American College of Radiology
ACR Appropriateness Criteria®

Clinical Condition: **Assessment of Fetal Well-Being**

Variant 1: **Low-risk pregnancy.**

Radiologic Procedure	Rating	Comments	RRL*
US pregnant uterus biophysical profile	2		O
US pregnant uterus modified biophysical profile	2		O
US duplex Doppler velocimetry	2		O
US echocardiography fetal	1		O
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			***Relative Radiation Level**

Variant 2: **Pregnancy at risk for adverse fetal outcome.**

Radiologic Procedure	Rating	Comments	RRL*
US pregnant uterus biophysical profile	9		O
US pregnant uterus modified biophysical profile	7	This procedure is an alternative to BPP but NST may be complementary in cases of IUGR or oligohydramnios.	O
US duplex Doppler velocimetry	6		O
US echocardiography fetal	5		O
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			***Relative Radiation Level**

Variant 3: **Preterm pregnancy. Abnormal antenatal testing.**

Radiologic Procedure	Rating	Comments	RRL*
US pregnant uterus biophysical profile	8		O
US pregnant uterus modified biophysical profile	8	This procedure is an alternative to BPP but NST may be complementary in cases of IUGR or oligohydramnios.	O
US duplex Doppler velocimetry	6		O
US echocardiography fetal	5		O
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			***Relative Radiation Level**

Variant 4: **Term and post-term pregnancy. Abnormal antenatal testing.**

Radiologic Procedure	Rating	Comments	RRL*
US pregnant uterus biophysical profile	8		O
US pregnant uterus modified biophysical profile	8	This procedure is an alternative to BPP but NST may be complementary in cases of IUGR or oligohydramnios.	O
US duplex Doppler velocimetry	6		O
US echocardiography fetal	3		O
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			***Relative Radiation Level**

ASSESSMENT OF FETAL WELL-BEING

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Summary of Literature Review

Introduction/Background

Although fetal death may occur in otherwise uncomplicated pregnancies, there are recognized risk factors that increase the likelihood of in utero demise. Overall, intrauterine fetal mortality affects close to 1% of all pregnancies [1]. Specific maternal, fetal, and obstetric factors raise the estimated risk from 2-fold to as high as 40-fold above the 5 per 1000 risk for low-risk pregnancies [1]. Although strong supportive evidence is lacking, serial surveillance of high-risk patients has the potential to detect signs of fetal compromise and ultimately to influence obstetric management and the timing of delivery to optimize outcomes [1-3]. Therefore, the primary goal of antenatal testing is to identify fetuses at increased risk of intrauterine death or injury from antepartum asphyxia.

A variety of maternal, fetal, and obstetric factors warrant increased surveillance of fetal well-being [1]. Advanced maternal age, obesity, hypertensive disorders, cyanotic heart disease, thrombophilia, diabetes, thyroid disorders, chronic renal disease, connective tissue disease, cholestasis, hemoglobinopathies, isoimmunization, and a history of unexplained stillbirth are among the maternal factors that have the potential to increase the risk of adverse perinatal outcome [1-3]. Antepartum fetal testing is also indicated when fetal factors such as intrauterine fetal growth restriction (IUGR), specific structural anomalies, genetic syndromes, fetal arrhythmias, blood group incompatibilities, fetal anemia, congenital infections, or multiple gestations have been diagnosed prenatally [1-4]. Pregnancies complicated by maternal perception of decreased fetal movement, preterm premature rupture of membranes, postdates, abnormal maternal serum markers such as low pregnancy-associated plasma protein A, placental abruption, vaginal bleeding, or amniotic fluid abnormalities also merit increased scrutiny of fetal health [1-3,5]. The judicious use of tests of fetal well-being is recommended to optimize perinatal outcome in such pregnancies with higher rates of stillbirth.

Despite the identification of many conditions associated with antepartum asphyxia and fetal death, up to half of all stillbirths occur in patients without recognized risk factors [6]. Unfortunately, there is no evidence that routine antenatal testing improves outcomes in pregnancies perceived to be low risk [6]. In fact, antenatal fetal surveillance in low-risk women has the potential to cause iatrogenic prematurity secondary to preterm delivery for false-positive results [2].

