J Surg Med. 2020;4(12):1169-1172.
DOI: 10.28982/josam.829499

Research article
Araştırma makalesi

Journal of Surgery and Medicine
e-ISSN=2602-2079

Evaluation of cerebroplacental ratio as a new tool to predict adverse perinatal outcomes in patients with isolated oligohydramnios

Serebroplasental oranın izole oligohidroamniyoslu hastalarda kötü perinatal sonuçların öngörülmesindeki yeri

Emre Destegül [1], Hatica Akkaya [2], Barış Büke [3], Güliz Gürer [4]

[1] Nigde Omer Halisdemir University Medical Faculty Training and Research Hospital Department of Obstetrics and Gynecology, Nigde, Turkey
[2] Ankara City Hospital Training and Research Hospital, Department of Obstetrics and Gynecology, Ankara, Turkey
[3] Private BB, Obstetric & Gyneocology Clinic, İzmir, Turkey
[4] Nigde Omer Halisdemir University Medical Faculty Training and Research Hospital Department of Pediatrics, Nigde, Turkey

ORCID ID of the author(s)
ED: 0000-0001-5726-0223
HA: 0000-0002-9613-1712
BB: 0000-0001-8761-2023
GG: 0000-0003-2922-430X

Corresponding author/Sorumlu yazar:
Emre Destegül
Address/Adres: Niğde Ömer Halisdemir Üniversitesi Rektörlüğü, Merkez Kampüs, Bor Caddesi, Kadın Hastalıkları ve Doğum Anabilim Dalı, Niğde, 51240, Türkiye
E-mail: destegulemre@hotmail.com

Ethics Committee Approval: This study was approved by Kayseri University Ethical Committee (03.10.2018 / 2018-455). All procedures in this study involving human participants were performed in accordance with the 1964 Helsinki Declaration and its later amendments.
Etik Kurul Onayı: Bu çalışma Kayseri Üniversitesi Etik Kurulu (03.10.2018 / 2018-455) tarafından onaylanmıştır. İnsan katılımcıların katıldığı çalışmalardaki tüm prosedürler, 1964 Helsinki Deklarasyonu ve daha sonra yapılan değişiklikler uyarınca gerçekleştirilmiştir.

Conflict of Interest: No conflict of interest was declared by the authors.
Çıkar Çatışması: Yazarlar çıkar çatışması bildirmemişlerdir.

Financial Disclosure: The authors declared that this study has received no financial support.
Finansal Destek: Yazarlar bu çalışma için finansal destek almadıklarını beyan etmişlerdir.

Published: 12/30/2020
Yayın Tarihi: 30.12.2020

Abstract

Aim: There is conflicting information in the literature regarding perinatal outcomes and management of isolated oligohydramniotic (IO) pregnancies. Recent studies show that IO is associated with poor perinatal outcomes. However, there is still no definitive method for deciding the optimal delivery timing for these patients. In this study, we aimed to assess the relationship between Doppler parameters, especially cerebro-placental ratio, and perinatal outcomes in isolated oligohydramnios (IO) patients.

Methods: This prospective case control study was conducted between October-November 2018. A total of 98 patients were recruited and divided into two groups, as pregnant women with normal amounts of amniotic volume and the isolated oligohydramnios group. Oligohydramnios diagnosis was made by amniotic fluid index measurement (AFI<5 cm). Pregnancies with hypertension, fetal growth restriction, thrombophilia, preeclampsia, diabetes mellitus, preterm births and chromosomal/structural abnormalities were excluded. Cerebro placental ratios of groups were compared in terms of composite adverse outcomes, low APGAR score in 1st and 5th minutes, C/S operation due to non-reassuring fetal heart rate patterns, admission to neonatal intensive care unit and still births.

Results: In the isolated oligohydramnios group (n=45) cerebro-placental ratio (CPR) was lower compared to control group (P<0.001). IO was associated with lower (APGAR score<7) 1st (55.6% vs. 7.5%, P<0.001) and 5th (13.3% vs. 1.9% P=0.028) minute APGAR scores and higher rates of NICU admission (26.7% vs. 3.8% P=0.001). Number of fetal distress cases was higher in patients with low CPR in the IO group (9 vs. 6 P=0.023).

