OBSTETRICS

The importance of the cerebroplacental ratio in the evaluation of fetal well-being in SGA and AGA fetuses

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The cerebroplacental ratio (CPR) is emerging as an important predictor of adverse pregnancy outcome, and this has implications for the assessment of fetal well-being in fetuses diagnosed as small for gestational age (SGA) and those appropriate for gestational age close to term. Interest in this assessment tool has been rekindled because of recent reports associating an abnormal ratio with adverse perinatal events and associated postnatal neurological outcome. Fetuses with an abnormal CPR that are appropriate for gestational age or have late-onset SGA (>34 weeks of gestation) have a higher incidence of fetal distress in labor requiring emergency cesarean delivery, a lower cord pH, and an increased admission rate to the newborn intensive care unit when compared with fetuses with a normal CPR. Fetuses with early-onset SGA (<34 weeks of gestation) with an abnormal CPR have a higher incidence of the following when compared with fetuses with a normal CPR: (1) lower gestational age at birth, (2) lower mean birthweight, (3) lower birthweight centile, (4) birthweight less than the 10th centile, (5) higher rate of cesarean delivery for fetal distress in labor, (6) higher rate of Apgar scores less than 7 at 5 minutes, (7) an increased rate of neonatal acidosis, (8) an increased rate of newborn intensive care unit admissions, (9) higher rate of adverse neonatal outcome, and (10) a greater incidence of perinatal death. The CPR is also an earlier predictor of adverse outcome than the biophysical profile, umbilical artery, or middle cerebral artery. In conclusion, the CPR should be considered as an assessment tool in fetuses undergoing third-trimester ultrasound examination, irrespective of the findings of the individual umbilical artery and middle cerebral artery measurements. A CPR calculator is available at http://www.ajog.org/pb/assets/raw/Health%20Advance/journals/ymob/CPR/index.htm.

Key words: biophysical profile, Doppler, fetal distress, intrauterine growth restriction, middle cerebral artery, perinatal morbidity, umbilical artery

The cerebroplacental ratio (CPR) is emerging as an important predictor of adverse pregnancy outcome, and this has implications for the assessment of well-being in fetuses diagnosed as small for gestational age (SGA) and those appropriate for gestational age (AGA) close to term. The CPR is calculated by dividing the Doppler indices of the middle cerebral artery (MCA) by the umbilical artery (UA) (Table 1 and Figure 1).[1-12]

The CPR represents the interaction of alterations in blood flow to the brain as manifest by increased diastolic flow as the result of cerebrovascular dilation resulting from hypoxia and increased placental resistance, resulting in decreased diastolic flow of the umbilical artery.[1-12] When these alterations occur, the increased diastolic flow of the MCA is manifest by a decrease in the systolic/diastolic ratio (S/D), resistance index (RI); [(systolic peak velocity/diastolic peak velocity)/systolic peak velocity], and the pulsatility index (PI); [(systolic peak velocity/diastolic peak velocity)/velocity time integral], whereas these measurements are increased in the umbilical artery as the result of increased resistance to blood flow as the result of placental pathology.[1-12] Although the S/D ratio, RI, and PI have been reported when computing the CPR, more recently the PI is the computation of choice.[1,5,6,8-12]

An abnormal CPR may result from 3 types of Doppler measurement patterns. The first is when the UA and MCA PI are in the upper and lower range of the distribution curve, resulting in an abnormally low CPR (Figure 2). The second is when the UA PI is normal but the MCA PI is decreased, resulting in an abnormally low CPR (Figure 3).[13] The third pattern consists of an abnormally elevated UA PI and an abnormally decreased MCA PI, resulting in an abnormally low CPR (Figure 4).

Whereas the CPR was first described in the 1980s, interest in this assessment tool has been rekindled because of recent reports associating an abnormal ratio with adverse perinatal outcome and postnatal neurological deficit.[14-18] The purpose of this article was to review the data from studies in which the CPR has been evaluated in fetuses that were AGA and those with SGA to determine whether this test should be considered for integration into clinical practice.

Appropriate-for-gestational-age fetuses: the role of CPR in the detection of fetuses at risk for adverse outcome

Prior et al[19] prospectively evaluated 400 AGA fetuses at term and reported an abnormal CPR in 11%. Of those who underwent cesarean delivery for fetal distress, 36.4% had an abnormal CPR compared with 10.1% ($P < .001$) that

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Received April 7, 2015; revised April 29, 2015; accepted May 13, 2015.

The author reports no conflict of interest.

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0002-9378/$36.00

http://dx.doi.org/10.1016/j.ajog.2015.05.024

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TABLE 1
Studies reporting the value for an abnormal cerebroplacental ratio

Study	Year	Study type	Doppler indices	Computation of ratio	Abnormal criteria
Arbeille et al[1]	1988	Cross-sectional	S-D/S	MCA/UA	Ratio <1
Arias[6]	1994	Cross-sectional	RI	MCA/UA	Ratio <1
Gramellini et al[5]	1992	Cross-sectional	PI	MCA/UA	Ratio <1.08
Bahado-Singh et al[8]	1999	Cross-sectional	PI	MCA/UA MoM	Ratio <0.05 MoM
Baschat and Gembruch[9]	2003	Cross-sectional	PI	MCA/UA	Less than fifth centile
Odibo et al[10]	2005	Cross-sectional	PI	MCA/UA	Ratio <1.08
Ebbing et al[11]	2007	Longitudinal	PI	MCA/UA	<2.5th centile
Morales et al[12]	2014	Cross-sectional	PI	MCA/UA	Less than fifth centile or MoM <0.6765

MCA, middle cerebral artery; *MoM*, multiple of the median; *PI*, pulsatility index; *RI*, resistance index; *S/D*, systolic/diastolic ratio; *UA*, umbilical artery.

