International Journal of Public Health Excellence (IJPHE)
Vol. 3, No. 1, December 2023, pp. 330~338
Journal Homepage: https://ejournal.ipinternasional.com/index.php/ijphe
ISSN: 2809-9826, DOI: 10.55299/ijphe.v3i1.674

Foetal Echocardiography vs. Neonatal Echocardiography for Diagnosis of Congenital Heart Diseases

Kevina Liora[1], Tiffanie Almas Santoso[2], Siti Alya Fahira[3], Theresia Aquila Yuliana[4], Oriza Malta Damayanti[5]
[1] RSUD Bajawa, Ngada, Nusa Tenggara Timur, Indonesia
[2] Faculty of Medicine, Universitas Padjadjaran, Jawa Barat, Indonesia
[3] Faculty of Medicine, Syiah Kuala University, Aceh, Indonesia
[4] Nangalili Public Health Center, Manggarai Barat, Nusa Tenggara Timur, Indonesia
[5] RSUD Sultan Imanuddin, Kotawaringin Barat, Kalimantan Tengah, Indonesia

Article Info

Article history:

Received November 26, 2023
Revised December 12, 2023
Accepted December 30, 2023

Corresponding Author:

Kevina Liora
RSUD Bajawa, Ngada, Nusa Tenggara Timur, Indonesia
Email: kevinliora@gmail.com

ABSTRACT

Congenital heart disease (CHD) is a structural abnormality in the heart or major intrathoracic blood vessels that has been present since birth. The antenatal detection of congenital cardiac disease has been greatly enhanced by the advent of fetal echocardiography as a crucial component of prenatal ultrasound evaluation. Nevertheless, antenatal CHD diagnosis rates are still lower than those for the majority of other significant structural defects. Aim : Assess the effectiveness of fetal in comparison to neonatal echocardiography. This study is conductedin accordance to the PRISMA statement. Studies were identified from several open-access electronic databases (PubMed Central, ScienceDirect, Google Scholar). Risk of bias of each study was evaluated using Cochrane Risk of Bias In Non-randomized Studies of Interventions (ROBINS-I) tool. Data were descriptively examined and narratively reported. Twelve studies were included in the review. All included studies were considered low-risk. From 12 studies that were included in our study, all recommend fetal echocardiography for prenatal assessment. Lowest reported sensitivity was 64.5%, highest value was 100%. Lowest repoted specificity was 88.9%, highest value was 99.96%. Diagnostic accuracy was reported in 4 studies, with a value of 93 – 99.82% Factors that might be associated with the accuracy of fetal echocardiography are high anatomic complexity, maternal comorbidities, and fellow as initial imager. Fetal echocardiography was found to have a high specificity but limited sensitivity. Low sensitivity suggests that fetal echocardiography results could be inaccurate whereas high specificity means that a negative echocardiography result is often sufficient to predict the absence of CHD. There are some factors that may affect the accuracy of fetal echocardiography, mostly resulting from fetal or maternal factors, such as high complexity of the anomaly, fetal position, late gestation, maternal obesity, and less-esperienced sonographer.

Keywords:

Congenital Heart Disease, Fetal Echocardiography, Prenatal Echocardiography And Neonatal Echocardiography

1. INTRODUCTION

Congenital heart disease (CHD) is a structural abnormality in the heart or major intrathoracic blood vessels that has been present since birth. (Braley et al, 2020) Congenital heart disease (CHD) is thought to affect 6 to 12 out of every 1000 live births [1]. According to the WHO, heart abnormalities are now the main cause of infant mortality, accounting for 42% of infant mortality [2]. The antenatal detection of congenital cardiac disease has been greatly enhanced by the advent of fetal echocardiography as a crucial component of prenatal ultrasound evaluation [3]. Today, fetal echocardiography is regarded as a crucial part of the standard fetal abnormality examination [4]. The majority of nations worldwide offer a mid-trimester fetal anomaly screening ultrasound scan with the goal of identifying significant anomalies, and international guidelines advise that such scans include particular views of the fetal heart

[5]. Obstetric practise, however, differs greatly around the globe. (Day et al, 2021) There are numerous gestational ages and prenatal ultrasound techniques currently accessible for fetal heart evaluation [6]. The most fundamental analysis is the four-chamber view. This makes it possible to examine the heart and atrioventricular junctions generally [7].