Conclusion: Measurement of CPR among IO patients seems useful for detection of fetuses with higher risk for poor neonatal outcomes.

Keywords: Cerebroplacental ratio, CPR, Isolated oligohydramnios, Perinatal outcome, Fetal Doppler

Öz

Amaç: İzole oligohidramniotik (IO) gebeliklerin perinatal sonuçları ve yönetimi ile ilgili literatürde hala çelişkili bilgiler mevcuttur. Son çalışmalarda ise IO'nun kötü perinatal sonuçlar ile ilişkili olduğu yönündedir. Yine de bu hastaların optimal doğum zamanlamasına karar vermek için elimizde hala kesin bir yöntem bulunamamaktadır. Biz de çalışmamızda IO hastalarında Doppler parametreleri, özellikle serebro-plasental oran ve perinatal sonuçlar arasındaki ilişkiyi değerlendirmektir.

Yöntemler: Bu prospektif vaka kontrol çalışması Ekim-Kasım 2018 arasında gerçekleştirildi. Çalışmaya 98 hasta dahil edilmiştir. İzole oligohidroamnios ve normal amnion miktarı olan gebeler grubu olmak üzere iki gruba ayrıldı. Oligohidramnios tanısı amniyotik sıvı indeksi ölçümü ile konuldu (AFI <5 cm). Hipertansiyon, intrauterin büyüme kısıtlılığı, trombofili, preeklampsi, diyabet ve kromozomal / yapısal anormallikleri olan gebelikler çalışma dışı bırakıldı. Gruplar cerebroplasental oran (CPR) ölçümleri göz önüne alınarak; kompozit advers sonuçlar, 1. ve 5. dakikalarda düşük APGAR skoru, güven verici olmayan fetal kalp hızı paternlerine bağlı sezaryen (C/S) operasyonu, yenidoğan yoğun bakım ünitesine yatışı ve ölü doğumlar bakımından karşılaştırıldı.

Bulgular: CPR <1,08 olan hastalarda fetal distress görülme oranı daha yüksekti (9'a karşı 6 P=0,023). İzole oligohidramnios grubunda (n=45) CPR kontrol grubuna göre daha düşük saptandı. Ayrıca IO, daha düşük (APGAR <7) 1. (%55,6 ve %7,5, P<0.001) ve 5. (%13,3 ve %1,9, P=0,028) dakika APGAR skorları ve daha yüksek YYBÜ kabul oranları ile (%26,7 ve %3,8, P=0,001) ilişkili idi.

Sonuç: CPR ölçümü, IO hastalarında kötü neonatal sonuçlar açısından daha yüksek risk taşıyan fetüslerin saptanmasında yararlı görünmektedir.

Anahtar kelimeler: Serebroplasental oran, CPR, İzole oligohidramnios, Perinatal sonuç, Fetal Doppler

How to cite/Atıf için: Destegül E, Akkaya H, Büke B, Gürer G. Evaluation of cerebroplacental ratio as a new tool to predict adverse perinatal outcomes in patients with isolated oligohydramnios. J Surg Med. 2020;4(12):1169-1172.

Introduction

The amniotic fluid volume being less than expected for gestational age is defined as oligohydramnios. Its incidence at term pregnancies ranges between 0.5-5% depending on measurement methods, patient population, and gestational age (GA) [1,2]. Definition of oligohydramnios is mostly performed by amniotic fluid index (AFI) <5cm and single deepest pocket (SDP) <2 cm. Adequate amniotic fluid is important for normal fetal growth, fetal lung development, and for protecting the fetus and umbilical cord from trauma.

Various conditions such as premature rupture of membranes, placental dysfunction, chromosomal and congenital abnormalities, and medications can cause oligohydramnios, or it may be isolated. It is well known that oligohydramnios, regardless of its etiology (except isolated oligohydramnios), is related to increased adverse perinatal outcomes, such as low APGAR scores, neonatal intensive care unit admission (NICU), meconium presence in amniotic fluid, meconium aspiration syndrome (MAS), and increased cesarean section ratings due to fetal distress [3-12].