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had a normal CPR (Table 2).[19] An abnormal CPR was a better predictor for an emergency cesarean delivery than an abnormal UA or MCA (Table 2). No fetuses with a CPR greater than the 90th centile required cesarean delivery for fetal distress in labor.[19] Therefore, the assessment of the CPR in term AGA fetuses before active labor predicted intrapartum fetal compromise and the need for emergency cesarean delivery.[19]

In a study reported by Morales-Rosello et al,[20] who evaluated the CPR in AGA fetuses between 37 and 41.9 weeks of gestation, they found that the UA and venous pH were significantly lower in AGA newborns who had an abnormal CPR than AGA fetuses with a normal CPR (Table 2). These data suggest that the CPR could be used to assess the risk of intrapartum fetal distress requiring cesarean delivery, or acidemia at birth, in AGA fetuses.

This poses a larger question as to whether a screening test at the time of admission to labor and delivery for induction of labor, or in early spontaneous labor, should be considered. I believe that this question will require further studies, but the data appear to support that the CPR is a candidate for such assessment.

Late-onset SGA fetuses: the role of CPR in the detection of fetuses at risk for adverse outcome

Late-onset SGA is diagnosed after 34 weeks of gestation and is characterized by abnormal Doppler indices involving the MCA, with a normal resistance of the UA.[3,21-23] Identifying and monitoring the fetus with late-onset SGA is problematic because of the paucity of studies suggesting perinatal identification and management protocols.[2,3,24,25]

Cruz-Martinez et al[26] evaluated the 210 fetuses at greater than 37 weeks of gestation suspected of having late-onset SGA and reported an abnormal CPR was associated with a significantly higher rate of emergency cesarean delivery for fetal distress in labor (37.8% vs 20.4%; $P < .001$) and was a better predictor than an isolated MCA measurement (Table 2).

Figueras et al[27] evaluated 509 fetuses with late-onset SGA and found 39.3% to have an abnormal CPR. When an abnormal CPR was present, there was a significantly higher rate of fetal distress (79.1% vs 10.7%; $P < .001$) in labor requiring emergent delivery. In addition, fetuses with an abnormal CPR also had a lower umbilical cord pH (7.17 vs 7.25; $P < .001$) and a higher rate of newborn intensive care unit (NICU) admissions (11.25% vs 5.6%; $P = .03$) (Table 2).[27] They found the best predictors for identifying fetuses at risk for emergency cesarean delivery in labor were the following: (1) an abnormally low CPR, (2) an estimated fetal weight less than the third centile, and (3) an elevated PI of the uterine arteries (Table 2).[27]

These data suggest that an abnormal CPR appears to identify late-onset SGA fetuses at increased risk for adverse intrapartum and neonatal complications. Because the majority of these fetuses have a normal Doppler resistance (PI, RI, or S/D ratio) of the UA, the physician may falsely conclude that there is no increased risk for adverse outcome, even though an abnormal CPR may be present but not measured. Therefore, it is imperative that Doppler assessment of the MCA occurs and the CPR computed in late-onset SGA fetuses to identify those at risk for perinatal complications.

Newborns classified as SGA: the role of CPR in the detection of fetuses at risk for adverse outcome

Recently Khalil et al[17] examined 2485 patients who underwent third-trimester screening ultrasound between 34 and 36 weeks of gestation, with delivery occurring after 37 weeks of gestation. Using multivariate logistic regression analysis, they found a significant association between SGA and an abnormal CPR as indicators for admission to the NICU (Table 2).[17]

In a subsequent study, Khalil et al[18] examined 8382 patients who underwent ultrasound examination after 37 weeks of gestation. In fetuses requiring an emergency cesarean delivery for fetal distress, an abnormal CPR was significantly more frequent (13.1% vs 9.4%; $P < .001$) than those not requiring operative delivery. Multivariate logistic regression identified an abnormal CPR and birthweight centile to be

independently associated with the risk for emergency operative delivery in both the SGA and AGA birthweight groups. Fetuses with an abnormal CPR had a higher rate of NICU admissions (14.3%) compared with those with a normal CPR (9.7%; $P < .004$) (Table 2).[18] In this group, however, birthweight centile was not independently associated with NICU admissions.

When the newborns were divided into groups based on whether SGA was present or absent and the CPR was normal or abnormal, those with an abnormal CPR had a higher cesarean delivery rate (11% vs 8.7%; $P = .043$) and higher instrumental delivery rate (11.2% vs 7.8%; $P = .003$).

These data underscore that an abnormal CPR was a better predictor than low birthweight for identifying those fetuses requiring emergent operative delivery for fetal distress in labor and NICU admission associated with neonatal complications. Therefore, when a fetus with late-onset SGA is identified, the examiner should strongly consider computing the CPR to stratify risk for intrapartum fetal distress and adverse neonatal outcome prior to the onset of labor.