For patients at risk, no single antenatal test has been shown to be superior to identifying the fetus at risk for intrauterine demise. Overall, a normal result for any test of fetal well-being is highly reassuring. A false-negative test, defined as a stillbirth occurring within 1 week of a normal test result, is uncommon regardless of the test used [1]. For most patients, antepartum fetal surveillance is initiated at 32–34 weeks' gestation but timing should be individualized based on the indication for testing, gestational age, and likelihood of neonatal survival. Weekly or twice-weekly testing has become standard clinical practice but the frequency of testing is not based on rigorous scientific evidence. Regardless of the timing of initiation or frequency of testing, antenatal fetal surveillance cannot be expected to predict stillbirth related to acute events such as placental abruption or a cord accident. Solid evidence that current strategies are effective in the prevention of antenatal stillbirth is lacking [7].

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Overview of Imaging Modalities

One of the most common indications for antenatal fetal surveillance is IUGR, and the primary tools to assess fetal well-being in IUGR have been reviewed by the American College of Radiology (ACR) Appropriateness Criteria® panel in a prior publication [8]. Although fetal movement counting and nonstress testing (NST) are still commonly used in obstetric practice, ultrasound (US)-based assessments have gained importance in evaluating fetal well-being in high-risk pregnancies. The main US-based studies used to determine fetal health are the biophysical profile (BPP), modified BPP (mBPP), and Doppler velocimetry. In cases at risk of cardiovascular compromise, fetal echocardiography may also be indicated to ensure fetal well-being.

Biophysical Profile

The BPP consists of 4 US-based assessments (fetal breathing movements, discrete body movements, fetal tone, and amniotic fluid volume) and can be performed with or without the addition of a NST [1,2]. The US examination is performed until all 4 components have met criteria or until 30 minutes have passed [9]. Fetal breathing movement meets criteria if there is at least 1 episode continuing for ≥30 seconds within the 30-minute BPP. At least 3 discrete body or limb movements must be observed during the examination, with 1 or more episodes of active extensions and return to flexion to meet criteria for movement and tone, respectively. Originally, the presence of a single pocket with a depth of ≥1 cm was used to define amniotic fluid, but later this component was redefined as normal if at least one 2 × 2 cm pocket was present [10]. Each US-based component of the BPP meeting the defined criteria receives a score of 2, for a composite score out of 8 [2,3]. If the NST is included, it is assigned a score of 2 if reactive, for a combined score for the BPP out of 10. If the specified criteria are not met for an individual component, it is scored as 0. A composite score of 8 or 10 is normal, 6 is equivocal, 4 or less is abnormal [2,3]. Similar to the NST, fetal acoustic stimulation can be used when performing a BPP to shorten testing time and reduce the number of false positives [11].

Modified Biophysical Profile

The mBPP consists of an US-based assessment of amniotic fluid volume coupled with a NST [1,2]. The NST is obtained with a cardiotocograph, a device that records the fetal heart rate via continuous-wave Doppler US along with uterine activity. Whereas the amniotic fluid volume reflects recent fetal renal perfusion and placental function, the NST provides information about immediate fetal oxygenation and acid-base balance [2,3]. A healthy fetus tends to increase its heart rate in response to fetal movement, which is the theoretical basis behind the NST. Although the woman may be asked to record when fetal movement occurs during the NST, it may or may not be recognized during testing. A NST is considered reactive if there are ≥2 fetal heart rate accelerations during 20 minutes of observation and nonreactive if after 40 minutes, ≤1 acceleration is detected [2]. An acceleration is defined as an increase in fetal heart rate of 15 beats above baseline lasting for 15 seconds for pregnancies at ≥32 weeks' gestation [2,3]. For pregnancies prior to 32 weeks, an acceleration is defined as 10 beats above baseline lasting for 10 seconds, reflecting differences related to prematurity [3].

Both the maximum vertical pocket (MVP) and amniotic fluid index (AFI) have been used in the performance of the mBPP [12]. The MVP is the single maximal vertical pocket measured anywhere in the uterus. In contrast, the AFI is the sum of the deepest vertical pocket in each of the 4 quadrants of the uterus, providing a quasi-quantitative assessment of amniotic fluid by US. Whereas a single MVP of ≥2 cm vertical depth is considered normal throughout gestation, the definition of normal AFI varies with gestational age [1,3]. An AFI of ≥5 cm at ≥37 weeks' gestation or ≥8 cm at <37 weeks is commonly used to define normal amniotic fluid, but normograms defining normal AFI between the 5th and 95th percentiles or ±2 standard deviations from the mean for gestational age can also be used [1-3]. Although the AFI is not considered an independent test of fetal well-being, abnormally low or abnormally high amniotic fluid may signify poor fetal health. For example, oligohydramnios may be associated with IUGR and polyhydramnios may indicate underlying maternal gestational diabetes, 2 conditions for which antenatal fetal testing is indicated.

