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Sensitivity and Specificity of Cardiomegaly according to Chest X-ray Indices in the Diagnosis of Congenital Heart Disease in Infants

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ABSTRACT

Background: Early diagnosis of congenital heart disease (CHD) has a significant impact on the prognosis of the patient. This study aimed to determine the sensitivity and specificity of cardiomegaly according to Chest X-ray (CXR) indices in comparison with echocardiography in the diagnosis of CHD in infants.

Methods: In this cross-sectional study, the clinical status of 166 infants aged 2 to 24 months who referred to the Pediatric Ward of Afzalipour Hospital in Kerman and needed CXR for any reason, was evaluated from November 2019 to November 2020. CXR and echocardiography were performed for all infants by a pediatric cardiologist and the probability of CHD was confirmed or ruled out. Therefore, the sensitivity and explicitness of CXR were determined. Data were analyzed using SPSS version 20.

Results: The most common anomalies observed in infants were Patent ductus arteriosus (PDA), atrial septal defect (ASD), ventricular septal defect (VSD) and pulmonary stenosis (PS), respectively. The sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) of CXR, for determining cardiomegaly in these infants were 65.7%, 51.1%, 26.4%, and 84.8%, respectively.

Conclusion: The results of this study showed that the sensitivity and specificity of CXR for determining cardiomegaly were 65.7% and 51.1%, respectively. Therefore, when echocardiography is not available, the chances of finding congenital heart abnormalities with the help of CXR will be quite high.

Keywords: Sensitivity, Specificity, Cardiomegaly, Congenital Heart Disease, Echocardiography, Infants

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Introduction

Congenital heart disease (CHD) is the most common cause of congenital anomalies, which as a major global health problem is associated with high mortality and morbidity (1, 2). This disease involves anomalies in the heart structure occurring before birth. Such anomalies occur while the fetus is growing in the womb. The cause of CHD can be genetic, environmental, or a combination of the two, so that one in every 100 children with genetic or chromosomal anomalies, such as Down syndrome, has CHD. Excessive alcohol consumption during pregnancy, using drugs, diabetes, and high blood pressure in the first trimester of pregnancy are the risk factors for CHD in children, and also, the presence of the disease in parents or siblings increases its risk. The signs and symptoms of CHD include shortness of breath, limited ability to perform activities, fatigue, abnormal heart sound (murmur), and failure to thrive (3). Twenty eight percent of congenital anomalies involve heart defects. The reported CHD birth prevalence varies in studies worldwide, but it has been estimated to be 8 in every 1000 live births (1). The reported CHD birth prevalence in Asia has ranged from 4 to 50 in every 1000 live births, which is increasing every day (2). According to recent studies conducted in Iran, CHD is a major problem in the Iranian healthcare system, the prevalence of which varies from 7.93 to 17.5 in every 1000 live births (4). Diagnosis of CHD is difficult and also critical, and early diagnosis of the disease has a significant impact on the patient's prognosis and future. Cardiography, Chest X-ray (CXR), echocardiography, MRI, and angiography are used to diagnose CHD (3). CXR is performed using a very low dose of ionizing radiation to produce images of the inside of the chest. It is used to assess the lungs, heart walls, and chest, and may also be used to help diagnose shortness of breath, persistent cough, fever, heart disease (cardiomegaly), and chest trauma. Since CXR is fast and easy, it is especially useful in the emergency diagnosis and treatment (5). Laya *et al.* reported that CXR alone could not diagnose specific cardiac lesions with an accuracy less than 71%, and CXR alone should be less emphasized in CHD diagnosis (6). In a study by Molaie *et al*. the accuracy of diagnosis, sensitivity, specificity, PPV, and NPV of CXR were reported to be 61%, 80%, 53%, 86%, and 42%, respectively. According to this study, when a cardiovascular disease is suspected on clinical examination, echocardiography without the need for CXR is recommended (7). Fonseca *et al.* stated that CXR was less sensitive to the diagnosis of cardiomegaly (59-26%) than echocardiography (8). In the study of Satou *et al*., the sensitivity of CXR for the detection of cardiomegaly was 58.8% and its specificity was 92.3% (9).