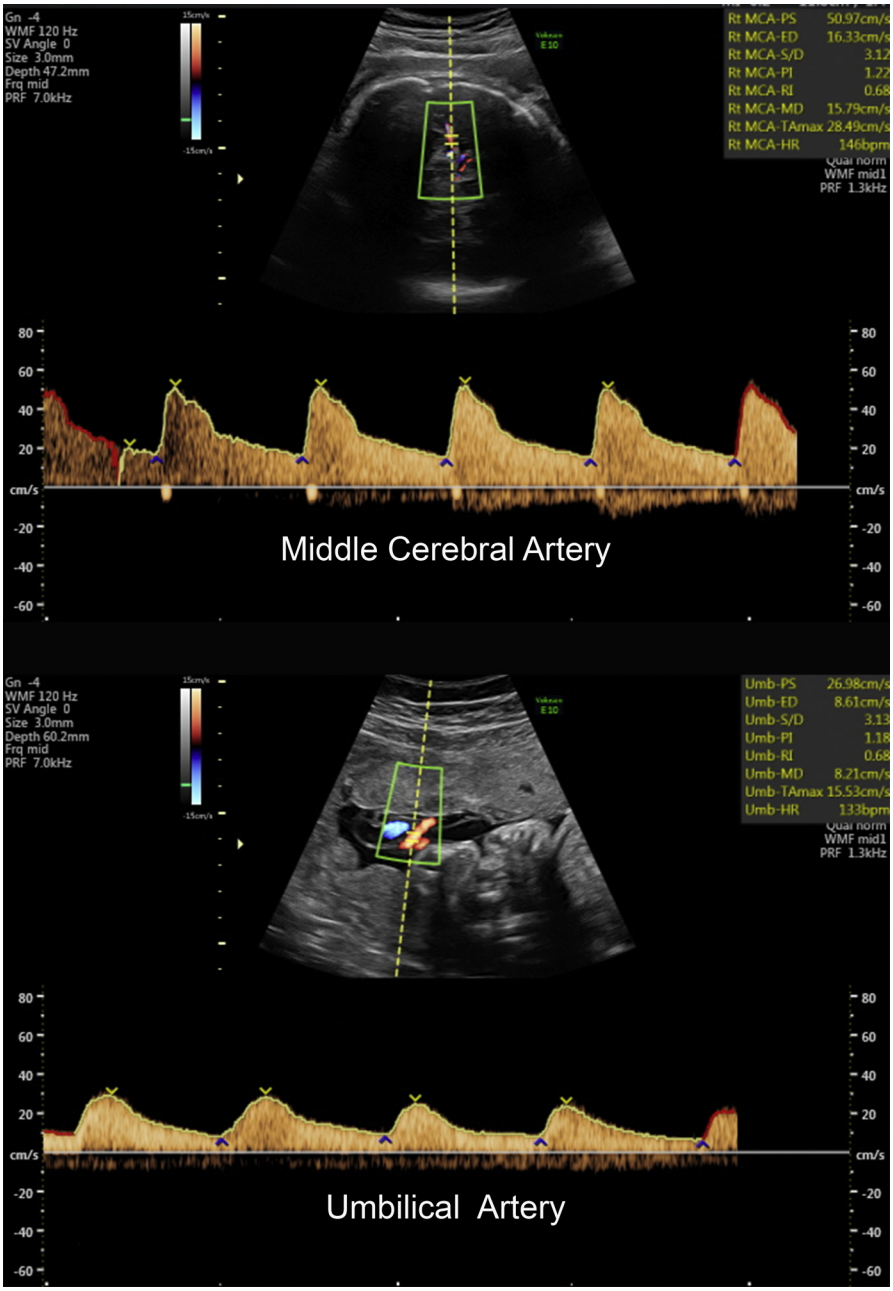
Early onset SGA fetuses: the role of CPR in the detection of fetuses at risk for adverse outcome

Early-onset SGA is characterized by the onset of abnormal growth prior to 34 weeks of gestation with concomitant abnormal Doppler indices of the UA and MCA.[3,21-23] Table 3 summarizes findings from 6 studies in which the CPR was evaluated in fetuses with early-onset SGA. In this group of fetuses, an abnormal CPR was associated with a higher incidence of the following when compared with fetuses with a normal CPR: (1) lower gestational age at birth, (2) lower mean birthweight, (3) lower birthweight centile, (4) birthweight less than the 10th centile, (5) higher rate of cesarean delivery for fetal distress in labor, (6) higher rate of Apgar scores less than 7 at 5 minutes, (7) an increased rate of neonatal acidosis, (8) an increased rate of NICU admissions, (9) higher rate of adverse neonatal outcome, and (10) a greater incidence of perinatal death (Table 3).[5,6,8,13,28-30]

In addition to predicting adverse fetal and neonatal outcome, an abnormal CPR was a better predictor of adverse outcome than the biophysical profile, suggesting that CPR changes may occur before the deterioration of this test.[28,29]

Although early-onset SGA fetuses are at highest risk for adverse outcome,

FIGURE 1
Recordings from a fetus whose mother was a late registrant for prenatal care



These recordings are from a fetus whose mother was a late registrant for prenatal care. There was a 14 day difference between the menstrual age and the mean ultrasound gestational age. The abnormal cerebroplacental ratio suggested that fetal growth restriction was the correct diagnosis. How to acquire the images and make the measurements is illustrated in the Video available at ajog.org.

