Evaluation of the Fetal Heart at 14 – 18 Weeks Gestation in Fetuses with a Screening
Nuchal Translucency Greater than or Equal to the 95th Percentile

THESIS

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By

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Abstract

The purpose of this study was to determine if normal fetal cardiac anatomy could be successfully demonstrated and major congenital heart disease detected transabdominally, earlier in the second trimester at 14 – 18 weeks gestation for fetuses who had a nuchal translucency greater than or equal to the 95 percentile.

In this retrospective chart review, gray-scale images, Z-scores, and Doppler evaluation, including, pulsed, color and spectral Doppler, were reviewed to determine if the fetal heart evaluation at 14 – 18 weeks gestation were normal or abnormal. In this pre-experimental study, the sensitivity and specificity for assessing fetal hearts were 100 percent. It is likely that sensitivity and specificity will be less than 100 percent when a large population is considered. A plan for a larger prospective study is presented.

The fetal heart can be successfully evaluated at an earlier gestational age but may be dependent on the skill of the sonographer and reading physician. Maternal decisions can be made earlier in gestation, before the pregnancy is obvious and allow planning for a pregnancy that will need to be delivered at a medical center that has a level three nursery.

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Fields of Study

Major Field: Allied Medical Professions

Table of Contents

Abstract	ii
Acknowledgments.....	iii
Vita.....	iv
Publications	iv
Fields of Study	vi
Table of Contents	vii
List of Tables	viii
List of Figures	ix
Chapter 1: Introduction	1
Chapter 2: Literature Review	9
Chapter 3: Methodology	29
Chapter 4: Analysis of Data.....	37
Chapter 5: Summary and Conclusions.....	56
References	67
Appendix A: Data Recording Forms	A-1

List of Tables

Table 1. Visualization of Cardiac Structures	45
Table 2. Abnormal Case 1	52
Table 3. Abnormal Case 2	52
Table 4. Abnormal Case 3	53
Table 5. Abnormal Case 4	53
Table 6. Assessment for the 17 Patients with Results of Newborn Assessments.....	54
Table 7. Study Visit Table	65

List of Figures

Figure 1. Conceptual Framework	31
Figure 2. Flow Chart for Evaluating Fetal Echocardiograms	34
Figure 3. A Two-Way Table for Calculating Sensitivity, Specificity and Likelihood Ratio	35
Figure 4. Number of Patients that Had an Early Fetal Echocardiogram	38
Figure 5. Distribution of Fetal Echocardiograms by Year.....	38
Figure 6. Image Quality for Low and High BMI Patients	39
Figure 7. Image Quality Versus BMI	40
Figure 8. Image Quality for Anterior and Posterior Placental Locations	41
Figure 9. Image Quality for BMI Data Grouped by Placental Location	42
Figure 10. Image Quality for Three Fetal Positions	43
Figure 11. Heart Rate as a Function of Gestational Age	44
Figure 12. Z-Scores for the Aortic Valve	48
Figure 13. Z-Scores for the Pulmonary Valve	48
Figure 14. Z-Scores for the Mitral Valve.....	49
Figure 15. Z-Scores for the Tricuspid Valve	50
Figure 16. Z-Scores for the Left Lateral Ventricle	51
Figure 17. Z-Scores for the Right Lateral Ventricle	51

Chapter 1: Introduction

Diagnostic sonography has been used for the past 40 years to evaluate obstetrical patients. Obstetrical sonography is considered safe, non-invasive, and cost-effective and approximately 60 to 70 percent of women in the United States have a medical indication for sonography. (Filly, 2002) Obstetrical sonography is used primarily to confirm and diagnose early pregnancies; determine gestational age; assess fetal size and well-being; determine placental localization; evaluate multiple pregnancies; guide invasive or therapeutic procedures; measure blood flow; and diagnose fetal anomalies.

It is well known that as a woman's age increases, her risk of having a fetus with Down syndrome increases. Since the 1970s, the age of 35 (at delivery) has been used as the cutoff in the United States for offering an invasive procedure for amniocenteses to detect genetic and chromosomal disorders. But, since more women under the age of 35 have pregnancies than women over the age of 35, the vast majority of chromosomal anomalies occur in this low-risk group. An effective screening test needed to be developed that could be used for all pregnant women to determine their risk of having a fetus with a genetic or chromosomal disorder. The initial blood-screening test developed was the Maternal Serum Alpha-Fetoprotein (MSAFP) which examined the level of Alpha-Fetoprotein (AFP) in the maternal blood during pregnancy at 16 – 21 weeks gestation. Decreased levels of AFP may indicate an increased risk for Down syndrome.

(Ormond, 1997) Two additional substances were added to the AFP maternal blood-screening test, Estriol and Human Chorionic Gonadotropin, (hCG), and a second trimester screening test became known as the Triple Screen Test. Using the Triple Screen Test, may indicate with better sensitivity that the fetus has an increased risk of having Down Syndrome. (Ormond, 1997) Later, the addition of the protein Inhibin A to the Triple Screen Test produced the Quad Screening Test, which is now the standard second-trimester screening test. (Wald, 2003) While sensitivity has been improved for detection of genetic disorders to make a diagnosis of a genetic abnormality, a diagnostic test such as an amniocentesis still must be performed. (Ormond, 1997)

An effective screening test that could be performed during the first trimester was developed so that women could have answers privately before their pregnancies were obvious. The late-first-trimester screening test incorporated a sonography examination that measured the nuchal translucency (NT), the thickness at the back of the neck and biochemistry, free beta hCG and pregnancy-associated plasma protein-A (PAPP-A). Nicolliades of Kings College London and his group have repeatedly shown since the mid-1990s that “when ultrasound is done correctly and is combined with the proper biochemistry, about 90 percent of fetuses with trisomy 21 syndrome and other major chromosomal abnormalities can be identified with a 5% false-positive rate.” (Evans, 2006 p. 43) If NT values are increased and there is a normal karyotype, the fetus may have other congenital anomalies, including cardiac anomalies. (Souka, 2005)

Nicolliades’s research led investigators to assess the feasibility of examining cardiac and non-cardiac anatomy in a low-risk population during a routine 11 – 14 week

sonographic examination. (Souka, 2004) Souka used a transvaginal approach to optimize imaging and evaluated the four-chamber view of the heart and the three-vessel view of the great vessels. (Souka 2004) Another researcher, Carvalho, evaluated the performance of early-fetal echocardiography transvaginally for the high-risk patient. (Carvalho, 2004) The optimal imaging period appeared to be 12 – 14 weeks gestation. Carvalho stressed that the reason to perform an early cardiac evaluation was two-fold: first to demonstrate normality of situs and cardiac connections, thereby reassuring the pregnant patient and reducing anxiety. Second is that in the event of a major abnormality being diagnosed, families have the option of interrupting the pregnancy at an early gestational age, if appropriate. (Carvalho, 2004)

Obstetrical sonography has reliably been used during the second trimester to detect birth defects given that the general population has a 3 – 5 percent risk of having a fetus with a birth defect. (www.acog.org/publications/patient) The sonographic features of all major malformations have been well described for more than 20 years. (Nicolaidis, 2007) Yet, the most common types of anomalies, cardiac malformations, continue to be difficult for the average sonographer to diagnose. Ironically the most common anomaly, congenital heart disease, is also the least detected anomaly with obstetrical sonography. Initially, evaluation of the fetal heart in the United States was performed by pediatric cardiologists and their corresponding cardiac sonographers. (Sahn, 1980) Their understanding of the cross-sectional sonographic evaluation of the pediatric heart allowed an easy understanding of fetal cardiac anatomy. However, as obstetrical imaging moved

into the sphere of the high-risk obstetrical imaging centers, more obstetrical sonographers and perinatologists became involved with the sonographic fetal cardiac evaluation.

Problem Statement

It would appear that congenital heart disease is a high risk problem, occurring at a rate of 8/1000 live births, making this the most common birth defect. The problem is can normal fetal cardiac anatomy be successfully demonstrated and major congenital heart disease detected transabdominally, earlier in the second trimester at 14 – 18 weeks gestation?

Purpose of the Study

The purpose of this pre-experimental study was to determine whether fetal cardiac anatomy can be reliably demonstrated during 14 – 18 weeks gestation transabdominally, utilizing 2-dimensional, color-flow Doppler, and pulsed Doppler imaging. Furthermore, the study sought to determine whether major congenital heart disease can be successfully detected in women with a nuchal translucency greater than or equal to the 95th percentile.

Limitations of the Study

The findings of this study were limited because convenience sampling was used. Since previously acquired sonography examinations were evaluated, the research design was considered to be pre-experimental, therefore the findings cannot be generalized.

The findings of this study were specific to the sample of fetuses that had a nuchal translucency measurement greater than or equal to the 95th percentile at 11 – 13 6/7

weeks gestation at The Ohio State University Medical Center. The sonographic examination was only performed if the maternal-fetal-medicine physician ordered the diagnostic test at 14 – 18 weeks gestation rather than at 21 – 24 weeks gestation.

The data collected during this study were consistent since the sonographer performing each examination and the physician reading the examination each have over 25 years of experience providing this highly specialized obstetrical cardiac sonographic examination. This may make the results more specific to these medical professionals and their level of expertise.

The findings of this study were specific to those fetuses that were suspected of major congenital heart disease and had an echocardiogram after birth. Examinations that were interpreted as normal were considered to have no pathology, therefore an echocardiogram was not performed on those newborns.

Finally, the span of time reviewed served as a limitation as well. Equipment and transducer designs vary over time, thereby making images varied in quality. A different timeline of data collection may yield different results.

The diagnostic quality of the sonograms was also a limitation due to maternal body habitus, an anterior placenta, or unfavorable fetal position.

Basic Assumptions

A major assumption of the study was that the patient's dates were correct because each patient had a previous sonogram that could only be performed at a specific gestational age.

Definition of Terms

Nuchal Translucency: A collection of fluid under the skin at the back of a fetus's neck at 11 – 14 weeks gestation that can be measured using ultrasound.

