

OB Biometry, Doppler & Dating Study Guide

An In-Depth Review by [Dr. Alice Matthews](#)

amatthews@concorde.edu

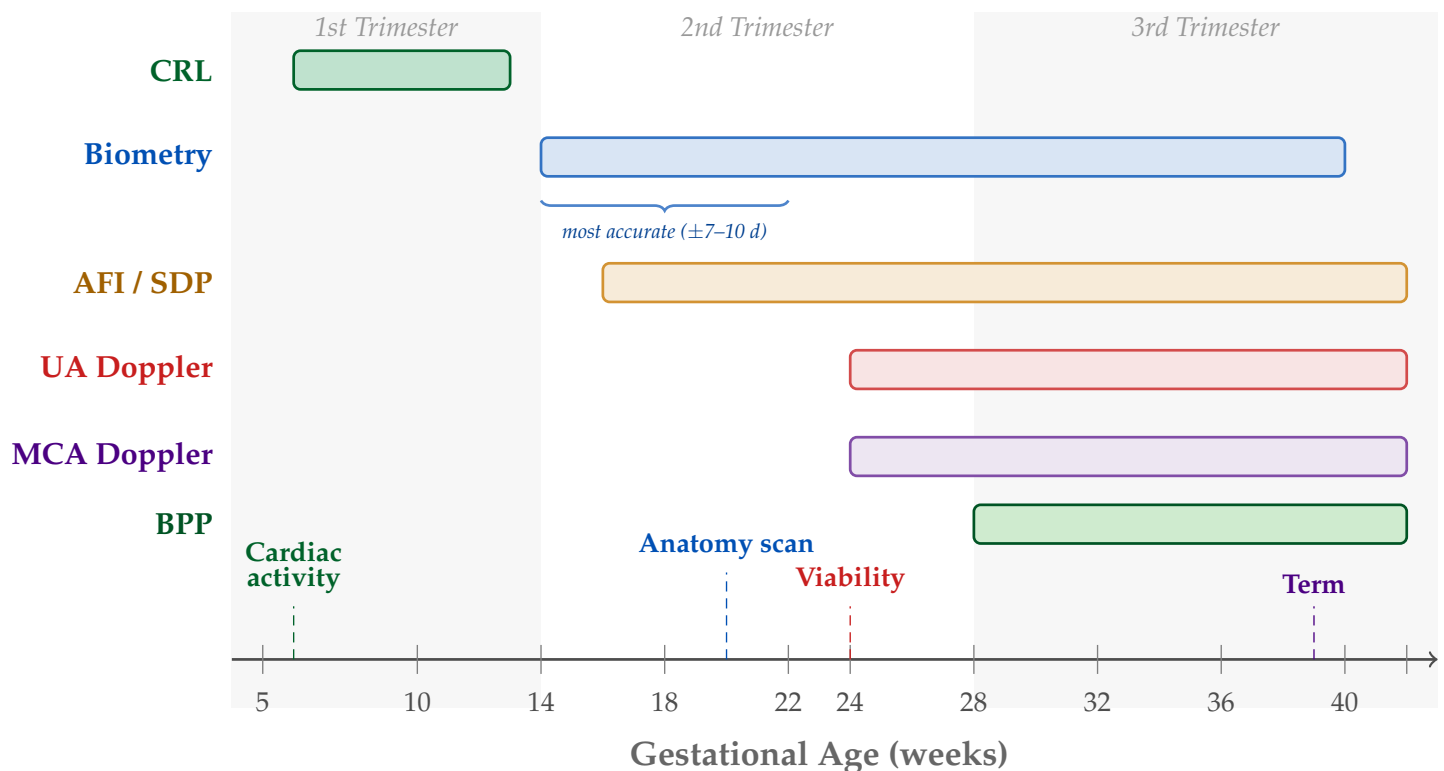
Based on ACOG, AIUM, SMFM Guidelines and Current OB Sonography Practice

PART 1: THE FOUNDATION

The Pregnancy Timeline: The One Diagram That Connects Everything

Every measurement in this guide belongs to a specific window on the pregnancy timeline. When you measure a CRL, you are in the first trimester where dating is most accurate. When you assess umbilical artery Doppler, you are evaluating placental resistance in the third trimester. When a question asks “which measurement is most accurate at 30 weeks,” the answer is visible here: you are past the CRL window, and your biometry measurements now carry a margin of error of two to three weeks.

Study this timeline until you can draw it from memory. If you can point to any gestational age and name which measurements are appropriate, which Doppler assessments are available, and what accuracy to expect, you understand the foundation of OB sonography.



{Key landmarks to memorize: (1) CRL is the gold standard for dating before 14 weeks ($\pm 3-5$ days). (2) Biometry is most accurate between 14 and 22 weeks ($\pm 7-10$ days). (3) The anatomy scan at 18–22 weeks is the single most important ultrasound of the pregnancy. (4) Viability begins at approximately 24 weeks. (5) Doppler assessment (UA, MCA) is meaningful from 24 weeks onward. (6) Dating accuracy degrades as pregnancy advances: first trimester ± 5 days, second ± 14 days, third ± 21 days.}

PART 2: DATING & BIOMETRY FORMULAS

Mean Sac Diameter (MSD)

$$GA \text{ (days)} = MSD \text{ (mm)} + 30$$

What this means: Add 30 to the mean sac diameter in millimeters to estimate gestational age in days. The MSD is the average of three perpendicular measurements of the gestational sac (length + width + height divided by 3).

Analogy: This is like measuring a balloon before you can see what is inside. Early in pregnancy, the sac grows about 1 mm per day, so its size alone can tell you the age.

An empty gestational sac is the first sonographic evidence of pregnancy, visible at approximately 4.5 to 5 weeks.

Clinical application: An MSD of 25 mm or greater with no visible embryo is diagnostic of an anembryonic pregnancy (previously called a blighted ovum). This is one of the ACOG criteria for pregnancy failure. Do not rely on a single scan if the MSD is below 25 mm; rescan in 7 to 14 days.

Crown-Rump Length (CRL)

$$GA \text{ (weeks)} \approx CRL \text{ (cm)} + 6.5$$

What this means: The CRL in centimeters plus 6.5 gives an approximate gestational age in weeks. This quick rule works from 6 to 13 weeks. Formal dating uses Robinson or Hadlock CRL tables, but this formula gets you in the right range at the bedside.

