OBSTETRICS

Routine first-trimester ultrasound screening using a standardized anatomical protocol

Yimei Liao, PhD[1]; Huaxuan Wen, MSc[1]; Shuyuan Ouyang, BSc; Ying Yuan, MSc; Jingru Bi, BSc; Yong Guan, MSc; Qian Fu, PhD; Xia Yang, MSc; Wenjia Guo, MSc; Yi Huang, MSc; Qing Zeng, MSc; Yue Qin, PhD; Haishan Xiang, MPH; Shengli Li, MD

BACKGROUND: First-trimester ultrasound scans were introduced to China for nearly 20 years. The ability of first-trimester ultrasound screening to detect different malformations was variable. A recent systematic review concluded that the use of a standardized anatomic protocol was the most crucial factor to improve the sensitivity of first-trimester ultrasound screening for anomalies. Standardized sectional scans have long been used for routine anatomy screening during the second trimester. However, during the first trimester, most of the previous studies have described the observation of anatomic structures but have not specified clearly the standard sectional views.

OBJECTIVE: We aimed to determine the performance of routine first-trimester scans using a standardized anatomic protocol for detecting structural abnormalities in China.

STUDY DESIGN: This was a large retrospective study involving 59,063 sequential unselected pregnancies. Scans at 11 to 13^{+6} weeks were performed in a single center during a 7-year span. All fetuses were examined following a predefined protocol for standardized views.

RESULTS: From October 2008 to December 2015, first-trimester scans were performed in 53,349 pregnant women with available outcome. Of these, there were 1578 (3%) pregnancies that presented with at least 1 fetal structural abnormality. The detection rate for first-trimester screening was 43.1% (95% confidence interval, 40.6%—45.5%). Routine first-trimester scans detected 95.6% of abdominal wall defects, 66.3% of nervous system defects, 33.8% of limbs and skeleton malformations, 30.8% of facial abnormalities, 21.2% of urogenital abnormalities, 18.4% of thoracic and lung abnormalities, and 4.1% of gastrointestinal tract abnormalities. During the first trimester, 37.7% of cardiac defects were identified and included 57.9% of major cardiac defects and 2.6% of mild cardiac defects. A robust high detection rate for anencephaly, exencephaly, cephalocele, holoprosencephaly, exomphalos, gastroschisis, Pentalogy of Cantrell, sirenomelia, and body stalk anomaly was achieved during routine first-trimester scans.

CONCLUSION: A standardized anatomic protocol is advised when performing routine first-trimester ultrasound screening. It is recommended that screening for severe structural abnormalities should be extended to the first trimester.

Key words: abnormality, fetus, first trimester, standardized anatomic protocol, ultrasound

Introduction

First-trimester evaluation of fetal anatomy and detection of anomalies was performed in the 1990s.[1–3] The introduction of nuchal translucency (NT) aneuploidy screening during the 11 to 13^{+6} week scan has renewed interest for early anatomy scanning. With the use of noninvasive prenatal DNA tests and improvements in ultrasound technology, ultrasounds performed during the first trimester have been increasingly used for the visualization of fetal anatomy.[4,5] Ultrasound screening of fetal malformation at 11 to 13^{+6} weeks decreases the diagnostic time for severe structural malformations of the fetus, reduces late-term termination of pregnancy, and provides sufficient time for prenatal genetic testing and appropriate consultation of pregnant women. However, the ability of first-trimester ultrasound screening to detect different malformations was variable. Syngelaki et al[6,7] suggested that fetal abnormalities fall into 3 categories in relation to detectability during the 11 to 13 week scan: always detectable, never detectable, or sometimes detectable. In addition, the detection rate of first-trimester ultrasound also varied between different risk groups.[4] A recent systematic review[4] concluded that the use of a standardized anatomic protocol was the most crucial factor to improve the sensitivity of first-trimester ultrasound screening for all anomalies and major anomalies in various patient risk groups.

Standardized sectional scans have long been used for routine anatomy screening during the second trimester.[8] However, during the first trimester, most of the previous studies[6,7] have described the observation of anatomic structures but have not specified clearly the standard sectional views. Colosi et al[9] proposed 10 standard sections for abnormality screening during the first trimester. In this study, we provide a relatively complete set of standard sectional scans for first-trimester ultrasound structural screening and report the 7-year experience from a tertiary screening center using an unselected cohort. The reference NT values in normal Chinese fetuses were established using this large cohort.

Materials and Methods

This was a retrospective study that evaluated first-trimester scanning with predesigned standardized sections. Data from routine clinical examinations were retrospectively analyzed. The study was approved by the ethics committee of Shenzhen Maternity & Child Healthcare

Cite this article as: Liao Y, Wen H, Ouyang S, et al. Routine first-trimester ultrasound screening using a standardized anatomic protocol. Am J Obstet Gynecol 2021;224:396.e1-15.

0002-9378/$36.00

https://doi.org/10.1016/j.ajog.2020.10.037

AJOG at a Glance

Why was this study conducted?

This study aimed to determine the performance of routine first-trimester scans using a standardized anatomic protocol for detecting structural abnormalities in a large unselected population involving more than 50,000 pregnancies.

Key findings

This study highlights the value of first-trimester scanning using standardized sections for detecting fetal anomalies. It demonstrated that the detection rate of fetal abnormalities during the first trimester reached 43.1%. Of the fetuses with structural abnormalities that could be detected using prenatal ultrasound, approximately half were diagnosed during the first trimester. Moreover, it presented the largest cohort of normal Chinese fetuses to establish the reference nuchal translucency values.

What does this add to what is known?

We introduced a standardized anatomic protocol with 14 standard sections when performing routine first-trimester ultrasound screening and reported its performance for detecting structural abnormalities in a large unselected population.

Hospital. The Shenzhen Maternity & Child Healthcare Hospital offers routine first-trimester scans to all pregnant women opting to have their prenatal care in the hospital. In our center, first-trimester ultrasound screening was initiated in 2005, and in 2008, the scan sections were standardized. All sonographers who performed early pregnancy ultrasound scanning were required to undergo a rigorous 6-month training. A survey of fetal anatomy during 11 to 13^{+6} weeks was performed using ultrasound equipment with high resolution, using Siemens ACUSON Sequoia 512, Antares S2000, S3000, and SC2000 (Siemens Medical Solutions, Mountain View, CA); GE Voluson E8 (GE Healthcare, Zipf, Austria); and Samsung A30 and Samsung WS80A (Samsung Medison Co Ltd, Seoul, Korea). From October 2008 to December 2015, routine first-trimester anomaly screening was performed in 59,063 women with a singleton pregnancy in our center.

First-trimester scanning and sections

The 14 standard sections required for routine first-trimester ultrasound screening were as follows (for the details of each plane, see the Appendix): midsagittal view of the fetus (Figure 1, A and a), midsagittal view of the face and neck (Figure 1, B, C, b, and c), the transventricular plane (Figure 1, D and d), the axial plane of the posterior fossa (Figure 1, E and e), the oblique coronal plane at the level of the orbits and ears (Figure 1, F and f), the oblique coronal plane of the retronasal triangle (Figure 1, G and g), the oblique coronal plane of the nose and lips (Figure 1, H and h), the 4-chamber (4C) view of the heart (Figure 1, I, J, i, and j), the 3-vessel trachea (3VT) view of the heart (Figure 1, K, L, k, and l), the axial plane of the upper abdomen (Figure 1, M and m), the axial plane of the cord insertion into the abdomen (Figure 1, N and n), the axial plane of the bladder (Figure 1, O and o), the coronal and sagittal sections of the upper limbs (Figure 1, P and p), and the coronal and sagittal sections of the lower limbs (Figure 1, Q and q).