Increased Nuchal Translucency: A measurement of the collection of fluid under the skin at the back of the neck when measured that is greater than or equal to the 95th percentile for the gestational age.

Karotype: An organized profile of an individual's chromosomes.

Amniocentesis (Amnio): A prenatal invasive diagnostic procedure where amniotic fluid is removed from the uterus to determine chromosomal disorders. This procedure is usually performed at 15 – 18 weeks gestation.

Chorionic Villus Sampling (CVS): An invasive prenatal diagnostic procedure to determine chromosomal or genetic disorders. This procedure, which acquires placental tissue, is usually performed at 10 – 13 weeks gestation.

Fetal Echocardiogram: A specialized diagnostic ultrasound examination that is performed by a highly trained sonographer to evaluate the development of the fetal heart, the great vessels, and the aortic and ductal arches, but also incorporating pulsed, color-flow Doppler, and M-mode when necessary to assess cardiac function.

Obstetrical Cardiac Examination: When four-chamber view and cardiac outflow tracts are evaluated as part of the fetal obstetrical ultrasound.

Major Congenital Heart Disease: Structural cardiac anomalies associated with poor perinatal outcomes or those with the potential to be ductal dependent after birth or both.

Minor Congenital Heart Disease: Defects expected to have favorable perinatal outcomes, such as atrial septal defects, small ventricular septal defects, and mild valvular stenosis.

Transabdominal Sonography (TAS): A technique where the transducer is placed on the skin surface. With obstetrical sonography the transducer is placed on the skin of the abdomen and pelvis.

Transvaginal Sonography (TVS): A technique where the transducer is inserted into the vagina to evaluate the female pelvic organs. Better resolution is obtained since the transducer is closer to the organ of interest than with the transabdominal approach.

Significance of the Research

The findings of this current study will try to demonstrate that it is possible to perform a complete evaluation of fetal cardiac anatomy transabdominally early in the second trimester and detect major structural heart defects. Decisions can be made earlier in gestation and allows for elective termination of the pregnancy before the pregnancy is obvious as well as planning for a pregnancy that will need to be delivered at a medical center that has a level three nursery.

Given the complexities of cardiac anatomy, a gestational age of 14 – 18 weeks would be considered a more desirable time for sonographic evaluation than the first trimester since many sonographers and physicians performing echocardiography are uncomfortable evaluating the fetal heart transvaginally. The majority of the research articles written using the first-trimester transvaginal technique were written by European physicians who frequently perform their own sonograms. In the United States, 43

percent of credentialed sonographers performing fetal echocardiography have a cardiac background, (ARDMS.org, 2010), not an obstetrical background, therefore they may be unfamiliar with the transvaginal scanning approach. The transvaginal scanning technique is predominately used by sonographers performing obstetrical and gynecological sonography. The transabdominal scanning technique at 14 – 18 weeks gestation is exactly the same approach that is used at 21 – 24 weeks gestation to evaluate the fetal heart.

As this study will be utilizing a small sample, the study will demonstrate feasibility of diagnosing fetal cardiac anomalies with the transabdominal approach at 14 – 18 weeks gestation. A larger randomized study would be the next level of evidence to produce a more generalized clinical guideline.

Chapter 2: Literature Review

Filly and Crane in 2002 reported that the practice of obstetrics has been remarkably impacted by diagnostic sonography. Obstetrical sonography is a safe procedure and much information can be gained to aid the medical imagers and patients. While a medical procedure, this examination has become an expectation as well as a social experience for the patient and her family. Women normally receive sonographic images of their fetus and, while not as common, may even receive a DVD of the examination. Women now expect a routine sonogram and yet historically this procedure was only performed if the patient met a requirement from a list of indications that had been published by the National Institutes of Health (NIH). The American College of Obstetrics and Gynecology in 1997 performed an extensive literature review and concluded that perinatal morbidity and mortality were not improved with routine sonographic examinations. Filly concluded on the basis of evidence-based practice that approximately 60 to 70 percent of women meet the NIH requirements for a medically-indicated sonogram, routine sonography in low-risk patients did not decrease perinatal mortality and morbidity or result in fewer unnecessary obstetric interventions, and routine sonography needed to have an improved anomaly detection rate. Anomaly detection rates can be improved by women having sonograms at 18 – 20 weeks gestation. Also, a

fetal anatomic survey should be more comprehensive than current standards and include a comprehensive evaluation of the fetal heart, extremities, and face.

Second Trimester Screening for Down Syndrome

Ormond reported in 1997 that a screening program provides a low-risk way to acquire information that may be useful for the patient and the physician. Screening second trimester, evaluating maternal serum levels of alpha fetoprotein, human chorionic gonadotropin, and unconjugated estriol (Triple Screen) can be used to screen pregnancies for open neural tube defects (ONTD), Down syndrome, trisomy 18, and pregnancy complications. Ormond concluded that the use of second-trimester maternal serum testing has become widespread and can identify low-risk women who are at an increased risk of having a fetus with an ONTD or Down syndrome. These women can be offered diagnostic testing, such as an amniocentesis, to determine the karyotype of the fetus.

In 2003, Wald and associates evaluated the risk of Down syndrome from the concentration of four maternal serum markers: alpha-fetoprotein, unconjugated estriol, human chorionic gonadotropin, and inhibin A. (Quad Screen) This second-trimester screening test was used to evaluate 46,193 pregnancies over 5 years with data derived from 5 hospitals. All the women with a positive screening result were offered amniocentesis or chorionic villus sampling. Positive screening results were obtained in 3,200 of the women and there were 88 observed Down syndrome pregnancies. Seventy-one of the Down syndrome pregnancies had a positive screening result, which was an 81

percent detection rate. The authors concluded that the Quad test should be the test of choice in second-trimester screening for Down syndrome.

Screening during the second trimester for Down syndrome has proven to be more successful for evaluating a woman's risk than age alone, which has a detection rate of only 26 percent. The Quad test is more sensitive than the Triple test and should be offered to all women obtaining screening in the second trimester.

Fetal Echocardiography

Sahn and associates in 1980 reported on a small cohort of fetuses in the evaluation of the fetal heart with diagnostic sonography. They evaluated 69 normal fetuses during the second half of the pregnancy, from 20 – 40 weeks gestation, obtained an estimated fetal weight and studied normal fetal cardiac development quantitatively. They attempted to reproduce common cross-sectional views of the heart including long-axis, short-axis, apical four-chamber, and subxiphoid four-chamber views. Each fetus in the study also had a newborn cardiac echocardiogram for the assessment of circulatory changes that occurred after birth. Correlations of cardiac dimensions to fetal weight were obtained. Sahn concluded that fetal quantitative data of the sizes of the chambers and great vessels would be useful as baseline data for the prenatal diagnosis of congenital heart disease (CHD).

Carvalho and colleagues performed a large cohort prospective observational study in approximately 2 ½ years during routine prenatal screening in 2002. This was an unselected obstetrical population that was receiving their prenatal care and delivery at a

London hospital. Routine anomaly sonograms were performed at 18 – 23 weeks gestation utilizing high-resolution ultrasound equipment. A comprehensive training program was begun by a pediatric cardiologist, was mandatory for all sonographers and radiographers working in the obstetrical ultrasound unit, and included instruction on a detailed assessment of the four-chamber heart view and the cardiac outflows. Sonographers were taught appropriate equipment settings to obtain acceptable heart images. When a cardiac anomaly was suspected or suboptimal cardiac images were acquired, the patients were referred for a fetal echocardiogram that was performed in the department. When possible, the sonographer would observe the fetal echocardiogram and would be provided with the outcome, and postnatal, or postmortem results on terminated pregnancies. During this timeframe, 9,277 women were seen for prenatal care and 890 pregnancies (9.6%) and 517 children were referred for echocardiography. Major defects of the heart and outflow tracts were identified in 40 pregnancies while 30 pregnancies were fetuses with normal karyotype. Thirty of the 40 abnormal pregnancies (75%) were diagnosed prenatally. The authors concluded that the sonographers were a major contributor to the prenatal detection of congenital heart disease in this small cohort of fetuses and that training was essential.

In 2003, Wong and associates retrospectively looked at factors that influenced the prenatal detection of heart anomalies in a small cohort of patients that delivered in a major obstetric hospital in Australia. For this study, assessment of the heart included a four-chamber view and cardiac outflow tracts. Sonograms were performed in the hospital or in private radiology clinics and all of the sonographers were certified to

perform these obstetrical examinations. In a 3 ½ year period, 211 fetuses and babies with congenital heart disease were identified. Prenatal sonograms were performed on 151 fetuses and babies with congenital heart disease and 89 percent of the examinations were performed at 17 – 24 weeks gestations with the remaining exams performed after 24 weeks gestation. A detection rate of 50 percent was obtained for complex heart disease. The detection rate for abnormal four-chamber views was significantly higher in the tertiary institution at 78 percent compared with only 47 percent in the private clinics. Two-thirds of the isolated outflow tract anomalies were not detected prenatally in the tertiary unit, which was relevant since cardiac outflow tracts were routinely assessed. Cardiac-anomaly detection improved if chromosomal anomalies or other anomalies were also detected. The authors concluded that continued education, training, and supervision of sonographers were necessary for improvement in scanning skills at tertiary and private clinics.

Randal and partners in 2005 published a systematic review to determine the detection rate of congenital heart disease utilizing fetal echocardiography in unselected and low-risk populations. The eligible studies needed to assess the accuracy of fetal echocardiography against a postnatal reference standard. Five studies met the inclusion criteria, supplying a large cohort of 60,901 subjects. One of the five studies assessed the accuracy of fetal echocardiograms among an unselected population and the other studies assessed low-risk populations. All five studies were observational in design with one study a retrospective review and the other four studies prospective designs. The authors stated that “fetal echocardiography had close to 100% specificity for correctly diagnosing

babies without congenital heart disease.” The detection rate for diagnosing congenital heart disease varied from 85 percent among the unselected population to 35 to 86 percent in the low-risk populations. However, the authors believe that the “potential for ascertainment bias and choice of reference standard, limits the validity of the findings.” The authors concluded that fetal echocardiography should not be used routinely in the second trimester to detect congenital heart disease in an unselected or low-risk population.

