● Recommendations

RECOMMENDATIONS FOR PRENATAL ECHOCARDIOGRAPHY: A REPORT FROM INTERNATIONAL PRENATAL CARDIOLOGY COLLABORATION GROUP.

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Abstract

International Prenatal Cardiology Collaboration Group (IPCCG) links specialists from prenatal cardiology all over the world. In this recommendation we would like to focus on the fetal/prenatal echocardiography official report. So far many recommendations focused mainly on technical aspects of the fetal heart examination.

Key words: *report, consensus, fetal heart*

INTRODUCTION

The sonographic fetal heart examination is complicated because of the fetal heart's complex structure, rapid rate, rhythmical beating and changing of its shape, usually more than twice a second[1]. Congenital heart defects (CHDs) are four and six times more frequent than chromosomal abnormalities and neural tube defects, respectively, although the rate of detection is still disappointingly low[2].

International Prenatal Cardiology Collaboration Group (IPCCG) links specialists from prenatal cardiology all over the world[3]. In this recommendation we would like to focus on the fetal/prenatal echocardiography report. So far many recommendations focus mainly on technical aspects of the fetal heart examination[4-9].

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THE BASIC ULTRASOUND FETAL CARDIAC EVALUATION

The basic ultrasound cardiac evaluation usually is performed between 18 and 22 weeks' of gestation. First localization of the placenta, and amniotic fluid volume assessment as well as the fetal biometry are necessary before the proper fetal cardiac examination and its interpretation. The cardiac evaluation must be preceded by the showing the position of the fetus on the ultrasound monitor. A selection of graphic body marks are available in our machines with supine or prone: cephalic, breech and transverse fetal presentations. The definition of the laterality and abdominal situs must be examined, as should be shown by presenting of pictogram or a double screen: one with heart apex and second one with the stomach position. This way dextrocardia or situs inverus are unlikely to be missed.

The basic fetal heart examination should be performed according to standard protocol and optimally finished with final conclusion such as:

A: Normal heart anatomy and normal heart study.

B: Probably normal heart anatomy, however fetal echocardiography might be helpful to resolve the question about disproportion, pericardial effusion, bright spot, etc.

C: Probably abnormal fetal heart anatomy and fetal echocardiography is strongly recommended with a suggested time frame (days, weeks, months).

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TARGETED FETAL ECHOCARDIOGRAPHY:

The FE (Fetal Echocardiography) examination may be performed in a variety of settings, including within large academic medical centers (for instance in Poland: such center which had at least 100 fetal heart defect in previous calendar year of our National Registry). The goal of fetal echocardiography is to establish the nature of structural pathology of the fetal heart, degree of functional heart anomaly, define the diagnosis, plan further management and discuss with the short and long-term prognosis[10]. Fetal echocardiography should be performed by using all kinds of ultrasound methods: two dimensional and color Doppler techniques like: M-mode, spectral, continuous-wave, tissue Doppler and three/four dimensional modalities. The results should be documented in still and video images. The fetal echocardiographic recommendations from ISUOG in 2008[5] recommended evaluating blood flow across the ductus arteriosus, aortic arch, foramen ovale, atrioventricular valves and semilunar valves.

American Institute of Ultrasound in Medicine (AIUM) guidelines from 2013 required evaluating the great arteries' (aorta main, branch pulmonary arteries, ductus arteriosus) size, patency and flow evaluation as well as other mandatory components of the fetal echocardiogram. Color Doppler ultrasound has been recommended in superior, inferior vena cava, ductus venosus, pulmonary veins, foramen ovale, atrioventricular valves, atrial and ventricular septa, semilunar valves, ductal arch, aortic arch and in the umbilical vein and artery. The flow evaluation should be presented for the potential disturbances by assessing the velocity and direction of blood flow. Fetal heart rhythm irregularities should be documented by using 2D, Doppler and/or M-mode techniques. By assessing the mitral inflow- aortic outflow or superior vena cava-ascending aorta or atrial- ventricular contractions, among other approaches, fetal arrhythmias may be evaluated and differentiated[9].

Optional cardiac biometry is recommended for suspected structural and/ or functional anomalies by using percentiles and Z-scores for valve annulus sizes, ventricular lengths, aortic arch and isthmus diameter, main pulmonary artery and ductus arteriosus, end-diastolic ventricular diameter, ventricular free wall and interventricular septum thickness[9].