Nevertheless, antenatal CHD diagnosis rates are still lower than those for the majority of other significant structural defects. Data from international registries indicate a broad range in the prenatal detection rate. The detection rate (DR) of screening programmes in the majority of affluent nations has been estimated to range from 30 to 60%, depending on the kind of heart abnormality [8]. Evidence suggests that infants with many serious CHD diagnosed postnatally rather than antenatally have a lower chance of surviving long enough to have heart surgery, a lower chance of surviving after such surgery, and a higher chance of experiencing negative long-term neurological outcomes. Furthermore, a precise antenatal diagnosis enables parents to decide on the continuation of a pregnancy in an informed manner [9]. In some situations, it may even enable therapeutic intervention [10]. In light of this background information, it is hypothesised that fetal echocardiogram is more useful than neonatal echocardiography since it enables prompt postnatal diagnosis and therapy [11]. In comparison to neonatal echocardiography, the effectiveness of fetal echocardiography is being assessed in this systematic review [12].

METHODS

This study is a systematic review that aims to evaluate the efficacy of fetal echocardiography compared to neonatal echocardiography, conducted in accordance to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement. Studies were identified from several open-access electronic databases (PubMed Central, ScienceDirect, Google Scholar) [13]. The keywords that were used during the search was congenital heart disease, fetal echocardiography, prenatal echocardiography and neonatal echocardiography. References from all retrieved studies were manually searched for relevant articles. Studies were considered eligible if they met the following criteria : (1) design of the study is cohort; (2) the study was published in the last 5 years (2019– 2023); (3) the study reported diagnostic values of fetal or neonatal echocardiograph; (4) the study was published in English. Studies are excluded if (1) the study was a case report, cross-sectional study or a review; (2) full-text version of the study was not accessible; (3) relevant outcomes were not reported; (4) the study was published before 2019 [14]. Data were extracted independently by a reviewer, including the first author, location of study, number of participants, outcomes and conclusion [15]. Risk of bias of each study was evaluated using Cochrane Risk Of Bias In Non-randomized Studies of Interventions (ROBINS-I) tool. Data were descriptively examined and narratively reported [16].

2. RESULTS AND DISCUSSION

Study Characteristics

From 3 databases, 23,080 studies were identified. After adjusting the filter option on each database, 4,752 studies were chosen for further screening. After screening titles and abstracts, 35 studies were excluded. A number of studies were inaccessible, and the final number of studies included in this study were 12.

We evaluated the available full text articles and extracted data, which are compiled into Table 1. Meta-analysis were not possible to be conducted due to significant heterogenicity in data reporting and variable interventions between studies. All included studies were considered low-risk, as seen from Table 2.