Although data about the importance of isolated oligohydramnios (IO) in the literature is controversial, last reviews showed an increase in adverse perinatal adverse outcomes such as increased cesarean delivery rates, low APGAR scores, and a higher rate of NICU admission [13-25].

Routine Antenatal Imaging with Ultrasound (RADIUS) trial reported that in IO patients, fetal growth did not deteriorate, but placental insufficiency could be present, even with growth percentiles higher than 10% [26]. Furthermore, Locatelli and colleagues reported an underlying fetal growth retardation in 13.2% of pregnancies with IO, which could not be detected before delivery [14].

On the other hand, The American College of Obstetricians and Gynecologists (ACOG) pointed out in 1999 that insufficient data was present for labor induction in IO. Therefore, ACOG did not declare a definitive statement regarding the optimal timing of delivery [27]. Despite this information, when an IO diagnosis is made in term pregnancies (beyond 37 weeks of GA) clinicians almost always lean towards induction of labor [28].

Evaluation of fetal vascular structures, maternal uterine artery circulation and amniotic fluid is widely used in the assessment of fetal well-being in contemporary obstetric practice. Umbilical artery (UA), middle cerebral artery (MCA), ductus venosus doppler have been used so far for assessment of fetal status. The cerebro placental ratio (CPR), which was reported first in 1987 [29], represents the alteration of the blood flow towards the brain due to cerebrovascular dilatation. Also, an increase in placental bed resistance and decreased diastolic flow in the umbilical artery contribute to CPR. CPR can be calculated as MCA resistance index (RI) divided by UA resistance index or MCA pulsatility index (PI) divided by UA pulsatility index. We know that CPR measurement is more valuable than UA and MCA Doppler in pregnancies with fetal growth restriction (FGR) [30]. Also, near-term, detection of potential FGR can be difficult because of the imprecise evaluation of the fetal weight due to intra and inter-observer variability [31]. Detection of acute hypoxia with CPR is the most useful parameter [32].

In this study, we aimed to assess the CPR changes in IO patients, because research seems lacking in this area.

Materials and methods

This prospective case-control study was held in a University hospital between October - November in 2018. After approval of study by the local ethics committee (Kayseri Erciyes University Medical Faculty Ethics Committee, approval ID no: 2018/455), each participant was informed, and consent was obtained. The study population was recruited from 37-40 gestational weeks singleton, isolated oligohydramniotic pregnant women (IO group) based on the last menstrual period and gestational age, gravida, parity, body mass index-matched pregnant women with normal amounts of amniotic fluid volume according to her gestational age (control group). All recruited patients were examined before active labor (cervical dilatation ≤4cm). Patients who gave birth in three days after the fetal Doppler measurement were included in the study. Fetuses with chromosomal/structural abnormalities and fetal growth restriction, pregnancies with ruptured membranes, multiple gestations, fetal placental, and umbilical cord abnormalities, Rh isoimmunization, patients with maternal systemic disease, pregnancy-induced hypertension, pregestational or gestational diabetes, prior cesarean section, preterm and post-term pregnancies were excluded.

All the participants underwent an ultrasound examination performed by an experienced clinician (E.D.). Obstetric and general health data of each patient were also recorded.

Doppler ultrasound examinations were performed using a Mindray DC-7 ultrasound machine (Shenzhen Mindray Bio-Medical Electronics Co., China), equipped with a 3,5-MHz convex array sector transducer, taking into consideration fetal movements, and breathing periods. After fetal ultrasound examination of fetal middle cerebral artery (MCA), and umbilical artery (UA), pulsatility index, systolic-to-diastolic ratio (S/D), peak systolic velocity (PSV) of MCA were measured and recorded. Amniotic volume was measured with a four-quadrant amniotic fluid index technique and AFI ≤5 cm was considered oligohydramnios. IO group and control group were compared in terms of fetal CPR and adverse perinatal outcomes.