Cardiothoracic ratio, fractional shortening, myocardial performance index, ventricular strain are used in these conditions as well[6]. Relative disproportion of the heart with cardiomegaly may reflect heart failure that can lead to hydrops fetalis. Cardiomegaly seen in the structurally normal heart may occur in choriohemanangiomas, sacrococcygeal teratoma, cord atrioventricular fistulas or vein of Gallen malformations which cause increasing volume load on the fetal heart. Increased velocities across the atrioventricular and semilunar valves and ductus arteriosus with coexisting cardiomegaly can suggest fetal anemia. Persistent bradycardia or complete heart block may cause cardiomegaly and ventricular hypertrophy[11].

Suboptimal imaging may be a results of small cardiac structures, rapid fetal heart rate and movements, fetal prone position, maternal obesity (Body Mass Index: BMI≥ 30kg/m^2), abdominal scars or limited acoustic windows[12].If significantly, limited conditions exist, despite the attempts of optimizing the probe placement and transducer pressure, such limitations should be reported[13,14]. The information about the possibility of missing some CHDs seen in newborns should be noted in the report (for instance as an standard additional information at the bottom of the report). Small ventricular septal defects, mild valvar stenosis, coarctation of the aorta may not be detected and their presence has no influence on obstetrical or neonatal management.

Scanning needs to optimize the level of image quality by optimizing the settings on the ultrasound machine and preserving the cardiac apex oriented visualization with the adequate angle of acquisition in relation to the interventricular septum. The American Heart Association suggested return visits if "acoustic limitation" is present and suboptimal conditions are noticed[12]. Sklansky and DeVore recommended more aggressive inclusion of specific imaging techniques within guidelines, noting that many cases of CHD are missed because of inadequate image quality or inappropriate angles of acquisition[13].

TARGETED FETAL ECHOCARDIOGRAPHY: REPORTING AND PARENTAL SUPPORT

Reporting is as essential part of fetal echocardiography and digital clips should be documented both with and without color Doppler flow[9]. With the acquisition and storage of cine clips, rather than still frame images, abnormalities of the fetal heart are less likely to be missed[15]. The fetal echocardiography report in the reference center, in the case of normal heart anatomy and in subtle functional disorders usually is prepared immediately after the examination[8]. When critical CHD is detected, additional time is required for scanning, counseling, and writing up of the compelte official report[16]. In Poland, the written report is prepared and given to the pregnant woman and to her obstetrician. In the United States, reports are typically sent to the referring physicians and primary obstetricians. In cases of planned delivery in a tertiary institute copies of reports may be provided to the heads of the obstetrical, neonatal, intensive care and cardiology departments.

In Germany basic four chamber view scanning is provided by first line examiners, and then upon indication patients are referred to a center to get a detailed anomaly scan including a detailed complete fetal echocardiography according to DEGUM and ISUOG guidelines. This visit is covered by the insurances. Otherwise women are free to book an appointment on a personal request basis and this will not be covered by health care providers. Interdisciplinary counselling with pediatric cardiologists is provided in most cases at first visit in referral center. On a second visit parents are invited to visit the pediatric heart center and to meet social workers, nurses and supporting staff.

In case of planned delivery in a tertiary institute the copies of reports are provided to the heads of obstetrical department, neonatology department, intensive care unit department, cardiology department, and pediatric cardiac surgery if indicated (both as a hard copy as well as via electronic means). It may also be helpful for the parents to tour the pediatric facility and meet some of the pediatric specialists who will be caring for their child.

In case of abnormalities, the fetal echocardiographic consultation should be prepared as a written report with schematic presentation of suspected and analyzed anomaly, and additional time for an oral explanation in the consulting room should be reserved. Patients may be advised to read the dedicated books and websites, which might be helpful in process of understanding and acceptance of their situation. They should be informed about the actual possible forms and results of prenatal and postnatal treatment. The possibility of the legal termination of pregnancy must be presented as well and the support should be provided by the team, which may include social workers, genetic counselors and nurse practitioners[12].

There are different types of diagnoses group based on fetal echocardiography: normal heart, congenital heart defect with specific diagnosis and state of circulation, cardiomyopathy, normal heart anatomy with functional disorders including: insufficiency of the valves, increased velocity flow through the valves, aortic arch, ductus arteriosus, ductus arteriosus constriction, increased velocity flow through pulmonary veins, superior and inferior vena cava, abnormal spectrum in systemic veins, pulmonary veins, fetal heart arrhythmias, fetal tumors etc[8].