Tegnander and colleagues from Norway in 2006 prospectively evaluated their detection rate of congenital heart disease in a nonselected large cohort population over a ten year period. Prenatal sonograms, which included a four-chamber view and the outflow tracts, were performed on 29,460 fetuses at approximately 18 weeks gestation. Major congenital heart disease was found in 97 infants with a prenatal detection rate of 57 percent. The experience of the operators, nurses/midwives performing the examinations, ranged from 3 months to 17 years. The authors concluded that prenatal detection of fetal heart anomalies is challenging and that teaching and training are key to improving sonographic evaluation of the fetal heart.

In 2004, Kovalchin and Silverman wrote on the impact of fetal echocardiography clinically. The fetal echocardiogram provided much information that was unavailable previously for parents and care-providers. The prenatal diagnosis of congenital heart disease has allowed for accurate identification of heart anomalies, better counseling during and after pregnancy, aid in determining the timing, location, and delivery plan, and family preparation for the expectant post-natal management plans. The authors

concluded that collaboration and continued education between obstetricians, pediatric cardiologists, sonographers, and other members of the maternal-fetal-medicine team are crucial to optimize care of mother, fetus, and newborn.

Schneider and colleagues in 2005, published on utilizing fetal Z-scores for cardiac dimensions. Z-scores are expressed as the number of standard deviations a measurement departs from the population mean. Seventeen fetal cardiac dimensions were measured on one hundred and thirteen pregnant women from 15 to 39 weeks gestation and compared cardiac measurements to femur length, biparietal diameter or gestational age. The authors concluded that this study allowed quantitative analysis of cardiac dimensions and permitted exact assessment of growth of fetal cardiac structures in normal and abnormal fetal hearts.

Congenital heart disease is the most common type of birth defect. Yet the detection rate and correct diagnoses varies considerably and has ranged from 35 to 86 percent in multiple studies. Fetal echocardiography appears to have high specificity in correctly diagnosing a normal fetal heart or excluding congenital heart disease which can help alleviate parental anxiety. Continued education and training for those performing fetal echocardiography can help to improve the antenatal detection of congenital heart disease, which should allow for better optimized care for the mother and newborn.

First-Trimester Screening for Down Syndrome

Nicolaides and associates from the Harris Birthright Research Center for Fetal Medicine in London, in 1992 reported the results of a prospective screening study on 872

fetuses that underwent first-trimester karyotyping by early amniocentesis or chorionic villus sampling transabdominally. The referral reasons included advanced maternal age, parental anxiety, or a family history of a chromosomal anomaly in the absence of balanced parental translocation. Prior to the diagnostic procedure, these women had a transabdominal sonogram to obtain a midline sagittal section of the fetus to acquire a crown rump length (CRL) measurement. A maximum thickness of the subcutaneous translucency between the skin and the soft tissue overlying the cervical spine was also measured. In 51 of fetuses (6%) with a nuchal translucency that was 3 – 8 mm in thickness, the incidence of chromosomal anomalies was 35% (18 cases). There were 52 fetuses with a nuchal translucency of 1 – 2 mm in thickness and all of these fetuses had normal chromosomes. A conclusion from this prospective study was that the risk of chromosomal abnormalities increased with the thickness measurement of the nuchal translucency. The authors coined the term “translucency”; as reported in the study, that term was used “rather than nuchal oedema or cystic hygroma . . . because this was the ultrasonic feature that was observed.”

Snijders and colleagues in 1998 reported on the risk of trisomy 21 by maternal age and fetal nuchal translucency thickness at 10 – 14 weeks gestation in the UK. These ultrasound examinations were performed at 22 centers by 306 sonographers who had all passed a course that contained a theory and practical component of the nuchal translucency measurement guideline as determined by the Fetal Medicine Foundation. Live fetuses of 100,311 singleton pregnancies were examined with this sonographic technique. Results were obtained in 96,127 pregnancies with prenatal or postnatal

karotyping and/or a clinical evaluation of a newborn to determine that there were no physical features suggestive of chromosomal abnormalities. Three hundred and sixty-two pregnancies were affected with trisomy 21 and the fetal nuchal translucency was above the 95th percentile in 234 (71.8%) of those with trisomy 21. Snijders concluded that with a screen-positive rate of 5 percent, the sensitivity of this method (about 80 percent) is higher than that of screening by maternal age alone (about 30 percent) or that of maternal age and serum biochemistry at 16 weeks gestation (about 60 percent).

Wapner and associates from twelve North American prenatal diagnostic centers performed a prospective study screening for trisomies 21 and 18 (First Trimester Maternal Serum Biochemistry and Ultrasound Fetal Nuchal Translucency Screening or BUN study), based on maternal age, maternal serum analytes (pregnancy-associated plasma protein A and free B human chorionic gonadotropin), and a sonographic measurement of fetal nuchal translucency in 2003. Only singleton pregnancies were evaluated in this large cohort study and screening was completed in 8,514 women. Forty-one sonographers participated and underwent NT training and certification according to the standards of the Fetal Medicine Foundation. Nuchal translucency measurements were monitored for quality throughout the duration of the study and, when necessary, retraining was instituted. This screening approach identified 85.2% of the 61 cases of trisomy 21, with a false positive rate of 9.4%, and 90.9% of the 11 cases of trisomy 18, with a 2% false positive rate. The authors concluded that first-trimester screening combining maternal age, maternal blood analytes, and nuchal translucency thickness was

accurate in clinical practice. Most importantly, these markers offer women earlier results, privacy, and options earlier than second-trimester screening.

Malone and associates from fifteen medical centers across the United States performed a large prospective study in 2005 evaluating the first-trimester or second-trimester screening or both for Down syndrome (FASTER Trial) sponsored by the NIH. This research study was conducted in 3 years and 38,189 women were eligible. All racial groups were represented but not equally. However, diversity was provided since the medical centers were in different regions of the U.S. Sonographers obtaining the nuchal translucency measurements followed a standardized protocol. Images were reviewed and scored by a single reviewer and feedback was provided to the sonographers. With integrated screening the first-trimester results were not released until after completion of second-trimester screening, which allowed for an unbiased comparison. The authors concluded that “first-trimester combined screening at 11 weeks of gestation is better than second-trimester quad screening but at 13 weeks has similar results to second-trimester quad screening.” “When there is appropriate quality control for measurement of nuchal translucency, first-trimester combined screening is a powerful tool for the detection of Down’s syndrome.”

Dugoff and colleagues performed a secondary analysis of data from a large cohort of patients who were enrolled in the FASTER trial for adverse obstetrical outcomes. Three first-trimester markers were evaluated: PAPP-A, fBhCG, and nuchal translucency. All of the women who participated in the FASTER trial with those first-trimester markers, 34,411, were analyzed. Fetuses with chromosomal or structural anomalies and

women with insulin-dependent diabetes mellitus were excluded which left a total of 33,395 cases for inclusion. The authors found that a first-trimester PAPP-A level at less than 5 percent was associated significantly with spontaneous fetal loss at less than 24 weeks gestation, preterm birth, gestational hypertension, preeclampsia, and low birth weight. There was also evidence that low PAPP-A levels are also associated with intrauterine fetal death at greater than 24 weeks gestation, preterm premature rupture of membranes, and abruption of the placenta. The authors concluded that the associations between low PAPP-A levels and adverse obstetric outcomes are statistically high but the sensitivity and positive predictive value for the individual outcomes are relatively low.

Early Fetal Echocardiography (10 – 14 weeks gestation)

In 2001, Ghi and partners published on the incidence of major congenital heart disease associated with increased nuchal translucency thickness in chromosomally normal fetuses. They prospectively evaluated 1,319 fetuses in their referral unit in London at 10 – 14 weeks gestation. The first fetal echocardiogram was performed at 10 – 23 weeks gestation depending on the size of the nuchal thickness. Major cardiac structural defects were detected in 60 of the 1319 fetuses (4.5%). Interestingly, as the nuchal translucency increased in thickness, the risk of cardiac disease markedly increased as well. In fetuses with a nuchal thickness ranging from 2.5 – 3.4 mm, the incidence of congenital heart disease was 2.5% and in those with an nuchal translucency thickness greater than or equal to 3.5 mm, it was 7%. The authors conclude that while there is some dispute about the correct threshold for specialist echocardiography, an NT

measurement exceeding the 99th percentile is a strong indication for a specialized examination of the fetal heart. A nuchal translucency at the 95th percentile with an incidence of congenital heart disease at 2.5 percent is comparable with established indications for fetal echocardiography such as family history and maternal diabetes mellitus.

Souka and associates in 2005 reported that a nuchal translucency that is increased in thickness from 11 – 14 weeks gestation with a normal karyotype is clinically relevant. Increased nuchal translucencies with a normal karyotype can be associated with a variety of fetal anomalies especially cardiac defects, skeletal dysplasias, genetic syndromes, and fetal death. Souka concluded that a nuchal translucency greater than the 95th percentile is an indication for a fetal echocardiogram as the overall prevalence of heart disease in this patient population is 1 to 2 percent.

Italian researchers lead by Rustico in 2000 prospectively performed early transvaginal sonography of the fetal heart at 13 – 15 weeks gestation on two groups of patients: an unselected and a referral population. The sonograms were performed by physicians with different skill levels and experience on 4,785 low-risk and 221 referred fetuses. The examination consisted of a four-chamber view plus the origin of the great vessels. Color-flow Doppler was only utilized when the heart was abnormal. All patients had a conventional transabdominal fetal echocardiogram at 20 – 22 weeks gestation, a postnatal follow-up within the first 3 months of life, and an autopsy in all cases of an intrauterine fetal demise or termination of pregnancy. Complete visualization of the four-chamber view and great vessels were obtained in 47.5 percent of the unselected

population and 76.9 percent in the referral population. Limitations of this study included the skill of the physicians performing the early fetal echocardiograms. While training continued throughout the study's timeframe, the ability to obtain complete visualization was not achieved and visualizing all cardiac structures did not equate to correctly interpreting the images. The authors concluded that early screening for heart anomalies in an unselected population is ill advised.