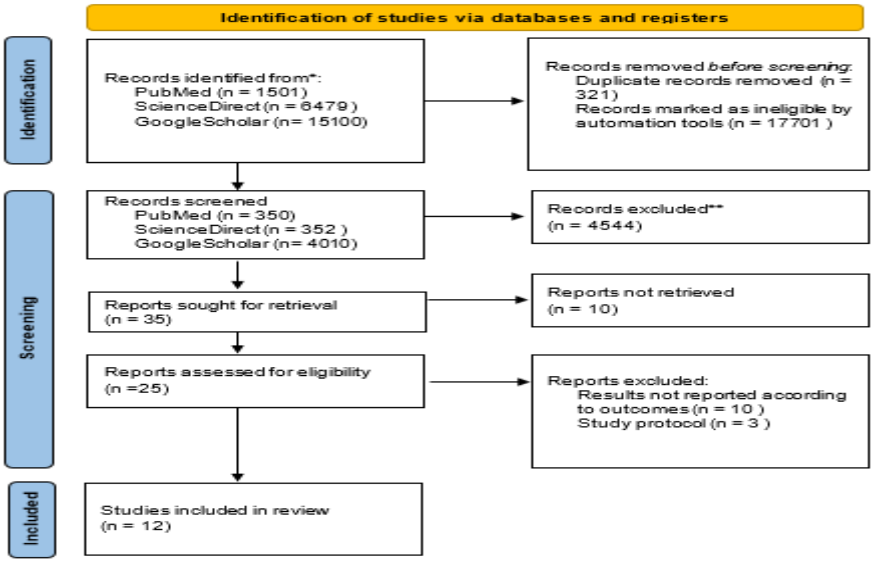

Figure 1. Study Flowchart

Table 1. Characteristics Of Included Studies

No.	Author	Year	Location	Sample Size	Intervention	Reference Standard	Results	Conclusion
1.	Varunashee et al	2021	India	1482	Fetal Echocardiography	Postnatal echocardiography	Sensitivity 83.91% Specificity 99.96% Diagnostic accuracy 99.82%	Recommends fetal echocardiography
2.	Carvalho et al.	2021	Brazil	44	Fetal Echocardiography	Postnatal echocardiography	Sensitivity 100% Specificity 96.8% Diagnostic accuracy 97.7%,	Recommends fetal echocardiography
3.	Rakha et al.	2019	Egypt	458	Fetal Echocardiography	Postnatal echocardiography	Sensitivity 97.03% Specificity 99.07% Diagnostic accuracy 98.47%	Recommends fetal echocardiography
4.	Mozumdar et al.	2020	New York	222	Fetal Echocardiography	Postnatal echocardiography	Diagnostic discrepancy 13.5%	Recommends fetal echocardiography
5	Mamalis et al.	2023	Germany	242	Fetal Echocardiography	Post-natal echocardiography	Sensitivity 90-100% Specificity 97-100% NPV 97–100% PPV 85–100%	Recommends fetal echocardiography
6	Nurmi et al	2020	Findland	250	Fetal Echocardiography	Post-natal follow-up (not-specified)	Specificity 92.6% No discrepancy in 167 of 257 case.	Recommends fetal echocardiography
7	Tutunji et al.	2022	Jordan	208	Fetal Echocardiography	Postnatal echocardiography	Sensitivity 91.7% Specificity 95.4%	Recommends fetal echocardiography
8	Khorsid et al.	2020	Egypt	60	Fetal Echocardiography	Post-natal echocardiography	Detected 8 cases out of 24 cases diagnosed with CHD (33.3%), Neonatal echocardiography detected 24 cases out of 24 cases	Recommends fetal echocardiography by qualified professionals.
9	Ngeow et al.	2021	Singapore	155	Fetal Echocardiography	Post-natal echocardiography	For all CHD : Sensitivity 64.5% Specificity 99.7% Positive likelihood ratio 215 Negative likelihood ratio 0.36	Recommends fetal echocardiography

							For critical CHD : Sensitivity 92.9% Specificity 99.1% Positive likelihood ratio 103 Negative likelihood ratio 0.07	
10	Pinheiro et al.	2019	Brazil	96	Fetal Echocardiography	Post-natal echocardiography	Sensitivity 97.7% Specificity 88.9% Diagnostic accuracy 93%	Recommends fetal echocardiography
11	Bhambani et al	2020	India		Fetal Echocardiography	Post-natal echocardiography	Sensitivity 91.7% Specificity 100%	Recommends fetal echocardiography
12	Kurosaki et al.	2020	Japan	207	Fetal Echocardiography	Post-natal echocardiography	Pre- and postnatal diagnoses of CHD differed in 12% of neonates.	Recommends fetal echocardiography

Table 2. Risk of Bias Assessment

No.	**Author**	**Bias due to confounding**	**Bias in selection of participants into the study**	**Bias in classification of interventions**	**Bias due to deviations from intended interventions**	**Bias due to missing data**	**Bias in measurement of outcomes**	**Bias in selection of the reported results**	**Overall bias**
1.	Varunashee et al	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk	Favors experimental
2.	Carvalho et al.	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk	Favors experimental
3.	Rakha et al.	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk	Favors experimental
4.	Mozumdar et al.	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk	Favors experimental
5	Mamalis et al.	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk	Favors experimental
6	Nurmi et al	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk	Favors experimental
7	Tutunji et al.	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk	Favors experimental
8	Khorsid et al.	High risk	Low risk	Low risk	Moderate risk	Low risk	Moderate risk	Low risk	Favors experimental
9	Ngeow et al.	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk	Favors experimental

10	Pinheiro et al.	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk	Favors experimental
11	Bhambani et al	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk	Favors experimental
12	Kurosaki et al.	Low risk	Low risk	Low risk	Low risk	Low risk	Moderate risk	Low risk	Favors experimental