Duplex Doppler Velocimetry

Umbilical arterial and venous Doppler velocimetry are used to evaluate fetal adaptive changes to placental insufficiency. It has been suggested that interrogation of the umbilical artery be done at the abdominal cord insertion to optimize reproducibility [4]. However, it is well recognized that indexes are higher intra-abdominally and at the fetal end of the cord compared to the placental end [13-15]. To avoid sampling intra-abdominally, interrogating the umbilical artery about 1 cm from the fetal abdomen is suggested. The normal umbilical artery waveform in a healthy fetus has forward flow throughout the cardiac cycle, but with increasing vascular resistance, the diastolic flow declines. A variety of indexes can be automatically calculated from the umbilical

artery waveform, including the systolic diastolic ratio, pulsatility index (PI), and resistance index [2]. Elevated indexes signify increased vascular resistance, and obliteration of 50%–70% of the terminal placental villi results in absent or reversed end-diastolic flow, implying that fetal well-being is at risk [1,4]. Therefore, fetuses with IUGR or monochorionic twin gestations complicated by unequal placental sharing with discordant twin growth or twin-twin transfusion syndrome should be followed with serial umbilical artery Dopplers. Redistribution of fetal blood to vital organs in IUGR represents a compensatory mechanism to prevent fetal damage from hypoxemia. Interrogation of the middle cerebral artery may be useful to assess the brain-sparing reflex, detected by increased end-diastolic flow and reflected by a decreased PI [1,3,4]. Normalization of cerebral Doppler indexes in growth-restricted fetuses is observed as this autoregulation becomes dysfunctional. IUGR fetuses with cerebral redistribution may be at increased risk for neurodevelopmental abnormalities [16].

The cerebroplacental ratio (CPR), calculated by dividing the Doppler indexes of the middle cerebral artery by the umbilical artery, has also been evaluated as a measure of placental insufficiency in both IUGR and normally grown fetuses near term [17]. Although a low CPR may prove to be an independent predictor of adverse perinatal outcome related to placental insufficiency, the published studies are contradictory [18,19]. Further prospective investigation of the effectiveness of CPR as a surveillance tool of fetal well-being is warranted before adopting it into routine clinical practice [19,20].

Abnormal venous waveforms, such as an absent or reversed A wave in the ductus venosus, become evident with decompensation of cardiovascular function. Color flow mapping can be used to locate the high-velocity flow in the ductus venosus on axial or sagittal views of the fetal abdomen for subsequent assessment with pulse Doppler. Blood flow in the umbilical vein, interrogated by pulse Doppler alongside the umbilical artery, is uniform and forward throughout systole and diastole in a healthy fetus. Umbilical venous pulsations reflect increased central venous pressure and in the absence of fetal breathing movements are indicative of a deterioration of fetal acid-base status [1,3]. In general, Doppler velocimetry is not a routine test of fetal well-being but may be useful in cases of IUGR or conditions associated with cardiovascular compromise [4,8].

Fetal Echocardiography

The terminal phase of fetal disease often impacts the fetal heart, and serial surveillance of cardiac function may identify pregnancies at an early stage during which interventions such as medical therapy, in utero procedures, or delivery may improve survival. Fetal echocardiography to evaluate cardiac performance is useful in cases of congenital heart disease, sustained fetal dysrhythmias, or conditions with the potential for hemodynamic compromise and the development of hydrops [21]. This includes extracardiac malformations such as congenital diaphragmatic hernia and fetal lung masses, IUGR, and high-cardiac-output states associated with fetal anemia, sacrococcygeal teratoma, vein of Galen aneurysm, placental chorioangioma, absent ductus venosus, twin-twin transfusion syndrome, and twin-reversed arterial perfusion sequence [22,23]. Fetal echocardiography is now considered an important modality for the antenatal assessment of fetal well-being in cases at risk for in utero hemodynamic deterioration [24].