Gabriel and associates in 2002 presented their experience with early fetal echocardiography in a Spanish multicenter collaborative prospective trial of 334 high-risk fetuses. Early fetal echocardiograms were performed from 12 – 17 weeks gestation with both transvaginal and transabdominal sonography. This diagnostic test was performed in a high-risk population for congenital heart disease and included women with a family history, increased nuchal translucency ($NT > 99\%$), sonographic markers for aneuploidy, abnormal ductus venosus flow, maternal pregestational diabetes mellitus, suspected cardiac or extracardiac anomalies, exposure to teratogens, and pregnancy affected by aneuploidy. The heart was evaluated in a segmental approach to visualize the four chambers, crossing of the great vessels, ductal and aortic arches, and systemic venous return. These sonograms were performed by three experienced imagers and optimal visualization of the fetal heart was 94.6% (316 of 334 fetuses). A total of 48 fetuses had structural heart disease and 38 of the 48 fetuses were diagnosed at the early fetal echo.

In 2004, Carvallo published a review article on evaluating the fetal heart in the first trimester of pregnancy utilizing either the transvaginal or transabdominal scanning approach. At specialized centers that have a high level of expertise evaluating the fetal

heart at later gestational ages, specifically 18 – 22 weeks gestation, there are primarily two main reasons to evaluate the fetal heart during the late first trimester. For women considered high-risk for having a fetus with congenital heart disease, either because of a previous family history of congenital heart disease or an increased nuchal translucency, an early sonogram can demonstrate normality of cardiac position in the thorax and four chambers and normal connection of the great arteries. Carvallo concluded that with a normal sonogram of the fetal heart, the physician could reassure the pregnant patient during the late first trimester of pregnancy of these results and minimize her anxiety. If the late first trimester sonogram of the fetal heart is abnormal, after discussion with the physician the patient could decide to terminate the pregnancy at an earlier gestational age. Carvallo concluded that for all pregnancies that were continued, a sonographic evaluation of the fetal heart should still be performed at 18 – 22 weeks gestation to evaluate for developmental lesions that are not apparent during the late first trimester.

Smreck and colleagues from Germany performed a retrospective chart review in 2006 of 2,165 singleton high- and low-risk pregnancies that had a detailed fetal 2-dimensional, color-flow Doppler, and spectral Doppler examination of the fetal heart at 11 – 13 6/7 weeks gestation. The sonograms were performed either transvaginally or transabdominally. The intrauterine detection rate for congenital heart disease was 86.9% (40 fetuses) and an additional 6 cases of congenital heart disease (13%) were detected after birth. The lesion that was most frequently missed during the prenatal fetal echocardiogram was a ventricular septal defect. These authors also concluded that an early fetal echocardiogram should always be followed by a mid-gestation fetal echo.

In 2006, Westin and associates reported on the performance of the nuchal translucency measurement as a screening method for congenital heart disease among fetuses with a normal karyotype. This large cohort Swedish multicenter trial involved eight Swedish hospitals and enrolled almost 40,000 unselected pregnancies in approximately 4 years. Women who consented were randomized to a routine sonogram either at 12 – 14 weeks gestation or 18 weeks gestation. The 12 – 14 weeks gestation sonogram included NT screening for Down syndrome. Approximately 19,796 women were randomized to the 12 – 14 weeks gestation sonogram. The attrition of subjects was attributed to gestational age greater than acceptable ($CRL > 84\text{ mm}$), sonologists being unable to acquire an NT measurement, aneuploidy, and fetuses lost before follow-up. The total 12 – 14 week study population included 16,383 fetuses. Women obtained fetal echocardiograms for two reasons: NT thickness greater than or equal to 3.5 mm or a cardiac anomaly suspected on the NT sonogram. Diagnosed cardiac defects were subdivided into major and minor anomalies. The authors concluded that NT measurement could not discriminate reliability between fetuses with and without congenital heart disease. Since only a small proportion of fetuses with congenital heart disease had an increased NT, this measurement is not a reliable screening test for CHD.

An observational cohort study was carried out at fifteen clinical centers in the United States by Simpson and associates in 2007 from the FASTER trial research consortium. They also decided to evaluate whether nuchal translucency assessment was a useful screening tool for major congenital heart disease in an unselected population. Enrollment was 38,033 pregnancies with outcome data available for 34,370 of the cases

(90%). Analysis was performed on 34,266 of the cases and aneuploidy was found in 104 cases. There were 224 cases of congenital heart disease with 52 major defects, but only 18 were detected prenatally (35%) while 34 were detected postnatally (65%). With increasing nuchal translucency thickness, the incidence of major CHD increased. First-trimester nuchal translucency assessment did not perform well as a screening test for major CHD. The authors concluded that in this large study of unselected patients, NT measurement had a sensitivity of only 9.6 percent for major CHD, which would suggest that NT measurement is not a good screening tool for major CHD in the general population.

Rasiah and associates published a systematic review of the accuracy of detecting major congenital heart disease with a first trimester sonogram in 1996. Suitable for inclusion were ten studies performed in tertiary care centers involving 1,243 patients who were examined before 13 6/7 weeks gestation. Transabdominal sonography was utilized in four studies, transvaginal sonography was used in four studies, and a combination of both was used in two studies. The authors determined sensitivity, specificity, and likelihood ratios by comparing first-trimester fetal echocardiogram results to a traditional scheduled fetal echocardiogram, newborn fetal echocardiogram, or postmortem evaluation. With the exception of two studies, eight studies were performed on high-risk women who had a previous child with congenital heart disease or an increased nuchal translucency thickness. The authors concluded that for this examination to be successful, it is dependent on maternal adiposity, quality of the sonographic equipment, and staff training. The authors stated that major congenital heart disease can be diagnosed with

high accuracy (specificity approaching 100 percent) and when negative, first-trimester evaluation of the fetal heart diagnosed fetuses with a normal heart with reasonable accuracy (sensitivity approximately 85 percent). This systematic review revealed that disease was better diagnosed in high-risk mothers and excluded disease better in low-risk mothers. While study numbers were relatively small, transabdominal sonography appeared to be more sensitive than transvaginal sonography.

In 2010, Bellotti and associates from Italy looked at the reliability of first trimester cardiac scanning by ultrasound trained obstetricians, who had second trimester experience evaluating the fetal heart, compared to fetal cardiologists. This prospective research assessed the fetal heart transabdominally, 2-dimensionally, and with color-flow Doppler of 133 fetuses with an NT measurement that was greater than the 95th percentile at 11 – 14 weeks gestation. The obstetrician's role was to confirm or refute normal cardiac anatomy rather than establish a specific diagnosis. The patients had two exams performed by the two different types of physicians so that the obstetrician's fetal echocardiogram results could be immediately compared to the cardiologist's fetal echocardiogram results. Agreement of results between the two groups was 95 percent. Pregnancies that were continued had repeated fetal echocardiography at 20 and 32 weeks gestation in addition to a postnatal echocardiogram. The obstetricians correctly identified 18 of the 23 fetuses with major congenital heart disease and missed the 5 fetuses with minor congenital heart disease. The authors concluded that while this study was limited by a small sample size, obstetricians who are well trained to evaluate the heart in the second trimester can differentiate reliability between normal and abnormal heart findings

in the first trimester. However, some types of congenital heart disease evolve with advancing gestational age and may not be diagnosed in the first trimester so later fetal echocardiograms are necessary.

Early fetal echocardiography in the first-trimester, 11 – 13 6/7 weeks, primarily appears to be performed when a patient has a previous child with congenital heart disease or has an increased nuchal translucency thickness measurement. A normal sonographic evaluation of the fetal heart can reassure the patient which can help alleviate maternal anxiety. If the sonogram of the fetal heart is abnormal, termination of pregnancy can occur at an earlier gestational age. These articles suggest that if a pregnancy is continued, a subsequent fetal echocardiogram should be performed at 18 – 22 weeks gestation since congenital heart disease can evolve with advancing gestational age. Early fetal echocardiography should be performed only in high-risk groups and should not be performed as a screening test in a low-risk population.

ACOG Practice Bulletin

In January 2007, the American Congress of Obstetricians and Gynecologists (ACOG) developed a new Practice Bulletin on the Clinical Management Guidelines for Obstetrician-Gynecologists, Number 77, Screening for Fetal Chromosomal Abnormalities which replaced the former Practice Bulletin Number 27, May 2001. Their recommendations based on good and consistent scientific evidence were as follows:

- First-trimester screening using both NT measurement and biochemical markers is an effective screening test for Down syndrome in the general population.

- Measurement of NT alone is less effective for first-trimester screening than is the combined test.
- Women found to have increased risk of aneuploidy with first-trimester screening should be offered genetic counseling and the option of CVS or second-trimester amniocentesis.
- Specific training, standardization, use of appropriate ultrasound equipment, and ongoing quality assessment are important to achieve optimal NT measurement for Down syndrome risk assessment, and this procedure should be limited to centers and individuals meeting these criteria.
- Neural tube defect screening should be offered in the second trimester to women who elect only first-trimester screening for aneuploidy.

The following recommendations are based on limited or inconsistent scientific evidence. Not all of the recommendations in this section are included in this literature review.

- Screening and invasive diagnostic testing for aneuploidy should be available to all women who present for prenatal care before 20 weeks gestation regardless of maternal age. Women should be counseled regarding the differences between screening and invasive diagnostic testing.
- Patients who have a fetal NT measurement of 3.5 mm or higher in the first trimester, despite a negative aneuploidy screen or normal fetal chromosomes, should be offered a targeted ultrasound examination, fetal echocardiogram, or both.