Diagnostic Values of Fetal Echocardiography

From 12 studies that were included in our study, all recommend fetal echocardiography for prenatal assessment. Most studies stated that fetal echocardiography are useful to prevent postnatal mortality. Ten studies reported parameters such as specificity and sensitivity, except two studies that only reported diagnostic discrepancies. Lowest reported sensitivity was 64.5%, highest value was 100%. Lowest reported specificity was 88.9%, highest value was 99.96%. Diagnostic accuracy was reported in 4 studies, with a value of 93 – 99.82% Postivie predictive value (PPV) was reported in 2 studies. Negative predictive value (NPV) was reported in 2 studies. PPV and NPV both are found to be high [17].

Factors Associated with Fetal Echocardiography Accuracy

There are some factors that might be associated with the accuracy of fetal echocardiography. Rakha et al. stated that minor diagnoses were harder to detect; they had three false-positive minor diagnoses and four false-negative cases with only one requiring intervention. According to Momzudar et al., on multivariate analysis, variables associated with diagnostic discrepancy included high anatomic complexity, maternal comorbidities, and fellow as initial imager [18]. A greater number of fetal echocardiograms was associated with reduced diagnostic discrepancy. Mamalis et al stated that Prenatal echocardiography could be shown to be a reliable method for detection of congenital heart disease when regarding the slightly lower accuracy of diagnosis for double outlet right ventricle and right heart anomalies. While Nurmi et al found that fetal echocardiography has slightly lower accuracy of borderline ventricles, ventricular septal defects, aortic arch anomalies and tricuspid dysplasia. Mamalis et al. also stated that etal echocardiography may be inaccurate in detecting high anatomic complexity and cases with maternal comorbidities, fellow as the initial sonographer, and fewer fetal echocardiograms [19].

Discussion

It is estimated that 6–12 live births out of every 1000 are affected with CHD. The WHO reports that heart defects are currently the leading cause of infant death. Congenital heart disease has a significant impact on the course of pregnancy; 20–30% of foetuses with documented cardiac anomalies experience intrauterine death, and 40–60% of cases contribute to neonatal death, with long-term survival rates ranging from 15–40% [20].

Genetic and environmental variables have a complex role in the development of the cardiovascular system. Women might not take preventative measures against environmental variables because 49% of pregnancies are unplanned. This is supported by the fact that up to 40% of referral for fetal echocardiography and detection of CHD are found in low-risk pregnant women, while only 10% has risk factors of CHD [21].

A growing number of physicians and sonologists gained extensive training in diagnosing congenital malformations, particularly cardiac anomalies, as ultrasonography technology advanced and more advanced ultrasound machines became accessible. (Tasha et al, 2014) Optimising and coordinating care for both the foetus and the pregnant person is made possible by prenatal identification of CHD. Benefits cover all aspect of prenatal and perinatal care, including fetal intervention, optimisation of prenatal care, and counselling. Improved long-term neurodevelopmental results and a decreased risk of postnatal hemodynamic compromise.

Fetal echocardiography is frequently used to identify CHD and most cases of CHD can be diagnosed in the first 20 weeks of pregnancy. (Hematian et al, 2022) Fetal echocardiography and ultrasonography (US) can be used to diagnose pregnancies. However, research revealed that obstetric ultrasound did not have enough sensitivity and specificity for detecting CHD, particularly in low-risk pregnancies. Additionally, structured cardiac anomalies may go undetected because of the complex anatomy and constant motion of the heart. Because fetal echocardiography has such a high sensitivity and specificity, it is therefore thought to be a more superior option for detecting prenatal CHD. (Ghiasi, 2022)

In our study, fetal echocardiography was found to have a high specificity but limited sensitivity. Lowest reported sensitivity was 64.5%, highest value was 100%. Lowest reported specificity was 88.9%, highest value was 99.96%. Diagnostic accuracy of fetal echocardiography 93 – 99.82%. PPV and NPV both are found to be high. A positive result effectively confirms the presence of CHD when there are sufficient risk factors for the condition, as indicated by the high positive likelihood ratios. The low negative likelihood ratio for CHD suggests that a negative result can be reassuring in low-risk cases. Low sensitivity suggests that fetal echocardiography results could be inaccurate whereas high specificity means that a negative echocardiography result is often sufficient to predict the absence of CHD [22].