Analogy: Think of measuring a curled-up shrimp from head to tail. Early in development, all embryos are nearly the same size at the same age, just as all seedlings planted on the same day are the same height. Individual genetic variation has not yet caused size differences, which is why CRL dating is so accurate.

CRL is measured from the top of the head (crown) to the bottom of the rump, excluding the yolk sac and limbs.

Clinical application: CRL is the single most accurate dating parameter in all of obstetric ultrasound, with an accuracy of ± 3 to 5 days. If the CRL dates differ from LMP dates by more than 7 days, the ultrasound date should replace the LMP date (ACOG guideline). A CRL of 7 mm or greater with no cardiac activity is diagnostic of embryonic demise.

Biparietal Diameter (BPD)

$$BPD = \text{outer edge of near calvarial wall to inner edge of far calvarial wall}$$

What this means: The BPD is measured on a transverse (axial) view of the fetal head at the level of the thalami and cavum septum pellucidum. It is measured from the leading edge (outer) of the near skull table to the leading edge (inner) of the far skull table.

Analogy: Picture placing calipers across the widest part of an egg at its equator. The BPD captures the side-to-side diameter of the fetal skull in a standardized plane.

The cephalic index (CI) should be checked: $CI = (BPD / OFD) \times 100$. Normal range is 70 to 86. Values outside this range indicate dolichocephaly (elongated) or brachycephaly (round), which make BPD unreliable for dating.

Clinical application: BPD is widely used for dating in the second and third trimesters, but it is unreliable when the head shape is abnormal (abnormal cephalic index). In such cases, use the head circumference instead. BPD can also help assess conditions like hydrocephalus (enlarged) or microcephaly (small).

Head Circumference (HC)

$$HC = \pi \times \frac{(BPD + OFD)}{2}$$

What this means: The head circumference equals pi times the average of the biparietal diameter and the occipitofrontal diameter, both measured at the same level (thalami and cavum septum pellucidum). Most modern machines calculate HC directly from an ellipse traced around the outer skull.

Analogy: Think of wrapping a string around a basketball. Even if you squeeze the basketball into an oval, the total length of string (circumference) stays nearly the same. This is why HC works even when the head is an unusual shape.

Clinical application: HC is more robust than BPD for dating when the head shape is dolichocephalic or brachycephalic. It is also used to calculate the HC/AC ratio, which helps distinguish symmetric from asymmetric growth restriction. A normal HC/AC ratio is approximately 1.0 at 32 to 34 weeks, then gradually falls below 1.0 as the abdomen grows relatively faster.

Abdominal Circumference (AC)

$$AC = \pi \times \frac{(APD + TD)}{2}$$

Where APD = anteroposterior diameter and TD = transverse diameter of the fetal abdomen.

What this means: The AC is measured on a transverse view of the fetal abdomen at the level of the stomach bubble and the junction of the umbilical vein with the portal sinus (J-shape). The measurement should be circular, not oblique. APD and TD are used to calculate the circumference, or the machine traces an ellipse directly.

Analogy: You are measuring the fetal waistline. Just as an adult's waist size reflects nutritional status (well-fed vs. malnourished), the fetal AC reflects whether the baby is receiving adequate nutrition through the placenta.

Clinical application: The AC is the most sensitive single biometric measurement for detecting intrauterine growth restriction (IUGR). A lagging AC indicates the fetus is redistributing blood flow away from the liver and gut (asymmetric growth restriction). The AC is also the most variable measurement, so it is the least accurate for dating. It is the dominant parameter in the Hadlock EFW formula.

Femur Length (FL)

$$FL = \text{diaphysis only (exclude epiphyses)}$$

What this means: The femur length is measured from one end of the ossified diaphysis (shaft) to the other, excluding the cartilaginous epiphyses. The beam should be perpendicular to the long axis of the femur, and the bone should occupy at least 50% of the image width.

Analogy: A leg bone on an X-ray. Long bones maintain their growth trajectory even when the body is rationing nutrition to the brain and heart. This makes FL relatively resistant to growth restriction.

Clinical application: A femur length that is significantly shorter than expected for gestational age (below the 5th percentile) is a soft marker for trisomy 21 (Down syndrome), particularly when the FL/BPD ratio is less than 0.71. Short FL can also indicate skeletal dysplasia, constitutional short stature, or simply inaccurate dating. Always correlate with other findings.

Estimated Fetal Weight (EFW)

$$\log_{10}(EFW) = 1.3596 + 0.0064(HC) + 0.0424(AC) + 0.174(FL) + 0.00061(BPD)(AC) - 0.00386(AC)(FL)$$

{Hadlock four-parameter formula, 1985. EFW in grams, all measurements in cm.}

Simplified two-parameter version (AC + FL only):

$$\log_{10}(EFW) = 1.304 + 0.05281(AC) + 0.1938(FL) - 0.004(AC)(FL)$$

{Hadlock AC-FL formula, 1985. Most commonly used when BPD or HC is unreliable.}

What this means: The Hadlock formulas estimate fetal weight from biometric measurements. The four-parameter version is the most accurate ($\pm 15\%$), but the simplified AC + FL version is widely used and easier to remember. In both, the AC is the most influential variable.

Analogy: Estimating the weight of a watermelon at the grocery store. You look at overall size (HC, AC), length (FL), and shape (BPD). You can get close, but you will not know the exact weight until you put it on the scale. That 15% margin is real.

Clinical application: EFW below the 10th percentile for gestational age defines small for gestational age (SGA). EFW below the 3rd percentile, or below the 10th percentile with abnormal Dopplers, defines fetal growth restriction (FGR). EFW above the 90th percentile defines large for gestational age (LGA). Macrosomia is typically defined as EFW greater than 4,000 g (some use 4,500 g).