Continued evidence is needed on the feasibility of transabdominal fetal echocardiography. This study will provide further information based on the following research question:

For a pregnant patient with a first-trimester nuchal translucency greater than or equal to the 95th percentile, can an early second-trimester fetal echocardiogram at 14 – 18 weeks gestation reliably demonstrate cardiac anatomy and major congenital heart disease as well as the traditionally timed fetal echocardiogram at 20 – 24 weeks gestation?

Chapter 3: Methodology

Congenital heart disease is a national problem with an occurrence rate of 8/1000, making it the most common of all birth defects. The introduction of first-trimester screening combining a sonographic examination, which includes a measurement of the neck thickness (nuchal translucency) and maternal serum biochemical testing at 11 – 13 6/7 weeks gestation can identify at least 90 percent of fetuses with a major chromosomal abnormality. An increased fetal nuchal translucency may be associated with chromosomal abnormalities, congenital heart disease, genetic syndromes, skeletal dysplasia, and fetal and postnatal death. (Souka, 2004)

Traditionally, fetal echocardiography is performed at 21 – 24 weeks gestation to detect major congenital heart disease. With first-trimester screening and the known association of fetal congenital heart disease with an increased nuchal translucency, researchers have begun to evaluate the fetal heart at 11 – 14 weeks gestation. While researchers have evaluated the fetal heart first-trimester transabdominally and transvaginally, this technique has been beneficial primarily in determining normality of the fetal heart. It has been recommended to always perform a follow-up fetal echocardiogram after 18 weeks gestation to confirm the diagnosis from the first-trimester fetal echocardiogram.

We will determine if fetal cardiac anatomy can be reliably demonstrated at 14 – 18 weeks gestation and if major congenital heart disease can be detected. In an American system of healthcare this study is needed, to offer women earlier sonographic evaluation of the fetal heart but still only perform one fetal echocardiogram unless major congenital heart disease is detected. The skills of the individuals performing and interpreting the sonographic examination for the detection of congenital heart disease are the most important component of the examination. (Sharland, 1998) Early second trimester, fetal echocardiograms were performed only if the maternal-fetal-medicine physician ordered the examination. For this subset of patients, women were offered fetal echocardiograms and invasive testing. The conceptual framework shown in Figure 1 is included to show clinically how patients were managed with a NT greater than or equal to the 95th percentile.

Type of Research

The purpose of this study was to retrospectively review patient charts of women who were seen for an early-second-trimester fetal echocardiogram between 2006 and 2011 and had a first-trimester NT sonogram resulting in a neck measurement greater than or equal to the 95th percentile.

Figure 1. Conceptual Framework

Population and Sampling

This is a secondary data analysis reviewing already collected data, specifically sonograms and a chart review. The target population for the study was pregnant women who were referred to The Ohio State University Medical Center (OSUMC) from 2006 to 2011 for a first-trimester screening examination to determine their risk of having a fetus with a chromosomal abnormality. If this screening test revealed an NT measurement greater than or equal to the 95th percentile for the gestational age at the time of the

examination, the women were offered an early-fetal echocardiogram that was scheduled at 14 – 18 weeks gestation. A total of forty-eight women had an early-fetal echocardiogram during this time period and thirty-seven of those women were identified as meeting the above criteria.

Instrumentation

This study used the American Institute of Ultrasound in Medicine (AIUM) Guidelines for the Performance of Fetal Echocardiography as the instrument. The AIUM is a multidisciplinary association dedicated to advancing the safe and effective use of sonography in medicine through professional and public education, research, development of guidelines, and accreditation. The AIUM develops practice guidelines so that high-quality sonography can be performed uniformly nationwide. The Fetal Echocardiography Guidelines were created in 2010 by a task force of individuals from the AIUM, the American College of Radiology, the American College of Obstetricians and Gynecologists, and the Society of Maternal-Fetal Medicine. The instrument was used to evaluate the previously acquired sonograms.

This pre-experimental study used three commercially available diagnostic sonography pieces of equipment. These machines were FDA approved and manufactured by two different companies. The Sequoia, used for patient examinations in 2006 and 2007, was manufactured by Siemens-Acuson Ultrasound. The other two machines, the Accuvix XQ and the V20, were manufactured by Samsung-Medison, USA and were used for all of the other patient examinations.

Data Collection

The secondary data analysis was of women referred to OSUMC Ob Ultrasound for an early-fetal echocardiogram when the nuchal translucency measurement acquired at 11 – 14 weeks gestation was greater than or equal to the 95th percentile. Those women were referred for the examination by one of the maternal-fetal-medicine physicians from OSUMC. As a pre-experimental research study, fetal echocardiograms that occurred from April 2006 through December 2011 were evaluated using the flow chart shown in Figure 2.

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Figure 2. Flow Chart for Evaluating Fetal Echocardiograms
that Occurred from April 2006 Through December 2011

Data Analysis

Descriptive Statistics. Image quality was evaluated for three variables, maternal BMI, placental location, and fetal position. Also examined was the mean as well as the maximum and minimum fetal heart rate of the fetuses evaluated in this pre-experimental study. The success of visualizing twelve cardiac structures was evaluated. Fetal cardiac measurements as related to published population mean and standard deviation were examined as a function of gestational age.

Inferential Statistics. A two-way table, shown in Figure 3, was used to calculate statistics such as sensitivity, specificity and likelihood ratio for the evaluation of the fetal heart at 14 – 18 weeks gestation in fetuses with a screening nuchal translucency greater than or equal to the 95th percentile.

		Major Congenital Heart Disease (CHD)	
		Present	Absent
Test Result	Positive	Fetus had CHD and ultrasound read as abnormal/anomaly <i>A</i>	Fetus had normal heart and ultrasound read as abnormal/anomaly <i>B</i>
	Negative	Fetus had CHD but ultrasound read as normal <i>C</i>	Fetus had normal heart and ultrasound read as normal <i>D</i>

Figure 3. A Two-Way Table for Calculating Sensitivity, Specificity and Likelihood Ratio

The sensitivity is the likelihood that the fetus with major congenital heart disease (CHD) will be positive on fetal echocardiogram. For this study, the sensitivity (Sens) is

$$Sens = \frac{A}{A + C}$$

though absolute confirmation of one patient was not entirely possible because it was a still birth. The specificity is the likelihood that the fetus without major congenital heart disease (CHD) will be negative on fetal echocardiogram. For this study, the specificity (Spec) is

$$Spec = \frac{D}{D + B}$$

The positive likelihood ratio (LR_p) that a positive test result was observed for fetuses with major CHD compared to fetuses without major CHD. The LR is

$$LR_p = \frac{Sens}{1 - Spec}$$

The negative likelihood ratio (LR_n) that a negative test result was observed for fetuses without major CHD compared to likelihood that a negative test results would be seen in fetuses with major CHD. The LR is

$$LR_n = \frac{1 - Sens}{Spec}$$

Chapter 4: Analysis of Data

Indications for fetal echocardiography are often based on variety of parental and fetal risk factors for congenital heart disease. (AIUM) One indication for a fetal echocardiogram is an increased nuchal translucency (NT). The reason for the fetal echocardiogram is that there is a high association between an increased NT and congenital heart disease in both chromosomally normal and abnormal fetuses.

This led to our research question: *For a pregnant patient with a first trimester nuchal translucency greater than or equal to the 95th percentile, can an early second-trimester fetal echocardiogram at 14 – 18 weeks gestation reliably demonstrate cardiac anatomy and major congenital heart disease as well as the traditionally timed fetal echocardiogram at 20 – 24 weeks gestation?*

Between April 2006 and December 2011, a total of 48 early fetal echocardiograms were performed at 14 – 18 weeks gestation, and 37 of the early fetal echocardiograms were performed when the nuchal translucency measurement was greater than or equal to the 95th percentile. Body mass index was obtained on all of the women at the time of the nuchal translucency examination. The patients' mean age was 32.2 and ranged from 23 to 41 years of age. Thirty-four of the women had singleton pregnancies and three women had multiple gestations: two women with Diamniotic/Dichorionic twin pregnancies and one woman with a quadruplet pregnancy. The three women with

multiple gestations only had an early fetal echocardiogram on the fetus with the nuchal translucency measurement that was greater than or equal to the 95th percentile.

A total of 37 patients with an increased nuchal translucency had an early fetal echocardiogram at 14 – 18 weeks gestation. Figure 4 shows the distribution by weeks over the range of gestational ages.

Figure 4. Number of Patients that Had an Early Fetal Echocardiogram

Figure 5 shows the distribution of fetal echocardiogram by year.

Figure 5. Distribution of Fetal Echocardiograms by Year

Image quality is essential for assessing the fetal heart. The cardiac structures of some fetuses are more clearly imaged than others. For this study, the physician that interpreted the clips/images assessed the quality in 5 levels: poor, satisfactory, good, very good, and excellent. All of the clips/images in this study were assessed by one physician and these qualifiers were included in the final report which was sent to the referring physician. One key to obtaining high quality clips/images is having the ultrasound probe as close to fetal heart as possible. If the maternal body habitus has a large layer of subcutaneous tissue between the uterus and the ultrasound probe, there is the potential that image quality could be compromised. Body mass index (BMI) is used to quantify the maternal body habitus, with less than 18.5 considered underweight, between 18 to 25 considered normal weight, between 25 to 29.9 considered overweight, and greater than 30 considered obesity. For data analysis, Figure 6 shows the image quality for a BMI less than 25, which is represented as a low BMI, and for a BMI greater than 25, which is represented as a high BMI.

Figure 6. Image Quality for Low and High BMI Patients

A second way to assess this data is to use a scatter diagram. Figure 7 shows the image quality versus BMI.

Figure 7. Image Quality Versus BMI

Another factor that can affect image quality is placental location, which may be either on the anterior or posterior wall of the uterus. If the placenta is on the anterior wall of the uterus, the sound energy would have to travel through the placenta, which can degrade the image quality. If the placenta is on the posterior wall of the uterus, the sound energy would have a shorter and less obstructive path to the fetus. Figure 8 shows the image quality for anterior and posterior placental locations.