Given that CHD has a relatively high prevalence rate worldwide and according to recent studies in Asia and Iran, in addition to the high prevalence of the disease, its rapid growth and ascending trend is also significant. Moreover, there are high rates of mortality and multiple complications in patients with this disease. Therefore, early diagnosis of this disease has a significant effect on reducing mortality, reducing and even eliminating all its complications. CHD can be diagnosed with a regular screening program and using simple, cost-effective, and primary diagnostic methods, and referred to higher levels for more complete diagnosis and treatment. By recognizing the efficiency and advantages of simple diagnostic methods, such as CXR in the diagnosis of CHD, and also, considering the complications of this diagnostic method, if it is effective and has diagnostic value, it can be used routinely and help reduce mortality and morbidity of CHD.

This study aimed to determine the sensitivity and specificity of cardiomegaly according to CXR indices in comparison with echocardiography in the diagnosis of CHD in infants aged 2 to 24 months (the age group in which such a study was not performed) from November 2019 to November 2020 in Afzalipour Hospital in Kerman.

Materials and Methods

In this cross-sectional study, the sensitivity and specificity of cardiomegaly based on the chest graph were assessed in the diagnosis of congenital heart disease in 166 infants aged 2 to 24 months who referred to the Pediatric Ward of Afzalipour Hospital in Kerman in 2019-2020. The study population was 2 to 24-month-old infants who needed chest X-rays (CXR) for any reasons with their parents' agreement were enrolled in the study after obtaining informed consent from their parents. Patients with a history of previously heart disease and informed dissatisfaction were excluded from the study, and then, the patients' clinical and demographic information was completed by the physician. They were divided into two groups with

cardiomegaly (+-heart disease) and without cardiomegaly (+-heart disease).

If the congenital heart disease is diagnosed correctly and in time in this age group, it is possible to treat patients in a timely manner. This study was approved by the Ethics Committee of Kerman University of Medical Sciences (Ethical code: IR.KMU.AH.REC.1399.113).

Considering the alpha value of 5%, the sensitivity (70%) calculated based on the previous studies (6), the prevalence of the disease, the margin of error of 10%, and the following formula, the sample size was estimated to be 166 people.

$$n_{Se} = \frac{Z_{\frac{\alpha}{2}}^2 \widehat{Se}(1 - \widehat{Se})}{d^2 \times Prev}$$

After performing the chest x-ray, the first step was to make a checklist containing clinical and demographic information including patient's personal information such as name, surname, father's name, sex, age, mother's pregnancy age, birth weight, preterm or term. Then, CXR and also echocardiography as the gold standard method of diagnosing CHD were performed by a pediatric cardiologist for all the infants who entered the study. Philips Affiniti 50 echocardiography made in the USA was used in Afzalipour Hospital in Kerman. Thus, the possibility of CHD was confirmed or ruled out, and the sensitivity and specificity of CXR were determined. Due to the fact that the standard CXR at this age is defined as lying down, the graphic of these children in the supine and Antro-Posterior (AP) view were taken. The X-ray was interpreted and studied by valid radiology reference indexes in two ranges of 0.5 and 0.6 CT-ratio. However, the selection of this age group for appropriate and early treatment measures is not acceptable according to the reasonable response of this age range.

Cardiomegaly was considered to be more than 53% in the infants based on the ratio of the largest transverse diameter of the heart to the transverse diameter of the thoracic cavity above the diaphragm (cardiothoracic index CTI) (10). However, in this study, in order to increase the sensitivity of the test, statistical analysis was performed separately with two indices of 55% and 60%. Furthermore, demographic variables, such as infant gender, current age, gestational age (between 35 and 37 weeks, < 35 weeks, and > 37 weeks) (11), and current weight status according to the national standard weight-for-age percentile (12) along with the CXR result, were entered into a diagnostic model.

Mean and standard deviation were used to describe the quantitative variables and frequency and percentage were used to describe the qualitative variables. The sensitivity and specificity of CXR were calculated based on the area below the receiver operating characteristic (ROC) curve. All the analyses were performed using Stata software version 15.

Results

In this study, the sensitivity and specificity of cardiomegaly according to CXR indices in CHD diagnosis in 166 infants aged 2 to 24 months (mean age 9.08 ± 6.19 months) who referred to the Pediatric Ward of Afzalipour Hospital in Kerman were evaluated in 2019-2020. Most of the infants were female (51.80%). The gestational age in more than 60% of the samples (66.87%) was over 37 weeks. The birth weight of 56% of the infants was more than 3 kg. Approximately three-quarters of the infants had a current normal weight. Echocardiography was normal in most infants (78.92%). More than 50% of them had cardiomegaly in CXR (52.41%) (Table 1). The most common heart anomaly observed in infants on echocardiography was patent ductus arteriosus (7.3%). After that, the most anomalies were atrial septal defect (ASD, 6.6%), ventricular septal defect (VSD, 5.4%) and pulmonary stenosis (PS, 3.6%), and other cases (1.8%).