Dating Accuracy by Trimester

Trimester	Weeks	Best Parameter	Accuracy
First	< 14	CRL	$\pm 3-5$ days
Early second	14-22	BPD, HC, FL, AC composite	$\pm 7-10$ days
Late second	22-28	BPD, HC, FL, AC composite	± 14 days
Third	> 28	BPD, HC, FL, AC composite	± 21 days

{Rule: Once an accurate early ultrasound date is established, never change the due date based on a later ultrasound. First trimester CRL dating supersedes all other methods (ACOG).}

Fetal Size Classification

Category	Percentile	Threshold	Significance
FGR (severe)	< 3rd	—	Highest risk; add Doppler surveillance
SGA	< 10th	EFW < 10th %ile	May be constitutionally small or growth restricted
AGA (normal)	10th-90th	—	Normal growth
LGA	> 90th	EFW > 90th %ile	Screen for gestational diabetes
Macrosomia	—	EFW > 4,000 g	Shoulder dystocia risk; consider delivery planning

PART 3: AMNIOTIC FLUID ASSESSMENT

Amniotic Fluid Index (AFI)

$$AFI = Q_1 + Q_2 + Q_3 + Q_4$$

Where Q_1 through Q_4 are the deepest vertical pockets (in cm) in each of the four uterine quadrants (upper right, upper left, lower right, lower left), measured with the transducer perpendicular to the floor and free of fetal parts or umbilical cord.

What this means: Divide the uterus into four quadrants using the linea nigra (vertical) and the umbilicus (horizontal). In each quadrant, find the deepest vertical pocket of clear amniotic fluid and measure it. Add all four measurements together.

Analogy: Imagine measuring the deepest spots in the four quadrants of a swimming pool. If the total is high, the pool is overfilled. If the total is low, the pool is draining and the swimmer (fetus) has less room.

Clinical application: AFI is the standard quantitative method for fluid assessment after approximately 16 weeks.

Single Deepest Pocket (SDP)

$$SDP = \text{deepest vertical pocket in any quadrant (cm)}$$

What this means: Measure the single deepest vertical pocket of amniotic fluid anywhere in the uterus. The pocket must be free of cord and fetal parts, and the transducer must be perpendicular to the floor.

Analogy: Instead of checking every room in a house, you just check the wettest room. If even the wettest room is dry, the whole house has a problem.

Clinical application: SDP is used in the BPP (biophysical profile) and is the preferred method in multiple gestations (measure each sac individually). Some evidence suggests SDP leads to fewer unnecessary interventions than AFI.

Amniotic Fluid Thresholds

Condition	AFI (cm)	SDP (cm)	Clinical Significance
Oligohydramnios	< 5	< 2	Renal agenesis, PPROM, IUGR, post-dates
Low normal	5–8	2–3	Borderline; increase surveillance
Normal	8–24	3–8	Adequate fluid
Mild polyhydramnios	25–30	8–12	Screen for GDM, fetal anomalies
Severe polyhydramnios	> 30	> 12	GI obstruction, hydrops, preterm labor risk

Common Causes of Abnormal Fluid

System	Oligohydramnios (too little)	Polyhydramnios (too much)
Renal	Renal agenesis, bilateral obstruction, Potter sequence	—
GI	—	Esophageal atresia, duodenal atresia (double bubble)
Placental	Placental insufficiency, IUGR	Twin-to-twin transfusion (recipient)
Maternal	PPROM, post-dates, medications (ACE inhibitors)	Gestational diabetes, Rh isoimmunization
Fetal	Chromosomal anomalies	Anencephaly (no swallowing), hydrops fetalis

{Memory aid: Oligohydramnios = the fetus cannot *make* urine (renal problems) or fluid is *leaking out* (PPROM). Polyhydramnios = the fetus cannot *swallow* (GI obstruction) or there is *too much production* (high glucose crosses the placenta and acts as an osmotic diuretic).}

PART 4: OB DOPPLER ASSESSMENT

Doppler in OB ultrasound assesses vascular resistance, not stenosis. Unlike adult echocardiography where you measure how fast blood squeezes through a narrowed valve, OB Doppler measures how much resistance the downstream vascular bed is applying. High placental resistance means the fetus is not getting adequate blood flow. Low cerebral resistance means the fetal brain is demanding more blood. The combination of these two signals forms the basis of fetal surveillance.

Doppler Resistance Indices

$$RI = \frac{S - D}{S}$$

$$PI = \frac{S - D}{\text{Mean}}$$

$$S/D \text{ Ratio} = \frac{S}{D}$$

Where S = peak systolic velocity, D = end-diastolic velocity, and Mean = time-averaged mean velocity across the cardiac cycle.

What this means: All three indices measure the same thing: how much resistance the downstream vascular bed is applying. Higher values = more resistance = less diastolic flow. As resistance drops, diastolic flow increases and all three indices decrease.

Analogy: Squeezing a tube of toothpaste. If the cap is on tight (high resistance), the toothpaste barely flows. If the cap is off (low resistance), it flows freely. The ratio of how hard you squeeze to how much flows out tells you how tight the cap is.

Clinical application: RI ranges from 0 to 1 (0 = no resistance, 1 = no diastolic flow). PI can exceed 1 because it uses the mean in the denominator. S/D ratio becomes undefined when diastolic flow reaches zero. In practice, PI is the most commonly used index in OB because it remains valid even with absent or reversed diastolic flow.

Umbilical Artery (UA) Doppler

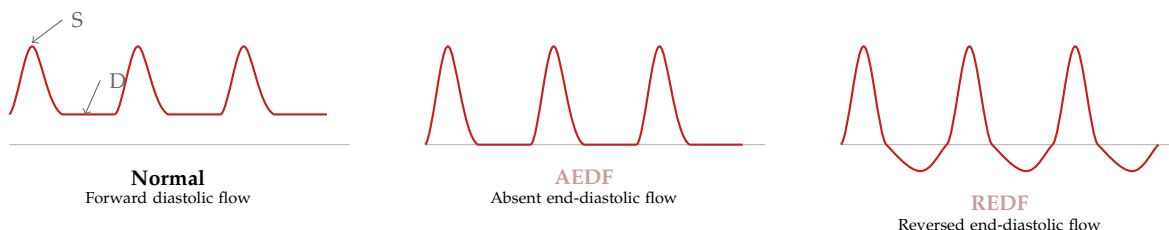
Normal: $S/D < 3.0$ after 30 weeks; diastolic flow always forward

What this means: The umbilical artery carries deoxygenated blood from the fetus to the placenta. Its Doppler waveform reflects placental vascular resistance. Normally, as the placental vascular bed develops and expands, resistance falls and diastolic flow increases throughout the second and third trimesters.

Analogy: A highway with on-ramps. Normally, the highway has many exits (low-resistance placental vessels) and traffic flows smoothly. As placental disease develops, exits close one by one. Traffic slows (elevated S/D), then stops at the end of each cycle (absent end-diastolic flow), then tries to reverse direction (reversed end-diastolic flow).

