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The Extended Fetal Cardiac Examination, is it feasible in a High Risk Practice?

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Abstract

To demonstrate the feasibility of obtaining additional cardiac views as proposed on an extended fetal cardiac exam and to see if there was any variation in individual components of that examination stratified by sonographer training, patient body habitus, or equipment.

We retrospectively reviewed 200 consecutive detailed 2nd trimester high-risk fetal obstetrical sonograms that included additional extended cardiac views. We analyzed the percentage of the time individual views were obtained, with variation based upon 1) a sonographer with greater than

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3 years of training compared to a group with 6 to 12 months of training; 2) two different ultrasound units and 3) different Body Mass Indices (BMIs).

Overall, the highest rate of visualization was achieved with the 4 chamber view (98.2%) while the 3 vessel tracheal view had the lowest percentage of visualization (40.2%), among the less experienced sonographers. Differences in successful completion of the extended cardiac views were not statistically different between the sonographer with a level of training greater than 3 years as compared to those with 6 to 12 months training except for the 3 vessel tracheal view ($p < 0.001$). There is no statistically significant difference in our ultrasound equipment, when considering only inexperienced sonographers. Increasing BMI had an inverse relationship with obtaining the components of the detailed cardiac exam

Using state of the art ultrasound equipment and with focused additional training of obstetrical sonographers, the majority of extended cardiac views can be obtained. There are exceptions.

Keywords

Congenital heart diseases; 3 vessel view; obstetric ultrasound; prenatal diagnosis; fetal echocardiography

I. Introduction

Current recommendations by the AIUM in conjunction with ACOG and ACR for an obstetrical ultrasound include a four chamber view of the heart as well as right and left ventricular outflow tracts[1]. For the practice of fetal echocardiography the same organizations recommend the addition of cardiac views including the 3 vessel view, the three vessel tracheal view, short axis views, long axis views, aortic arch and ductal arch views as well as superior and inferior vena cava views[2]. More recently the above mentioned organizations formed a task force with other organizations with recommendations for an indication driven anatomical survey using CPT code 76811[3]. Their recommendations, which have not yet been incorporated into the AIUM, ACOG and ACR recommendations for an obstetrical exam, include the views that are within current AIUM, ACOG and ACR guidelines for fetal echocardiography. We have incorporated these additional views into our higher risk obstetrical ultrasound examination for over a year. We have done this with sonographers with different levels of training in extended fetal cardiac scanning. Our study examined the adequacy of the extended cardiac exam among sonographers with different levels of training; evaluated the effect of maternal body habitus on successful completion of the additional cardiac views; and evaluated the performance of two different type ultrasound machines used on obstetrical ultrasound performed between 18 and 22 weeks. We also documented the percentage of time each cardiac view was obtained.

II. Materials and Methods

This is an IRB-approved HIPPA-compliant study including 200 consecutive high risk obstetrical ultrasound examinations. Any examination that was performed between 18 and 22 weeks was included in this study. Those with examinations outside of that menstrual age were excluded. All exams were performed either on a General Electric (Milwaukee,

Wisconsin) E9 or E10 ultrasound unit using 4–8 MHz or 6–10 MHz curved array transducer. Endovaginal scanning was performed only to check cervical length or low lying placenta and was not used in evaluation of the fetal heart. Our basic cardiac examination always started with assessment to determine the right or left sidedness of the fetus. Then we include of view of the stomach to check for situs with the heart apex pointing to the same side as the stomach. We also evaluate cardiac axis on this view. We included 4-chamber view of the heart, and real-time imaging of the crisscrossing of the outflow tracts, and a 3 vessel (3V) view of the heart. Dedicated right and left ventricular views are included in our basic examination. This has been standard at our institution for over 10 years. All sonographers in this study had over 8 years of experience in performing these exams. One year prior to starting this study, we began to include additional cardiac views on all our high-risk obstetrical ultrasound. To do this, we increased our high-risk obstetrical ultrasound examination from 45 minutes to 1 hour. We hired a lead sonographer (GJ) with greater than 5 years of experience in obtaining extended cardiac views. We began training our other experienced obstetrical sonographers on these additional views. These less experienced sonographers were trained with didactic lectures. This was followed by one-on-one hands-on training by the more senior sonographer. The all had from 6 months to one year performing these exams under the supervision of the more experienced sonographer prior to the study. The extended cardiac views included a three vessel-tracheal view (3VT), bicaval view, and both aortic and ductal arch views. The three-vessel tracheal view as described by Yagel is defined as the transverse view of the upper mediastinum slightly cranial to the three-vessel view[4,5]. Color flow images were included and all routine views. However we did not judge for adequacy of the color flow image as part of this study.