Statistical analysis

The SPSS for Windows 21.0 (SPSS Inc.IL, USA) software was used for statistical analyses. *P*-value <0.05 was considered statistically significant. The Shapiro-Wilk test was used to assess the normality of distribution of variables. Normally distributed variables were expressed as mean (SD). Comparisons of variables between the groups were performed by independent samples t-test, Mann– Whitney U test, and Chi-square test.

Results

A total of 98 women who met the inclusion criteria were recruited for the study. Comparison of both groups' demographic and fetal Doppler parameters was shown in Tables 1 and 2. The demographic features of both groups were similar, but perinatal

adverse outcomes were significantly higher in the IO group. The mean maternal age of the whole study population was 27.3 (5.9) years. Twenty-seven of 98 pregnant women (27.6%) were on their first pregnancy, while 71 (72.4%) women were on their second or more pregnancy. The average gestational age of inclusion in the study was 38.3 (1.05) weeks according to the last menstrual period (LMP) (Table 1).

Comparison of all Doppler indices showed a statistical difference between the groups (UA PI P=0.014, UA S/D P=0.01, MCAPI P=0.004, MCA PSV P=0.037 and CPR P<0.001) (Table 2). Patients with low fetal biophysical profiles (BPP≤4) and impaired CPR (CPR <1.08) showed a significant correlation among themselves (r=0.23 positive correlation P=0.02, Spearman Rho test). The coexistence of low BPP scores and low CPR levels in the IO group resulted in a significant increase in C/S rates due to fetal distress (Table 3). Also, there was a significant correlation between low CPR and fetal distress among the groups (r= 0.035, P<0.001). In patients with low BPP in the IO group, the CPR levels of 7 patients were higher than 1.08, while 8 patients' CPR was <1.08 (P=0.078). Statistical results showed significant differences between the groups in terms of 1st and 5th minute APGAR scores and admission to NICU. In both groups, patients with low BPP scores were associated with lower 1st and 5th minute APGAR scores (r=0.40 p <0.001, r=0.32 P=0.001 respectively), higher fetal distress (r=0.34 P=0.001) and C/S rates (r=0.25 P=0.013) (P=0.023). No stillbirth or neonatal deaths were observed in any of the groups.

Table 1: Maternal demographic and obstetric features of the whole study population

Characteristics	Oligohydramnios group n=45	Control group n=53	*P*-value
Maternal age(year)*	26.4(5.48)	28.1(6.23)	0.15
Gestational age(week)**	37.2(1.9)	37.5(1.8)	0.2
Gravida**	1.98(0.9)	2.24(0.97)	0.15
Parity**	0.82(0.8)	0.87(0.83)	0.81
BMI (kg/m^2)*	27.01(4.7)	27.18(4.4)	0.85
Gender male†	28(62.2%)	25(47.2%)	0.13
Induction and/or augmentation of labor (oxytocin) †	12(26.7%)	17(32.1%)	0.55
Mode of delivery C/S†	20(44.4%)	16(30.2%)	0.14
Fetal distress (emergency C/S)	15(33.3%)	5(9.4%)	0.003
NICU admission rate	12(26.7%)	2(3.8%)	0.001
1-min Apgar score ≤7†	25(55.6%)	4(7.5%)	<0.001
5-min Apgar score ≤7†	6(13.3%)	1(1.9%)	0.028
Birth weight (g)*	3132(307)	3222(373)	0.21
Birth length (cm)	49.2(1.4)	48.9(2.04)	0.4

* Independent Sample t Test, ** Mann-Whitney u test, † Chi -Square test

Table 2: Fetal Doppler indices of the whole study population

Characteristics	Oligohydramnios group n=45	Control group n=53	*P*-value
Umbilical artery S/D*	2.64(0.61)	2.38(0.37)	0.01
Umbilical artery PI**	0.84(0.17)	0.76(0.13)	0.014
MCA PI*	1.50 (0.39)	1.74(0.44)	0.004
MCA PSV(cm/s)*	69.2(14.2)	63.1(14.6)	0.037
Cerebro Placental Ratio**	1.99(1.6)	2.34(0.70)	<0.001
Amniotic Fluid Index*	36.8(7.17)	101.3(41.2)	<0.001
Biophysical profile ≤4 (n, %)	15(33.3%)	7(13.2%)	0.017