Individual markers of hemodynamic compromise include increased fetal heart size, valvular regurgitation, abnormal Doppler waveforms, and decreased ventricular wall shortening [21,23]. The cardiothoracic ratio, calculated by the area or circumference occupied by the heart in diastole to thoracic area or circumference, is used to assess relative fetal heart size. Throughout gestation, a normal cardiothoracic ratio using area is 0.25–0.35 and <0.5 using circumference [25]. Ventricular dimensions, wall thickness, atrioventricular valve annuli measured in end diastole, and semilunar valve annuli measured in systole can be compared with gestational age normal values and expressed as Z scores [26,27]. Atrioventricular or semilunar valvular regurgitation can be detected by color or pulsed Doppler. Diastolic function can be assessed by atrioventricular inflow and ductus venous Doppler patterns, with dysfunction identified by a monophasic rather than a biphasic inflow waveform and the presence of an absent or reversed A wave, respectively. Abnormal retrograde flow in the aortic isthmus tends to occur prior to abnormal flow in the ductus venosus and therefore may help identify at-risk fetuses earlier [28]. Persistent umbilical vein pulsations, related to atrial contractions, are observed in end-stage cardiac failure recognized by decreased ventricular wall fractional shortening by M-mode echocardiography (normal >28%) and decreased ventricular systolic output [21,23].

Whereas individual echocardiographic parameters may identify fetuses at risk for adverse outcomes, the cardiovascular profile score (CVPS) provides a semiquantitative assessment of fetal cardiac well-being. This 5-category score incorporates heart size, myocardial function, arterial and venous Doppler assessments, and the presence or absence of hydrops [21]. A healthy, unaffected fetus would have a composite score of 10, and a score

of 0 indicates clear cardiovascular compromise [21]. Abnormalities in the score may occur prior to the clinical diagnosis of hydrops fetalis and therefore may be useful for clinical management. In utero cardiac function can also be estimated using the Tei index, also known as the myocardial performance index (MPI) [29-31]. Using pulsed Doppler to demonstrate ventricular inflow and outflow, the MPI of each ventricle is calculated from the (isovolumetric contraction time + isovolumetric relaxation time)/ejection time and reflects overall systolic and diastolic ventricular function. The MPI is gestational age independent and in healthy fetuses is about 0.35 for both the right ventricle and left ventricle [29-31]. The greater the MPI, the greater the global ventricular dysfunction, which may reflect hypervolemia, increased cardiac afterload, myocardial hypertrophy, or diastolic dysfunction from compression [29-31].

Serial fetal echocardiography may also be useful in monitoring patients with systemic lupus erythematosus or Sjogren syndrome whose fetuses are at risk for congenital heart block. Using pulsed Doppler to demonstrate ventricular inflow and outflow, the mechanical PR interval can be measured [32]. This represents the time between atrial and ventricular contraction and normally is 120 ± 10 msec [32]. Lengthening of the mechanical PR interval, representing first-degree heart block, may identify cases that are more likely to progress to complete heart block and warrant intervention [33]. Although serial fetal echocardiography is not yet a routine test for fetal well-being, it potentially has a role to play in select cases.

Discussion of Imaging Modalities by Variant

Variant 1: Low-risk pregnancy

Despite that many fetal deaths occur in women without identifiable risk factors, there is no convincing evidence that routine antenatal testing in low-risk pregnancies improves perinatal outcome [1]. This is true for all imaging modalities, including the BPP, mBPP, Doppler velocimetry, and functional fetal echocardiography. Although there is a paucity of data on the use of the BPP, mBPP, and cardiovascular function testing in low-risk patients, a review of 5 trials involving 14,185 women concluded the use of umbilical artery Doppler US in low-risk or unselected populations had no maternal or perinatal benefits [34]. Furthermore, false-positive results related to antepartum fetal testing in low-risk pregnancies may lead to unnecessary interventions that may increase the risk of cesarean delivery or complications related to premature delivery [35]. Consequently, routine antenatal fetal surveillance by any imaging modality is **not** recommended in pregnancies at low risk for intrauterine fetal demise [2,36].

Variant 2: Pregnancy at risk for adverse fetal outcome

In contrast to low-risk pregnancies, antepartum surveillance is recommended to assess fetal well-being in high-risk pregnancies [1-3]. Although there is limited evidence from randomized controlled trials for each maternal, fetal, or obstetric condition associated with stillbirth, some data exist on the use of antenatal testing in high-risk women [1-3].