Non-cardiac images of the diaphragm, liver and lungs are included as views in the 76811 manuscript[3]. However, we did not include all of these views in this study. For instance, there was no exact definition of what would be classified as “lungs”, thus the lung evaluation was excluded from our analysis. The liver was not included in the analysis, as the stomach was used as the landmark in determination of situs. We did not analyze data regarding the situs of the stomach. However visualization of the diaphragm was accepted as satisfactory if a sagittal and/or coronal view demonstrated both diaphragms in either one complete or two separate images of each diaphragm.

Criteria for acceptable views include the following: 4 chamber view of the heart that clearly demonstrated all 4 chambers; left ventricular outflow track that clearly demonstrated the long axis view of the aorta exiting from the left ventricle; and the right ventricular outflow track as the short axis view of the pulmonary artery exiting and bifurcating from the right ventricle. We also included a crisscross of the great vessels seen in real time. This is real-time images of the ascending aorta and the main pulmonary artery perpendicular to each other as they exit their respective cardiac ventricles[6]. A 3 vessel view of the outflow tracts was satisfactory when all 3 vessels were identified and a 3 vessel tracheal view was satisfactory when there was a v-shaped junction between the aorta and the pulmonary artery (Figures 1 and 2). A bicaval view was considered as satisfactory if both the SVC and IVC are seen in a sagittal plane entering into the right atrium. Aortic arch and ductal arches were identified when both the “candy cane” and the “hockey stick” view were seen, including

portions of the descending arch. A satisfactory aortic arch includes visualization of the great vessels from the arch.

We then compared a single designated lead sonographer with over 5 years expertise in performing all views with a group of 6 sonographers with 8–25 years of experience performing routine obstetrical ultrasound and at least 6 months but less than one year of training and experience in performing the extended cardiac views. We also compared 2 different ultrasound units, a GE E9 and a GE E10. We analyzed one other co-variable of maternal body habitus and included body mass index (BMI) less than 25, those with the BMI from 25–30, and those with the BMI over 30(obese). All ultrasound images were stored on an ultrasound mini-pacs unit (I Morgan, Sunnyview, CA). These images were evaluated by one of two physicians with 8 and 30 years of high-risk obstetrical ultrasound experience. These results were re-checked for consensus by a physician with 35 years of high risk obstetrical ultrasound experience. We did not analyze results in any group considering fetal position because of the variability of fetal position during the exam. Differences due to sonographer training were tested using mixed effects models with random intercept for each sonographer. Differences due to BMI and equipment were tested using Fisher's exact test. The experienced sonographer was removed from the equipment analysis to avoid confounding, as that sonographer used only the E10 equipment, while the other less experienced sonographers used both the GE E-9 and the E-10 units.

III. Results

Two hundred consecutive obstetrical ultrasound exams were analyzed. Of those, 42 were eliminated because of advanced menstrual age outside the limits of 18–22 weeks. We ended with a total of 158 ultrasounds exams for review. There were a total of 39 exams performed by the senior sonographer and 119 exams performed by 6 less experienced sonographers. The numbers of anatomical regions that were visualized by the two groups and analyzed by BMI and ultrasound unit are listed in Table I. There was a high percentage of visualization of the following views by both sonographer groups: 4 chamber view of the heart, the left ventricular outflow tract and right ventricular outflow tract. (Table I) There was no statistical difference in visualization of the 3 vessel view or the outflow tracts crossing in real time, between the less and the more experienced sonographers. Ductal and aortic arch were less commonly seen in both groups, but without statistical significance. There was a trend with greater percentage of inadequate visualization of the bicaval view and documentation of the diaphragm with the less experienced sonographers. Visualization of the 3 vessel tracheal view seemed to be the most difficult view to obtain among the least experienced sonographers (Table I). This difference was statistically significant at the $p<0.001$ level, in comparing the two sonographer groups.