Finding	Waveform	Significance
Normal	Forward diastolic flow, $S/D < 3.0$	Normal placental resistance
Elevated indices	Reduced diastolic flow, $S/D \geq 3.0$	Increased placental resistance; increase surveillance
AEDF	Absent end-diastolic flow	> 60% of placental vessels obliterated; serious
REDF	Reversed end-diastolic flow	Critical; high perinatal mortality; consider delivery

{Key point: AEDF and REDF are never normal at any gestational age after the early second trimester. REDF is associated with a perinatal mortality rate of up to 40% if not delivered.}



{Schematic UA waveforms. Baseline = zero flow. Normal: diastolic flow (D) stays above baseline. AEDF: diastolic flow drops to baseline. REDF: diastolic flow reverses below baseline.}

Middle Cerebral Artery (MCA) Peak Systolic Velocity

$$MoM = \frac{\text{Measured MCA PSV}}{\text{Median MCA PSV for GA}}$$

What this means: The MCA PSV is the fastest blood velocity in the middle cerebral artery, measured at the proximal third of the vessel near the Circle of Willis with zero angle correction. The measured value is converted to multiples of the median (MoM) for the gestational age using published reference tables (Mari et al., 2000).

Analogy: A thinned-out milkshake flowing faster through a straw. In fetal anemia, the blood has fewer red blood cells (lower viscosity), so it flows faster to compensate. The more anemic the fetus, the faster the MCA PSV.

Clinical application: MCA PSV MoM ≥ 1.5 predicts moderate to severe fetal anemia with a sensitivity of approximately 100% (Mari et al., NEJM 2000). This non-invasive test has largely replaced amniocentesis for monitoring Rh isoimmunization. False positives increase after 35 weeks. Always measure at the proximal third of the MCA with zero angle of insonation.

Cerebroplacental Ratio (CPR)

$$CPR = \frac{MCA\ PI}{UA\ PI}$$

What this means: The CPR compares cerebral resistance (MCA PI) to placental resistance (UA PI). In a healthy fetus, the brain has higher resistance than the placenta, so the ratio is greater than 1.0. When the fetus redistributes blood flow to protect the brain (brain sparing), cerebral resistance drops and the ratio falls below 1.0.

Analogy: Comparing the difficulty of two routes: the brain highway and the placenta highway. Normally, the brain highway has tighter traffic control (higher PI). When the placenta highway gets congested (high UA PI) and the brain opens its lanes (low MCA PI), the ratio flips, meaning the fetus is prioritizing brain blood flow at the expense of everything else.

Clinical application: CPR < 1.0 indicates fetal brain sparing and is associated with increased risk of adverse perinatal outcomes, including emergency cesarean section, NICU admission, and acidosis at birth. The CPR may be abnormal even when the individual UA PI and MCA PI values are each within normal range, which is why the ratio adds clinical value beyond either measurement alone.

Uterine Artery Doppler

Abnormal: bilateral notching after 24 weeks or mean PI > 95th percentile

What this means: The uterine arteries supply blood to the placenta. Normally, trophoblast invasion remodels the spiral arteries during the first and early second trimesters, converting them from high-resistance muscular vessels to low-resistance dilated channels. Failed remodeling keeps resistance high and produces a characteristic early diastolic notch on the Doppler waveform.

Analogy: Water supply pipes to a factory that failed renovation. The factory (placenta) was supposed to get wide, low-resistance pipes, but the renovation never happened. The narrow pipes restrict water flow, and you can see the “notch” of turbulence at the pipe junction.

Clinical application: Bilateral uterine artery notching persisting after 24 weeks is associated with a significantly increased risk of preeclampsia and intrauterine growth restriction. Mean uterine artery PI above the 95th percentile at the first-trimester screening (11 to 13 weeks) is a component of the preeclampsia risk algorithm and can identify candidates for low-dose aspirin prophylaxis.

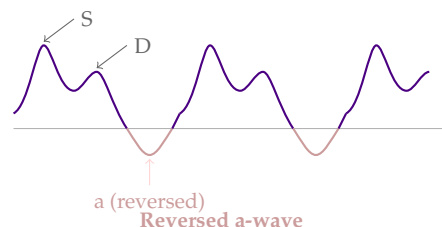
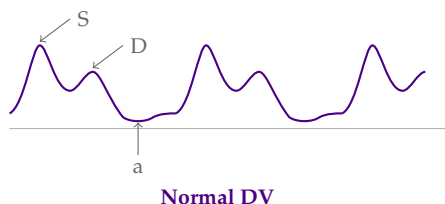
Ductus Venosus (DV) Doppler

Critical finding: absent or reversed a-wave

What this means: The ductus venosus is a small venous shunt that carries oxygen-rich blood from the umbilical vein directly to the right atrium, bypassing the hepatic circulation. Its waveform has an S-wave (systole), D-wave (diastole), and a-wave (atrial contraction). The a-wave reflects right atrial pressure and cardiac compliance.

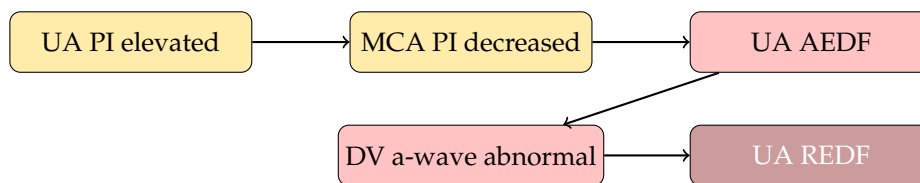
Analogy: The VIP express lane on a highway. Blood coming from the placenta gets a fast lane straight to the heart. When the heart starts failing (cardiac compromise), traffic backs up into the express lane, and you see flow reversing during atrial contraction, like cars being pushed backward onto the on-ramp.

Clinical application: An absent or reversed a-wave in the DV indicates significant fetal cardiac compromise and is a late finding in the deterioration cascade. In the first trimester (11 to 13 weeks), an abnormal DV a-wave is also a marker for aneuploidy. In the setting of IUGR, an abnormal DV is one of the final signs before fetal decompensation and often triggers urgent delivery.