Table 1. Distribution of demographic information (n=166)

Variable		Frequency (%)
Gender	**Female**	(80.51) 86
	Male	(19.48) 80
Gestational age (week)	35-37	(11.27) 45
	< 35	(02.6) 10
	> 37	(87.66) 111
Birth weight (kg)	2.5-3	(52.29) 49
	< 2.5	(46.14) 24
	≥ 3	(02.56) 93
Current weight (kg)	Normal weight	(70.74) 124
	Low weight	(30.22) 42
Echocardiography	Normal	(92.78) 131
	Abnormal	(08.21) 35
CXR	With cardiomegaly	(41.52) 87
	Without cardiomegaly	(59.47) 79
Total		(100) 166

In the group with cardiomegaly, most infants had PDA (30.4%) or ASD (30.4%). ASD was more associated with other congenital anomalies than PDA (43.5%). In the group without cardiomegaly, the most anomalies observed in infants were PDA (25%) and VSD (25%) (Table 2). Eighty-seven infants had a positive CXR and 79 had a negative CXR. Also, 131 and 35 infants had normal and abnormal echocardiography, respectively.

Table 2. Distribution of anomalies in the groups with and without cardiomegaly in echocardiography

Subgroup	With Cardiomegaly (n=87)	Without cardiomegaly (n=79)
	%	%
PDA	(4.30)7	(25)3
VSD	(5.8)2	(25)3
ASD	(4.30)7	(3.8)1
PS	(5.8)2	(6.16)2
Other	(4)1	(6.16)2
VSD + other anomalies	8(7.34)	4(3.33)
ASD + other anomalies	10 (5.43)	-
Other anomalies + PDA	-	4(3.33)
PS + other anomalies	4(3.17)	-

The sensitivity and specificity of CXR for determining cardiomegaly were 65.7% and 51.1% with ROC area of 0.584, respectively. Moreover, the PPV and NPV of CXR were 26.4% and 84.8%, respectively (Table 3).

Table 3. Sensivity and specificity of CXR for diagnosis of cardiomegaly

Sensitivity	7.65% (47.8-80.9%)
Specificity	1.51% (42.3-60%)
ROC area	584.0 (494.0-675.0)
Likelihood ratio +	35.1 (1-81.1)
Likelihood ratio -	67.0 (411.0-09.1)
Odds ratio	01.2 (931.0-32.4)
PPV	4.26% (6.17-37%)
NPV	8.84% (75 - 9.91 %)

In comparing CTR 0.6 with CTR 0.55, the present study had a sensitivity of 62.9% versus 65.7% and a specificity of 54.2% versus 51.1%, which did not make much difference in the value of the study (Figure 1).

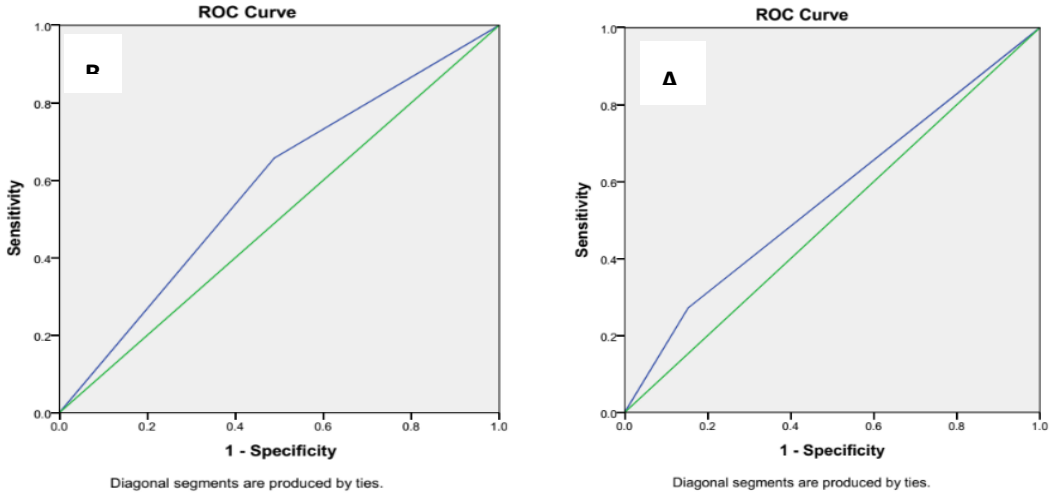

Figure 1. Comparison of sensitivity and specificity of CXR for determining cardiomegaly with two CTI indices: A) CTR= 0.6, b) CTR= 0.55