TARGETED FETAL ECHOCARDIOGRAPHY: QUALIFICATIONS OF FETAL CARDIOLOGIST

Fetal Echocardiography (FE) in CHD generally takes a long time, approximately 45-60 minutes depending on complexity of the malformation, and it requires technical skills, experience and special knowledge. In Poland a physician performing fetal echocardiography ought to have finished a training in prenatal cardiology at an academic referral center and be certified by the Section of Fetal Echocardiography or Prenatal Cardiology Society (since last year) and Prenatal Cardiology of Polish Ultrasound Society. In Germany the DEGUM (Deutsche Gesellschaft für Ultraschall in der Medizin) system qualify from a basic to advanced examiner (DEGUM I-III). In the USA, most Maternal Fetal Medicine specialists, many pediatric cardiologists, and some perinatal sonographers have specialized training in fetal echocardiography, and the ARDMS offers special certification in this for sonographers. This varies from country to country.

Physician with Certificate of Fetal Echocardiography in Poland may become a fetal cardiologist if he or she are doing research and publishing in the field. This is not required for Basic Fetal Heart Exam Certificate in Poland. Ten fetal congenital heart defects in National Registry is a minimum of requirements and Basic Certificate is for 5 years.

The DEGUM classification in Germany of a DEGUM I or II does not require publications. DEGUM II classification needs a certain amount of anomalies being diagnosed by the doctor and we have recertification every 5 years. DEGUM III requires PhD and participation at conferences. Publications are not needed.

SOME DETAILS REGARDING FETAL ECHOCARDIOGRAPHY IN 1ST, 2ND AND 3RD TRIMESTER OF PREGNANCY:

1st trimester echocardiography

First trimester fetal echocardiogram at 11-14 or first trimester and early second trimester 11-17 weeks could be proposed in case of an increased nuchal translucency (NT ≥ 3.5 mm), or evidence of fetal hydrops or effusions, with abnormal ductus venosus flow[10]. In cases of suspected genetic anomalies, or in diabetic pregnant women with elevated HbA1C levels (HbA1C> 6%), or in the history of heart defects in previous child and after in vitro fertilization treatment[12,17]. The mandatory first trimester evaluation should contain the fetal heart position, size, axis, and the four chamber view, while the additional left/ right outflow tracts and aortic arch views are not always technically feasible[10].

1 trimester	
Basic components:	Situs
	Position of the heart and it's axis
	Fetal heart size
	4CV (Four Chamber View)
Basic evaluation:	Normal?/ Abnormal?

Table 1: The data which should be included in fetal echocardiography report in referral center for fetal cardiology in the 1st trimester

2nd trimester echocardiography

The repeated or initial cardiac examination should be

2 trimester				
Fetal echocardiographic components:	Situs			
	Position of the heart and it's axis			
	Fetal heart size			
	4CV, 3VV			
	LVOT and RVOT			
	Aortic arch			
	Ductus arteriosus (DA)			
	Systemic veins			
	Pulmonary veins			
Ultrasound techniques:	2D- presentation			
	Color Doppler presentation			
	Spectral Doppler			
	M-mode presentation			
Heart measurements (optional, depending on the defect) :	Atrioventricular valves			
	Semilunar valves			
	Pulmonary trunc			
	Main branches of pulmonary artery			
	Ascending aorta			
	Transverse part of aortic arch			
	Ventricles diameters on systole and diastole			
	FO size [mm]			
Heart rate:	Atria and ventricles measurement at M-mode presentation			
	Flow through atrium and ventricle at Doppler technique			
	Flow through foramen ovale: R-L?/ L-R?/ bilateral?			
	Time of atrio-ventricular conduction			
Basic evaluation:	Normal?/ Abnormal?			
In case of abnormal fetal heart:	Normal heart anatomy + Functional abnormalities			
	CHD + No functional abnormalities			
	CHD + Functional abnormalities			
	Fetal heart rhtythm evaluation			
CVPS assessment: (Huhta's scale)[18] Cardiovascular profile score is 10 if there are no abnormal signs and reflects 2 points for each of 5 categories: hydrops, venous Doppler, heart size, cardiac function, and arterial Doppler. AEDV- Absent End-Diastolic Velocity dP/dt- change in pressure over time of tricuspid regurgitant jet DV- Ductus Venosus FS- ventricular Fractional Shortening LV- Left Ventricle MR- Mitral valve Regurgitation MV- Mitral Valve REDV- Reversed End-Diastolic Velocity RV- Right Ventricle TR- Tricuspid valve Regurgitation TV- Tricuspid Valve UA- Umbilical Artery UV- Umbilical Vein		Normal, 2 points	-1 Point	-2 Points
	Hydrops	None	Ascites or pleural effusion or pericardial effusion	Skin edema
	Venous Doppler (umbilical vein and ductus venosus)	Normal UV		
	Normal DV	Normal UV		
	Absent/ Reversed a-wave DV	Normal UV		
	Absent/ Reversed a-wave DV			
	Heart size (heart area/ chest area)	>0.20 and ≤ 0.35	0.35-0.50	>0.50 or <0.20
	Cardiac function	Normal TV, and MV		
	RV/LV FS> 0.28			
	Biphasic diastolic filling			
		Holosystolic TR or RV/LV FS < 0.28	Holosystolic MR or TR dP/dt< 400 or monophasic filling	
	Atrerial Doppler (umbilical artery)	Normal UA	UA AEDV	UA REDV