S/D: Systole/ Diastole PI: Pulsatility index PSV: Peak systolic velocity CPR: Cerebro-Placental Ratio

Table 3: Relationship between CPR and BPP in oligohydramnios group

Oligohydramnios group	CPR ≤1.08	CPR >1.08	*P*-value
*BPP≤4	8	7	0.078
BPP>4	8	22	
Apgar1st Min. ≤7	9	16	0.94
Apgar1st Min. >7	7	13	
Fetal distress (+)	9	6	0.023
Fetal distress (-)	7	23	

* Biophysical profile

Discussion

In this prospective case-control study, we found that patients with low CPR levels were more likely to have a cesarean section (C/S) for non-reassuring fetal heart rates (NRFHR) in the IO group, and poor perinatal outcomes, such as low 1st and 5th minutes APGAR scores and a higher number of admissions to NICU.

In the literature review, perinatal outcomes of fetuses with IO have conflicting results. A meta-analysis made by Rossi and Prefumo in 2013 showed no significant differences concerning perinatal outcomes, except a rise in C/S rates due to NRFHR [19], which did not lead to an increased low incidence of APGAR scores, low umbilical artery pH, NICU admissions, or mortality compared to pregnancies with normal amniotic fluid. Also, they did not find any increase in meconium-stained amniotic fluid, which is another conflicting issue in oligohydramnios. The other two studies revealed similar results. In one of them, Karahanoglu et al. [33] investigated the optimal timing of delivery for IO patients. They stratified the patients as early term, full-term, and late-term, and analyzed the perinatal outcomes to find no differences in terms of NICU admission, low APGAR score, and low cord pH. However, this study had two limitations, one being its retrospective nature and the other, the lack of a control group. In the second study, which was also retrospectively designed, Naveiro-Fuentes et al. [34] stated that IO was not associated with poor perinatal outcomes, except for fetuses with SGA.

On the other hand, the recent two meta-analyses reported a relationship between IO and poor perinatal outcomes. In 2016, Shrem et al. [25] showed higher C/S rates due to NRFHR, lower 1st, and 5th minute APGAR scores, and more admission to NICU in the IO group compared to pregnancies with normal amniotic fluid, similar to our study. Another meta-analysis was performed by Rabie et al. [24] in 2017, which also reported results parallel to ours: Low APGAR score in 5th minute and higher C/S rates due to NRFHR. They also found an increase in meconium aspiration syndrome which we did not assess. In another study, Casey et al. [8] reported higher stillbirth rates in the IO group. We did not observe any stillbirth, but this may have resulted from a relatively small sample size of the cohort.

In 2017, Khalil et al. [35] demonstrated that low CPR is significantly associated with impaired fetal growth and poor neonatal outcomes, even in appropriate for gestational age (AGA) fetuses. They stated that low CPR is a biometric marker of failure to reach growth potential even in AGA fetuses (≥ the 10th percentile). Also, several studies have been reported a relationship between low CPR and adverse outcomes in low risk and/or AGA pregnancies [36-44]. In 2018, Kalafat and Khalil published a review about the utility of CPR in SGA and AGA fetuses, and they underlined the importance of close intrapartum surveillance of AGA fetuses due to the risk of fetal intrapartum compromise and operative delivery [45].

In the present study, further evaluation of fetal well-being status was also performed with a biophysical profile (BPP). Fetuses with low BPP (BPP≤4) had more C/S rates due to NRFHR and lower 1st and 5th minute APGAR scores. These results were consistent with the literature [46,47]. Moreover, CPR levels were positively correlated with BPP scores. We think that these results may be related to an unrecognized subtle placental insufficiency in IO.

Limitations

Although our study is the first on this subject, several limitations remain. The main limitation of our study is the relatively small size of the cohort. Secondly, we did not assess umbilical cord pH alterations and the existence of meconium-stained amniotic fluid among the groups to evaluate the poor neonatal outcome.