If the fetus is improperly positioned or uterine contraction obstructs the examination, the ultrasound examination should be repeated 15 to 20 minutes later. Transabdominal ultrasonography is usually performed, with transvaginal ultrasonography performed with the consent of the pregnant woman, if necessary. Examination of a normal fetus should be completed within 30 minutes, whereas the examination of an abnormal fetus should be completed within 1 hour. All abnormalities detected during early pregnancy must be confirmed by 2 doctors (one of whom is a senior doctor). An additional follow-up scan after 2 weeks and fetal medical consultation will be suggested if there are any abnormalities. All acquired ultrasound images were stored in an ultrasonic database. Imaging quality control was conducted on a monthly basis by a senior physician.

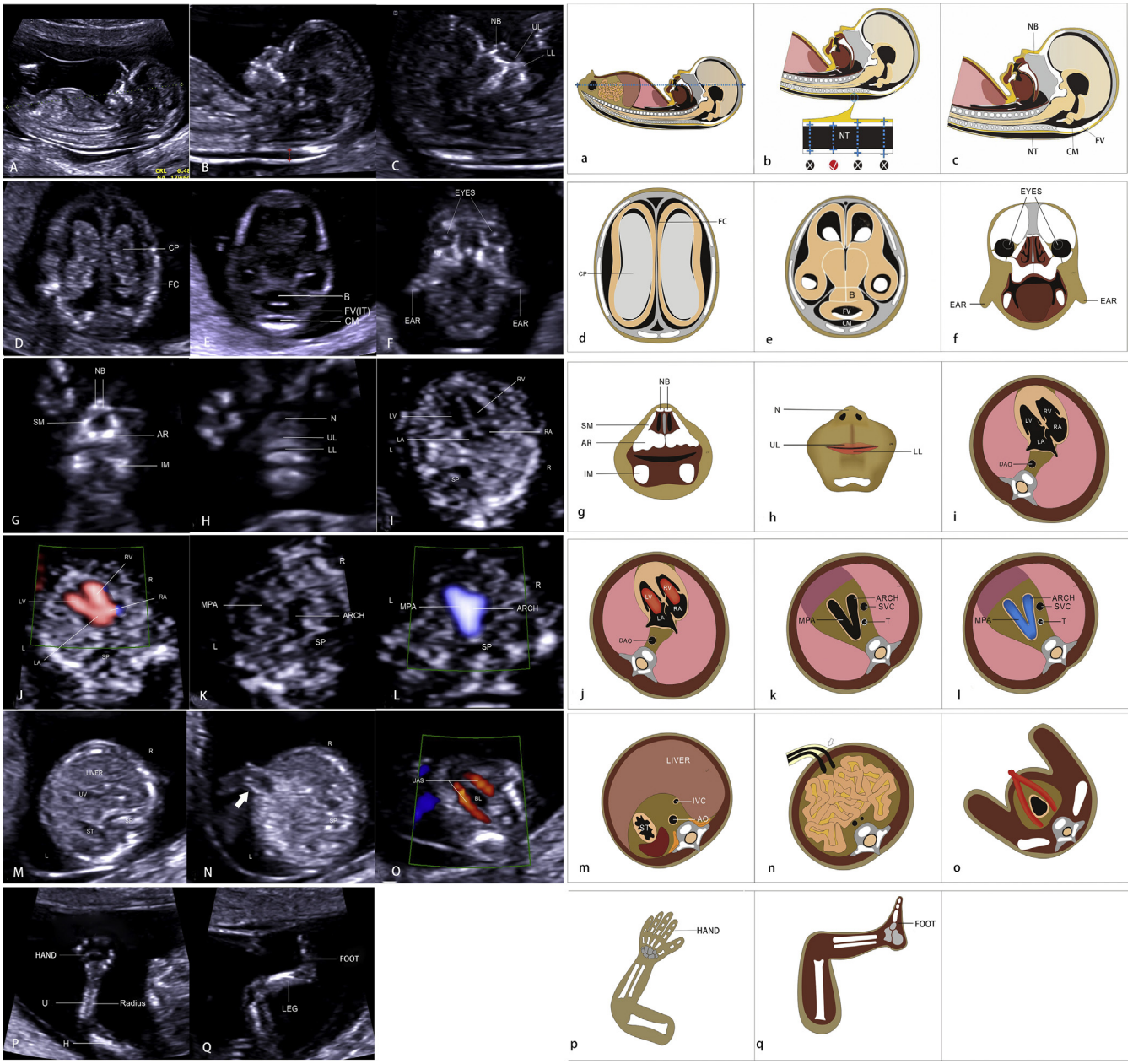
Second- and third-trimester scanning and follow-up

If the pregnancy continued, an 18 to 24 week anatomy scan and a 28 to 32 week growth scan were performed. Data on pregnancy outcomes used in this study were primarily obtained from the Shenzhen Birth Defects Surveillance Database maintained by the Chinese Birth Defects Monitoring Network. In addition, data from maternity medical records and telephone calls were obtained. The citywide Birth Defects Surveillance Database contains data from all pregnancies. Pregnancy records after 12 weeks of gestation in any hospital of the city and follow-up data of all newborns or fetuses were recorded. Every neonate or stillbirth was immediately examined after birth by trained healthcare professionals to screen for birth defects. In cases of pregnancy termination, results of genetic tests and autopsies were extracted from medical records if available.

Inclusion and exclusion criteria

A singleton pregnancy with a live fetus between 11 and 13^{+6} weeks with complete outcomes was included in the analysis. Incomplete pregnancy outcome information, unexplained miscarriages, and fetal death were not included in this study. Increased NT, cystic hygroma, and dysplasia of the nasal bone were not considered as isolated structural deformities. All structural abnormalities diagnosed prenatally and during the neonatal period were included, except for fetal growth restriction. Rhabdomyoma, ventricular septal defect (VSD), autism spectrum disorder+VSD, persistent left superior vena cava, and vascular rings were considered as mild cardiac malformations. Transposition of the great arteries, coarctation of the aorta, absence

FIGURE 1
Ultrasound images (*left*) and corresponding schematic drawings (*right*) of the standardized sections for fetal anatomy screening during the first trimester



AO, aorta; *AR*, alveolar ridge; *ARCH*, aortic arch; *B*, brainstem; *BL*, bladder; *CM*, cisterna magna; *CP*, choroid plexuses; *DAO*, descending aorta; *FC*, Falx cerebri; *FV*, fourth ventricle (or IT); *H*, humerus; *IM*, inferior mandible; *IT*, intracranial translucency; *IVC*, inferior vena cava; *L*, left; *LA*, left atrium; *LL*, lower lips; *LV*, left ventricle; *MPA*, main pulmonary artery; *N*, nose; *NB*, nasal bone; *NT*, nuchal translucency; *R*, radius; *R*, right; *RA*, right atrium; *RV*, right ventricle; *SM*, supermaxilla; *SP*, spine; *ST*, stomach; *SVC*, superior vena cava; *T*, trachea; *U*, ulna; *UAs*, umbilical arteries; *UL*, upper lips; *UV*, umbilical vein.