Table 2: The data which should be included in fetal echocardiography report in referral center for fetal cardiology in the 2nd trimester

performed in the second trimester at 18-22. Referral for cardiac evaluation are similar to those for the first trimester, however the fetal heart examination would include more details.

3rd trimester echocardiography

The third trimester echo scan (beyond 28 weeks) is recommended to exclude the progression of previously seen heart defects and to identify defects which were not evident before, like for example pericardial effusion, cardiomegaly, pulmonary venous flow, rhabdomyomas, fetal heart failure due to cardiac problem or due to extracardiac anomalies, for instance caused by Vein of Gallen malformation[10]. Even significant 4 chamber or outflow tract structural abnormalities may be detected at the time of the third trimester scan when missed during earlier scanning. In fact, inclusion of routine third trimester fetal cardiac evaluation would improve prenatal detection rates for CHD more than first trimester imaging.

The size of the fetal thymus in the third trimester may be measured. A hypoplastic fetal thymus is linked to 22q11 microdeletion which could be incidental to CHDs[19]. High impedance flow patterns with a pulsatility index> 1.75 or absent (AEDF) or reversed (REDF) flow during end diastole suggests increased afterload on the heart, mostly likely from placental insufficiency or partial placental abruption. Increased diastolic flow with a pulsatility index < 1.5 in the middle cerebral artery would suggest redistribution of cardiac output away from other organs to preserve cerebral perfusion. This may suggest relative hypoxia and lead to the presence of cardiomegaly and dilation of the coronary arteries. Increased diastolic MCA flow can be seen in cerebral arteriovenous malformations. Peak MCA systolic velocity > 55 cm/s at > 30 weeks of gestation is a marker of fetal anemia[11].

3 trimester	
Basic components:	Situs
	Position of the heart and axis
	Fetal heart size
	FCV (Four Chamber View)
	3VV (3 Vessel View)
	LVOT and RVOT
	Aortic arch
	Ductus arteriosus (DA)
	Systemic veins
	Pulmonary veins
	Pulmonary veins and arteries flow
	Middle cerebral artery flow
	Umbilical artery and vein flows
Optional	Size of thymus

Table 3: The data which should be included in fetal echocardiography report in referral center for fetal cardiology in the 3rd trimester

Many studies show that the isolated cases of TAPVC are often overlooked in the basic cardiac ultrasound evaluation in the second trimester[20], so there is a special need for some of the later and again targeted fetal heart study in any case of suboptimal or uncompleted examination. Defects that were "silent" in the first and second trimester of pregnancy like for example HLHS, TAPVC can be detected later in 28-39 weeks which allows for a planned optimal perinatal and neonatal management and improves results of subsequent cardiac surgery and neonatal follow-up[21].

Hypertrophic cardiomyopathy (HCM) may be found in newborns born to diabetic mothers, and up to 5% of cases of diabetic HCM may have impaired cardiac function related to thickened interventricular septum and right ventricular wall thickening. The late development of diabetic HCM requires late echocardiographic evaluation in the third trimester[22].

Velocities higher than 150 cm/s with increased diastolic flow in the ductus arteriosus suggest ductal constriction. Ductal constriction with tricuspid valve regurgitation could be observed as the effect of non-steroidal, anti-inflammatory medications intake in the third trimester[11].