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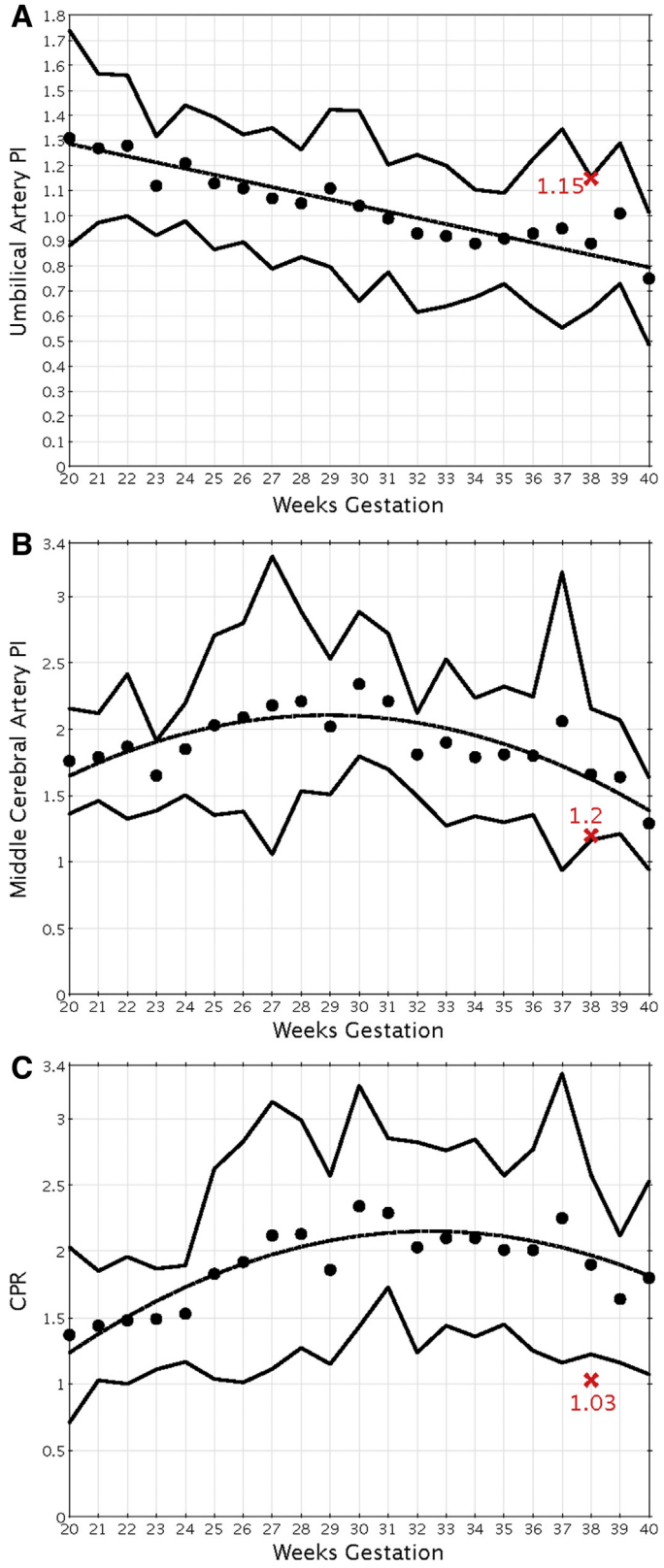
FIGURE 2
Fetus with several abnormalities



This is an example of a fetus with **A,** a high but normal PI of the umbilical artery, **B**, low but normal PI of the middle cerebral artery, and **C,** an abnormal cerebroplacental ratio below the fifth centile (*red*). Each graph illustrates the raw data for the mean (*dots*) and 95th and fifth centiles (*solid lines*). The *dotted line* is the mean of the regression line. The reference ranges are from a study by Baschat and Gembruch.[9]

CPR, abnormal cerebroplacental ratio.

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classification by birthweight has failed as a discriminator within this group for fetal and neonatal complications. It would appear from the studies reviewed in this paper that an abnormal CPR might be a powerful identifier for adverse pre- and postnatal outcomes in fetuses with early-onset SGA and should be included as part of the prenatal ultrasound evaluation.

Which CPR measurement is the best predictor of adverse outcome?

In 2014, Flood et al[30] reported results from 881 fetuses with early-onset SGA that were examined for a composite of adverse outcomes that included intraventricular hemorrhage, periventricular leukomalacia, hypoxic ischemic encephalopathy, necrotizing enterocolitis, bronchopulmonary dysplasia, sepsis, and death. They computed the sensitivity and specificity for adverse outcome using the following thresholds for an abnormal CPR: PI less than 1, RI less than 1, PI less than 1.08[5,6,10,29] and the fifth centile from 1 cross-sectional[9] and 1 longitudinal study (Table 1).[11] They determined that the ratios had lower sensitivities but higher specificities, whereas values less than the fifth centiles had higher sensitivities but lower specificities (Table 4).

The clinical application of CPR evaluation during the third trimester of pregnancy

Given the data reviewed in this paper, there are several questions that clinicians might consider.