Liao et al. First-trimester ultrasound using standardized scan sections. Am J Obstet Gynecol 2021.

of both aortic and pulmonary valves, absence of the pulmonary valve, pulmonary atresia and stenosis, double outlet right ventricle, single atrium and univentricular heart, Tetralogy of Fallot, hypoplastic left heart syndrome, hypoplastic right heart syndrome, common arterial trunk, Ebstein anomaly, tricuspid valve dysplasia with severe regurgitation, atrioventricular septal defect, heterotaxy syndrome, atrial, isomerism, situs inversus, and anomalous pulmonary venous connection were classified as major cardiac malformations. The final diagnosis (autopsies were not considered) was determined on the basis of ultrasound diagnosis, and cases with available autopsies or follow-up ultrasound and magnetic resonance imaging (MRI) were diagnosed based on autopsies or follow-up ultrasound and MRI.

Megacystis was defined during the first trimester by a longitudinal bladder diameter of 0.7 cm or greater obtained from the midline sagittal plane of the fetus.[10,11] Omphalocele was defined as a congenital defect of the anterior midline abdominal wall with herniation of abdominal viscera, such as bowel and/or liver, into the base of the umbilical cord, with gestational age >12 weeks.[12,13] If the gestational age was <12 weeks but with herniation containing the liver or stomach, it was also considered omphalocele. Physiological midgut herniation is a herniation of the small bowel in the small midline sac, measuring <7 mm and physiologically observed until the 12th week of gestation,[12,14,15] and afterward, follow-up ultrasound demonstrating the bowel returning to the abdominal cavity. Because early pregnancy structural ultrasound screening and serologic screening are often performed at the same time or earlier, many fetuses with severe structural malformations would have been terminated without invasive prenatal testing. In these cases, fetal chromosomal abnormalities with structural malformations were included in the study, whereas chromosomal abnormalities without detectable structural malformations were excluded.

Statistical analysis

Continuous variables were expressed as mean±standard deviation. The detection rate was expressed as a percentage and was calculated as the number of abnormal fetuses detected by ultrasound divided by the total number of abnormal fetuses. A linear regression model was used to evaluate the correlation between NT and crown lump length (CRL). Increased NT was defined as the value greater than the 95th percentile of NT in normal fetuses at the same gestational age. Differences in dichotomous and categorical variables were compared using a chi-square test or Fisher exact test. Statistical analyses were performed using the Statistical Package for the Social Sciences 20.0 software (SPSS Inc, Chicago, IL).

Results

Ultrasound examinations at 11 to 13^{+6} weeks in 59,063 singleton pregnancies were obtained from examinations conducted between October 1, 2008 and December 30, 2015. The initial evaluation of fetal anatomy could be complete by transabdominal ultrasound in most patients. Only <1% of pregnant women underwent the transvaginal ultrasound, particularly in case with high maternal body mass index or when the images' quality was not satisfactory for diagnosis. Outcome data were unavailable for 5294 (8.96%) cases. A total of 420 pregnancies resulted in miscarriages or unexplained fetal death and were excluded from the study. In these cases, there were no detectable abnormalities during the 11 to 13^{+6} week scan, and postmortem examinations were not performed. Of the remaining 53,349 cases, 1578 fetuses had at least 1 structural abnormality. The incidence of fetal structural malformations was about 3% (1578/53,349) in this cohort. Table 1 outlines the maternal and fetal characteristics of the study population. During first-trimester screening, we identified at least 1 abnormality in 680 of the 1578 pregnancies with a detection rate of 43.1% (95% confidence interval [CI], 40.6%−45.5%). Routine first-trimester scans detected 95.6% of abdominal wall defects, 66.3% of nervous system defects, 33.8% of limb and skeletal malformations, 30.8% of facial abnormalities, 21.2% of urogenital abnormalities, 18.4% of thoracic and lung abnormalities, and 4.1% of gastrointestinal tract abnormalities. During the first trimester, 37.7% of cardiac defects were identified and included 57.9% of major cardiac defects and 2.6% of mild cardiac defects. Anatomy scans during the 18 to 24 week period detected 488 (30.9%) abnormalities in 52,669 pregnancies. At the third-trimester scan after 28 weeks, 112 (7.1%) abnormalities were detected in 52,181 pregnancies. Finally, 298 (18.9%) abnormalities were observed in the remaining 52,069 live births by pediatricians during the neonatal period. Based on these results, 81.1% (95% CI, 79.2%−83.0%) of fetuses with structural abnormalities could be detected by prenatal ultrasound screening.

In the 1578 fetuses with at least 1 structural abnormality, 556 (35.2%) patients with major malformations opted for termination of pregnancy after abnormal first-trimester screening results. A total of 1022 (64.8%) underwent a follow-up ultrasound, and then 87 (5.5%) terminated in early second trimester because the severe anomalies were confirmed. A total of 239 (15.1%) terminated in the late second trimester for initial diagnosis of abnormalities. In the third trimester, 20 (1.3%) patients opted for termination of pregnancy for severe hydrocephalus, fetal hydrops and thalassemia, chromosome abnormalities, microcephalus, bilateral renal dysplasia, and intracranial infection and tumor. Miscarriage and fetal death occurred in 34 (2.2%), and the remaining 642 (40.7%) had live births.

Detection of fetal structural abnormalities during the first trimester

All fetal structural abnormalities are summarized in Table 2. Fetal structural abnormalities were classified into 3 groups based on whether they were detected at the 11 to 13^{+6} week scan.

Anomalies with stable high detection rates during the first trimester

The detection rate for several severe structural malformations during the first trimester was >90% for anencephaly, exencephaly, cephalocele, and holoprosencephaly. Among the 58 fetuses with holoprosencephaly, 49 had typical facial deformities. All facial deformities related to holoprosencephaly were identified. The detection rate of abdominal wall defects, that is, omphalocele, gastroschisis, Pentalogy of Cantrell, and ectopia cordis, was >96%. In addition, the ultrasonic detection rate of some syndromes with multiple severe malformations, such as short-rib-polydactyly syndrome and body stalk anomaly reached 100%.

During the first trimester, 41 cases of megacystis were detected. However, a case with megacystis, posterior urethral valves, and severe hydronephrosis was not detected until the second trimester. The

TABLE 1
Sample characteristics of the 53,349 singleton pregnancies

Characteristic	Mean (SD) *or* n (%)	Median (range)	95% CI
Maternal			
Maternal age, y	29.4 (±4.07)	29.0 (16.0–48.0)	29.31–29.38
BMI, kg/m^2	20.9 (±2.7)	20.5 (13.0–54.9)	20.86–20.91
BMI >30	400 (<1%)	—	—
Fetal			
CRL, mm	61.7 (±7.7)	61.0 (45.0–84.0)	61.65–61.78
NT, mm	1.7 (±0.7)	1.7 (0.6–28.0)	1.74–1.75
NT ≥3.0 mm	931 (1.75%)	—	—
NT unable to be measured	68 (0.13%)	—	—
Anomalies in the cohort	1578 (3%)	—	—
Underwent *first*-trimester scan	53,349	—	—
Anomalies during the *first*-trimester scan	680 (43.1%)	—	40.6%–45.5%
Underwent *second*-trimester scan	52,669	—	—
Anomalies during the *second*-trimester scan	488 (30.9%)	—	—
Underwent *third*-trimester scan	52,181	—	—
Anomalies during the *third*-trimester scan	112 (7.1%)	—	—
Live births	52,069	—	—
Anomalies after birth	298 (18.9%)	—	—

BMI, body mass index; *CI*, confidence interval; *CRL*, crown rump length; *NT*, nuchal translucency; *SD*, standard deviation.
Liao et al. First-trimester ultrasound using standardized scan sections. Am J Obstet Gynecol 2021.

incidence of physiological mesenteric hernia between 45 and 84 mm in this cohort was about 1:4446 (12/53,349). All physiological mesenteric hernias returned to normal subsequently.