There are some factors that may affect the accuracy of fetal echocardiography, mostly resulting from fetal or

maternal factors. Factors that may contribute to inaccuracy of fetal echocardiography are high complexity of the anomaly, fetal position, maternal comorbidities, and less-experienced sonographer. In terms of fetal position, it took an average of slightly more than two minutes to obtain the cardiac views; however, in cases with unfavorable fetal position (anterior spina), the cardiac examination was delayed by fifteen to twenty minutes [23]. This may complicate the process which contributes to lower accuracy, especially in the hands of less-experienced physicians. (Bravo-Valenzuela et al, 2018) Because of the restricted fetal position and limited amniotic fluid, late gestation imaging is more difficult. This explains why it is critical to identify and refer suspected abnormalities as soon as possible [24].

Mamalis et al. found that double outlet right ventricle and right heart anomalies had slightly lower diagnosis accuracy. Nurmi et al. found that tricuspid dysplasia, ventricular septal defects, aortic arch abnormalities, and borderline ventricles had somewhat lower accuracy. One of the associated factors is the imaging view. The utility of the 4-chamber view could be the reason for low sensitivity, which often overlooked malformations of the great thoracic arteries or cardiac structure.

To enhance the detection of CHD, the standard four-chamber and outflow views have been supplemented with the three vessels (3 V) and three vessels with trachea (3VT) views. (Bravo-Valenzuela et al, 2018) Many cases of CHD, particularly those involving conotruncal and outflow defects (such as transposition of the great vessels, tetralogy of Fallot, double-outlet right ventricle, truncus arteriosus, and outlet septal defects), were not well detected by the four-chamber view. The methodical use of standard two-dimensional views provides a comprehensive evaluation of mid-gestation cardiac anatomy. The visceral and cardiac situs, four-chamber, right and left ventricular outflow tracts, 3VT, 3V, bicaval, ductal arch, aortic arch, and short-axis of the ventricles and great arteries make up the minimum standard views.

Even though it is advised to view the patient from various angles during the sonographic cardiac screening exam, other potential technical limitations should also be noted, such as increased maternal abdominal wall thickness. (Pinheiro) One important factor that has been identified as potentially contributing to misdiagnosis in prenatal screening is maternal [25]. Aguilera and Dummer observed that mothers with an average BMI of 32.9 kg/m2 contribute to diagnostic discrepancies [26].

Maternal obesity has also been associated with the misdiagnosis of major CHD such as truncus arteriosus, interrupted aortic arch, and TGA. Momzudar et al. discovered that obesity was the most prevalent maternal comorbidity and that maternal comorbidities as a whole were demonstrated to be a significant independent predictor of diagnostic discrepancy. Therefore, it is suggested that these patients should undergo repeat ultrasound exams, with more experienced sonographers and undergo a longer examination time when imaging is not ideal [27].

Experience of the sonographer or physician is also crucial for assessing fetal echocardiography accuracy. Some studies have found that fetal echocardiography and anatomic survey by OBGYN/MFM physician is comparable to fetal echocardiography done by pediatric cardiologists antenatally or neonatally. There are still not enough specialized centers, technical conditions, and qualified professionals to perform this exam on all pregnant women. Nonetheless, fetal echocardiography should be included in the training of obstetric physician, pediatric cardiologist and also at all primary and secondary level antenatal care providing centres to prevent delay for further examinations [28].

Current Guidelines Regarding Fetal Echocardiography

The heart develops early during embryonic development, and CHD is commonly detected during an obstetric anomaly ultrasound scan between the ages of 18 - 20 weeks. All cardiac structures can be analysed more precisely after 18 weeks of gestation. The exam is based on visualisation of the cardiac chambers, with additional images of large vessels and the aortic arch. Furthermore, for high-risk populations, first-trimester early CHD screening may be used. Some major cardiac defects can be detected as early as 12 weeks of pregnancy. (Ravi et al, 2021) It should be kept in mind that because of the small size of the fetal heart in early gestation, the success rate of visualisation of cardiac structures on detailed anatomic survey is significantly higher after 12 + 3 gestational weeks Fetuses who have or are suspected of having an abnormality on routine cardiac ultrasound screening are candidates for fetal echocardiograms. Even when the risk is estimated to be 1% to 2%, fetal echocardiography may be considered. Table 3 lists the most common indications for fetal echocardiography.