Discussion

The present study aimed to evaluate the sensitivity and specificity of cardiomegaly according to CXR indices in the diagnosis of CHD in 166 infants aged 2 to 24 months who referred to the Pediatric Ward of Afzalipour Hospital in Kerman in 2019-2020. The most common anomalies observed in these infants were PDA, followed by ASD, VSD, PS, and other anomalies. In the group with cardiomegaly, most infants had PDA or ASD. ASD was more associated with other congenital anomalies than PDA with other anomalies. In the group without cardiomegaly, the most common anomalies observed in the infants were PDA and VSD. Eighty seven infants had a positive CXR and 79 had a negative CXR. Moreover, 131 and 35 infants also had normal and abnormal echocardiography, respectively.

PDA, followed by ASD, are the most common cardiac anomalies associated with cardiomegaly, and in complementary examinations such as echocardiography, in cases reported in CXR, cardiomegaly will be more prominent. In this study, 26.4% of the cases with cardiomegaly had anomalies in echocardiography. In studying 79 infants with normal CXR, 15.1% CHDs were reported. It is worth mentioning that PDA and VSD anomalies in echocardiography accounted for a total of 5% of children who did not have cardiomegaly on CXR. Moreover, only one child with ASD had normal CXR; while ASD is generally the most common anomaly reported in children with cardiomegaly.

The sensitivity of CXR in this study for cardiomegaly diagnosis was 65.7%. This level of sensitivity indicates that with a probability of 65.7% using cardiomegaly diagnosis in CXR, there will be a chance of presenting one of the congenital anomalies mentioned in the ages of 2-24 months. The specificity of CXR in this case was 51.1%, which is not significant. Therefore, in cases where echocardiography may not be available, there is an acceptable chance of finding these anomalies using CXR.

Based on the calculations, the area below the ROC curve in this study is 0.584. The ideal value is 1, and the number 0.5 indicates that the test does not help differentiate between the cases with the desired status and those without it. In this study, it is closer to 0.5 than to 1, and also, based on the likelihood ratio index, the positive likelihood ratio was 1.35 and the negative likelihood ratio was 0.67. So that the higher the positive number and the closer the negative number to zero, the more valuable it is for diagnosing cardiomegaly. Although based on these two indices, the presence of cardiomegaly on CXR does not help to accurately diagnose the type of CHD; it can indicate the presence of a concomitant heart anomaly.

In this study, the PPV was 26.4%, indicating that if a person has cardiomegaly in CXR, he/she has a 26.4% chance of having CHD on echocardiography. The NPV was 84.8%, indicating that in the absence of cardiomegaly in CXR, the probability that a person will not have a CHD on echocardiography is 84.8%, which is valuable. In other words, the chance of not having CHD in infants aged 2 to 24 months will be more than 84% in the absence of cardiomegaly in CXR.

Laya *et al.* conducted a study on CXR of 281 patients aged less than 12 years. They reported that the mean accuracy of five radiologists in diagnosing and distinguishing normal individuals from patients with CHD was 78% (range 72% to 82%). The overall accuracy in diagnosing specific congenital heart lesions in 13 groups of patients was 71% (range 63% to 79%). As a result, CXR alone was not able to diagnose specific heart lesions (with an accuracy of less than 71%) (6), which is consistent with the results of the present study. However, in this study, radiographic examinations were performed for heart size, heart shape, mediastinum, and arteries.

In a study by Molaie *et al*., on the diagnostic value of CXR in cardiovascular diseases in children aged under 10 years, the sensitivity, specificity, PPV, and NPV of CXR were 61%, 80%, 53%, 86%, and 42%, respectively. According to the results of this study, when a patient with cardiovascular disease is suspicious on physical examination, echocardiography is recommended without the need for CXR (7). This result is also consistent with the results of the present study.

Fonseca *et al*. conducted a study in 2004 on 128 infants with a gestational age of 42-23 weeks and a birth weight of 4621-500 g, and patients' CXR was studied, and finally, measured by echocardiography. They found that the correlation of CXR has low sensitivity for the diagnosis of cardiomegaly compared to echocardiography (26-59%) (8).