Figure 8. Image Quality for Anterior and Posterior Placental Locations

Since BMI did not compare with image quality, the BMI data was grouped by placental location and then examined. Figure 9 shows the image quality for high and low BMI patients, sorted by placental location.

Figure 9. Image Quality for BMI Data Grouped by Placental Location

Fetal position can potentially play a role in image quality. While the documentation of fetal position can be in the breech, cephalic, transverse or oblique lie, the fetuses presented in the first three only. Figure 10 shows the image quality for three fetal positions.

Figure 10. Image Quality for Three Fetal Positions

The sonography machine also has a significant impact on image quality. Newer equipment tends to provide better image quality. Three commercially available machines were used in this study, a 2000 vintage Siemens-Acuson Sequoia, a 2007 Medison XQ, and a 2011 Samsung-Medison V20.

The fetal heart rate is measured on all obstetrical ultrasound examinations. The mean value was 148 beats per minute (bpm). The minimum value was 130 bpm and the maximum was 164 bpm. The normal heart rate at 20 weeks gestation is 120 to 160 bpm

falling to 130 bpm; two patients were slightly above the maximum and none were below the minimum. (Nyberg, 1990)

The heart rate as a function of gestational age for the patients with repeat studies is shown in Figure 11.

Figure 11. Heart Rate as a Function of Gestational Age for the Patients with Repeat Studies

Gray-scale imaging was recorded and evaluated on all of the early fetal echocardiograms. The following structures were evaluated on each fetus. The data in Table 1 shows the visualization of cardiac structures for the cases that were read as a normal examination.

Table 1. Visualization of Cardiac Structures

Cardiac Structures Gray-Scale Imaging	Visualized	
	Yes	No
Normal 4-chambers	33	0
Normal situs	33	0
Normal rhythm	33	0
Normal function	33	0
Normal valves	33	0
Crossing outflow tracts	33	0
Normal proximal great arteries	33	0
Normal Aortic arch	32	1
Normal Ductal arch	32	1
IVC/SVC visualized	33	0
Pericardial, pleural or ascites visualized	0	33
Pulmonary veins visualized	26	7

Eight patients received a repeat fetal echocardiogram. Three repeated studies were performed because a cardiac anomaly was detected on the early fetal echocardiogram. The other repeated exams were for various reasons. Two of the early fetal echocardiograms had good imaging and all structures were visualized and believed to be normal but both women had prior pregnancy losses; one a late intrauterine fetal demise and one shortly after delivery for a newborn with lymphangiectasia. One fetal echocardiogram was repeated for image quality technically challenging due to unfavorable fetal breech position. Two of the early fetal echocardiograms, one at 14 weeks gestation and one at 15 weeks gestation were read as a normal examination but were repeated due to early gestational age. For the one patient where the aortic arch and ductal arch were not visualized well, the pediatric cardiologist requested a follow up echocardiogram but it was not performed.

Doppler Sonography

Doppler sonography was attempted on all early fetal echocardiograms and included spectral and color Doppler to evaluate the following structures for potential flow disturbances. Color Doppler was used to evaluate the aortic and pulmonary valves, aortic and ductal arch, intraventricular septum, and pulmonary veins. Spectral Doppler was used to evaluate flow; distal to the aortic and pulmonary valves, umbilical artery and vein, and ductus venosus.

Color Doppler was used on all of the early fetal echoes and was used to evaluate flow across and distal to the aortic and pulmonary valves and the intraventricular septum. Beginning December of 2009, color-flow Doppler was also used to evaluate the pulmonary veins and was utilized on 12 of the 13 cases. Spectral Doppler was used to evaluate flow distal to the aortic and pulmonary valves, flow within the umbilical artery and vein, and the ductus venosus. Spectral Doppler was not consistently performed on the aortic and pulmonary valve. Spectral Doppler information was collected on 16 cases for the aortic valve and 30 cases for the pulmonary valve. The umbilical artery S/D ratio and continuous flow in the umbilical vein was performed on 31 cases and not performed on 6 cases. Ductus venosus flow was evaluated with color and spectral Doppler on 12 of 13 cases beginning December of 2009.

Cardiac Measurements Z-scores

Fetal cardiac measurements were obtained on all early fetal echocardiograms from the gray-scale, real-time images, normal as well as abnormal and were based on

gestational age. Early in the study, cardiac measurements were not obtained but for this retrospective chart review, for the first seven cases the cardiac measurements were obtained at the time of chart review as all images and clips were stored on a hospital PACS system and it was possible to go back and obtain the cardiac measurements. Fetal cardiac measurements were obtained of the aortic, pulmonary artery diameters at the level of the valve annulus, mitral and tricuspid valve diameters at the level of the valve annulus, and end-diastolic ventricular dimensions just inferior to the atrioventricular valve leaflets. Z-scores were then calculated using the Microsoft Excel spreadsheet that was created by Devore from the article published by Schneider, *Development of Z-Scores for Fetal Cardiac Dimensions from Echocardiography*.

Figures 12 and 13 shows the Z-scores for the aortic and pulmonary valve respectively. Note that the Z-scores do not vary with age and are generally centered around a Z-score of 0. For the aortic valve, the values are centered on a value of 0.0; 21 of the 33 (64%) of the normal cases had a score within one standard deviation and 91% had a score within 2 standard deviations. For the pulmonary valve, the values are centered on a value of -0.3; 16 of the 33 (48%) of the normal cases had a score within one standard deviation and 82% had a Z-score within 2 standard deviations.

Figure 12. Z-Scores for the Aortic Valve

Figure 13. Z-Scores for the Pulmonary Valve

Figures 14 and 15 shows the Z-scores for the mitral and tricuspid valve respectively. Note that the Z-scores do not vary with age, however the majority of the values are below the mean. For the mitral valve, the values are centered on a value of -1.5; 20 of the 33 (61%) of the normal cases had a score within one standard deviation of this value and 88% of the scores are within 2 standard deviations. Figure 15 shows the Z-scores for the tricuspid valve. For the tricuspid valve, the values are centered on a value of -1.0; 23 of the 33 (70%) of the normal cases had a score within one standard deviation of this value and 88% of the scores are within 2 standard deviations.

Figure 14. Z-Scores for the Mitral Valve

Figure 15. Z-Scores for the Tricuspid Valve

Figures 16 and 17 shows the Z-scores for the left and right lateral ventricle respectively. Note that the Z-scores do not vary with age. For the left lateral ventricle, the values are centered on a value of 3.5; 17 of the 33 (52%) of the normal cases had a score within one standard deviation of this value and 73% of the scores are within 2 deviations. For the right lateral ventricle, the values are also centered on a value of 3.5; 18 of the 33 (55%) of the normal cases had a score within one standard deviation of this value and 70% of the scores are within 2 standard deviations.

Figure 16. Z-Scores for the Left Lateral Ventricle

Figure 17. Z-Scores for the Right Lateral Ventricle

Results of Abnormal Fetal Echocardiograms

Four of the 37 patients examined in this study had abnormal fetal echocardiograms. The findings are in Tables 2 through 5. These tables include the results of the nuchal translucency examination, whether:

- ultrasound examination detected other anomalies;
- diagnostic testing such as amniocentesis and Chorionic Villus Sampling (CVS) was performed (results if yes); and
- fetal and newborn echocardiogram results and the delivery outcome.

Table 2. Abnormal Case 1

1008	Gestational age (weeks.days)	Finding
Nuchal Translucency	13 0/7	4.5 mm > than the 99th percentile
Other Anomalies	16 0/7	Large anterior wall defect and omphalocele
Diagnostic Testing	16 0/7	CVS 46XX – Normal Female Karyotype
Echocardiogram	17 6/7	Ventricular Septal Defect (VSD)
Delivery	32 0/7	Stillbirth. Pathology of placenta revealed suspected body stalk anomaly

Table 3. Abnormal Case 2

1007	Gestational age (weeks.days)	Finding
Nuchal Translucency	12 3/7	2.8 mm – 95th percentile was 2.4 mm
Diagnostic Testing	No	
Echocardiogram	15 3/7	Atrioventricular Septal Defect (AVSD) High ventricular septal defect with a large single atrioventricular valve. Right ventricle larger than left ventricle
Echocardiogram	24 2/7	Balanced AVSD
Delivery	39 2/7	Balanced AVSD – Trisomy 21

Table 4. Abnormal Case 3

1000	Gestational age (weeks.days)	Finding
Nuchal Translucency	13 5/7	3.1 mm – 95th percentile was 2.6 mm
Diagnostic Testing	No	
Echocardiogram	17 6/7	VSD. Membranous portion of ventricle septum
Echocardiogram	24 6/7	Balanced AVSD. Relatively discrete right and left atrioventricular valve but shared leaflet spanning a septal defect
Echocardiogram	34 6/7	AVSD with large overriding Aortic Root. Ascites, diffuse skin edema, and slight pleural effusion
Delivery	34 6/7	Balanced AVSD with Tetralogy of Fallot – Trisomy 21

Table 5. Abnormal Case 4

1024	Gestational age (weeks.days)	Finding
Nuchal Translucency	13 2/7	7.5 mm > than the 99th percentile
Diagnostic Testing	Yes	CVS 46XX – Normal Female Karyotype
Echocardiogram	16 2/7	Hypoplastic Left Heart Syndrome (HLHS) Hypoplasia of the mitral valve and left ventricle
Echocardiogram	20 6/7	HLHS. Small left atrium, left ventricle very small, Left Ventricular Outflow Tract quite small, mitral leaflets not seen. Probable small muscular defect in lower muscular portion of ventricular septum as antegrade flow from left ventricle into small aorta
Delivery	37 3/7	Form of HLHS. Baby died at 5 months of age

Newborn Assessment

All newborns born at The Ohio State University Medical Center, within twenty-four hours of birth have a thorough evaluation performed to identify anomalies or a

medical condition. This assessment is extensive but evaluation of the chest includes an evaluation of the lungs and cardiovascular system. Auscultation is performed with a stethoscope to evaluate the rate and rhythm, listening for the first and second heart sounds and the presence of a murmur.