Prenatal detection and accurate delineation of fetal CHD morphology and function are critical for prenatal counselling, perinatal, and early postnatal care planning [29]. Prenatal diagnosis also enables targeted screening for CHD-associated chromosomal abnormalities and other malformations. Accurate CHD diagnosis is critical for conveying CHD severity as well as prognosis assessments to parents during counselling. Anticipation of neonatal care and early intervention needs are critical components of postnatal care planning [30].

Table 3. Indications of fetal echocardiography

Fetal	factors	1. Suspected cardiac structural anomaly 2. Fetal extracardiac anomaly known to be associated with CHD 3. Suspected abnormality of cardiac function or cardiomegaly Hydrops fetalis 4. Persistent fetal tachycardia (heart rate ≥ 180 bpm)

	5. Suspected heart block or persistent fetal bradycardia (heart rate ≤ 110 bpm) 6. Frequent episodes or persistently irregular cardiac rhythm 7. Nuchal translucency ≥ 3.5 mm 8. Confirmed or suspected genetic abnormality Monochorionic twinning†
Patient or familial disease or environmental exposure	1. First-degree relative of fetus with CHD (parents, siblings, half-siblings) 2. First- or second-degree relative with disease of Mendelian inheritance and history of childhood cardiac manifestations 3. Pregestational diabetes, regardless of HbA1c level 4. Anti-Ro/SSA antibodies 5. Phenylketonuria (unknown status or periconceptional phenylalanine level > 10 mg/dL) 6. Retinoid exposure 7. Confirmed fetal infection (TORCH- and parvovirus-B19-positive)
Other indications when fetal echo may be considered	8. Second-degree relative of fetus with CHD 9. Gestational diabetes diagnosed in first or early second trimester 10. Nuchal translucency between 3.0 and 3.4 mm 11. Selected teratogen exposure (e.g. paroxetine, carbamazepine, lithium, sodium valproate) 12. Conception by IVF, including ICSI 13. Use of ACE inhibitors (antihypertensive medication)
Other considerations	Though historical reports may suggest otherwise, there is insufficient evidence to show that risk of CHD is significantly over baseline for certain patient and fetal factors, including: 1. Patient obesity (BMI ≥ 35 kg/m^2) 2. SSRI antidepressant exposure other than paroxetine, non-cardiac ‘soft marker’ for aneuploidy 3. Abnormal serum analytes (e.g. α-fetoprotein level) 4. Isolated SUA (single umbilical artery) 5. Gestational diabetes diagnosed after second trimester 6. Warfarin exposure 7. Alcohol exposure 8. Echogenic intracardiac focus 9. Prenatal fever or viral infection with seroconversion only 10. Isolated CHD in a relative further removed than second-degree to fetus.

3. CONCLUSION

Prenatal detection and accurate delineation of fetal CHD by fetal echocardiography are critical for prenatal counselling, perinatal, and early postnatal care planning. However, it may be affected by some factors, such as high complexity of the anomaly, fetal position, late gestation, maternal obesity, and less-esperienced sonographer. Measures to overcome these factors are utilization of more detailed imaging views, repeated examinations in patients with maternal obesity, sonography performed at ages of 18 - 20 weeks, and performed by more experienced sonographer as well as giving specialized training to physicians to increase skills.

REFERENCES

[1] L. Yeo, S. Luewan, and R. Romero, “Fetal Intelligent Navigation Echocardiography (FINE) Detects 98% of Congenital Heart Disease,” *J. Ultrasound Med.*, vol. 37, no. 11, pp. 2577–2593, Nov. 2018, doi: 10.1002/jum.14616.

[2] H. Y. Sun, “Prenatal diagnosis of congenital heart defects: echocardiography,” *Transl. Pediatr.*, vol. 10, no. 8, pp. 2210–2224, Aug. 2021, doi: 10.21037/tp-20-164.

[3] N. Mozumdar *et al.*, “Diagnostic Accuracy of Fetal Echocardiography in Congenital Heart Disease,” *J. Am. Soc. Echocardiogr.*, vol. 33, no. 11, pp. 1384–1390, Nov. 2020, doi: 10.1016/j.echo.2020.06.017.