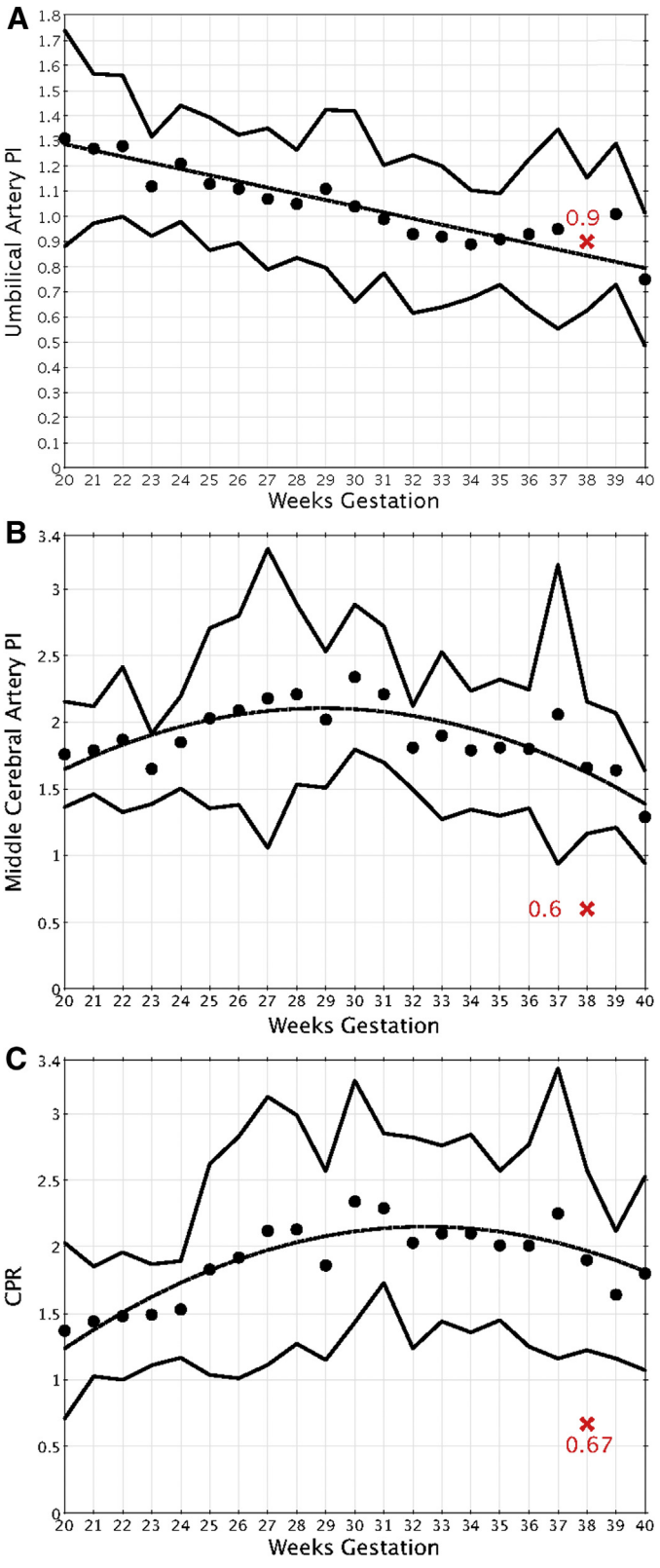
1. Which CPR reference should be used to determine an abnormal value?

Table 1 lists the studies and cutoff values to identify an abnormal CPR. In the earlier studies, investigators determined the threshold for an abnormal CPR from their respective control groups.[5,6,8] After the publication by Bashat and Gembruch[9] in 2003, which provided the mean and SD for the UA, MCA, and CPR, Figueras et al,[27] Flood et al,[30] and Cruz-Martinez et al,[26] used this dataset to determine abnormal values for their studies. Flood et al[30] compared the sensitivity and specificity of ratios and gestational age-related fifth centile cutoffs to determine the abnormality of the CPR (Table 4).

Several authors have also reported using the multiple of the median (MoM) (Table 1).[8,12,31] Other than using the ratios of less than 1 and less than 1.08, computation of gestational age-related centiles and MoM requires off-line computing unless the equations are part of an online software program incorporated into the ultrasound machine.

Depending on the clinical setting, the clinician may use the PI , RI, or the S/D CPR ratios of less than 1 or the PI CPR ratio of less than 1.08 because these are easy computations (Table 1). If serial examinations of the CPR are performed to track the trends, the longitudinal study reported by Ebbing et al[11] should be considered. For those desiring to evaluate all options, an Excel spreadsheet of the computations listed in Table 1 that

FIGURE 3
Fetus with other abnormalities



This is an example of a fetus with **A,** a normal PI of the umbilical artery, **B**, abnormal low PI of the middle cerebral artery, and **C,** an abnormal CPR below the fifth centile (*red*). Each graph illustrates the raw data for the mean (*dots*) and 95th and fifth centiles (*solid lines*). The *dotted line* is the mean of the regression line. The reference ranges are from a study by Baschat and Gembruch.[9]

CPR, cerebroplacental ratio; *SGA*, small for gestational age; *PI*, pulsatility index.