Biophysical Profile

Early studies have shown that a normal BPP is a strong predictor of fetal well-being in high-risk pregnancies. Of 44,828 BPPs, the likelihood of a stillbirth occurring within 1 week of a normal test result was only 0.8/1000, with a negative predictive value of >99.9% [37]. After an extensive review of the literature, the ACR concluded that the BPP is indicated in the evaluation of fetal well-being in cases of IUGR [8]. This may be true for other factors associated with increased risk for stillbirth, such as advanced maternal age, but the data are less robust. A recent retrospective study comparing 1541 women ≥35 years of age to 2928 women <35 years of age found the incidence of fetal death was similar between the groups when weekly BPPs were performed, suggesting BPP may be beneficial in older women [38]. Additional studies are needed to evaluate the role of BPP for other specific indications.

Modified Biophysical Profile

The mBPP has been less extensively studied as a surveillance tool for fetal well-being. A review of 5 randomized and quasi-randomized controlled trials involving 2974 high-risk patients found no significant difference in perinatal deaths when comparing BPP to mBPP (NST + AFI) [39]. The likelihood of a stillbirth within a week of a normal mBPP is extremely low, similar to that of a normal BPP at <1 in 1000 [35,37]. Although the NST, mBPP, and BPP perform comparatively, the mBPP and BPP permit a more thorough evaluation of fetal well-being than NST alone by providing the opportunity to assess fetal anatomy and amniotic fluid volume [26,28,30]. Therefore, as a single test for fetal surveillance, one that includes US imaging may be preferred.

An assessment of amniotic fluid volume is an essential component of both the mBPP (as AFI) and BPP (as MVP). Although normal amniotic fluid is reassuring, adverse perinatal outcomes have been associated with both oligohydramnios and polyhydramnios. Oligohydramnios has been defined as a MVP <2 cm or AFI <5 cm; however, the optimal cutoff to guide clinical decision making is uncertain [2]. Contemporary studies suggest that the maximal vertical pocket of amniotic fluid may perform better than the AFI [12,40,41]. Although neither performs above the other at preventing intrauterine fetal demise, more patients are diagnosed with oligohydramnios with the AFI, resulting in more obstetric interventions [12,42]. Although intrapartum fetal heart rate tracing abnormalities, operative vaginal deliveries, and cesarean births are higher with low fluid, a meta-analysis that included 679 cases with isolated oligohydramnios at term compared to 3264 cases with normal amniotic fluid found that there were no differences in the presence of meconium, Apgar scores, pH, small for gestational age, neonatal intensive care unit admission, or perinatal deaths [43]. In contrast, a large retrospective study of 228,239 singleton births with 1694 fetal deaths observed oligohydramnios to be an independent risk factor for stillbirth (odds ratio [OR], 2.6; 95% confidence interval [CI], 2.1–3.2; P<0.001) [44]. This is comparable with previous studies that report a stillbirth rate of 1%–2%, supporting the current practice of antenatal testing in patients with low fluid [1,45].

Adverse fetal outcomes have also been reported in pregnancies complicated by polyhydramnios. Polyhydramnios has been defined as a MVP >8 cm or an AFI >25 cm or >95th percentile for gestational age [1-3]. A comparison of 4001 patients with normal amniotic fluid to 210 with polyhydramnios found that polyhydramnios was an independent risk factor for perinatal mortality (OR, 5.8; 95% CI, 3.68–9.11) [46]. This is similar to the adjusted OR of 5.5 (95% CI, 4.1–7.6) for fetal demise in nonanomalous singleton pregnancies with polyhydramnios recently reported from a large cohort in California [47]. This association also held true in a large retrospective study of over 200,000 singleton births in which logistic regression confirmed polyhydramnios is independently associated with stillbirth (OR, 1.8; 95% CI, 1.4–2.2; P<0.001) [44]. As with isolated oligohydramnios, isolated polyhydramnios has been reported to have a lower perinatal mortality than cases with additional fetal abnormalities [48]. Though there are reasons to specifically screen for amniotic fluid abnormalities, such as diabetes, IUGR, and postdates, this is usually done as a component of routine antenatal testing using the BPP/mBPP.