The E10 did not perform statistically better than E9 for any of the views. However, there was a trend for decrease visualization of the 3 vessel tracheal view by less experienced sonographers, using the E9 equipment ($p=0.008$) (Table I).

Views appeared to be easier to obtain in normal and over-weight patients compared to obese patients (BMI>30). The LVOT and RVOT seemed to be more difficult to obtain with

increasing BMI (p=0.008) (Table I). There was not statistical difference in obtaining the other views. The more experienced sonographer appeared to outperform the less experienced sonographers for some views, even after controlling for equipment and BMI.

IV. Discussion

Among current CPT Codes from obstetrical ultrasound are included CPT code 76800 and CPT code 76811[7]. In addition there is a separate CPT code for fetal echocardiogram. The CPT code 76800 includes a 4 chamber view of the heart, but does not include other cardiac views. The CPT code 76811 includes a 4 chamber view of the heart as well as right and left ventricular outflow track views. There is no mention of other cardiac views within this CPT code. The current (2015) AIUM, ACOG and the ACR guidelines for obstetrical ultrasound include the 4 chamber and outflow tract views. The 2017 obstetrical ultrasound guidelines are in final review and have included the 3 vessel view, when feasible (personal communication)[8]. The 76811 task force comprised of members from numerous organizations (AIUM ACOG, ACOOG, ACR, SMFM, SDMS AND SRU) recommended additional cardiac views for an indication driven obstetrical examination as detailed in our materials section. This task force recommended that the 76811 exam should be used an indication driven examination for high risk pregnancies. They advocate that this examination includes basic views and extended cardiac views including a 3 vessel view, a 3 vessel tracheal view, a bicaval view and an aortic and ductal arch view. Therefore, we performed this study to see if these additional views could be routinely obtained, to see if the level of sonographer experience affected the ability to obtain these views, and if body habitus or equipment type limited the success of obtaining these views satisfactorily.

There is little doubt obtaining additional cardiac views increase detection of fetal cardiac malformations? We did not evaluate this question, as the literature supports obtaining additional cardiac views to help in detection of fetal cardiac anomalies. The overall sensitivity of prenatal diagnosis of congenital heart disease has varied widely within the literature. Early publications demonstrated the increased detection of fetal cardiac malformations by addition of right and left ventricular outflow tracts[9–11]. For instance Achiron 1992[9] demonstrated 48% detection of fetal cardiac malformations by a four-chamber view alone. However when the right ventricular outflow tract and left ventricular outflow tract views were added the detection rate of fetal cardiac malformations increased to 78%. Larger, more recent studies have shown that the addition of extended cardiac views increases detection of fetal cardiac malformations. For instance, recently Zhang YF el al[12] performed a meta-analysis of over 2456 English published articles and 1456 Chinese published articles and found 43 articles that met criteria in their meta-analysis. They found overall specificity of sonographic diagnosis of congenital heart disease (CHD) was always high at 99.8% in the combined group. However, sensitivity varies from 49% with a basic examination of the heart including only a 4 chamber view to a sensitivity as high as 83.7% with a 4 chamber view, outflow tracts, and 3-vessel and tracheal view of the heart. This is an improved sensitivity from 66.1% when only the basic exam plus outflow tracts are obtained. Thus, it seems that additional views such as outflow tracts views increases prenatal detection of CHD and that addition of the 3-vessel and tracheal view further improved sensitivity. This would seem reasonable to add these views to the basic cardiac exam in a high risk

pregnancy. Others have likewise previously shown increased sensitivity in prenatal detection of fetal cardiac disease with additional views[13,14]. There may be some exceptions and limitations. For instance there is generally a low prenatal ultrasound detection rate of coarctation of the aorta[15–18]. However, most every study has shown increased sensitivity in prenatal detection of fetal cardiac disease with additional views[12–14]