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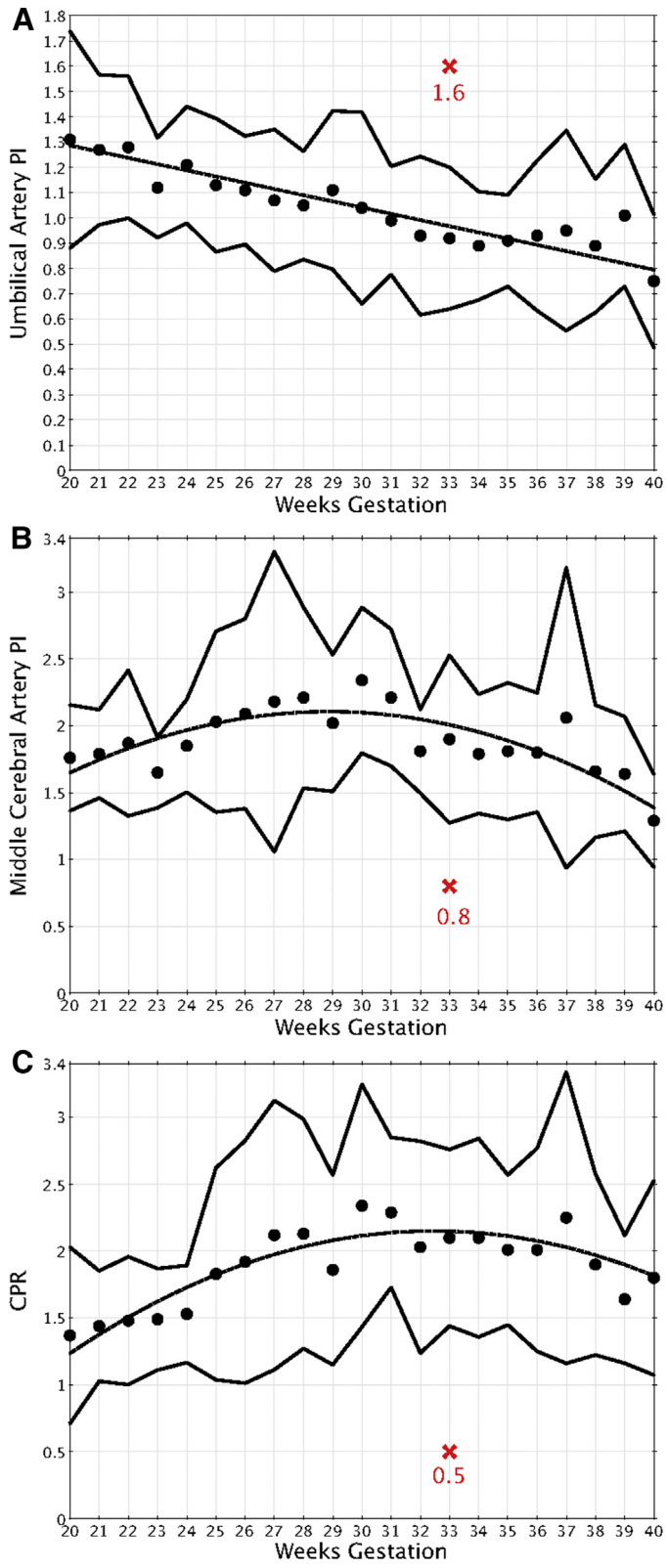
FIGURE 4
Fetus with an elevated PI of the UA, low PI of the MCA, and an abnormal CPR



This is an example of a fetus with **A,** an elevated PI of the umbilical artery, **B,** low PI of the middle cerebral artery, and **C,** an abnormal CPR below the fifth centile (*red*). Each graph illustrates the raw data for the mean (*dots*) and 95th and fifth centiles (*solid lines*). The *dotted line* is the mean of the regression line. The reference ranges are from a study by Baschat and Gembruch.[9]

CPR, cerebroplacental ratio; *MCA*, middle cerebral artery; *PI*, pulsatility index; *SGA*, small for gestational age; *UA*, umbilical artery.

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includes the ratios and computation of gestational age-related centiles is provided for the reader at ajog.org.

2. Should the CPR be used to detect fetuses with early-onset and late-onset SGA?

When the clinician assesses the fetal weight and gestational age using diagnostic ultrasound, fetuses are classified as early-onset SGA, late-onset SGA, or AGA. Once SGA is detected, the question is whether there is an increased risk for adverse outcome. Using pulsed Doppler to measure the UA and MCA and computing the CPR, fetuses at higher risk for adverse outcomes may be detected. This is particularly useful if the sonologist is confronted with patients who have entered the health care system in the third trimester and have a discrepancy between the gestational age by last menstrual period and the ultrasound gestational age (Figure 1). If the CPR ratio is abnormal, the sonologist has to strongly consider SGA and incorrect gestational age assignment using the last menstrual period.

3. Is there a role for late third-trimester evaluation of all fetuses, given the ability to detect AGA fetuses whose weights are greater than the 10th centile but are at risk for adverse outcome because of an abnormal CPR?

Studies summarized in this paper have demonstrated that AGA fetuses have a higher incidence of adverse

TABLE 2
Comparison of findings at birth and adverse neonatal outcomes in term fetuses with normal vs CPRs