CHDS CLASSIFICATION AND SPECIALIZED DELIVERY ROOM CARE

Classifying cardiac defects may help plan for delivery and neonatal treatment, an counseling and planning may begin soon after the prenatal diagnosis[23-27]. The congenital heart defects diagnosed prenatally may be divided into four groups: the severest, severe urgent, severe planned and planned. In the severest cardiac defects (for instance Ebstein's anomaly with pulmonary hypoplasia, critical aortic stenosis with cardiomegaly) spontaneous, vaginal delivery is recommended and there is no possible treatment, thus the approach is conservative. The severe urgent heart defect usually require elective cesarean section and emergent invasive cardiac intervention after birth. The initiation of prostaglandin might be not enough and emergency catheterization with balloon valvuloplasty should be available without extra delay (for instance in case of critical aortic stenosis or pulmonary stenosis)[24].

Special delivery rooms should be prepared for fetuses and neonates with suspected perinatal cyanosis or low pH in the cord blood. It is reasonable to plan special delivery care for fetuses with HLHS with restrictive or intact atrial septum and abnormal pulmonary vein flow (pulmonary vein forward/ reversed flow ratio < 3) or abnormal hyperoxia test in the third trimester or in fetuses with congenital heart block (CHB) and low ventricular rate, cardiac dysfunction, or hydrops fetalis. Fetuses with Tetralogy of Fallot (TOF) with absent pulmonary valve or Ebstein anomaly with hydrops fetalis may be considered for the specialized delivery rooms with the specially teams including cardiac intensive care, interventional cardiology, electrophysiology and cardiac surgery[25].

CRITICAL CHD

Other forms of CHD for urgent life- saving intervention may be TAPVR (Total Anomalous Pulmonary Veins Return), d-TGA (Transposition of the Great Arteries) with restrictive atrial septum, normal heart anatomy with ectopia cordis. Certain forms of CHD's can progress *in utero*, for example: progressive atrial obstruction can be seen in 64% of fetuses with HLHS, 83% with d-TGA, sometimes only in the late weeks before delivery[27].

Determination and monitoring of the echocardiographic parameters which can identify a group of patients with the special need for immediate treatment in the delivery room could help avoid severe morbidity: cardiac arrest, end organ failure or brain damage[27].

Late echocardiography in the third trimester (the final examination just before the delivery) is crucial to determine the severity of the critical cardiac defects. An increased A wave (reversal wave during atrial systole) in the pulmonary veins may reflect a restriction at the foramen ovale (FO) in HLHS. Reverse velocity time integral ratio (VTIf/VTIr) of pulmonary vein flow <5 is a sensitive predictor of need for emergent atrial septostomy[28]. The width of FO as a single parameter does not have the predictive value in HLHS, in contrast to the pulmonary veins flow, tricuspid valve insufficiency status, right ventricular's function changes[28].

The fetuses with d-TGA with the late gradual increase of pulmonary flow, which indicate the process of early closure of the FO and the patency of the ductus arteriosus may require immediate atrial septostomy after delivery[29]. Assessment of the Doppler flow pattern in the pulmonary veins is beneficial in detecting the obstructed TAPVR (Total Abnormal Pulmonary Venous Return) which is connected with a very high mortality and immediate surgery is needed after birth[30].

FETAL MEDICAL THERAPY

Fetal medical therapy should be recommended for fetuses with AV block, sustained SVT (SVT- Supraventricular Tachycardia) or atrial flutter with hydrops or ventricular dysfunction if they are not near term and considering delivery is not reasonable. The following drugs may be given transplacentally in a first or second line: digoxin, flecainide and sotalol[12,31].

In case of pharmacotherapy special flow chart monitoring should be applied.

Fetal catheter intervention may be discussed with parents to be for fetuses with AS (AS- Aortic Stenosis) and antegrade flow and evolving HLHS, fetuses with AS and severe mitral regurgitation with restrictive atrial septum, fetuses with HLHS and severly restrictive or intact atrial septum or fetuses with PA/IVS (PA, Pulmonary Atresia/ IVS- Intact Ventricular Septum)[12].

CHRONIC INTERMITTENT MATERNO-FETAL HO (HYPEROXYGENATION)

In some tertiary care centers fetal-maternal hyperoxygenation testing might be used. The maternal hyperoxia test with 100% O_2 in the third trimester via nonrebreather facemask may predict fetuses with selected abnormalities (HLHS, diaphragmatic hernia, pulmonary hypoplasia) and postnatal compromise. Maternal HO might have the impact to change flow pattern in the transverse aortic arch and enhance left ventricular filling by increase of pulmonary venous return[32-36].

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