[4] S. Gao *et al.*, “Comparison of fetal echocardiogram with fetal cardiac autopsy findings in fetuses with congenital heart disease,” *J. Matern. Neonatal Med.*, vol. 34, no. 23, pp. 3844–3850, Dec. 2021, doi: 10.1080/14767058.2019.1700498.

[5] S. Rakha and H. El Marsafawy, “Sensitivity, specificity, and accuracy of fetal echocardiography for high-risk

pregnancies in a tertiary center in Egypt," *Arch. Pédiatrie*, vol. 26, no. 6, pp. 337–341, Sep. 2019, doi: 10.1016/j.arcped.2019.08.001.
[6] S. Gao *et al.*, "Comparison of fetal echocardiogram with fetal cardiac autopsy findings in fetuses with congenital heart disease," *J. Matern. Neonatal Med.*, vol. 34, no. 23, pp. 3844–3850, 2021.
[7] M. Donofrio, "Predicting the Future: Delivery Room Planning of Congenital Heart Disease Diagnosed by Fetal Echocardiography," *Am. J. Perinatol.*, vol. 35, no. 06, pp. 549–552, May 2018, doi: 10.1055/s-0038-1637764.
[8] A. H. Khorshid, M. I. A. E.-K. Aldeftar, A. Al-Habbaa, H. A. E. Gaber, A. A. E.-S. Elhewala, and M. H. H. Ezzt, "Comparison between Fetal Echocardiography and Neonatal Echocardiography in Diagnosing Congenital Heart Diseases," *Egypt. J. Hosp. Med.*, vol. 76, no. 2, pp. 3600–3606, Jul. 2019, doi: 10.21608/ejhm.2019.39167.
[9] M. O. Nurmi, O. Pitkänen-Argillander, J. Räsänen, and T. Sarkola, "Accuracy of fetal echocardiography diagnosis and anticipated perinatal and early postnatal care in congenital heart disease in mid-gestation," *Acta Obstet. Gynecol. Scand.*, vol. 101, no. 10, pp. 1112–1119, Oct. 2022, doi: 10.1111/aogs.14423.
[10] V. T. Truong *et al.*, "Application of machine learning in screening for congenital heart diseases using fetal echocardiography," *Int. J. Cardiovasc. Imaging*, vol. 38, no. 5, pp. 1007–1015, May 2022, doi: 10.1007/s10554-022-02566-3.
[11] J. Wong, K. Kohari, M. O. Bahtiyar, and J. Copel, "Impact of prenatally diagnosed congenital heart defects on outcomes and management," *J. Clin. Ultrasound*, vol. 50, no. 5, pp. 646–654, Jun. 2022, doi: 10.1002/jcu.23219.
[12] A. Chakraborty, S. R. Gorla, and S. Swaminathan, "Impact of prenatal diagnosis of complex congenital heart disease on neonatal and infant morbidity and mortality," *Prenat. Diagn.*, vol. 38, no. 12, pp. 958–963, Nov. 2018, doi: 10.1002/pd.5351.
[13] M. Aguilera and K. Dummer, "Concordance of fetal echocardiography in the diagnosis of congenital cardiac disease utilizing updated guidelines," *J. Matern. Neonatal Med.*, vol. 31, no. 7, pp. 940–945, Apr. 2018, doi: 10.1080/14767058.2017.1297791.
[14] H. Mottaghi, E. Heidari, and S. S. Ghiasi, "A review study on the prenatal diagnosis of congenital heart disease using fetal echocardiography.," *Rev. Clin. Med.*, vol. 5, no. 1, 2018.
[15] C. S. Haxel *et al.*, "Care of the fetus with congenital cardiovascular disease: from diagnosis to delivery," *Pediatrics*, vol. 150, no. Supplement 2, 2022.
[16] P. T. Levy *et al.*, "Application of neonatologist performed echocardiography in the assessment and management of neonatal heart failure unrelated to congenital heart disease," *Pediatr. Res.*, vol. 84, no. Suppl 1, pp. 78–88, 2018.
[17] M. Aguilera and K. Dummer, "Concordance of fetal echocardiography in the diagnosis of congenital cardiac disease utilizing updated guidelines," *J. Matern. Neonatal Med.*, vol. 31, no. 7, pp. 940–945, Apr. 2018, doi: 10.1080/14767058.2017.1297791.