Doppler

As an individual test of fetal well-being, Doppler velocimetry has been most widely studied in the setting of IUGR. In fact, umbilical artery Doppler findings can be used to predict perinatal outcomes in IUGR [49]. In normal fetuses, there is high-velocity diastolic flow in the umbilical artery that tends to decrease with increased placental resistance. In growth-restricted fetuses, normal umbilical artery Doppler indexes reduce the likelihood of metabolic acidemia and perinatal death [50,51]. In a recent Cochrane review of 18 studies of >10,000 high-risk pregnancies, the use of Doppler US was associated with a reduction of perinatal death (risk ratio [RR], 0.71; 95% CI, 0.52–0.98) [52]. There were also fewer inductions of labor and cesarean deliveries [52]. Based on the potential for benefit, it is recommended that antenatal testing for well-being in IUGR begin at the time of diagnosis but not before fetal viability [4]. However, there is limited evidence from randomized controlled trials to recommend best practice for fetal surveillance in cases of IUGR with normal umbilical artery Doppler US [53,54]. One trial of 167 women comparing twice-weekly versus fortnightly umbilical artery Dopplers found no difference in perinatal outcomes, but it was underpowered to assess fetal and neonatal death [54]. Nevertheless, there were more inductions of labor in women undergoing more frequent testing (RR, 1.25; 95% CI, 1.04–1.5) [54]. Although it may prove to be useful in pregnancies complicated by hypertension or in multiple gestations with monochorionic placentation, no survival benefit has been demonstrated for umbilical artery Doppler for conditions other than IUGR [55,56]. A recent retrospective cohort study found that isolated Doppler abnormalities were common in uncomplicated monochorionic diamniotic twins prior to 28 weeks' gestation, and these abnormalities may not be predictive of adverse outcomes [57]. Currently, routine Doppler studies of other vessels in cases of IUGR are not recommended, particularly if the umbilical artery evaluation is normal [4].

Fetal Echocardiography

Fetal echocardiography for antenatal fetal surveillance is only warranted in select cases of congenital heart disease, fetal arrhythmias, and conditions that may lead to hemodynamic compromise or hydrops. Fetuses with congenital heart disease and a CVPS of ≤7 have been shown to be at risk for perinatal death [58]. Validation studies have also shown that the CVPS is useful in predicting outcome in IUGR fetuses [59]. Serial assessments of the mechanical PR interval can be used to screen patients with anti-SSA/Ro and anti-SSB/La antibodies for congenital heart block. Currently, a prolonged mechanical PR interval in the second trimester is an indication for

medical therapy in an effort to halt progression to complete heart block. However, in a study of 98 at-risk pregnancies, prolongation of the mechanical PR interval was uncommon and advanced block was observed to occur within a week of a normal fetal echocardiogram [60]. Functional echocardiography may also be useful in optimizing the timing of in utero therapy or delivery in cases of IUGR, twin-twin transfusion syndrome, congenital infections, or maternal diabetes [61]. Overall, most fetal echocardiographic studies are small and underpowered to detect a significant reduction in stillbirth. As a result, fetal echocardiography to assess cardiovascular adaptations and fetal well-being in various conditions remains investigational.

Variant 3: Preterm pregnancy. Abnormal antenatal testing

Biophysical Profile/Modified Biophysical Profile

Prior to term, the risks of prematurity must be weighed against the risks of intrauterine fetal demise in the setting of abnormal antenatal testing such as a BPP of ≤6 or an mBPP with a nonreactive NST with or without amniotic fluid abnormalities. In preterm pregnancies with oligohydramnios or polyhydramnios, serial surveillance is warranted after a thorough evaluation for possible causes. Repeat testing or use of an alternate antepartum test for reassurance is usually indicated in preterm pregnancies rather than immediate delivery in an effort to decrease iatrogenic prematurity and its complications. Unfortunately, both the BPP and mBPP are more specific than sensitive, performing well at identifying the healthy fetus but poorly at recognizing the fetus at risk for stillbirth [1-3]. Subsequent surveillance may vary depending on the indication for testing and ongoing results but often is scheduled weekly or twice weekly until delivery [4].