As to our results, we found that the views that we had been performing for our 10 years were the views that were most often satisfactory obtained by both groups. These views include the 4 chamber view, the RVOT, LVOT, the outflow crisscross and the 3 vessel view. All of these views were adequate in approximately 85% or greater for both groups. Our results show the most difficult exam to be obtained by less experienced sonographer for extended the cardiac exam was the 3-vessel tracheal view. We felt this is probably due to the fact that this may be one of the newer and more difficult exams to learn. The experienced sonographer obtained this view 79% of the time compared to 40% of the time with the less experienced sonographer ($p<.001$). We also found a trendy for statistical significance for obtaining a bicaval view by the experienced sonographer compared to the less experienced sonographers (84% versus 69 %). This was not statistically significant (p-0.06). Likewise, the more senior sonographer more often documented the diaphragm compared to the less experience sonographers (96.5% versus 79.5 %). Bicaval, ductal and aortic arch differences in visualization were not statistically significant between the two groups.

Our overall results show similar trends as from other reports from the current literature, but using different technology in obtaining these additional fetal cardiac views[19]. For instance, Novaes JY el al[20] showed level of training was important in obtaining these additional views. However, they used spatiotemporal STIC image correlation as a screening program to detect 5 axial views of the heart, as originally proposed by Yagel[5]. They compared physicians as STIC specialists and those as non-STIC specialists. Their comparison is interesting after seeing our results. In their analysis of 5 views (abdominal situs, 4 chamber outflow tracts, 3 vessel, and trachea view) was achieved 67% of the time with the more advanced users, compared to 36% of the time with the non-advanced users. Just considering a four chamber view and outflow tracts view the more experienced group was successful in 89% of the time compared to the 59% with the less experienced group.

In analyzing our data in terms of BMI, there is general decreased visualization with increasing BMI. There was most significant drop in visualization of the RVOT and the LVOT with higher BMIs at $p=0.008$. In a study performed by Adekola H et al[21], they studied optimal visualization of the 4 chamber view of the heart in the non-obese and morbidly obese population and found it was adequate in 44% of the obese compared to 87% in the non-obese group. Similar outflow tracts were optimally seen in only 43% of their obese group compared with 89% in the non-obese group. We found our sonographers had more difficulty in the group with a BMI > 30 for the RVOT and LVOT views (Table I). Likewise, a 3 vessel tracheal view was only adequately documented 41.5%, with patients with BMI>30.

Finally, in analyzing equipment, we found no statistical difference between our two ultrasound units. One could argue that this is not a valid comparison, as these machines are variations of ultrasound units made by the same manufacture. However, in our analysis of

the less experienced group, comparing the two units we found no difference in obtaining cardiac views

We have several limitations to our study. Our study was not intended to analyze the percentage of time a particular cardiac view contributed to the diagnosis of cardiac anomalies or a particular cardiac malformation. Our study only analyzed the percentages of time a particular cardiac view was obtained. Secondly, our results may not be applicable to different obstetrical ultrasound practices or different sonographers, who in fact may have either greater or less experience than our group of sonographers. Finally, we used only a single equipment vendor, when in fact there are different vendors with equipment with different software, and transducers, that may perform better or worse than our equipment.

In conclusion, we feel our data show there is a learning curve for obtaining all extended cardiac views. This was most problematic for the 3 vessel tracheal view. In comparison the 3 vessel view was adequately imaged nearly twice as frequently. Thus, we feel with adequate training of obstetrical sonographers in extended fetal cardiac views, that these views may be incorporated into the obstetrical ultrasound examination. Success in obtaining all of the extended cardiac views may be limited by the patient BMI.