Variable	Cruz-Martinez et al (2011)[26]	Prior et al (2013)[19]	Figueras et al (2014)[27]	Morales-Rosello et al (2015)[20]	Khalil et al (2015)[17]	Khalil et al (Part I) (2015)[18]
Type of study	Prospective	Prospective	Prospective	Retrospective	Retrospective	Retrospective
Purpose of study	Evaluate CPR to predict emergency cesarean delivery for fetal distress in term fetuses with late-onset SGA	Evaluate CPR obtained before labor to detect fetuses at risk for emergency cesarean delivery for fetal distress	Develop an integrated model to predict adverse outcome in fetuses with late-onset SGA	Determine whether SGA and appropriate-for-gestational-age term fetuses with a CPR have worse neonatal acid–base status than those with a normal CPR	Compare CPR and EFW at term to detect NICU admission when CPR obtained during midthird trimester	Evaluate CPR and birthweight models in term fetuses to predict operative delivery for fetal compromise and admission to the NICU
Gestational weeks ultrasound studies were obtained	>37	37–42	34–40	37–41.9	34^{+0} to 35^{+6}	>37
Classification and number of fetuses studied, n, %	Control (n = 210), suspected SGA (n = 210)	Low-risk patients (n = 400)	No control SGA (n = 509)	All patients (n = 2927), SGA (n = 640, 25.8%)	All patients (n = 2485) SGA (n = 640, 25.8%)	All patients (n = 8382) SGA (n = 1282, 15.3%)
Interval from ultrasound to delivery	Induction after 37 wks	Examined within 72 h of delivery	Not stated	Up to 2 wks	Up to 6 wks	2 wks
Type of CPR measurement (abnormal Value)	PI less than fifth centile[9]	PI <10th centile (<1.24)	PI (<10th centile)[9]	PI MoM <0.6765	PI MoM <0.6765	PI MoM <0.6765
Did CPR perform better than other tests?	Yes (MCA)	Yes (UA, MCA)	No (CPR combined with UtA PI >95th centile and EFW less than third centile)	Yes (birthweight)	Yes (EFW, birthweight centile)	Yes (birthweight centile)
Findings at birth: classification by abnormal vs normal CPR						
Weeks of gestation at delivery	—	40^{+5} vs 40^{+3} ($P < .004$)	38.1 vs 38.5 (not significant)	—	—	—
Mean birthweight, g	—	Not significant	2280 vs 2466 ($P < .001$)	—	—	—
Birthweight centile, n,%	—	48 vs 55 ($P = .04$)	—	—	—	—
Abnormal fetal heart rate monitoring during labor	—	86% vs 31% ($P < .001$)	—	—	—	—
Operative delivery for fetal distress (cesarean delivery, instrumental delivery)	CPR less than fifth: 37.8% (14/37) CPR more than fifth: 20.4% (29/142) ($P < .001$)	36.4% vs 10.1% ($P < .001$)	79.1% vs 10.7% ($P < .001$)	—	—	13.1% vs 9.4% ($P < .01$)

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(continued)

TABLE 2
Comparison of findings at birth and adverse neonatal outcomes in term fetuses with normal vs CPRs *(continued)*

Variable	Cruz-Martinez et al (2011)[26]	Prior et al (2013)[19]	Figueras et al (2014)[27]	Morales-Rosello et al (2015)[20]	Khalil et al (2015)[17]	Khalil et al (Part I) (2015)[18]
Neonatal findings: classification by abnormal vs normal CPR						
Meconium stained liquor	—	22.7% vs 9% ($P = .02$)		—	—	—
Apgar <7 at 5 minutes	—	Not significant	0.7% vs 1.3% (not significant)	—	—	—
Abnormal cord pH	—	Not significant	UA 7.17 vs 7.25 ($P < .001$)	UA and UV	—	—
Newborn intensive care unit admission	—	Not significant			All patients 12.6% vs 6.1% ($P <$ .001) SGA 22.5% vs 8.4% ($P <$ .001) AGA 9.8% vs 5.5% Not significant	14.3% vs 9.7% ($P = .004$)
Neonatal complications	—	Not significant	11.25% vs 5.6% ($P =$ .03)	—	—	—

AGA, appropriate for gestational age; *CPR*, abnormal cerebroplacental ratio; *EFW*, ultrasound estimated fetal weight; *MCA*, middle cerebral artery; *MoM*, multiple of the median; *NICU*, newborn intensive care unit; *PI*, pulsatility index; *SGA*, late-onset small for gestational age; *UA*, umbilical artery; *UV*, umbilical vein.

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outcome when they have an abnormal CPR. Because these fetuses may not be identified using traditional clinical tools such as fundal height measurements, evaluation of the amniotic fluid, or antepartum testing, the question has to be asked whether it would be prudent to consider routine late third-trimester evaluation of growth as well as measurement of the CPR? Although routine third-trimester ultrasound is more common in European and other countries, it is not routine practice in North America.

Given the findings of the studies cited in this paper, the data would suggest that third-trimester routine ultrasound might be of value for identifying those fetuses at risk for adverse outcome during labor and subsequent neonatal complications.

For some clinicians, the data reported in this paper may be sufficient to integrate this approach into clinical practice. For others, further studies may be required before this becomes the standard practice. Although third-party payers do not reimburse the clinician for evaluation for the MCA unless fetal anemia is suspected, acquiring the Doppler waveform takes less than a few minutes and may be advantageous when detecting fetuses at increased risk for adverse outcome.

4. Should CPR be a component part of antepartum testing?

In studies reported by Makhseed et al[28] and Ebrashy et al,[29] they found that CPR identified more fetuses with adverse outcome than did the biophysical profile. Because the cost of ultrasound equipment is decreasing, portable ultrasound machines can be purchased for less than $15,000, and these machines allow the clinician to use color Doppler to identify the UA and MCA and acquire pulsed Doppler waveforms in which the UA and MCA PI and are automatically measured and the CPR computed as described in Table 1. Although further studies may be considered before this becomes accepted protocol, clinicians might consider this as an option to refine the predictability of adverse outcome in

TABLE 3
Studies evaluating the CPR as a diagnostic tool in fetuses with predominantly early-onset fetal growth restriction (SGA)