{Schematic DV waveforms. S = systole, D = diastole, a = atrial contraction. Normal: a-wave dips but stays above baseline. Reversed: a-wave drops below baseline (red), indicating cardiac compromise.}

IUGR Doppler Deterioration Cascade



Worsening fetal compromise →

{Memorize this sequence. Placental resistance rises first (UA). The brain compensates by vasodilating (MCA). The placenta deteriorates further (AEDF). The heart begins to fail (DV). The situation becomes critical (REDF). Each step represents a narrowing window for intervention.}

PART 5: FETAL WELL-BEING ASSESSMENT

Biophysical Profile (BPP)

The BPP evaluates five fetal parameters, each scored 0 (absent) or 2 (present), for a maximum score of 10.

Component	Normal (score = 2)	Assessment
Fetal breathing	≥ 1 episode of ≥ 30 seconds in 30 minutes	Ultrasound
Fetal movement	≥ 3 discrete body or limb movements in 30 minutes	Ultrasound
Fetal tone	≥ 1 episode of extension/flexion of a limb or trunk	Ultrasound
Amniotic fluid	SDP ≥ 2 cm	Ultrasound
NST (reactivity)	≥ 2 accelerations of ≥ 15 bpm for ≥ 15 seconds in 20 minutes	Cardiotocography

Analogy: A five-point vet checklist for a pet that cannot talk. You check breathing, movement, muscle tone, the environment (fluid), and heart rate response. Each item tells you something about how well the “patient” is doing without being able to ask them.

Score	Interpretation	Management
8–10	Normal	Routine surveillance
8/10 (abnormal AFI)	Normal but monitor fluid	Repeat in 24–48 hours; investigate oligohydramnios
6	Equivocal	Repeat in 6–24 hours; deliver if ≥ 36 weeks
4	Abnormal	Deliver if ≥ 32 weeks; close monitoring if earlier
0–2	Strongly abnormal	Deliver regardless of gestational age

Modified Biophysical Profile (mBPP)

$$mBPP = NST + AFI$$

What this means: The modified BPP combines two components: the non-stress test (NST) to assess acute fetal status and the amniotic fluid index (AFI) to assess chronic placental function. It is faster than a full BPP and is used for routine antepartum surveillance.

Analogy: A quick vital signs check versus a full physical exam. The modified BPP gives you the two most important pieces of information (heart rate reactivity and fluid status) without the time investment of a full assessment.

Clinical application: The mBPP is considered normal when the NST is reactive and the AFI is greater than 5 cm. An abnormal mBPP (non-reactive NST or AFI ≤ 5) warrants a full BPP or further evaluation. The mBPP is typically used for twice-weekly surveillance in high-risk pregnancies.

Non-Stress Test (NST) Interpretation

Category	Criteria
Reactive	≥ 2 accelerations of ≥ 15 bpm above baseline lasting ≥ 15 seconds within 20 minutes (at ≥ 32 weeks)
Reactive (preterm)	≥ 2 accelerations of ≥ 10 bpm above baseline lasting ≥ 10 seconds (at < 32 weeks)
Non-reactive	Does not meet reactive criteria within 40 minutes

{Key rule: A non-reactive NST is not necessarily abnormal. Common causes include fetal sleep cycles (20–40 minutes), maternal sedation, and prematurity. Extend the testing period to 40 minutes or use vibroacoustic stimulation before calling a

result non-reactive. A reactive NST is reassuring, but a non-reactive test has a high false-positive rate and requires further evaluation.}

Order of Loss in Fetal Compromise

When a fetus becomes progressively hypoxic, BPP components are lost in a predictable order that mirrors fetal brain center development (last to develop = first to go):

Order	Component Lost	Brain Center
1st	Fetal heart rate reactivity (NST)	Posterior hypothalamus / cortex
2nd	Fetal breathing movements	Ventral medulla
3rd	Fetal body movements	Cortex / subcortex
4th (last)	Fetal tone	Cortex (earliest to develop)

{**Memory aid:** Heart rate, Breathing, Movement, Tone (HBMT). The most recently developed brain center (controlling FHR reactivity) is the most sensitive to oxygen deprivation and fails first. Tone, controlled by the oldest brainstem centers, is the last to disappear and its loss indicates severe compromise.}

PART 6: QUICK REFERENCE

Biometry by GA (50th Percentile)

GA (wk)	BPD	HC	AC	FL
12	2.0	7.1	5.6	0.8
16	3.4	12.4	10.4	2.0
20	4.7	17.5	14.6	3.3
24	5.9	21.9	19.0	4.4
28	7.1	26.2	23.2	5.4
32	8.0	29.5	27.6	6.2
36	8.7	32.0	31.5	6.9
40	9.3	34.2	35.0	7.5

All values in cm. BPD and FL = linear; HC and AC = circumference.

Amniotic Fluid Thresholds

	AFI (cm)	SDP (cm)
Oligohydramnios	< 5	< 2
Normal	5–24	2–8
Polyhydramnios	> 24	> 8

BPP Quick Scoring

Score	Action
8–10	Normal; routine care
6	Equivocal; repeat or deliver
4	Abnormal; deliver if viable
0–2	Deliver

Normal Doppler Values (3rd Trimester)

Parameter	Normal
UA S/D ratio	< 3.0
UA PI	< 1.0 (term)
UA RI	< 0.7
MCA PI	1.2–2.4
CPR (MCA PI / UA PI)	> 1.0
Uterine artery PI	< 1.45 (mean)
DV a-wave	Forward (positive)

Key Thresholds & Red Flags

Finding	Action
MSD $\geq$ 25 mm, no embryo	Anembryonic pregnancy
CRL $\geq$ 7 mm, no heartbeat	Embryonic demise
MCA PSV $\geq$ 1.5 MoM	Severe fetal anemia
UA AEDF / REDF	Urgent; consider delivery
CPR < 1.0	Brain sparing
BPP $\leq$ 4	Deliver if viable
AFI < 5	Oligohydramnios workup

1st Tri & Screening Cutoffs

Finding	Significance
NT $\geq$ 3.0 mm	Aneuploidy risk
Cervix < 25 mm (TVS)	Short; progesterone/cerclage
hCG > 2,000, no IUP	Suspect ectopic
TTTS: oligo + poly	Quintero staging
Discordance > 25%	Severe; full Doppler workup

PART 7: FIRST TRIMESTER COMPLICATIONS & SCREENING

Criteria for Early Pregnancy Failure (ACOG)