[18] M. Kondo, A. Ohishi, T. Baba, T. Fujita, and S. Iijima, "Can echocardiographic screening in the early days of life detect critical congenital heart disease among apparently healthy newborns?," *BMC Pediatr.*, vol. 18, no. 1, p. 359, Dec. 2018, doi: 10.1186/s12887-018-1344-z.
[19] M. Cruz-Lemini *et al.*, "Prenatal diagnosis of congenital heart defects: experience of the first Fetal Cardiology Unit in Mexico," *J. Matern. Neonatal Med.*, vol. 34, no. 10, pp. 1529–1534, May 2021, doi: 10.1080/14767058.2019.1638905.
[20] M. Z. Adışen and M. Aydoğdu, "Comparison of mastoid air cell volume in patients with or without a pneumatized articular tubercle," *Imaging Sci. Dent.*, vol. 52, no. 1, p. 27, 2022, doi: 10.5624/isd.20210153.
[21] J. J. Crivelli *et al.*, "Clinical and radiographic outcomes following salvage intervention for ureteropelvic junction obstruction," *Int. braz j urol*, vol. 47, pp. 1209–1218, 2021.
[22] F. P. Machado, J. E. F. Dornelles, S. Rausch, R. J. Oliveira, P. R. Portela, and A. L. S. Valente, "Osteology of the pelvic limb of nine-banded-armadillo, dasypus novemcinctus linnaeus, 1758 applied to radiographic interpretation," *Brazilian J. Dev.*, vol. 9, no. 05, pp. 14686–14709, 2023.
[23] L. Munhoz, C. HIROSHI IIDA, R. Abdala Junior, R. Abdala, and E. S. Arita, "Mastoid Air Cell System: Hounsfield Density by Multislice Computed Tomography.," *J. Clin. Diagnostic Res.*, vol. 12, no. 4, 2018.
[24] R. Krishnan, L. Deal, C. Chisholm, B. Cortez, and A. Boyle, "Concordance Between Obstetric Anatomic Ultrasound and Fetal Echocardiography in Detecting Congenital Heart Disease in High-risk Pregnancies," *J. Ultrasound Med.*, vol. 40, no. 10, pp. 2105–2112, 2021, doi: https://doi.org/10.1002/jum.15592.
[25] S. Menahem, A. Sehgal, and S. Meagher, "Early detection of significant congenital heart disease: The contribution of fetal cardiac ultrasound and newborn pulse oximetry screening," *J. Paediatr. Child Health*, vol. 57, no. 3, pp. 323–327, Mar. 2021, doi: 10.1111/jpc.15355.
[26] N. R. Sayal, S. Boyd, G. Zach White, and M. Farrugia, "Incidental mastoid effusion diagnosed on imaging: are we doing right by our patients?," *Laryngoscope*, vol. 129, no. 4, pp. 852–857, 2019.
[27] D. d'Ovidio, F. Pirrone, T. M. Donnelly, A. Greco, and L. Meomartino, "Ultrasound-guided percutaneous

antegrade pyelography for suspected ureteral obstruction in 6 pet guinea pigs (Cavia porcellus)," *Vet. Q.*, vol. 40, no. 1, pp. 198–204, Jan. 2020, doi: 10.1080/01652176.2020.1803512.

[28] M. A. Wasserman *et al.*, "Recommendations for the adult cardiac sonographer performing echocardiography to screen for critical congenital heart disease in the newborn: from the American Society of Echocardiography," *J. Am. Soc. Echocardiogr.*, vol. 34, no. 3, pp. 207–222, 2021.

[29] E. P. Lestari, D. D. Cahyadi, S. Novelina, and H. Setijanto, "PF-30 Anatomical Characteristic of Hindlimb Skeleton of Sumatran Rhino (Dicerorhinus sumatrensis)," *Hemera Zoa*, 2018.

[30] L. Meomartino, A. Greco, M. Di Giancamillo, A. Brunetti, and G. Gnudi, "Imaging techniques in Veterinary Medicine. Part I: Radiography and Ultrasonography," *Eur. J. Radiol. Open*, vol. 8, p. 100382, 2021, doi: 10.1016/j.ejro.2021.100382.