Variable	Gramellini et al (1992)[5]	Arias et al (1994)[6]	Bahado-Singh et al (1999)[8]	Makhseed et al (2000)[28]	Ebrashy et al (2005)[29]	Flood et al (2014)[30]
Type of study	Retrospective	Prospective	Prospective	Prospective	Prospective	Retrospective
Purpose of the study	Compare CPR, UA, and MCA to predict adverse outcome in SGA	Evaluate CPR to predict adverse outcome in SGA	Evaluate CPR to predict adverse outcome in SGA	Compare CPR and UA to predict adverse outcome in SGA	Evaluate CPR to predict adverse outcome in women with preeclampsia	Evaluate CPR to predict adverse outcome in SGA
Gestational weeks ultrasound studies were obtained	30–41	24–38	<34	29–42	>28	29–36
Classification and number of fetuses studied (n)	Control (n = 45), SGA (n = 45)	Control (n = 25), risk SGA (n = 61)	Control (n = 82), risk SGA (n = 125)	No control, SGA (n = 70)	Control (n = 30), SGA (n = 38)	No control, SGA (n = 881)
Interval from ultrasound to delivery	Not stated	<2	<3	3.8–8.6	Not stated	32–42
Type of CPR measurement (abnormal value)	PI (<1.08)	RI (<1.0)	MoM (<0.5)	RI (<1.05)	RI (<1.0)	RI (<1); PI (<1, <1.08); PI (less than fifth centile[9]) PI (less than fifth centile[11])
Did CPR perform better than other tests?	Yes (UA and MCA)	Yes (UA and MCA)	Yes (UA)	Yes (BP, AEDV of UA)	Yes (BP, UA, MCA)	Equal (UA)
Findings at birth: classification by abnormal vs normal CPR						
Weeks of gestation at delivery	34.9 vs 39.4 ($P < .001$)	—	31.6 vs 35.7 ($P < .0001$)	35.4 vs 37.3 ($P < .05$)	—	34.6 vs 38.3 ($P < .001$)
Mean birthweight, g	1659 vs 3031 ($P < .001$)	—	1138 vs 2098 ($P < .0001$)	1835 vs 2351 ($P < .0001$)	—	1763 vs 2611 ($P < .0001$)
Birthweight <10th centile	100% ($P < .001$)	45.4% vs 7.6% ($P < .001$)	94.4% vs 57.5% ($P < .001$)	—	—	—
Cesarean delivery for fetal distress	88.8% vs 12.5% ($P < .05$)	86.3% vs 51.2% ($P = .01$)	41.7% vs 13.8% ($P < .01$)	65.7% vs 42.9% ($P < .05$)	—	—
Neonatal findings: classification by abnormal vs normal CPR						
Apgar <7 at 5 min	16.6% vs 2.7% ($P < .001$)	—	Not significant	Not significant	Relative risk 1.4 ($P < .05$)	—
Abnormal cord pH	UV 7.25 vs 7.33 ($P < .001$)	—	—	—	—	—
Newborn intensive care unit admission	77.7% vs 11.1% ($P < .001$)	26 d vs 14.5 d ($P = .03$)	77.8% vs 41.4% ($P < .001$)	74.3% vs 31.4% ($P < .001$)	Relative risk 1.4 ($P < .05$)	64% vs 22% ($P < .0001$)
Neonatal complications	33.3% vs 1.38% ($P < .001$)				Relative risk 1.4 ($P < .05$)	18% vs 2% ($P < .001$)

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TABLE 3
Studies evaluating the CPR as a diagnostic tool in fetuses with predominantly early-onset fetal growth restriction (SGA) *(continued)*

Variable	Gramellini et al (1992)[5]	Arias et al (1994)[6]	Bahado-Singh et al (1999)[8]	Makhseed et al (2000)[28]	Ebrashy et al (2005)[29]	Flood et al (2014)[30]
Brochopulmonary dysplasia	—	—	1.7% vs 1.1% ($P < .01$)	—	—	—
Necrotizing enterocolitis	—	—	Not significant	—	—	—
Perinatal death	—	18% vs 0% ($P < .05$)	8.3% vs 0% ($P < .05$)	—	—	2% vs 0% ($P < .0001$)

AEDV, absent end-diastolic flow; *BP*, biophysical profile; *CPR*, abnormal cerebroplacental ratio; *EFW*, ultrasound estimate of fetal weight; *MCA*, middle cerebral artery; *MoM*, multiple of the median; *PI*, pulsatility index; *RI*, resistance index; *SGA*, small for gestational age; *UA*, umbilical artery; *UtA*, uterine artery.

DeVore. Cerebroplacental ratio in fetal well-being in SGA and AGA fetuses. Am J Obstet Gynecol 2015.

TABLE 4
Sensitivities, specificities, and odds ratio for CPR computations for detecting adverse perinatal outcome[a30]

Cerebroplacental ratio	Measurement standard	Sensitivity	Specificity	Odds ratio
<1	Pulsatility index	66%	85%	11.7
<1	Resistance index	66%	84%	11.8
Less than fifth centile (cross-sectional study)[9]	Centile	80%	60%	6.2
Less than fifth centile (longitudinal study)[11]	Centile	85%	41%	4.1

CPR, abnormal cerebroplacental ratio.

[a] Intraventricular hemorrhage, periventricular leukomalacia, hypoxic ischemic encephalopathy, necrotizing enterocolitis, bronchopulmonary dysplasia, sepsis, and death.

DeVore. Cerebroplacental ratio in fetal well-being in SGA and AGA fetuses. Am J Obstet Gynecol 2015.

high-risk fetuses undergoing antepartum testing. A CPR calculator is available at http://www.ajog.org/pb/assets/raw/Health%20Advance/journals/ymob/CPR/index.htm. ■

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