Category	Finding
Definitive failure	CRL $\geq$ 7 mm with no cardiac activity
Definitive failure	MSD $\geq$ 25 mm with no embryo
Definitive failure	No embryo with heartbeat $\geq$ 2 weeks after scan showing gestational sac without yolk sac
Definitive failure	No embryo with heartbeat $\geq$ 11 days after scan showing gestational sac with yolk sac
Suspicious	CRL $<$ 7 mm with no heartbeat
Suspicious	MSD 16–24 mm with no embryo
Suspicious	Empty amnion (amnion visible but no embryo)
Suspicious	Enlarged yolk sac $>$ 7 mm
Suspicious	Small gestational sac relative to embryo (MSD – CRL $<$ 5 mm)

{Key rule: A suspicious finding requires follow-up in 7 to 14 days. Never diagnose pregnancy failure on a single scan when findings are below definitive thresholds.}

Ectopic Pregnancy

Discriminatory hCG zone (TVS): 1,500–2,000 mIU/mL

What this means: If the serum hCG is above the discriminatory zone and no intrauterine pregnancy (IUP) is seen on transvaginal ultrasound, suspect ectopic pregnancy. Below this level, it may simply be too early to visualize an IUP.

Analogy: A package tracking number. Once the tracking says “delivered” (hCG above discriminatory zone), you expect to find the package at your door (IUP in the uterus). If the package is not there, it was delivered to the wrong address (ectopic).

Feature	Detail
Most common location	Ampulla of fallopian tube (70%)
Second most common	Isthmus (12%), then fimbrial (11%)
Tubal ring sign	Hyperechoic ring surrounding extraovarian adnexal mass
Pseudosac vs. true sac	Pseudosac: single decidual layer, central; no double decidual sign
Double decidual sign (DDS)	Two concentric rings = true IUP
Heterotopic pregnancy	1 in 30,000 (natural); up to 1 in 100 with ART
Interstitial ectopic	Eccentric sac, thin myometrial mantle $<$ 5 mm; interstitial line sign

Clinical application: Ectopic pregnancy is the leading cause of first-trimester maternal death. Ruptured ectopic presents with acute abdomen and free fluid in the cul-de-sac. Always check the adnexa when no IUP is seen above the discriminatory hCG zone.

Nuchal Translucency (NT) Screening

Normal NT: $<$ 3.0 mm CRL window: 45–84 mm (11+0 to 13+6 weeks)

What this means: The NT is the sonolucent space at the back of the fetal neck, measured in the mid-sagittal plane. It reflects fluid accumulation. An increased NT is associated with aneuploidy (trisomy 21, 18, 13), cardiac defects, and other structural anomalies.

Analogy: Checking for a puffy collar on a jacket. A little puffiness is normal; a very thick puffy collar suggests something underneath is causing the swelling.

{Measurement technique (all must be met):}

1. Mid-sagittal plane (nasal bone, palate, diencephalon visible)
2. Head and thorax fill $\geq 75\%$ of image
3. Fetus in neutral position (not flexed or extended)
4. Calipers placed on inner borders of NT (on-to-on)
5. Measure at thickest part
6. Amnion must be seen as separate from NT line

Test	Components	T21 Detection Rate
NT alone	NT measurement	~75%
Combined first-trimester	NT + free β -hCG ($\uparrow$) + PAPP-A ($\downarrow$)	~90% at 5% FPR
Cell-free DNA (cfDNA)	Maternal blood draw	> 99%

{**Additional first-trimester markers:** Absent nasal bone (T21), reversed ductus venosus a-wave, tricuspid regurgitation. These are used in specialized centers to refine risk when NT is borderline.}

PART 8: PLACENTAL PATHOLOGY & CERVICAL LENGTH

Placenta Previa and Low-Lying Placenta

Previa: covers internal os Low-lying: edge within 2 cm of os but not covering

What this means: The placental position relative to the internal cervical os determines whether a patient is at risk for hemorrhage during labor. Transvaginal ultrasound is the gold standard for measuring the distance from the placental edge to the os. TVS is safe (the probe does not enter the os).

Analogy: A rug placed over a trapdoor. If the rug completely covers the trapdoor (previa), you cannot open it without moving or cutting through the rug. If the rug edge is close but not covering (low-lying), the trapdoor can open, but there may be complications.

Clinical application: Approximately 90% of second-trimester previas resolve by term due to lower uterine segment growth ("placental migration"). Follow-up scan at 32 to 36 weeks confirms persistence. Previa is the most common cause of painless third-trimester bleeding. Digital cervical examination is contraindicated in known previa.

Placenta Accreta Spectrum (PAS)

Type	Depth	Frequency	Key Feature
Accreta	Villi attach to myometrial surface	~75%	Loss of retroplacental clear zone
Increta	Villi invade into myometrium	~18%	Myometrial thinning
Percreta	Villi penetrate through to serosa	~7%	May invade bladder

Analogy: Tree roots growing into a sidewalk. Accreta is roots gripping the surface. Increta is roots cracking into the concrete. Percreta is roots breaking through the other side. The deeper the roots, the harder the removal.

{Ultrasound findings: Placental lacunae ("Swiss cheese" appearance, most predictive), loss of retroplacental clear zone, bladder wall irregularity, myometrial thinning < 1 mm, bridging vessels on color Doppler crossing the uterine-bladder interface.}

{Key risk factor: Prior cesarean delivery + current placenta previa. Risk of PAS increases with each prior cesarean: 3% (1 prior), 11% (2 prior), 40% (3 prior), 61% (4+ prior). PAS is a leading cause of peripartum hysterectomy.}

Vasa Previa

Unprotected fetal vessels within 2 cm of the internal cervical os

What this means: Fetal blood vessels cross over or near the internal os without the protection of the umbilical cord (Wharton's jelly) or placental tissue. If these vessels rupture during labor or membrane rupture, the fetus exsanguinates rapidly.

Feature	Detail
Type I	Velamentous cord insertion with vessels crossing os
Type II	Vessels connecting succenturiate or bilobed lobe cross os
Diagnosis	Color Doppler over internal os (TVS)
Mortality (undiagnosed)	~60%
Mortality (diagnosed, planned C-section)	~3%
Risk factors	Low-lying placenta, bilobed/succenturiate lobe, IVF, multiples

Clinical application: Diagnosis before labor is life-saving. When a resolving low-lying placenta is identified at the anatomy scan, check for vasa previa at follow-up. Planned cesarean delivery at 34 to 37 weeks (with antenatal corticosteroids) is the standard management.