In another study by Satou *et al.,* the usefulness of CXR in heart size in children (the gold standard in this study was echocardiography) was investigated. The sensitivity of CXR for diagnosis of cardiomegaly was 58.8% and its specificity was 92.3%, which despite its high specificity, considering the limitations of CXR as a diagnostic test in children, it is recommended for diagnosis of heart disease. This study reported less sensitivity and more specificity, which is not consistent with the results of the present study, but it should be noted that Satou's study samples aged between 2 days to 20 years and the mean age was 5 years (9).

In the present study, comparing CTR 0.6 with CTR 0.55 indicated a sensitivity of 62.9% versus 65.7% and a specificity of 54.2% versus 51.1%, which does not make a significant difference in the study.

Conclusion

The results of the present study showed that the most anomalies observed in 166 infants aged 2 to 24 months who referred to the Pediatric Ward of Afzalipour Hospital in Kerman were PDA, followed by ASD, VSD, and PS and other anomalies. The CXR sensitivity for determining cardiomegaly in the infants was 65.7%, indicating that with a probability of 65.7% and the help of cardiomegaly diagnosis in CXR, there is a chance of diagnosing one of the congenital anomalies at the age of 2-24 months. Therefore, in cases where echocardiography is not available, CXR may be somewhat appropriate for diagnosing congenital anomalies. Moreover, the PPV and NPV of CXR were 26.4% and 84.8%, respectively. Therefore, if a person has cardiomegaly in CXR, he/she has a 26.4% chance of having CHD on echocardiography. In the absence of cardiomegaly in CXR, the probability that a person does not have CHD on echocardiography is 84.8%. In other words, the probability of not having CHD in infants aged 2 to 24 months, in the absence of cardiomegaly in CXR, is more than 84%.

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Consent for publication

Not applicable (Design is original article not case report or series. Consent for publication had been a part for consent for participate).

Conflicts of interest

There are no conflicts of interest.

References

1. Van Der Linde D, Konings EE, Slager MA, Witsenburg M, Helbing WA, Takkenberg JJ, et al. Birth prevalence of congenital heart disease worldwide: A systematic review and meta-analysis. J Am Coll Cardiol. 2011; 58(21):2241-7. doi: 10.1016/j.jacc.2011.08.025.
2. Sun PF, Ding GC, Zhang MY, He SN, Gao Y, Wang JH. Prevalence of congenital heart disease among infants from 2012 to 2014 in Langfang, China. Chin Med J (Engl). 2017; 130(9):1069-73. doi: 10.4103/0366-6999.204923.
3. Sun RR, Liu M, Lu L, Zheng Y, Zhang P. Congenital heart disease: Causes, diagnosis, symptoms, and treatments. Cell Biochem Biophys. 2015; 72(3):857-60. doi: 10.1007/s12013-015-0551-6.
4. Rahim F, Ebadi A, Saki G, Remazani A. Prevalence of congenital heart disease in Iran: A clinical study. J Med Sci. 2008; 8(6):547-52. [In Persian]
5. Birkebæk NH, Hansen LK, Elle B, Andersen PE, Friis M, Egeblad M, et al. Chest roentgenogram in the evaluation of heart defects in asymptomatic infants and children with a cardiac murmur: Reproducibility and accuracy. Pediatrics. 1999;103(2):e15. doi: 10.1542/peds.103.2.e15.
6. Laya BF, Goske MJ, Morrison S, Reid JR, Swischuck L, Ey EH, et al. The accuracy of chest radiographs in the detection of congenital heart disease and in the diagnosis of specific congenital cardiac lesions. Pediatr Radiol. 2006; 36(7):677-81. doi: 10.1007/s00247-006-0133-2.
7. Molaie A, Abdinia B, Zakeri R, Talei A. Diagnostic value of chest radiography in pediatric cardiovascular diseases: A retrospective study in Tabriz, Northwest of Iran. International Journal of Pediatrics. 2015; 3(2/1):9-13. doi: 10.22038/IJP.2015.4002.
8. Fonseca B, Chang RK, Senac M, Knight G, Sklansky MS. Chest radiography and the evaluation of the neonate for congenital heart disease. Pediatr Cardiol. 2005; 26(4):367-72. doi: 10.1007/s00246-005-8649-z.
9. Satou GM, Lacro RV, Chung T, Gauvreau K, Jenkins KJ. Heart size on chest X-ray as a predictor of cardiac enlargement by echocardiography in children. Pediatr Cardiol. 2001; 22(3):218-22. doi: 10.1007/s002460010207.
10. Caffey J. Pediatric X-ray diagnosis. 7th ed; 1978. p. 543.