Conclusion

As mentioned above, the perinatal outcomes of IO are controversial in the literature. Our present study showed an increase in C/S rates due to non-reassuring fetal heart rate patterns, lower 1st, and 5th minute APGAR scores, and higher NICU admission rates in IO patients with low CPR. Since our study is the first to investigate the relationship between IO and CPR, we recommend clinicians to closely follow up IO patients with low CPR levels and BPP scores due to risk of fetal distress and poor neonatal outcomes.

References

1. Hill LM, Breckle R, Wolfgram KR, O'Brien PC. Oligohydramnios: ultrasonically detected incidence and subsequent fetal outcome. Am J Obstet Gynecol. 1983;147:407–10.
2. Mercer LJ, Brown LG, Petres RE, Messer RH. A survey of pregnancies complicated by decreased amniotic fluid. Am J Obstet Gynecol. 1984;149:355–61.
3. Youssef AA, Abdulla SA, Sayed EH, Salem HT, Abdelalim AM, Devoe LD. Superiority of amniotic fluid index over amniotic fluid pocket measurement for predicting bad fetal outcome. South Med J. 1993;86:426–9.
4. Magann EF, Kinsella MJ, Chauhan SP, McNamara MF, Gehring BW, Morrison JC. Does an amniotic fluid index of ≤5 cm necessitate delivery in high-risk pregnancies? A case–control study. Am J Obstet Gynecol. 1999;180:1354–9.
5. Driggers RW, Holcroft CJ, Blakemore KJ, Graham EM. An amniotic fluid index < or =5 cm within 7 days of delivery in the third trimester is not associated with decreasing umbilical arterial pH and base excess. J Perinatol. 2004;24:72–6.
6. Rutherford SE, Phelan JP, Smith CV, Jacobs N. The four-quadrant assessment of amniotic fluid volume: an adjunct to antepartum fetal heart rate testing. Obstet Gynecol. 1987;70:353–6.
7. Magann EF, Chauhan SP, Martin JN Jr. Is amniotic fluid volume status predictive of fetal acidosis at delivery? Aust N Z J Obstet Gynaecol. 2003;43:129–33.
8. Casey BM, McIntire DD, Bloom SL, Lucas MJ, Santos R, Twickler DM et al. Pregnancy outcomes after antepartum diagnosis of oligohydramnios at or beyond 34 weeks' gestation. Am J Obstet Gynecol. 2000;182:909–12.
9. Alchalabi HA, Obeidat BR, Jallad MF, Khader YS. Induction of labor and perinatal outcome: the impact of the amniotic fluid index. Eur J Obstet Gynecol Reprod Biol. 2006;129:124–7.
10. Sultana S, Akbar Khan MN, Khanum Akhtar KA, Aslam M. Low amniotic fluid index in high-risk pregnancy and poor apgar score at birth. J Coll Physicians Surg Pak. 2008;18:630–4.
11. Venturini P, Contu G, Mazza V, Facchinetti F. Induction of labor in women with oligohydramnios. J Matern Fetal Neonatal Med. 2005;17:129–32.
12. Chauhan SP, Sanderson M, Hendrix NW, Magann EF, Devoe LD. Perinatal outcome and amniotic fluid index in the antepartum and intrapartum periods: a meta-analysis. Am J Obstet Gynecol. 1999;181:147.
13. Melamed N, Pardo J, Milstein R, Chen R, Hod M, Yogev Y. Perinatal outcome in pregnancies complicated by isolated oligohydramnios diagnosed before 37 weeks of gestation. Am J Obstet Gynecol. 2011;205:241.e241–241.e246
14. Locatelli A, Vergani P, Toso L, Verderio M, Pezzullo JC, Ghidini A. Perinatal outcome associated with oligohydramnios in uncomplicated term pregnancies. Arch Gynecol Obstet. 2004;269:130–3.
15. Rainford M, Adair R, Scialli AR, Ghidini A, Spong CY. Amniotic fluid index in the uncomplicated term pregnancy. Prediction of outcome. J Reprod Med. 2001;46:589–92.
16. Conway DL, Adkins WB, Schroeder B, Langer O. Isolated oligohydramnios in the term pregnancy: is it a clinical entity? J Matern Fetal Med. 1998;7:197–200.