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Figure 1.
Three-vessel view
There is fairly straight alignment from left anterior to the right posterior where the pulmonary arteries (PA) is slightly larger than the descending aorta (AoA) and the smaller SVC. (L = left, R = right) (Tr = trachea)

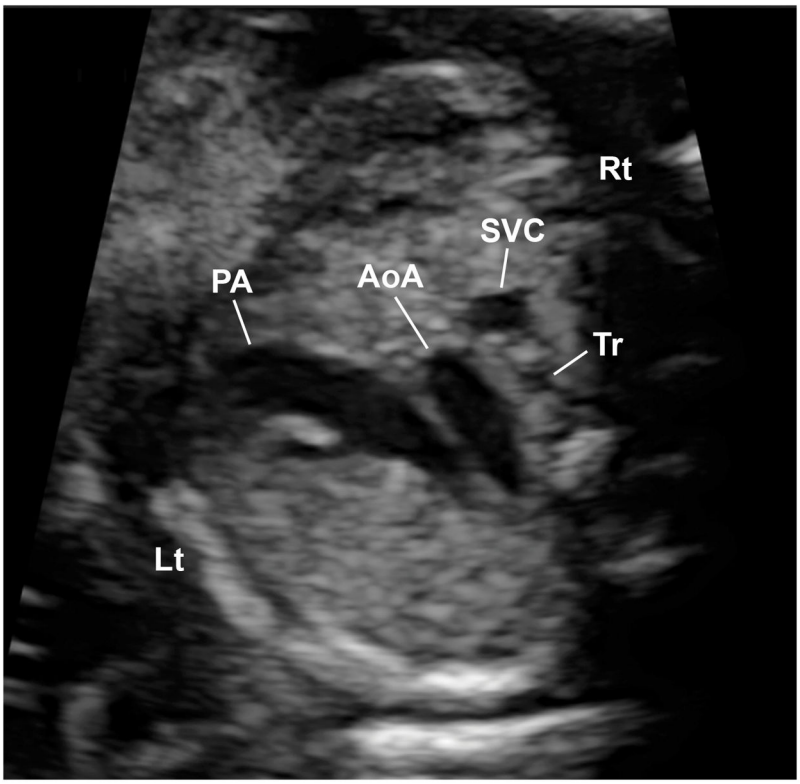

Figure 2.

Three vessel tracheal view

The pulmonary artery (PA)) is again to the left (Lt) with the more central ascending aorta (AoA). These structures connect to the descending aorta forming a V shaped appearance. (SVC = Superior Vena Cava) (Rt = right)

Table I

Percent successful views comparing sonographer training, equipment, and patient BMI. A dash in the p-value column indicates that the p-value could not be calculated due 100% success rates for the Fisher's exact tests, or lack of convergence in the mixed model due to several sonographers with 100% success rates. Significant effects are starred (*).

	Training[@]			**Equipment**[$]			**BMI**[$]			
	> 3 yrs	**3–6 months**	**p**	**E9**	**E10**	**p**	**<25**	**25–29.9**	**>30**	**p**
4 Chamber	98.3	98.2	--	96.4	99.1	.25	99.0	100	95.1	.21
RVOT	94.7	94.6	--	96.4	93.9	.72	96.9	100	85.4	.008*
LVOT	96.5	93.8	--	96.9	96.4	.72	96.9	100	85.4	.008*
Crisscross	87.7	93.8	.43	94.6	90.4	.55	91.8	96.8	87.8	.39
3V	91.2	84.8	.99	83.6	88.6	.46	88.7	90.3	80.5	.36
3V tracheal	79.0	40.2	<.001*	38.2	60.5	.008*	54.6	64.5	41.5	.14
Bicaval	83.9	68.8	.06	74.6	73.5	.99	74.0	80.7	68.3	.50
Aortic arch	89.5	79.3	.32	77.8	85.1	.28	87.5	80.7	73.2	.12
Ductal arch	75.4	76.4	.32	73.6	77.2	.70	74.7	87.1	70.7	.25
Diaphragm	96.5	79.5	.06	78.2	88.6	.10	84.5	96.8	78.1	.08

[@]Mixed effects models,

[$]Fisher's exact test.