31/(31+10)=75.6%
Negative	False negative (FN)=2	True negative (TN)=25	Negative predictive value=TN/(FN+TN)=25/(2+25) ≈92.6%
	Sensitivity=TP/(TP+FN)=31/(31+2) =93.9%	Specificity=TN/(FP+TN)=25/(10+25) =71.4%	

CXR, chest radiograph; RA, right atrial.

Table 5 Sensitivity and specificity of chest radiograph in the diagnosis of left atrial enlargement in our studied cases

	Patients with enlarged LA (as confirmed on echocardiology)		Test predictive value
	Condition positive	Condition negative	
Enlarged LA by CXR			
Positive	True positive (TP)=14	False positive (FP) =4	Positive predictive value=TP/(TP+FP)=14/(14+4) ≈77.8%
Negative	False negative (FN)=2	True negative (TN)=30	Negative predictive value=TN/(FN+TN)=30/(2+30) ≈93.8%
	Sensitivity=TP/(TP+FN)=14/(14+2) =87.5%	Specificity=TN/(FP+TN)=30/(4+30) =88.2%	

CXR, chest radiograph; LA, left atrial.

Table 6 Sensitivity and specificity of chest radiograph in the diagnosis of right ventricular enlargement in our studied cases

	Patients with enlarged RV (as confirmed on echocardiology)		Test predictive value
	Condition positive	Condition negative	
Enlarged RV by CXR			
Positive	True positive (TP)=13	False positive (FP)=3	Positive predictive value=TP/(TP+FP)=13/(13+3) =81.2%
Negative	False negative (FN)=6	True negative (TN)=28	Negative predictive value=TN/(FN+TN)=28/(6+28) ≈82.4%
	Sensitivity=TP/(TP+FN)=13/(13+6) =68.4%	Specificity=TN/(FP+TN)=28/(3+28) =90.3%	

CXR, chest radiograph; RV, right ventricular

Table 7 Sensitivity and specificity of chest radiograph in the diagnosis of left ventricular enlargement in our studied cases

	Patients with enlarged LV (as confirmed on echocardiology)		Test predictive value
	Condition positive	Condition negative	
Enlarged LV by CXR			
Positive	True positive (TP)=13	False positive (FP)=4	Positive predictive value=TP/(TP+FP)=13/(13+4) =81.2%
Negative	False negative (FN)=6	True negative (TN)=27	Negative predictive value=TN/(FN+TN)=27/(6+27) ≈82.4%
	Sensitivity=TP/(TP+FN)=13/(13+6) =68.4%	Specificity=TN/(FP+TN)=27/(4+27) ≈87.1%	

CXR, chest radiograph; LV, left ventricular.

In our study, CXR sensitivities for cardiac chamber enlargement in comparison with the gold standard test (ECHO) were 68.8% for the right atrium, 55.6% for the left atrium, 76.2% for the right ventricle, and 60% for the left ventricle. The CXR specificities for cardiac chamber enlargement in comparison with ECHO were 48.3% for the right atrium, 74.1% for the left atrium, 62.5% for the right ventricle, and 84% for the left ventricle. There is no statistically significant difference between CXR and echocardiography in detecting left atrium enlargement, right ventricle enlargement, and left ventricle enlargement, wherein there is a statistically significant difference between CXR and echocardiography in detecting right atrium enlargement.

As regards pulmonary vascularity, our results showed that 24.1% of normal pulmonary vasculature in CXR had increased pulmonary pressure in ECHO, and 42.9% of congestion on radiograph had increased pulmonary pressure on the echocardiogram.

Conclusion

Evaluating the accuracy of CXR in comparison with echocardiography in the diagnosis of cardiac diseases in children aged 4–10 years admitted in the Cardiology Unit of Assiut University Children Hospital, we can conclude the following (and they are):

Auditing the guidelines of interpretation of the CXR for children aged 1–4 years that were used in the Pediatric Cardiology Unit of Assiut University Hospital for Children, we came to the following conclusions:

(1) Chest roentgenogram is accurate in detecting cardiac site.
(2) CXR is also accurate in detecting cardiac situs.
(3) Enlarged C/T more than 50% is useful for diagnosing cardiomegaly because of cardiac chamber dilation and/or hypertrophy. However, decreased C/T less than or equal to 50% does not exclude cardiac chamber dilation and/or hypertrophy.
(4) The sensitivities and specificities of CXR in diagnosing specific chamber enlargement are still

inadequate, and depending on echocardiography in such data is the most accurate.

(5) The CXR has little value in the diagnosis of pulmonary pressure changes, and echocardiography is the method to be used in this regard.

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Conflicts of interest

There are no conflicts of interest.

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