Doppler

Antenatal fetal testing with Doppler velocimetry has been most extensively studied in cases of IUGR secondary to uteroplacental insufficiency. Adaptive changes in the fetal circulation due to a compromised intrauterine environment tend to follow a characteristic sequence, from abnormal arterial waveforms, to abnormal venous waveforms, and finally to abnormal biophysical testing (BPP or mBPP) [62]. Although abnormal blood flow in the umbilical artery is often the earliest sign of fetal compromise, a study of 328 IUGR fetuses demonstrated that Doppler and BPP results do not always show a consistent relationship with each other [63]. A retrospective study of 151 singleton pregnancies with IUGR comparing the efficiency of NST, BPP, and Dopplers reported that absent or reversed diastolic flow in the umbilical artery was most predictive of adverse perinatal outcomes [49]. Given that absent or reversed end-diastolic flow is associated with fetal hypoxemia, experts support the use of umbilical artery Dopplers in the management of pregnancies with suspected IUGR [2,4]. Perinatal death has been observed to occur in >20% of pregnancies with absent or reversed end-diastolic flow in the umbilical artery [64,65]. Middle cerebral artery Doppler can detect brain sparing in IUGR, which has been associated with neurobehavioral impairment in survivors [66]. Although ductus venosus flow is very resistant to alterations, absent or reversed A waves in IUGR, as well as in cases of structural or functional cardiac disease, reflect diastolic dysfunction and potential for compromise. In a study of 177 patients, absent or reversed A wave in the ductus venosus for >7 days predicted stillbirth with 100% sensitivity and 80% specificity [67]. Retrograde flow in the aortic isthmus in fetuses with growth restriction has also been found to correlate with adverse perinatal outcome [68]. Pulsatile flow in the umbilical vein, signifying myocardial dysfunction against increased afterload, is also associated with fetal acidemia and perinatal mortality in IUGR [69]. In a study of 74 preterm pregnancies with both pulsatile flow in the umbilical vein and absent or reversed A wave flow in the ductus venosus, there were 16.2% perinatal deaths, of which 10.8% were stillbirths [70]. These late vascular adaptations are strong predictors of perinatal death [4,62,71]. However, a recent multicenter study of over 1100 fetuses with suspected IUGR observed multiple different patterns of Doppler deterioration prior to birth [72]. Despite a lack of endorsement for routine Doppler of multiple vessels in IUGR, the results of these studies may be useful to guide the timing of delivery in preterm pregnancies complicated by IUGR.

There are limited trials to address the optimal frequency of Doppler testing in preterm IUGR. Weekly Doppler studies may be adequate if diastolic flow is present in the umbilical artery but should be increased to 2 to 3 times per week testing if diastolic flow is absent or reversed or if associated oligohydramnios is present prior to term [4]. Given that the interval between the development of abnormal arterial and venous Doppler velocimetry is estimated to be 2 weeks and between abnormal venous Dopplers and abnormal biophysical parameters is about 7 days, expanded and more frequent testing should be considered once abnormal umbilical artery Doppler indexes are detected if delivery is not an option [62]. This should include NST or mBPP as abnormal fetal heart rate patterns may precede abnormal venous Dopplers in about 50% of cases [71,73]. In IUGR with reassuring biophysical testing but abnormal umbilical artery Dopplers, expectant management is recommended until 34 weeks with absent umbilical artery diastolic flow and 32 weeks with reversed diastolic flow [4].

Fetal Echocardiography

Although fetal echocardiography is used to evaluate cardiovascular health in cases of congenital heart disease, fetal dysrhythmias, and conditions that may lead to hydrops, it is uncommon to continue pregnancies once significant hemodynamic compromise has been detected unless delivery is not a consideration due to periviable gestational age, decision for comfort care, or options for in utero therapy. For example, follow-up fetal echocardiography is warranted to monitor fetal response to antiarrhythmic agents administered for sustained tachyarrhythmia or to steroids prescribed after prolongation of the mechanical PR interval is detected in preterm pregnancies [21,26,60]. As previously mentioned, most fetal echocardiographic studies are not powered to detect a significant reduction in stillbirth and thus, apart from its use in selected cases, serial fetal echocardiography has not been endorsed as a standard surveillance test of fetal well-being.

Depending on maternal, fetal, and obstetric factors, repeat antenatal testing or alternate testing such as continuous electronic fetal heart rate monitoring may be warranted at early gestational ages to prevent needless preterm birth. Unfortunately, no antenatal fetal surveillance regimen, regardless of the tests utilized and the frequency of testing, has been shown to be clearly superior in preventing preterm stillbirth.