Anomalies could be detected during the first trimester

More than 50% of spinal malformations could be detected and included spina bifida, severe scoliosis, and severe spinal dysplasia. The detection rate of Meckel–Gruber syndrome and venous system abnormalities also exceeded 70%. About half of diaphragmatic hernias could be detected during early pregnancy. Fetal hydrops was easy to diagnose if it appeared; however, about 20% of fetal hydrops did not appear until late pregnancy. In addition, the detection rates of severe limb reduction defects and skeletal dysplasia were over 70%, with about 40% detection of split hand and foot deformities. The detection rate for cleft lip and palate (CLP) was only 30.5%.

About half of the severe heart abnormalities were detected during the first trimester. Absence of both aortic and/or pulmonary valves, single atrium and univentricular heart, hypoplastic left heart syndrome, common arterial trunk, tricuspid valve dysplasia with severe regurgitation, and atrioventricular septal defects was diagnosed >50%. The absence of aortic and pulmonary valves was detected by observing the *to-and-fro* signal in the 3-vessel view using color Doppler. However, the detection rate of Ebstein anomaly, transposition of great arteries, Tetralogy of Fallot, coarctation of the aorta, and anomalous pulmonary venous connection was low. The fetal detection rate for mild cardiac abnormalities was very low (approximately 2.8%). VSD was first detected during the neonatal period in 64% of cases, and 83% of the vascular rings were detected during the second trimester of pregnancy.

Anomalies with lower detection rates during the first trimester

The detection rate for gastrointestinal tract malformations during early pregnancy was the lowest, about 4.1%. We observed 2 fetuses with cysts near the stomach during early pregnancy scans, with 1 fetus having duodenal atresia with trisomy 21, whereas the other was confirmed to have intestinal duplication after birth. Only 18.3% of fetuses with club foot were detected during the first trimester and about half during the second trimester. Most of the polydactyly cases were found after birth, and only about 25% of them were detected using ultrasound during the first trimester.

Some of the malformations were difficult to accurately evaluate during early pregnancy because the fetal structure was not fully developed. These included agenesis of the corpus callosum, congenital hydrocephalus, hypoplastic vermis and cerebellum, and

TABLE 2
Fetal structural abnormalities diagnosed during routine first-trimester scans

Fetal abnormality	Total	Increased NT	Diagnosis					Pregnancy outcome		
			First	Detection rate, %	Second	Third	Postnatal	TOP	Misc/IUD	LB
Nervous system	279	71	185	66.30	51	27	16			
Anencephaly	36	2	36	100.0	0	0	0	36	0	0
Exencephaly	61	7[a]	61	100.0	0	0	0	61	0	0
Cephalocele	19	5[a]	18	94.7	0	0	1	19	0	0
Holoprosencephaly	58	29[a]	55	94.8	3	0	0	58	0	0
Agenesis of corpus callosum	13	2	0	0.0	10	1	2	11	0	2
Congenital hydrocephalus	20	3	0	0.0	10	9	1	17	0	3
Hypoplastic vermis	6	3[a]	0	0.0	6	0	0	6	0	0
Hypoplastic cerebellum	9	2	0	0.0	6	1	2	6	0	3
Cortical dysplasia	3	0	0	0.0	0	0	3	0	0	3
Microcephalus	5	1	1	20.0	3	1	0	4	1	0
Arachnoid cyst	6	1	0	0.0	3	3	0	1	0	5
Blake's pouch cyst	7	4[a]	0	0.0	7	0	0	4	0	3
Brain tumor	2	0	0	0.0	0	2	0	2	0	0
Intracranial infection/ hemorrhage/ subependymal cysts	16	2	0	0.0	2	9	5	3	0	13
Spina bifida	24	10[a]	14	58.3	8	0	2	21	0	3
Face	169	22	52	30.80	53	5	59			
Cleft lip and palate	59	22	18	30.5	41	0	0	52	1	6
Cleft lip only	8	12[a]	3	37.5	2	1	2	1	1	6
Cleft palate only	9	1	0	0.0	1	0	8	1	0	8
Cleft lip and palate[b]	32	1	30	93.8	2	0	0	—	—	—
Proboscis[b]	12	—	12	100.0	0	0	0	—	—	—
Nasal hypoplasia[b]	29	—	29	100.0	0	0	0	—	—	—
Hypotelorism[b]	21	—	21	100.0	0	0	0	—	—	—
Cyclopia[b]	11	—	11	100.0	0	0	0	—	—	—
Microphthalmia	3	—	0	0.0	3	0	0	3	0	0
Cryptophthalmos	1	2[a]	0	0.0	0	0	1	0	1	0
Retinal dysplasia	3	0	0	0.0	0	0	3	0	0	3

Liao et al. First-trimester ultrasound using standardized scan sections. Am J Obstet Gynecol 2021.

(continued)

TABLE 2
Fetal structural abnormalities diagnosed during routine first-trimester scans *(continued)*

Fetal abnormality	Total	Increased NT	Diagnosis					Pregnancy outcome		
			First	Detection rate, %	Second	Third	Postnatal	TOP	Misc/IUD	LB
Dacryocystocele	4	0	0	0.0	0	3	1	0	0	4
Anomalies of the ears	46	0	0	0.0	3	0	43	3	0	43
Micrognathia	6	2	1	16.7	5	0	0	6	0	0
Transverse facial cleft	2	3[a]	0	0.0	0	1	1	0	1	1
Thoracic and lungs	49	12	9	18.40	29	3	8			
CPAM	14	2	1	7.1	12	1	0	2	0	12
Pulmonary sequestration	9	0	0	0.0	9	0	0	1	0	8
Congenital diaphragmatic hernia	16	10[a]	8	50.0	6	2	0	13	0	3
Pulmonary agenesis/ hypoplasia	4	0	0	0.0	1	0	3	1	0	3
Congenital high-airway obstruction syndrome	4	0	0	0.0	0	0	4	0	0	4
Bronchial atresia	2	0	0	0.0	1	0	1	0	0	2
Congenital heart defects	419	169	158	37.70	186	18	57			
Major heart defects	266	151[a]	154	57.90	100	6	6	221	8	37
Transposition of great arteries	11	3[a]	2	18.2	8	1	0	9	1	1
CoA	28	8[a]	8	28.6	19	1	0	21	0	7
Absent both aortic and pulmonary valves	11	11[a]	11	100.0	0	0	0	9	2	0
Absence of the pulmonary valve	7	7[a]	7	100.0	0	0	0	7	0	0
Pulmonary atresia/stenosis	29	9[a]	9	31.0	17	0	3	18	0	11
Double outlet right ventricle	20	11[a]	9	45.0	11	0	0	18	0	2
Single atrium/ univentricular heart	33	24[a]	26	78.8	7	0	0	32	1	0
Tetralogy of Fallot	28	9[a]	8	27.6	19	1	0	22	1	5
Hypoplastic left heart syndrome	42	34[a]	39	92.9	3	0	0	41	1	0
Hypoplastic right heart syndrome	5	2[a]	2	40.0	3	0	0	5	0	0
Common arterial trunk	14	11[a]	10	71.4	4	0	0	14	0	0
Ebstein anomaly	6	3[a]	2	33.3	4	0	0	5	1	0
Tricuspid valve dysplasia with severe regurgitation	4	1	2	50.0	2	0	0	3	0	1
Atrioventricular septal defect	58	39[a]	42	72.4	13	2	1	50	2	6

Liao et al. First-trimester ultrasound using standardized scan sections. Am J Obstet Gynecol 2021.