Cervical Length Assessment

Normal (24 wk): ~ 35 mm Short cervix: < 25 mm by TVS

What this means: Cervical length measured by transvaginal ultrasound between 16 and 24 weeks predicts preterm birth risk. A shorter cervix indicates the cervix is already effacing (thinning and shortening), which normally should not occur until near term.

Analogy: A cork in a wine bottle. A full-length cork holds everything in securely. As the cork shortens, the risk of the bottle opening too soon increases.

{Measurement technique:}

1. Transvaginal scan, bladder empty
2. Cervix fills $\geq 75\%$ of image
3. Calipers from internal os to external os along cervical canal
4. Do not apply excessive pressure (artificially lengthens)
5. Measure at least 3 times; report the shortest
6. Observe for dynamic shortening for 3 minutes

Finding	Measurement	Significance
Normal	≥ 30 mm	Low preterm birth risk
Shortened	25–29 mm	Borderline; consider serial monitoring
Short cervix	< 25 mm	Vaginal progesterone or cerclage
Funneling	Y $\rightarrow$ V $\rightarrow$ U shape	Progressive cervical incompetence

ART/IVF Pregnancy: Ultrasound Considerations

Pregnancies achieved through assisted reproductive technology (ART), including in vitro fertilization (IVF) and intracytoplasmic sperm injection (ICSI), carry specific risks that change the ultrasound surveillance plan. The SMFM Consult Series #60 (2022) provides the current standard of care.

Analogy: A custom-built house versus a standard-plan house. Both are houses, but the custom build needs extra inspections at specific stages because the construction process introduced variables that a standard build does not have.

#	Recommendation (SMFM #60)	Why It Matters
1	Detailed anatomy scan (CPT 76811), not standard	Higher rate of structural anomalies (1.3 $\times$)
2	Offer fetal echocardiography	Congenital heart defect risk increased with IVF/ICSI
3	Document cord insertion site at anatomy scan	Velamentous cord insertion is 2–3 $\times$ more common
4	Screen for vasa previa (TVS with color Doppler)	Risk jumps from ~1:2,500 to ~1:260 with IVF
5	Evaluate for placenta previa and accreta spectrum	Higher incidence due to altered implantation
6	Third-trimester growth scan	Higher rates of SGA and LGA
7	Offer prenatal genetic screening/diagnostic testing	Especially with ICSI; CVS or amniocentesis available
8	Screen for heterotopic pregnancy if symptoms arise	Risk up to 1:100 with ART (vs. 1:30,000 spontaneous)

{Additional ART-specific risks:}

- **Multiple gestation:** Even single embryo transfer carries a 2–3% monozygotic twin rate (higher than spontaneous 0.4%)
- **Vanishing twin:** One sac stops developing in early pregnancy; remnant may cause velamentous cord insertion in surviving twin
- **Subchorionic hemorrhage:** More common after IVF; monitor size and clinical symptoms

- **Preterm birth:** Higher rate even in singletons conceived by IVF; cervical length screening is recommended
- **Preeclampsia:** Donor oocyte pregnancies carry the highest preeclampsia risk of any ART subgroup

{**Key point for sonographers:** When you see “IVF” or “ART” on the clinical history, it should trigger a mental checklist: (1) look carefully at cord insertion, (2) assess for vasa previa if low-lying placenta, (3) expect a detailed anatomy scan order, (4) anticipate a fetal echo referral, and (5) plan for a third-trimester growth check.}

PART 9: MULTIPLE GESTATION

Determining Chorionicity and Amnionicity

The single most important determination in a twin pregnancy is chorionicity, because it defines the entire risk profile. This assessment is most accurate in the first trimester (before 14 weeks), when the amnion and chorion have not yet fused.

Sign	Indicates	Description
Lambda sign (twin peak)	Dichorionic	Triangular wedge of placental tissue projecting into base of intertwin membrane
T-sign	Monochorionic	Membrane inserts at right angle with no tissue wedge
Thick membrane (4 layers)	Dichorionic diamniotic	Amnion-chorion-chorion-amnion
Thin membrane (2 layers)	Monochorionic diamniotic	Amnion-amnion only
No membrane	Monochorionic monoamniotic	Highest risk; cord entanglement
Two separate placentas	Always dichorionic	Single mass can be either (fused or true mono)
Two yolk sacs (1st tri)	Diamniotic	One yolk sac = likely monoamniotic

{**Key rule:** Lambda sign sensitivity is 99% and specificity is 95% before 14 weeks. After 20 weeks, the twin peak may disappear even in dichorionic twins due to membrane thinning. Always determine chorionicity at the earliest scan.}

Twin Types and Risk Profiles

Type	Frequency	Key Risks
Dichorionic diamniotic (DCDA)	~80%	Discordant growth, preterm birth
Monochorionic diamniotic (MCDA)	~18%	TTTS, TAPS, selective IUGR, preterm birth
Monochorionic monoamniotic (MCMA)	~1–2%	Cord entanglement, TTTS, highest mortality

{**Surveillance:** DCDA twins are scanned every 4 weeks for growth. MCDA twins are scanned every 2 weeks starting at 16 weeks (watching for TTTS). MCMA twins require intensive inpatient monitoring with daily NSTs, often starting at 24 to 26 weeks.}

Twin-to-Twin Transfusion Syndrome (TTTS)

TTTS occurs in 10 to 15% of monochorionic pregnancies due to unbalanced arteriovenous anastomoses in the shared placenta. One twin (donor) pumps blood to the other (recipient) through these connections.