Variant 4: Term pregnancy. Abnormal antenatal testing

In term pregnancies, abnormal antenatal testing is usually an indication for delivery. This would include a BPP of ≤6, an mBPP with a nonreactive NST, abnormal umbilical artery Dopplers, or evidence of cardiovascular compromise [2,3]. Delivery is also indicated in term and post-term pregnancies when oligohydramnios or polyhydramnios is found during BPP or mBPP testing [2,3]. However, a prospective double-blind cohort study of 1584 pregnant women at ≥40 weeks' gestation found amniotic fluid assessment had a poor sensitivity for adverse perinatal outcome [74]. In most cases of abnormal antenatal testing, induction of labor is still a reasonable option if there are no other contraindications, but cesarean delivery may be warranted due to concerns about fetal well-being and intolerance of labor [2]. Infrequently, in cases that warrant a timed delivery for immediate, specialized treatment of the neonate, antenatal testing can be repeated and delivery delayed until the appropriate staff and equipment can be assembled. Admission to a hospital with continuous electronic fetal monitoring should be considered for patient safety in these rare cases. Although false-positive results do occur, delivery for abnormal antenatal testing is warranted in term pregnancies.

Summary of Recommendations

- There is limited evidence from randomized controlled trials that antepartum fetal testing decreases the risk of fetal death.
- Antenatal fetal testing is not recommended in low-risk pregnancies.
- Women with high risk factors for stillbirth should undergo antenatal fetal surveillance.
- No single antenatal test has been shown to be superior; all have high negative predictive values.
- Umbilical artery Doppler velocimetry is indicated in IUGR secondary to uteroplacental insufficiency.
- Timing for initiation of testing should be tailored based on the risk of stillbirth and likelihood of survival with intervention.
- Optimal interval of testing is unknown; weekly or twice-weekly testing has become the standard practice in high-risk pregnancies.
- Routine antenatal testing cannot predict stillbirth related to acute changes in maternal-fetal status such as those associated with abruption or cord accident.
- Response to abnormal testing must be individualized based on a number of clinical factors such as gestational age.

Summary of Evidence

Of the 74 references cited in the *ACR Appropriateness Criteria® Assessment of Fetal Well-Being* document, all of them are categorized as diagnostic references including 2 well designed studies, 2 good quality studies, and 24 quality studies that may have design limitations. There are 40 references that may not be useful as primary evidence. There are 6 references that are meta-analysis studies.

The 74 references cited in the *ACR Appropriateness Criteria® Assessment of Fetal Well-Being* document were published from 1984-2015.

While there are references that report on studies with design limitations, 4 well designed or good quality studies provide good evidence.

Relative Radiation Level Information

Potential adverse health effects associated with radiation exposure are an important factor to consider when selecting the appropriate imaging procedure. Because there is a wide range of radiation exposures associated with different diagnostic procedures, a relative radiation level (RRL) indication has been included for each imaging examination. The RRLs are based on effective dose, which is a radiation dose quantity that is used to estimate population total radiation risk associated with an imaging procedure. Patients in the pediatric age group are at inherently higher risk from exposure, both because of organ sensitivity and longer life expectancy (relevant to the long latency that appears to accompany radiation exposure). For these reasons, the RRL dose estimate ranges for pediatric examinations are lower as compared to those specified for adults (see Table below). Additional information regarding radiation dose assessment for imaging examinations can be found in the ACR Appropriateness Criteria® Radiation Dose Assessment Introduction document.

Relative Radiation Level Designations		
Relative Radiation Level*	**Adult Effective Dose Estimate Range**	**Pediatric Effective Dose Estimate Range**
O	0 mSv	0 mSv
☢	<0.1 mSv	<0.03 mSv
☢☢	0.1-1 mSv	0.03-0.3 mSv
☢☢☢	1-10 mSv	0.3-3 mSv
☢☢☢☢	10-30 mSv	3-10 mSv
☢☢☢☢☢	30-100 mSv	10-30 mSv
*RRL assignments for some of the examinations cannot be made, because the actual patient doses in these procedures vary as a function of a number of factors (eg, region of the body exposed to ionizing radiation, the imaging guidance that is used). The RRLs for these examinations are designated as "Varies".		

Supporting Documents

For additional information on the Appropriateness Criteria methodology and other supporting documents go to www.acr.org/ac.

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