(continued)

TABLE 2
Fetal structural abnormalities diagnosed during routine first-trimester scans *(continued)*

Fetal abnormality	Total	Increased NT	Diagnosis					Pregnancy outcome		
			First	Detection rate, %	Second	Third	Postnatal	TOP	Misc/IUD	LB
Heterotaxy syndrome, atrial isomerism, situs inversus	12	4[a]	7	58.3	4	1	0	10	0	2
Anomalous pulmonary venous connection	4	2[a]	0	0.0	2	0	2	2	0	2
Mild heart defects	153	18[a]	4	2.60	86	12	51	15	3	135
Rhabdomyoma	2	0	0	0.0	2	0	0	0	0	2
Ventricular septal defect	75	12[a]	2	2.7	22	6	45	11	2	62
Atrial septal defect and VSD	6	0	0	0.0	1	0	5	0	0	6
Persistent left superior vena cava	39	2	0	0.0	35	4	0	0	0	39
Vascular rings	31	4	2	6.5	26	2	1	4	1	26
Abdominal wall	160	76	153	95.60	1	0	6			
Omphalocele (content is bowel)	51	21[a]	49	96.1	1	0	1	44	2	5
Omphalocele (content including liver)	57	33[a]	57	100.0	0	0	0	55	2	0
Gastroschisis	14	6[a]	14	100.0	0	0	0	14	0	0
Pentalogy of Cantrell	18	12[a]	18	100.0	0	0	0	18	0	0
Ectopia cordis only	3	2[a]	3	100.0	0	0	0	3	0	0
Umbilical hernia	5	0	0	0.0	0	0	5	0	0	5
Physiological midgut herniation	12	2	12	100.0	0	0	0	1	0	11
Gastrointestinal tract	49	8	2	4.10	22	6	19			
Esophageal atresia	4	1	0	0.0	1	0	3	1	0	3
Duodenal atresia	8	3[a]	1	12.5	7	0	0	7	0	1
Small-bowel obstruction/atresia	6	0	0	0.0	2	2	2	1	2	3
Imperforate anus	5	1	0	0.0	1	0	4	1	0	4
Gastrointestinal duplication cyst	9	0	1	11.1	5	2	1	0	0	9
Gastric volvulus	2	0	0	0.0	0	0	2	0	0	2
Hypertrophic pyloric stenosis	2	0	0	0.0	0	0	2	0	0	2
Hirschsprung disease	4	1	0	0.0	0	0	4	0	0	4
Congenital choledochal cyst/biliary dilatation	6	1	0	0.0	3	2	1	0	0	6
Congenital biliary atresia	1	1	0	0.0	0	0	1	0	0	1
Gallbladder agenesis	1	0	0	0.0	1	0	0	0	0	1

Liao et al. First-trimester ultrasound using standardized scan sections. Am J Obstet Gynecol 2021. *(continued)*

TABLE 2
Fetal structural abnormalities diagnosed during routine first-trimester scans *(continued)*

Fetal abnormality	Total	Increased NT	Diagnosis					Pregnancy outcome		
			First	Detection rate, %	Second	Third	Postnatal	TOP	Misc/IUD	LB
Liver calcifications	2	0	0	0.0	2	0	0	0	0	2
Urogenital system	236	40	50	21.20	96	40	50			
Polycystic kidney disease	7	1	3	42.9	3	1	0	6	0	1
MCDK	31	3	1	3.2	27	3	0	17	1	13
Megacystis	43	18[a]	42	97.7	1	0	0	33	0	10
Severe hydronephrosis (≥1.5 cm)	50	0	0	0.0	16	22	12	4	0	46
Renal agenesis/ dysplasia	29	8[a]	2	6.9	23	4	0	17	1	11
Duplex kidney	13	1	0	0.0	12	1	0	3	0	10
Pelvic kidney, crossed renal ectopia, horseshoe kidney	17	4[a]	1	5.9	12	4	0	5	0	12
Renal cyst	5	0	0	0.0	3	2	0	0	0	5
Hyperechogenic kidneys	5	0	1	20.0	3	1	0	0	0	5
Hypospadias	31	3	0	0.0	0	4	27	0	0	31
Cryptorchidism	11	2	0	0.0	0	0	11	0	0	11
Limbs and skeleton	231	65	78	33.80	79	2	72			
Limb reduction defects (except ectrodactyly)	35	14[a]	27	77.1	8	0	0	35	0	0
Ectrodactyly	6	0	0	0.0	4	0	2	3	0	3
Skeletal dysplasia	19	13[a]	14	73.7	4	1	0	17	0	2
Syndactyly	11	1	0	0.0	7	0	4	4	0	7
Polydactyly	24	4[a]	6	25.0	3	1	14	8	1	15
Polysyndactyly	5	0	0	0.0	0	0	5	0	0	5
Kyphoscoliosis/ hemivertebrae	14	3[a]	8	57.1	6	0	0	11	0	3
Segmental spinal dysplasia, caudal regression, severe sacral agenesis	8	2	7	87.5	1	0	0	8	0	0
Sirenomelia	2	1	2	100.0	0	0	0	2	0	0
Split hand/foot	5	2[a]	2	40.0	3	0	0	4	0	1
Overlapping digits	12	6[a]	0	0.0	12	0	0	12	0	0
Clubfoot	71	16[a]	13	18.3	38	0	20	29	1	41
Strephexopodia	8	3[a]	0	0.0	0	0	8	1	0	7

Liao et al. First-trimester ultrasound using standardized scan sections. Am J Obstet Gynecol 2021.

(continued)

TABLE 2
Fetal structural abnormalities diagnosed during routine first-trimester scans *(continued)*

Fetal abnormality	Total	Increased NT	Diagnosis					Pregnancy outcome		
			First	Detection rate, %	Second	Third	Postnatal	TOP	Misc/IUD	LB
Joint or postural deformities (including knee joint flexion)	19	0	0	0.0	1	0	18	1	0	18
Craniosynostosis	1	0	0	0.0	0	0	1	0	0	1
Fetal tumor or masses	33	1	3	9.10	13	7	10			
Sacrococcygeal teratoma	9	0	1	11.1	8	0	0	6	0	3
Hemangioma	7	0	0	0.0	0	0	7	0	0	7
Lymphangioma	4	0	0	0.0	3	0	1	2	0	2
Adrenal hematoma/tumor	2	0	0	0.0	1	0	1	0	0	2
Intraabdominal cysts (undetermined origin)	11	1	2	18.2	1	7	1	1	0	10
Syndromes[a]	71	36	69	97.20	2	0	0			
Meckel—Gruber syndrome	4	1	3	75.0	1	0	0	4	0	0
Apert syndrome	1	1	0	0.0	1	0	0	1	0	0
Short-rib-polydactyly syndrome	2	2[a]	2	100.0	0	0	0	2	0	0
Body stalk anomaly	56	30[a]	56	100.0	0	0	0	54	2	0
Amniotic band sequence	8	2	8	100.0	0	0	0	7	1	0
Other	133	99	108	81.20	17	6	2			
Hydrops fetalis (include thalassemia)	116	92[a]	96	82.8	13	5	2	104	6	6
Anomalies of the abdominal venous vasculature (include agenesis of the ductus venosus)	17	7[a]	12	70.6	4	1	0	13	0	4

CoA, coarctation of the aorta; *CPAM*, congenital pulmonary airway malformation; *IUD*, intrauterine death; *LB*, live birth; *MCDK*, multicystic dysplastic kidney; *Misc*, miscarriage; *NT*, nuchal translucency; *TOP*, termination of pregnancy; *VSD*, ventricular septal defect.