Summary Analysis

A two-way table is used to summarize the success of fetal echocardiography to detect heart abnormalities at 14 – 18 weeks gestation in fetuses with a screening nuchal translucency greater than or equal to the 95th percentile. Table 6 has the assessment for the 17 patients where results of newborn assessments were available; 13 were normal and 4 were abnormal.

Table 6. Assessment for the 17 Patients with Results of Newborn Assessments

		Major Congenital Heart Disease (CHD)	
		Present	Absent
Test Result	Positive	Four (4) fetuses had CHD and ultrasound interpreted as abnormal/anomaly	No (0) fetuses had normal heart and ultrasound interpreted as abnormal/anomaly
	Negative	No (0) fetus had C HD but ultrasound read as normal	Thirteen (13) fetuses had normal heart and ultrasound interpreted as normal

The sensitivity is the likelihood that the fetus with major congenital heart disease (CHD) will be positive on a fetal echocardiogram. For this study, the sensitivity (Sens) is

$$Sens = \frac{4}{4 + 0} = 1$$

although absolute confirmation of one patient was not entirely possible because it was a still birth. The specificity is the likelihood that the fetus without major congenital heart disease (CHD) will be negative on fetal echocardiogram. For this study, the specificity (Spec) is

$$Spec = \frac{13}{13 + 0} = 1$$

The positive likelihood ratio (LR_p) that a positive test result was observed for fetuses with major CHD compared to fetuses without major CHD. The LR is

$$LR_p = \frac{Sens}{1 - Spec} = \frac{1}{1 - 1} = \frac{1}{0}$$

The negative likelihood ratio (LR_n) that a negative test result was observed for fetuses without major CHD compared to likelihood that a negative test results would be seen in fetuses with major CHD. The LR is

$$LR_n = \frac{1 - Sens}{Spec} = \frac{1 - 1}{1} = \frac{0}{1} = 0$$

Chapter 5: Summary and Conclusions

Women are referred for a first-trimester screening test which includes a sonographic measurement of the back of the neck, the nuchal translucency (NT), as a method of screening for aneuploidy. An increased NT is a nonspecific finding and may be associated with a wide range of chromosomal anomalies, fetal anomalies, and genetic syndromes. An increased nuchal translucency measurement greater than or equal to the 95th percentile is associated with congenital heart disease in fetuses with normal and abnormal karyotypes. An increased nuchal translucency warrants a specialized ultrasound examination of the fetal heart.

In 2002, Gabriel and associates performed a prospective early fetal echocardiography multicenter study in Spain of 334 fetuses at 12 – 17 weeks gestation with a median age of 14 weeks gestation. Fourteen weeks gestation was chosen as the optimal time to evaluate the fetal heart transvaginally as “visualization of heart structures is better,” however the sonographic examination was “completed nearly always by the transabdominal route.” Their rate of successful visualization was 94.6 percent.

This study helped lead to our research question: *For a pregnant patient with a first trimester nuchal translucency greater than or equal to the 95th percentile, can an early second-trimester fetal echocardiogram at 14 – 18 weeks gestation reliably demonstrate cardiac anatomy and major congenital heart disease as well as the traditionally timed fetal echocardiogram at 20 – 24 weeks gestation?*

In this study, we sought to determine if fetal cardiac structures could be visualized and if a normal fetal heart could be differentiated from an abnormal fetal heart. With gray-scale imaging, nine different cardiac structures were evaluated in addition to cardiac position in the thorax, cardiac rhythm, and function. Of the 33 normal evaluations, all of the structures were visualized in 32 of the examinations. Only an aortic and ductal arch was not well seen in one patient and the reading physician ordered a repeat examination but it was not performed.

In a systematic review executed by Randall and associates, five studies with 60,901 patients assessed the accuracy of fetal echocardiography among one unselected population and four low-risk populations. This systematic review for all of the populations revealed that “fetal echocardiography had close to 100% specificity for correctly diagnosing babies without congenital heart disease.” Our small cohort of patients whose fetal echocardiogram was interpreted as being normal seems to be consistent with the systematic review by Randall.

Fetal cardiac measurements were obtained and measured at specific places as determined by the Schneider technique so that a Z-score could be calculated. Fetal cardiac-diameter measurements were obtained of the aortic, pulmonary, mitral, and tricuspid valves at the level of the valve annulus and end-diastolic ventricular measurements just inferior to the atrioventricular (AV) valve leaflets. Since the Z-score values do not vary with age, they are a useful measurement for quantifying size and growth of cardiac dimensions, especially in fetuses with cardiac anomalies that need multiple examinations throughout gestation to evaluate changes in fetal cardiac size. Our

Z-score results were very similar to the Schneider results for the measurements of the aortic valve and just a slightly larger deviation for the pulmonary valve. Our results do show a variation from the Schneider data for measurements of the mitral and tricuspid valve annulus as our measurements were consistently smaller. This may have been technical since when evaluating the mitral and tricuspid valves, images are frequently acquired from an apical four-chamber view of the heart and if the frozen image is slightly off axis, the diameter measurement could be smaller than expected. Also, at this early gestational age, the cardiac valves are tiny and fractions of a millimeter can make a huge difference in the calculated Z-scores. For the left and right lateral ventricles, the resultant Z-scores were significantly larger than the values presented by Schneider. Adjustments to the mean values and possibly to the deviations used to calculate the Z-scores may be useful to shift the scores to zero, especially for the left and right lateral ventricles, but this would require additional patients.

Doppler sonography, including color and spectral Doppler, was used to evaluate cardiac and fetal structures for potential flow or rhythm disturbances. However, not every cardiac and fetal structure was evaluated on every fetal echocardiogram. This was related to factors that included fetuses in suboptimal positions to acquire spectral Doppler tracings, especially of the aortic valve and the addition of newer Doppler techniques, such as ductus venosus flow and visualization of the pulmonary veins with color-flow Doppler, later in the study period review.

Image quality is always essential for evaluating the fetal heart, but it is especially so at an earlier gestational age when the heart is much smaller. The interpreting

physician that read the fetal echocardiograms used descriptive qualifiers to comment on image quality. Body mass index (BMI), placental location, and fetal position were all compared to image quality. Surprisingly, there was no association between image quality and BMI. These results may be biased by the limited number of cases used in this study and additional data might reveal an association. Placental location, specifically whether it was positioned on the anterior or posterior wall of the uterus, was evaluated and compared to image quality. While image quality was better with a posterior placental location, high-quality images were also obtained with an anterior placenta. Fetal position affected image quality; the best quality was observed for a fetus in a transverse lie and the worst image quality was for a breech lie. Image quality may also be related to other factors that were not evaluated in this study, such as flank scanning or scanning under a panniculus. Rolling patients and performing flank scanning frequently positions amniotic fluid between the transducer and the fetal thorax which can improve image quality even though the structure of interest is still deep within the image. Scanning under a panniculus reduces soft tissue along the anterior abdominal wall and improves image quality. Both of these techniques are routinely used for patients exhibiting a high BMI at The Ohio State University Medical Center and would not be documented in the written report.

Eight cases had repeat echocardiograms; three repeated studies were performed because a cardiac anomaly was detected. Two patients had prior pregnancy losses, so while the early fetal echocardiogram was interpreted as being normal, a repeat examination was still performed later in gestation for maternal reassurance. Only three

normal fetal echocardiograms (9 percent) were repeated because the reading physician wanted to re-evaluate the fetal heart at a later gestational age; two were repeated due to early gestational age (one had been at 14 weeks gestation and the other at 15 weeks gestation); and one was repeated because the image quality was technically challenging due to an unfavorable fetal breech presentation.

Only four of the thirty-seven early fetal echocardiograms were interpreted as abnormal because a major cardiac anomaly was detected on each of the four. Two of the four early echocardiogram results were in agreement with the newborn evaluation: a balanced atrioventricular septal defect (AVSD), and a form of hypoplastic left-heart syndrome. The fetus with AVSD did not have any diagnostic testing during the pregnancy and the newborn did have trisomy 21. One fetus with multiple anomalies and an ventricular septal defect (VSD) was delivered at 32 weeks gestation as a stillbirth and did not have an autopsy, but pathology of the placenta revealed a suspected body stalk anomaly. The fourth case, at 17 weeks gestation, was interpreted as a VSD of the membranous portion of the ventricle septum. A repeat echocardiogram at 24 6/7 weeks gestation revealed a balanced AVSD with a relatively discrete right and left atrioventricular valves but a shared leaflet spanning a septal defect. A repeat echocardiogram at 34 6/7 weeks revealed a balanced AVSD with a large overriding aortic root, ascites, diffuse skin edema, and a slight pleural effusion. A newborn examination revealed a balanced AVSD with Tetralogy of Fallot and trisomy 21. Review of the early fetal echocardiogram did reveal an overriding aortic root in addition to the VSD. While confirmation is not available for the stillbirth, the other three abnormal early fetal

echocardiograms did reveal major congenital heart diseases. These earlier scans led to the correct diagnosis so that repeat examinations were carried out.