Diagnosis: Donor SDP < 2 cm + Recipient SDP > 8 cm (before 20 wk) or > 10 cm (after 20 wk)

Quintero Staging

Stage	Findings
I	Oligo/poly sequence; donor bladder still visible; Dopplers normal
II	Donor bladder not visible (anuria); Dopplers still normal
III	Critically abnormal Dopplers: any one of UA AEDF/REDF, pulsatile umbilical vein, or reversed DV a-wave
IV	Hydrops in one or both twins
V	Demise of one or both twins

{**Treatment:** Fetoscopic laser photocoagulation of placental anastomoses is the standard treatment for Stage II and above (typically performed at 16 to 26 weeks). Stage I may be managed expectantly with twice-weekly surveillance. The “stuck twin” (donor) appears plastered against the uterine wall with virtually no fluid, while the recipient develops massive polyhydramnios.}

Growth Discordance in Twins

$$\text{Discordance (\%)} = \frac{\text{Larger EFW} - \text{Smaller EFW}}{\text{Larger EFW}} \times 100$$

What this means: This formula calculates the percentage difference in estimated weight between the two twins, using the larger twin as the reference. Always divide by the larger twin’s weight.

Analogy: Comparing two pumpkins from the same vine. If one weighs 5 lbs and the other weighs 4 lbs, the discordance is $(5-4)/5 = 20\%$. The question is whether the smaller one is just naturally smaller or whether something is wrong with its share of the vine’s nutrients.

Discordance	Classification	Management
< 20%	Normal	Routine twin surveillance
20–25%	Significant	Increase surveillance; assess Dopplers
> 25%	Severe	Full workup: UA Doppler, MCA, AFI

{**Selective IUGR in monochorionic twins** is classified by UA Doppler pattern: Type I (positive end-diastolic flow, best prognosis), Type II (persistent AEDF/REDF, worst prognosis), Type III (intermittent AEDF/REDF, unpredictable). Type matters because monochorionic twins share a placenta, so demise of one twin can cause acute hypotension in the other through the anastomoses.}

HIGH-YIELD ANOMALY & MARKER REFERENCE

{This is a condensed reference for the most-tested fetal anomalies and chromosomal markers. A separate OB Anomalies Study Guide with detailed sonographic findings, images, and differential diagnosis is planned.}

Fetal Anomalies by Organ System

System	Anomaly	Key Sonographic Finding	Association / Notes
CNS	Anencephaly	Absent calvarium above orbits	Elevated MSAFP; lethal
CNS	Holoprosencephaly	Fused ventricles, no midline falx	Trisomy 13; alobar is most severe
CNS	Dandy-Walker	Enlarged posterior fossa, absent vermis	Ventriculomegaly in 80%
CNS	Ventriculomegaly	Atrium ≥ 10 mm	Mild 10–15; severe > 15 mm
CNS	Encephalocele	Herniation through skull defect	Occipital most common
CNS	Spina bifida	Open vertebral arches; lemon/banana signs	Elevated MSAFP; Chiari II
Face	Cleft lip/palate	Gap in upper lip $\pm$ palate on coronal	Isolated or syndromic
Neck	Cystic hygroma	Septated cystic mass, posterior neck	Turner syndrome (45,X); hydrops
Chest	CDH	Abdominal organs in thorax; shifted heart	Left-sided 80%; stomach in chest
Chest	CCAM/CPAM	Solid or cystic lung mass	Types I–III; may cause hydrops
GI	Omphalocele	Midline mass with membrane at cord site	Trisomy 18/13 if contains only bowel
GI	Gastroschisis	Right paraumbilical herniation, no membrane	Usually isolated; young mothers
GI	Duodenal atresia	Double bubble sign	Trisomy 21 in 30%
GU	Bilateral renal agenesis	Empty renal fossae, anhydramnios	Potter sequence; lethal
GU	MCDK	Large non-communicating cysts	Unilateral usually benign
GU	PUV	Dilated bladder (keyhole sign), bilateral hydro	Males only; worst prognosis
Skeletal	Thanatophoric dysplasia	Short curved femurs, narrow chest	Lethal; most common lethal SD
Skeletal	Osteogenesis imperfecta II	Fractured/bowed bones, poor mineralization	Lethal

{MSAFP = maternal serum alpha-fetoprotein. CDH = congenital diaphragmatic hernia. CCAM = congenital cystic adenomatoid malformation. MCDK = multicystic dysplastic kidney. PUV = posterior urethral valves. SD = skeletal dysplasia.}

Chromosomal Soft Markers for Aneuploidy

Soft Marker	Finding	Primary Association
Thickened nuchal fold	≥ 6 mm (15–20 wk)	Trisomy 21 (strongest 2nd tri marker)
Echogenic intracardiac focus	Bright spot in ventricle	Trisomy 21 (low individual risk)
Echogenic bowel	Bowel bright as bone	Trisomy 21, CF, CMV, swallowed blood
Mild pyelectasis	Renal pelvis ≥ 4 mm	Trisomy 21 (weak marker)
Short humerus / femur	< 5 th percentile	Trisomy 21 (FL) and Trisomy 18
Choroid plexus cysts	Cysts in choroid plexus	Trisomy 18 (if other markers present)
Absent / hypoplastic nasal bone	Not visualized on profile	Trisomy 21
Sandal gap toe	Wide gap 1st/2nd toes	Trisomy 21
Clenched hands	Overlapping fingers	Trisomy 18

Trisomy	Key Sonographic Pattern	Other Features
T21 (Down)	Thickened NF, absent nasal bone, duodenal atresia, AVSD, short FL	Most common live trisomy
T18 (Edwards)	Clenched fists, rocker-bottom feet, IUGR, strawberry skull, cardiac	Usually lethal
T13 (Patau)	Holoprosencephaly, polydactyly, midline clefts, cardiac	Usually lethal
Turner (45,X)	Cystic hygroma, hydrops, coarctation, horseshoe kidney	Only viable monosomy

[Key principle: A single isolated soft marker in a low-risk patient has minimal significance. Multiple markers dramatically increase aneuploidy risk. Always correlate with first-trimester screening results and maternal age.]

References Used

Ultrasound in Pregnancy (ACOG Practice Bulletin 175) | Hadlock et al. 1985 (EFW Formula) | Mari et al. 2000 (MCA PSV, NEJM) | AIUM Practice Parameter for OB Ultrasound (2024) | SMFM Clinical Guidelines | Antepartum Fetal Surveillance (ACOG Practice Bulletin 229) | Placenta Accreta Spectrum (ACOG Obstetric Care Consensus 7) | Fetal Growth Restriction (SMFM Consult Series 52, 2020) | Lambda Sign for Chorionicity (Defined Meta-Analysis) | ART and Adverse Outcomes (SMFM Consult Series 60, 2022)

Dr. Alice Matthews · amatthews@concorde.edu · alice@deepneuro.ai · Concorde Career College Portland