[a] The proportion of increased NT in the case group was significantly higher than normal fetuses ($P<.05$); [b] Facial abnormalities associated with holoprosencephaly.

Liao et al. First-trimester ultrasound using standardized scan sections. Am J Obstet Gynecol 2021.

Blake's pouch cyst. Although there were some indications of malformations, confirmed diagnosis was only possible during the later development of the fetus. One case of hypoplastic vermis was observed with normal posterior brain during the first trimester, whereas the other 5 cases presented enlarged intracranial translucency (IT) and diminished visibility of the choroid plexus of the fourth ventricle. The diagnosis was only confirmed during the second trimester. There was only 1 case of Blake's pouch cyst that showed mildly increased IT, whereas the others were normal.

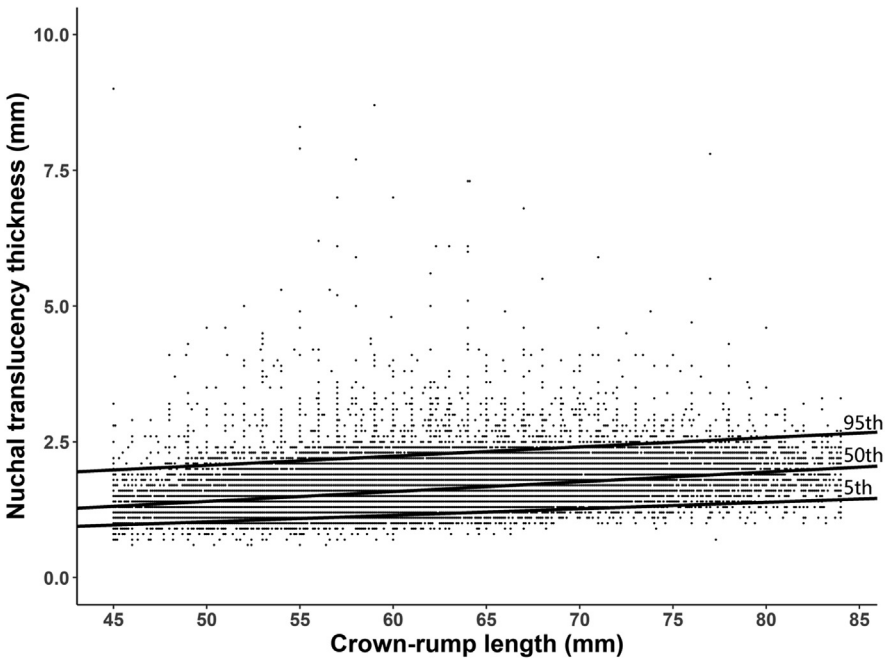
Other deformities may manifest later with severity changing with gestational age, for example, congenital hydrocephalus, micrognathia, microcephaly, congenital pulmonary airway malformation (CPAM), partial congenital diaphragmatic hernia, intracranial infection/brain hemorrhage/subependymal cysts, arachnoid cyst, and fetal tumor. Isolated hydrocephalus without intracranial structural malformations is usually normal during early pregnancy. The lateral ventricular does not enlarge until the second or third trimester, and in a few cases, even after birth. The severity of micrognathia may vary with gestational age. In this study, 1 case with severe micrognathia was diagnosed during the first trimester, whereas the other 5 cases with nearly normal facial profiles during early pregnancy were diagnosed with micrognathia during the second trimester. Only 1 case of severe microcephaly presented obvious retraction of the forehead and small head circumference (HC). HC measurements for the other cases during early pregnancy were consistent with gestational age. No obvious abnormalities or clues were observed for CPAM, diaphragmatic hernia, intracranial infection/brain hemorrhage/subependymal cysts, arachnoid cyst, and fetal tumor during first-trimester scans.

The nuchal translucency of normal and abnormal fetuses

The reference values of the NT thickness related to CRL were determined in normal fetuses. A Kolmogorov–Smirnov test showed that NT and CRL did not conform to Gaussian distribution ($P<.001$). The median NT thickness was 1.7±0.4 (95% CI, 1.701–1.708). The 95th percentile of NT values related to CRL (45–84 mm) ranged from 1.98 mm to 2.65 mm. The following regression formulas were used: median of NT=0.018×CRL (mm)+0.505 (R^2=0.908), 95th percentile of NT=0.017×CRL (mm)+1.219 (R^2=0.98), and 5th percentile of NT=0.012×CRL (mm)+0.429 (R^2=0.82) (Figure 2).

For abnormal fetuses, the increase in NT was 32.4% (511/1578). Compared with normal fetuses, the incidence of NT thickening was significantly increased ($P<.05$) in fetuses with major cardiac malformations, holoprosencephaly, diaphragmatic hernia, omphalocele, megacystis, renal agenesis/ dysplasia, and body stalk anomaly (Table 2).

FIGURE 2
A scatter plot showing the distribution of NT related to CRL with regression lines of 5th, 50th, and 95th percentile of NT



CRL, crown rump length; *NT*, nuchal translucency.

Liao et al. First-trimester ultrasound using standardized scan sections. Am J Obstet Gynecol 2021.

Comment

Principal findings

First-trimester screening for fetal structural deformities using 14 standardized sectional scans was routinely used in an unselected cohort of pregnant women. The detection rate of fetal abnormalities during the first trimester reached 43.1% (95% CI, 40.6%–45.5%). Of the 81.1% (95% CI, 79.2%–83.0%) of fetuses with structural abnormalities that could be detected using prenatal ultrasound, about half were diagnosed during the first trimester. We demonstrated that although first-trimester ultrasound screening could not replace second-trimester ultrasound screening, it advanced the detection time of some severe structural anomalies during early pregnancy, especially for malformations with a robust detection rate of >90%. Our study is consistent with previous publications[16] and emphasizes first-trimester standardized ultrasound structural abnormality screening during early pregnancies between 11 and 13^{+6} weeks. In addition, we established reference values for NT in normal Chinese fetuses based on a large study cohort and demonstrated that the 95th percentiles of NT for a CRL between 45 and 84 mm ranged from 1.98 mm to 2.65

mm. This result is consistent with previous multicenter studies that have been performed[17,18] by The Fetal Medicine Foundation. Their 95th percentiles of NT for a CRL between 45 and 84 mm ranged from 2.1 mm to 2.7 mm.