In 2005, Makrydimas and associates published data from major centers performing fetal echocardiography in London. All of the facilities agreed to provide data on all of their cases with congenital heart disease that were diagnosed during pregnancy using a standardized data-collection process. All of the 637 cases also had a fetal NT measurement evaluated during the first trimester. The median NT measurement in fetuses with a normal karyotype was significantly lower than in fetuses with an abnormal karyotype: 1.8 mm versus 4.3 mm. In their subset of fetuses with a normal karyotype, the NT measurement was greater than or equal to 2.5 mm in 35% of cases and greater than or equal to 3.5 mm in 22.9% of cases. In their subset of fetuses with an abnormal karyotype, the NT measurement was greater than or equal to 2.5 mm in 65% of the cases and greater than or equal to 3.5 mm in 58% of the cases. In our small cohort, the two patients who had CVS's and a normal karyotype had NT measurements of 4.5 mm and 7.5 mm, both of which are greater than the 99th percentile for fetuses with a normal karyotype. In the two fetuses diagnosed with trisomy 21 after delivery, the NT measurements were 3.1 mm and 2.8 mm, both of which are greater than the 95th percentile but less than the 99th percentile. Comparing our small cohort results to the Makrydimas data, we came to the opposite conclusion in that the NT measurement in our chromosomally normal fetuses was significantly higher than in the chromosomally abnormal fetuses. Even though the Makrydimas data is from London, the technique used to acquire the NT measurement is standardized and all sonographers regardless of their

place of employment need to be credentialed to perform this specific measurement. Our results may look different with a larger cohort.

A major strength of our study was that the majority of the early fetal echocardiograms were performed by one sonographer with more than twenty-five years of experience in performing fetal echocardiography. Likewise, the early fetal echocardiograms were interpreted by a pediatric cardiologist with more than twenty-five years of experience reading fetal echocardiograms. Since both the sonographer acquiring the clips/images and the physician interpreting them have advanced skills with fetal echocardiography, these results may not necessarily be generalized to all sonographers and physicians involved with fetal echocardiography.

This research information translates to our clinical practice and will have great positive impact on the fetal echocardiography clinic, which in turn should improve referrals from other physician groups. Technical improvements will be instituted to improve all sonographers' evaluations of the fetal heart, specifically with pulsed Doppler to evaluate flow distal to the aortic valve. Flow distal to this valve was not consistently acquired when compared to the pulmonary valve, and techniques to optimize evaluation have been instituted as a result of this study. The expertise and knowledge gained over the years now allows for a more detailed and efficient evaluation of the fetal heart. This information would be limited to our practice and cannot be generalized to other practices due to the pre-experimental research design and small cohort of patients.

The major limitation of this study was related to its design as a pre-experimental research study. It was a convenience sample and the findings are specific to the sample

of fetuses that had a nuchal translucency measurement that was greater than or equal to the 95th percentile at The Ohio State University Medical Center. Not all fetuses evaluated during the studied time-frame with a nuchal translucency greater than or equal to the 95th percentile had an early fetal echocardiogram, as that specific sonographic examination was performed only if the maternal-fetal-medicine (MFM) physician ordered the test. The results of this pre-experimental research study cannot be generalized since a convenience sample was used.

Another limitation of this study was a small data set due the availability of patients at our single site. In this pre-experimental study, the sensitivity and specificity were 100 percent. It is likely that sensitivity and specificity will be less than 100 percent when a large population is considered.

Some technical issues served as a limitation as well. Equipment and transducer design vary over time, making clips/images varied in quality. Three different ultrasound machines were used during the duration of the study and the newest machine, the Samsung-Medison V20, produced better images. The Siemens-Acuson Sequoia and the Medison XQ both produced mixed results, with more than half of the images rated as only satisfactory or poor. Better images with the newer equipment could also be related to improved sonographer techniques.

Another limitation of this study was that newborn echocardiograms were only performed on the fetuses that were suspected of having major congenital heart disease. Not all of the fetuses that had an early fetal echocardiogram were delivered at The Ohio State University Medical Center. The fetuses that were delivered at The Ohio State

University Medical Center and had a normal early fetal echocardiogram had a normal newborn assessment performed by the neonatology fellow or attending which would exclude major congenital heart disease. Nationwide Children's Hospital's cardiac sonographers perform, and the pediatric cardiologist interprets, all newborn echocardiograms from all of the Columbus hospitals. If any of the babies born at the other hospitals had a newborn echocardiogram, the results would have been available for this study as the pediatric cardiologist who interprets all of the early fetal echocardiograms is on faculty at NCH and tracks all cardiac anomalies in the Columbus area.

Clearly, these preliminary results demonstrate that the fetal heart, normal or abnormal, can be well evaluated early in the second trimester of pregnancy at 14 – 18 weeks gestation, so women do not need to wait until 21 – 24 weeks gestation for a fetal echocardiogram. An early second trimester fetal echocardiogram that is interpreted as normal can effectively reassure the majority of parents that there is no major cardiac defect and a repeat fetal echocardiogram is not necessary. The detection of a major defect can either lead to the correct diagnosis or raise suspicion, and in those instances a repeat examination can be performed. The results of this pre-experimental research study will require confirmation and a prospective larger study would be the next level of evidence to produce a more generalized guideline. It will be necessary to provide a newborn echocardiogram for all fetuses enrolled in the study so that newborn ultrasound data is obtained for all participants, not just the fetuses with cardiac anomalies.

By performing this pre-experimental research study, we learned a lot about early fetal echocardiography performed transabdominally at 14 – 18 weeks gestation. I believe that the perfect study to evaluate the fetal heart prospectively would include the following:

Healthy pregnant women at least 18 years of age who have had a first-trimester screening test with an NT measurement greater than or equal to the 95th percentile. These women would be eligible for enrollment in the study if they are able to provide written, informed consent. If these women choose to participate in this study, they may have up to two fetal ultrasound examinations after the first-trimester NT screening examination. A fetal echocardiogram will be performed at 14 – 18 weeks gestation. If a heart defect is found, a second fetal echocardiogram will be performed at 30 – 34 weeks gestation. After birth, all babies will have an echocardiogram while still in the nursery or at Nationwide Children’s Hospital (NCH). If termination of the pregnancy occurs for a fetus with a sonography-documented cardiac anomaly, a pathological examination for verification of the prenatally diagnosed malformation will be performed. Table 7 is a study visit table for the sonography examinations.

Table 7. Study Visit Table

	Visit 1	Visit 2	Visit 3
Visit Timeline	14 – 18 weeks Approx. 1 hour	30 – 34 weeks Approx. 1 hour	Delivery
Ultrasounds	Fetal Heart Exam	Fetal Heart Exam only if Visit 1 examination is abnormal	Heart examination on newborn in the nursery or at NCH

The fetal echocardiogram would again evaluate with gray-scale imaging the nine different cardiac structures, cardiac position in the thorax, cardiac rhythm, and function. Color-flow mapping of the cardiac chambers and great vessels would be performed with color and power Doppler. Evaluation with these techniques would include the four-chamber heart and the ventricular-aortic continuity, pulmonary veins draining into the left atrium, cardiac outflow tracts, and ductal and aortic arch visualization. Spectral Doppler evaluation would include flow analysis of the umbilical artery and vein, ductus venosus, and flow distal to the aortic, pulmonary, mitral, and tricuspid valves.

This study represents a small cohort of patients that were studied retrospectively and is a lower level of evidence. The next step in providing a higher level of evidence is to perform a prospective study with a larger cohort of patients and fetuses. The study outlined above is a first attempt at moving this initiative forward and represents the next level of evidence. To advance this particular specialty of medicine, random selection of facilities that build on the methods explored may culminate in formulating a suggested practice guideline. As this line of inquiry is advanced, new systematic reviews and meta-analyses will pose a clinical standard for the use of fetal echocardiography with fetuses that have a nuchal translucency measurement greater than or equal to the 95th percentile.

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Appendix A: Data Recording Forms

Control Data Form

Patient Demographics:

Study Identifier (#): _____

Age at delivery: _____

Height: _____

BMI: _____ Weight: _____ (pounds)

Abdominal scar: *Yes / No* Vertical / Horizontal

Referring Physician: _____

General Pregnancy Information

Estimated date of confinement: _____ (mm/dd/yyyy)

Gravidity and parity: G__P__Term__Preterm__Termination__Living__

Pregnancy history: _____

IDDM: *Yes / No*

First-Trimester Screening for Nuchal Translucency (NT)

Nuchal Translucency Thickness: _____ (mm)

Gestational age at date of NT: _____ (n.n weeks)

Diagnostic Testing

CVS: *Yes / No* If yes, Karyotype: _____

Gestational age at date of CVS: _____ (n.n weeks)

Amniocentesis: *Yes / No* If yes, Karyotype: _____

Gestational age at date of amnio: _____ (n.n weeks)

Delivery

Date of delivery: _____ (mm/dd/yyyy)

Gestational age at date of delivery: _____ (n.n weeks)

Live birth: *Yes / No*

APGARS: _____ 1 min. _____ 5 min.

Newborn exam: _____

Fetal Echocardiography Data Form

Impression:

Ultrasound Exam Data

Ultrasound exam date: _____(mm/dd/yyyy)
Gestational age: _____(n.n weeks)
Fetal position: Cephalic Breech Transverse Oblique
Heart rate: _____BPM
Placental Location: _____
Three vessel cord: *Yes / No*
Hrt/Thor circumference ratio: _____

Cardiac Imaging

Normal four chamber heart: *Yes / No*
Normal situs: *Yes / No*
Normal rhythm: *Yes / No*
Normal function: *Yes / No*
Normal valves: *Yes / No*
Crossing outflow tracts: *Yes / No*
Normal proximal great arteries: *Yes / No*
Normal Aortic arch: *Yes / No*
Normal Ductal arch: *Yes / No*
IVC/SVC visualized: *Yes / No*
Pericardial, pleural or ascites visualized: *Yes / No*
Pulmonary veins visualized: *Yes / No*

Doppler

Flow velocity distal to Aortic valve: _____(cm/sec)
Flow velocity distal to Pulmonary valve: _____(cm/sec)
Umbilical Artery S/D ratio: _____
Umbilical vein – continuous forward flow: *Yes / No*
Ductus Venosus – normal flow: *Yes / No*
Pulmonary veins seen with color-flow Doppler: *Yes / No*

Z-Scores

Aortic valve:	_____	_____
Pulmonary valve:	_____	_____
Mitral valve:	_____	_____
Tricuspid valve:	_____	_____
Left lateral ventricle:	_____	_____
Right lateral ventricle:	_____	_____