17. Ashwal E, Hiersch L, Melamed N, Aviram A, Wiznitzer A, Yogev Y. The association between isolated oligohydramnios at term and pregnancy outcome. Arch Gynecol Obstet. 2014;290:875–81.
18. Bachhav AA, Waikar M. Low amniotic fluid index at term as a predictor of adverse perinatal outcome. J Obstet Gynaecol India. 2014;64:120–3.
19. Rossi Ac, Prefumo F. Perinatal outcomes of isolated oli- gohydramnios at term and post-term pregnancy: a systematic review of literature with meta-analysis. eur J Obstet Gynecol reprod Biol. 2013;169(2):149–54.
20. Zhang J, Troendle J, Meikle S, Klebenoff MA, Rayburn WF. Isolated oligohydramnios is not associated with adverse perinatal outcomes. BJOC. 2004;111:220–5.
21. Magann EF, Chauhan SP, Dohorty DA, Barrileaux PS, Martin JR. JN. Predictability of intrapartum and neonatal outcomes with the amniotic fluid volume distribution: a reassessment using amniotic fluid index, single deepest pocket, and a dye-determined amniotic fluid volume. Am J Obstet Gynecol. 2003;188(6):1523–7.
22. Chauhan SP, Cowan BD, Magann EF, Roberts WE, Morrison JC, Martin JR. JN. Intrapartum amniotic fluid index. A poor diagnostic test for adverse perinatal outcome. J reprod Med. 1996;41(11):860–6.
23. Chauhan SP, Hendrix NW, Morrison JC, Magann EF, Devore LD. Intrapartum oligohydramnios does not predict adverse peripartum outcome among high risk parturients. Am J Obstet Gynecol. 1997;176(6):1130–6.
24. Rabie N, Mgann E, Steelman Sand S, Ounpraseuth S. Oligohydramnios in complicated and uncomplicated pregnancy: a systematic review and meta-analysis Ultrasound Obstet Gynecol. 2017;49:442–9.
25. Shrem G, Nagawkar SS, Hallak M, Walfisch A. Isolated oligohydramnios at term as an indication for labor induction: a systematic review and meta-analysis. Fetal diagnosis and therapy. 2016;40(3):161-73.
26. Ewigman BG, Crane JP, Frigoletto FD, LeFevre ML, Bain RP, McNellis D et al. Effect of prenatal ultrasound screening on perinatal outcome. New England journal of medicine. 1993;329(12):821-7.
27. American College of Obstetricians and Gynecologists. ACOG practice bulletin. Antepartum fetal surveillance. Number 9, October 1999. Clinical management guidelines for obstetrician-gynecologists. Int J Gynaecol Obstet. 2000;68:175-85.
28. Scwartz N, Sweeting R, Young BK. Practice patterns in the management of isolated oligo-hydramnios: a survey of perinatologists. J Matern Fetal Neonatal Med. 2009;22:357–36.
29. Arbeille P, Roncin A, Berson M, Patat F, Pourcelot L. Exploration of the fetal cerebral blood flow by duplex Doppler—linear array system in normal and pathological pregnancies. Ultrasound Med Biol. 1987;13:329–37.
30. Cruz-Martinez R, Figueras F, Hernandez-Andrade E, Oros D, Gratacos E. Fetal brain Doppler to predict cesarean delivery for non-reassuring fetal status in term 20 small-for- gestational-age fetuses. Obstet Gynecol 2011;117:618-26.
31. Chang TC, Robson SC, Spencer JAD, Gallivan S. Ultrasonic fetal weight estimation: Analysis of inter- and intra-observer variability. J Clin Ultrasound 1993; 21:515–9.
32. Arbeille P, Maulik D, Fignon A, Stale H, Berson M, Bodard S, et al. Assessment of the fetal PO2 changes by cerebral and umbilical Doppler on lamb fetuses during acute hypoxia. Ultrasound Med Biol. 1995;21:861–70.