Results

The advantages of fetal structural screening during the first trimester are advanced diagnosis time, easier and safer pregnancy termination during early gestation than later, and more adequate time for genetic tests to be performed. Nevertheless, a recent systematic review[4] demonstrated that the sensitivity for the detection of all types of fetal structural abnormalities in low-risk and unselected pregnant cohorts ranged from 11.54% to 65.7% depending on the studies that were performed. This wide range was attributed to whether or not a standardized anatomic protocol was used during first-trimester anomaly screening.[4] Most previous studies have described the observation of anatomic structures but have not clearly specified the standard scans for evaluation, except for the study performed by Colosi et al.[9] They used a checklist of 10 standardized scans for identification of major fetal malformations in a small cohort. The additional planes in this study allow for more comprehensive structural screening of the fetus. It demonstrated that the detection rate of all structural malformations including mild structure malformations was 43.1% (680/1578), which was similar to the detection rate (47.7%, 21/44) of fetal major malformations (χ^2=0.375, P>.05) by Colosi et al.[9] With regard to the similar fetal major malformations to Colosi et al[9], a much higher detection rate (70.7%, 607/859) would be obtained using the present standardized anatomic protocol (χ^2=10.397, P<.05). The first trimester detection rates of spina bifida, facial malformations, diaphragmatic hernia, and severe cardiac malformations were significantly improved in this study. Syngelaki et al[7] performed a large prospective study for the examination of fetal anatomy in 45,191 pregnancies. They assessed fetal anatomy through a series of sagittal and transverse views and included examinations of the brain at the level of the choroid plexuses but not the posterior fossa, assessment of the nasal bone but not the upper lip and maxilla, and examination of the 4C view of the heart but not the great vessels. For the standard scan views suggested in this study, the posterior fossa was examined using the transcerebellum view; maxilla and lips were also examined using the retronasal triangle view and the coronal view of the nose and lips, respectively; and visualization of the great vessels was performed using the 3VT view in color Doppler. A recent study by Syngelaki et al[6] analyzed 100,997 singleton pregnancies and improved their previous standardized protocol. However, the standardized sections were not clearly described. They demonstrated that 27.6% of malformations could be diagnosed during the first trimester, whereas 53.8% of malformations could be diagnosed during the second trimester. Therefore, they determined that the second trimester was the main screening period to determine fetal structural malformations. In our study, sonographers were required to obtain 14 predefined standardized sections during first trimester examinations similar to what was performed during the second trimester. With this standardized anatomic protocol, we demonstrated that a higher proportion (43.1%) of fetal abnormalities could be detected during the first trimester than the second trimester (30.9%). There are some benefits in establishing criteria for standardized sections during first-trimester scans; trained sonographers can obtain these sections in a short time, and it allows for retrospective image quality control and retrospective analysis of the characteristics of malformations during the first trimester.

Clinical implications

The overall incidence of fetal structural malformations was 3% in this study. Abdominal wall defects, nervous system defects, and major heart defects had higher detection rates, whereas gastrointestinal tract abnormalities had the lowest detection rates. A robust high detection rate for anencephaly, exencephaly, cephalocele, holoprosencephaly with associated facial malformations, exomphalos, gastroschisis, megacystis, sirenomelia, body stalk anomaly, and Pentalogy of Cantrell and ectopia cordis could be achieved during the first-trimester scan. In a recent study performed by Syngelaki et al,[6] the detection rates for spina bifida, severe cardiac malformation, and CLP were significantly improved compared with their previous study. The detection rates for spina bifida (59% vs 58.3%), severe cardiac malformation (52% vs 57.9%), and CLP (35% vs 30.5%) were nearly similar to the results from our study. First-trimester ultrasound screening for CLP was performed by evaluating the sagittal view of the maxilla or coronal oblique view of the retronasal triangle.[12] However, the diagnosis for isolated CLP is difficult during the first trimester and was consistent between our study and the study by Syngelaki et al.[6] Only a third of CLP malformations could be diagnosed during the first trimester. This may be due to the small size of the facial structures in addition to the coronal oblique view of the retronasal triangle being concealed by the acoustic shadow and fetal position. The identification of isolated second cleft palate without cleft lip during the first trimester was significantly lower than expected. This was not surprising because of the presence of the cleft in the second palate and an intact alveolar ridge being visible on the coronal plane of the retronasal triangle.

Some abnormalities may not be easily detected owing to incomplete development of the fetus in the first trimester, or the severity of the malformation may vary with gestational age. In these cases, a follow-up ultrasound should be recommended at the time of consultation. For instance, the anatomic structure of the fetus cerebellum has not completely developed at such an early gestation age; however, some abnormal signs could be observed in the posterior brain of the fetuses, such as open spina bifida and hypoplasia vermis. Some anomalies may resolve or progress with pregnancy, such as megacystis during the first trimester. These may be transient, with some cases

having spontaneous resolution with normal pediatric follow-up.[19,20] Early screening for fetal abnormalities could bring reassurance to at-risk mothers who have had problematic pregnancies before. This substantially minimizes unnecessary patient anxiety. However, it should be noted that false positives may occur.[21] In this study, we observed a lack of ossification of the maxilla and palate in fetal skeleton hypoplasia and unexplained delayed ossification of the palate. These may be responsible for some false-positive cases of CLP.

Research implications

A standardized anatomic protocol is advised when performing routine first-trimester ultrasound screening in this study. It is recommended that screening for severe structural abnormalities should be extended to the first trimester. Further refinements of the protocol should be explored to make detection rates more sensitive. A false-positive or false-negative diagnosis may occur. Therefore, future prospective research should focus on the follow-up scan after the first trimester to prevent misdiagnosis.

Strengths and limitations

In addition to the retrospective nature of this study, the study limitations are as follows. The final diagnosis for most cases was made by trained healthcare professionals who screened for defects after birth or induced labor. If autopsy results could not be obtained, available diagnosis using postnatal ultrasound or MRI was obtained. However, some inner abnormalities may be missed during examinations after labor, and some malformations such as small ventricular septal defects are hard to find even in postpartum. Unfortunately, genetic abnormalities were difficult to assess in this cohort. This was because some cases with severe structural malformations were terminated without genetic tests performed. However, these fetuses with suspected chromosomal abnormalities were included in the study.

Conclusions

This study highlights the value of first-trimester scanning using standardized sections for detecting fetal anomalies. First-trimester ultrasound screening can advance the detection time for some severe structural anomalies during early pregnancy. For some malformations, a robust detection rate of >90% was achieved. The different abnormalities detected should be carefully evaluated and followed up with additional scans and tests. This should be considered during consultation because of issues with a false-positive or false-negative diagnosis. ■

Acknowledgments

We thank the Shenzhen Birth Defects Surveillance Database maintained by the Chinese Birth Defects Monitoring Network for access to the data. We also thank staff at Shenzhen Maternity & Child Healthcare Hospital for performing the scans. The study was supported by the National Key Research and Development Program of China (2018YFC1002202), the National Nature Science Foundation of China (81771598,81571758), and the Shenzhen Science and Technology project (JCYJ20170307091013214).

References

1. D'Ottavio G, Meir YJ, Rustico MA, et al. Screening for fetal anomalies by ultrasound at 14 and 21 weeks. Ultrasound Obstet Gynecol 1997;10:375–80.
2. Economides DL, Braithwaite JM. First trimester ultrasonographic diagnosis of fetal structural abnormalities in a low risk population. Br J Obstet Gynaecol 1998;105:53–7.
3. Whitlow BJ, Chatzipapas IK, Lazanakis ML, Kadir RA, Economides DL. The value of sonography in early pregnancy for the detection of fetal abnormalities in an unselected population. Br J Obstet Gynaecol 1999;106:929–36.
4. Karim JN, Roberts NW, Salomon LJ, Papageorghiou AT. Systematic review of first-trimester ultrasound screening for detection of fetal structural anomalies and factors that affect screening performance. Ultrasound Obstet Gynecol 2017;50:429–41.
5. Rao R, Platt LD. Ultrasound screening: status of markers and efficacy of screening for structural abnormalities. Semin Perinatol 2016;40:67–78.
6. Syngelaki A, Hammami A, Bower S, Zidere V, Akolekar R, Nicolaides KH. Diagnosis of fetal non-chromosomal abnormalities on routine ultrasound examination at 11-13 weeks' gestation. Ultrasound Obstet Gynecol 2019;54:468–76.
7. Syngelaki A, Chelemen T, Dagklis T, Allan L, Nicolaides KH. Challenges in the diagnosis of fetal non-chromosomal abnormalities at 11-13 weeks. Prenat Diagn 2011;31:90–102.
8. Salomon LJ, Alfirevic Z, Berghella V, et al. Practice guidelines for performance of the routine mid-trimester fetal ultrasound scan. Ultrasound Obstet Gynecol 2011;37:116–26.
9. Colosi E, Musone R, Filardi G, Fabbo A. First trimester fetal anatomy study and identification of major anomalies using 10 standardized scans. J Prenat Med 2015;9:24–8.
10. Sebire NJ, Von Kaisenberg C, Rubio C, Snijders RJ, Nicolaides KH. Fetal megacystis at 10-14 weeks of gestation. Ultrasound Obstet Gynecol 1996;8:387–90.
11. Liao AW, Sebire NJ, Geerts L, Cicero S, Nicolaides KH. Megacystis at 10-14 weeks of gestation: chromosomal defects and outcome according to bladder length. Ultrasound Obstet Gynecol 2003;21:338–41.
12. Abuhamad A, Chaoui R. First trimester ultrasound diagnosis of fetal abnormalities, 1st ed. Philadelphia, PA: Wolters Kluwer Heath; 2017.
13. Tassin M, Descriaud C, Elie C, et al. Omphalocele in the first trimester: prediction of perinatal outcome. Prenat Diagn 2013;33:497–501.
14. Bowerman RA. Sonography of fetal midgut herniation: normal size criteria and correlation with crown-rump length. J Ultrasound Med 1993;12:251–4.
15. Timor-Tritsch IE, Warren WB, Peisner DB, Pirrone E. First-trimester midgut herniation: a high-frequency transvaginal sonographic study. Am J Obstet Gynecol 1989;161:831–3.
16. Salomon LJ, Alfirevic Z, Bilardo CM, et al. ISUOG practice guidelines: performance of first-trimester fetal ultrasound scan. Ultrasound Obstet Gynecol 2013;41:102–13.
17. Snijders RJ, Noble P, Sebire N, Souka A, Nicolaides KH. UK multicentre project on assessment of risk of trisomy 21 by maternal age and fetal nuchal-translucency thickness at 10-14 weeks of gestation. Fetal Medicine Foundation First Trimester Screening Group. Lancet 1998;352:343–6.
18. The 11-13 weeks scan. The Fetal Medicine Foundation. 2004. Available at: https://fetalmedicine.org/education/the-11-13-weeks-scan. Accessed May 26, 2020.
19. Girard N, Viaris de Lesegno B, Bussière P, Egoroff C, Cordier AG, Benachi A. Prognosis of isolated first-trimester fetal megacystis with spontaneous resolution. Fetal Diagn Ther 2017;42:271–7.
20. Iuculano A, Peddes C, Monni G. Early fetal megacystis: is it possible to predict the prognosis in the first trimester? J Perinat Med 2018;46:1035–9.
21. Van Mieghem T, Hindryckx A, Van Calsteren K. Early fetal anatomy screening: who, what, when and why? Curr Opin Obstet Gynecol 2015;27:143–50.

Author and article information

From the Department of Ultrasound, Affiliated Shenzhen Maternity & Child Healthcare Hospital, Southern Medical University, Shenzhen, Guangdong, China (Dr Liao, Mr

Wen, Ms Yuan and Bi, Mr Guan, Dr Fu, Ms Yang, Guo, Huang, and Zeng); Department of Central Laboratory, Affiliated Shenzhen Maternity & Child Healthcare Hospital, Southern Medical University, Shenzhen, Guangdong, China (Ms Ouyang); Institute of Maternity and Child Medical Research, Affiliated Shenzhen Maternity & Child Healthcare Hospital, Southern Medical University, Shenzhen, Guangdong, China (Dr Xiang).

[1]These authors contributed equally to this work.

Received July 14, 2020; revised Sept. 30, 2020; accepted Oct. 22, 2020.

The authors report no conflict of interest.

This research was supported by the National Key Research and Development Program and the National Nature Science Foundation of China, and the Shenzhen Science and Technology project.

Corresponding author: Shengli Li, MD. lsl13530386700@126.com

Appendix

The details of the 14 standard sections required for routine first-trimester ultrasound screening were as follows:

1) Midsagittal view of the fetus (Figure 1, A and a): Midsagittal plane displays facial profile and intracerebral structures, thorax, abdomen, bladder, and genitalia. The crown rump length (CRL) was determined using this section. CRL and nuchal translucency (NT) thickness were measured based on the guidelines of The Fetal Medicine Foundation, London.
2) Midsagittal view of the face and neck (Figure 1, B, C, b, and c): This section is defined by the presence of the echogenic tip of the nose and rectangular shape of the palate anteriorly, the translucent diencephalon in the center, and the nuchal membrane posteriorly. The fetus should be in a neutral position. NT is measured using this section.
3) The transventricular plane (Figure 1, D and d): The intact oval-shape cranium without focal protrusions or defects and the variable ossification of the skull are assessed using this section. The hyperechoic falx cerebri divides the 2 hemispheres symmetrically. The 2 echogenic butterfly shapes of choroid plexuses fill more than half of the lateral ventricles. The lateral ventricles are surrounded by a thin peripheral cortex.
4) The axial plane of the posterior fossa (Figure 1, E and e): In this transverse section, the anatomy of the posterior fossa is meticulously examined. This plane includes 3 hypoechoic areas. The 3 hypoechoic areas are indicated by the brainstem; the fourth ventricle, also known as intracranial translucency; and the future cisterna magna. Two separated thalami and partial falx cerebri could also be visualized.
5) The oblique coronal plane at the level of the orbits and ears (Figure 1, F and f): Two orbits with eyes are visualized with the nose between them. Two ears are located on either side of the head.
6) The oblique coronal plane of the retronasal triangle (Figure 1, G and g): The retronasal triangle consists of the nasal bones superiorly, the frontal processes of the maxilla laterally, and the alveolar ridge (primary palate) inferiorly. This coronal plane helps identify cleft palate during the first trimester.
7) The oblique coronal plane of the nose and lips (Figure 1, H and h): This section demonstrates the integrity of the mouth and lips.
8) The 4-chamber view of the heart (Figure 1, I, J, i, and j): The cardiac position in the chest, cardiac axis, both atrioventricular sizes, atrioventricular valves, ribs, and lungs can be assessed using this section. Color Doppler is used to confirm the separate filling in the diastole and the absence of significant atrioventricular valve regurgitation.
9) The 3-vessel trachea view of the heart (Figure 1, K, L, k, and l): The pulmonary artery and the aortic arch are displayed from left to right. The size of the great vessels, anatomic relationships, and direction of blood flow could be assessed, and the continuity of the ductal and aortic arches could be observed. The V-shape of the great vessels could be observed clearly using color Doppler.
10) The axial plane of the upper abdomen (Figure 1, M and m): This section reveals the left side of the stomach and the right side of the liver.
11) The axial plane of the cord insertion into the abdomen (Figure 1, N and n): This section is important to determine the integrity of the anterior abdominal wall and the absence of any masses.
12) The axial plane of the bladder (Figure 1, O and o): Normal anatomic features of the bladder can be observed. Color Doppler could be used to demonstrate the 2 umbilical arteries surrounding the bladder.
13) The coronal/sagittal sections of the upper limbs (Figure 1, P and p): This section is used to observe the upper arm with humerus, the forearm with radius and ulna, and hands.
14) The coronal/sagittal sections of the lower limbs (Figure 1, Q and q): This section is used to observe the femur, knee, tibia and fibula, and feet.