33. Karahanoglu E, Akpinar F, Demirdag E, Yerebasmaz N, Ensari T, Akyol A, et al. Obstetric outcomes of isolated oligohydramnios during early-term, full-term and late-term periods and determination of optimal timing of delivery. Journal of Obstetrics and Gynaecology Research. 2016;42(9):1119-24.
34. Naveiro-Fuentes M, Prieto AP, Ruiz RS, Badillo MPC, Ventoso FM, Vellejo JLG. Perinatal outcomes with isolated oligohydramnios at term pregnancy. Journal of perinatal medicine. 2016;44(7):793-8.
35. Khalil A, Morales-Rosello J, Khan N, Nath M, Agarwal P, Bhide, A, et al. Is cerebroplacental ratio a marker of impaired fetal growth velocity and adverse pregnancy outcome? American journal of obstetrics and gynecology. 2017;216(6):606-e1.
36. Chainarong N, Petpichetchian C. The relationship between intrapartum cerebroplacental ratio and adverse perinatal outcomes in term fetuses. Eur J Obstet Gynecol Reprod Biol. 2018;228:82–6.
37. Dall'Asta A, Ghi T, Rizzo G, Morganelli G, Galli L, Roletti E, et al. Early labor cerebroplacental ratio assessment in uncomplicated term pregnancies and prediction of adverse perinatal outcomes: a prospective, multicentre study. Ultrasound Obstet Gynecol. 2019;53(4):481-7.
38. Flatley C, Kumar S. Is the fetal cerebroplacental ratio better that the estimated fetal weight in predicting adverse perinatal outcomes in a low risk cohort? J Matern Fetal Neonatal Med. 2019;32(14):2380-6.
39. Fratelli N, Mazzoni G, Maggi C, Gerosa V, Lojacono A, Prefumo F. Cerebroplacental ratio before induction of labour in normally grown fetuses at term and intrapartum fetal compromise. Eur J Obstet Gynecol Reprod Biol 2018;227:78–80.
40. Morales-Roselló J, Khalil A, Fornés-Ferrer V, Perales-Marín A. Accuracy of the fetal cerebroplacental ratio for the detection of intrapartum compromise in nonsmall fetuses. The Journal of Maternal-Fetal & Neonatal Medicine. 2019;32(17):2842-52.
41. Atabay I, Kose S, Cagliyan E, Baysal B, Yücesoy E, Altınyurt S. A prospective cohort study on the prediction of fetal distress and neonatal status with arterial and venous Doppler measurements in appropriately grown term fetuses. Arch Gynecol Obstet. 2017;296:721–30.
42. Bligh LN, Alsolai AA, Greer RM, Kumar S. Cerebroplacental ratio thresholds measured within 2 weeks before birth and risk of Cesarean section for intrapartum fetal compromise and adverse neonatal outcome. Ultrasound Obstet Gynecol. 2018;52(3):340-6.
43. Bligh LN, Alsolai AA, Greer RM, Kumar S. Prelabor screening for intrapartum fetal compromise in low-risk pregnancies at term: cerebroplacental ratio and placental growth factor. Ultrasound in Obstetrics & Gynecology. 2018;52(6):750-6.
44. Migda M, Gieryn K, Migda B, Migda MS, Maleńczyk M. Utility of Doppler parameters at 36–42 weeks' gestation in the prediction of adverse perinatal outcomes in appropriate-for-gestational-age fetuses. J Ultrason. 2018;18:22–8.
45. Kalafat E, Khalıl A. Clinical significance of cerebroplacental ratio. Current Opinion in Obstetrics and Gynecology, 2018;30(6):344-54.
46. Ribbert LS, Snijders RJ, Nicolaides KH, Visser GHA. Relationship of fetal biophysical profile and blood gas values at cordocentesis in severely growth-retarded fetuses. Am J Obstet Gynecol. 1990;163:569–71.
47. Vintzileos AM, Fleming AD, Scorza WE, Wolf EJ, Balducci J, Campbell WA, et al. Relationship between fetal biophysical activities and umbilical cord blood gas values. Am J Obstet Gynecol. 1991;165:707–13.

This paper has been checked for language accuracy by JOSAM editors.
The National Library of Medicine (NLM) citation style guide has been used in this paper.