Conference Report

Ultrasound evaluation of amniotic fluid volume: methods and clinical accuracy

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Abstract. Ultrasound evaluation of amniotic fluid volume (AFV) is frequently used to detect fetuses at high risk for an adverse outcome – an event that is often correlated with AFV abnormalities. As is well known, ultrasound is a non invasive procedure, which makes it ideal for application on a very large scale: in practice, it can be used for routine monitoring of all pregnancies and, not infrequently, for repeat AFV determination in those cases where there is the suspect of amniotic fluid abnormalities. Sonographic quantification of AFV, whether it is performed through a simple visual estimation or through biometric measurement of one or more amniotic fluid pockets, can never represent a true "quantitative" method and its actual reliability has not consistently been proved by scientific evidence. Moreover, even though ultrasound AFV evaluation is indispensable in the management of high-risk pregnancies, there is no consensus on which ultrasound index is the most accurate in predicting perinatal morbidity and mortality. The sonographer can evaluate AFV by directly observing amniotic fluid pockets and his experience is crucial for a high reliability of the procedure. When pathological AFV changes are present, especially if the examination is performed by a not so expert sonographer, biometric measurements (Single Deepest Pocket, Amniotic Fluid Index, Two-Diameter Pocket) with their respective reference ranges might be helpful in confirming the diagnosis of oligohydramnios or hydramnios. A complete review of all tests performances and confidences is made by the Authors.

Key words: Amniotic fluid, ultrasound evaluation, methods

Introduction

Ultrasound evaluation of amniotic fluid volume (AFV) is frequently used to detect fetuses at high risk for an adverse outcome – an event that is often correlated with AFV abnormalities. Oligohydramnios is associated with structural anomalies (most commonly of the urinary tract), fetal growth restriction, pulmonary hypoplasia, fetal distress, and perinatal morbidity and death (1). Hydramnios is also associated with fetal abnormalities, e. g. neural tube defects, gastrointestinal tract obstruction, and ventricular and atrial septal defects, as well as to aneuploidy (especially trisomy 21) (2).

As is well known, ultrasound is a non invasive procedure, which makes it ideal for application on a very large scale: in practice, it can be used for routine monitoring of all pregnancies and, not infrequently, for repeat AFV determination in those cases where there is the suspect of amniotic fluid abnormalities. Ultrasound evaluation of AFV, whether it is performed through a simple visual estimation or through biometric measurement of one or more amniotic fluid pockets, can never represent a true "quantitative" method and its actual reliability has not consistently been proved by scientific evidence. Moreover, even though ultrasound AFV evaluation is indispensable in the management of high-risk pregnancies, there is no consensus on which ultrasound index is the most accurate in predicting perinatal morbidity and mortality.

Amount of amniotic fluid

Isotope and dye dilution techniques have been widely used to determine AFV variations correlated to gestational age (3, 4). In the first half of the second trimester, AFV progressively increases by 10 ml/day until it reaches on average 500 ml at week 20, and 700 ml and 1000 ml in the early and mid-third trimester, respectively, before decreasing to 800-900 ml at term.

However, the AFV range for a given gestational age is very broad. Brace and Wolf (5), who reviewed as many as 705 published AFV measurements from normal pregnancies in seven studies conducted with dye dilution techniques and five studies conducted by direct AFV measurement at the time of hysterotomy, reported a mean AFV of 817 ml at 30 weeks' gestation (range, 318-2100 ml). Their statistical approach – a polynomial regression model – was criticized by Magann et al. (6). Using a growth curve analysis to model AFV changes, these authors found that the amniotic fluid significantly increased in the second trimester and did not stabilize at 29-39 weeks, contrary to what was reported by Brace and Wolf.

While there are still doubts on the actual pattern of AFV during pregnancy, what is most important in clinical practice is not to know exactly its mean variations and their respective reference ranges, but to apply a method enabling detection of those AFV variations that can be correlated with fetal adverse outcome.

Ultrasound evaluation of AFV

Subjective evaluation

The sonographer can evaluate AFV by directly observing amniotic fluid pockets. However, in the second trimester the fetus normally occupies less of the amniotic cavity, sometimes giving the false impression of an increased AFV. During the third trimester, the fetal abdomen is generally close to both the anterior and the posterior wall of the uterus; if it is ballottable or floats within the amniotic fluid, AFV is generally increased (7). As with many other aspects of ultrasound diagnostics, the sonographer's experience is crucial for a high reliability of the procedure: more experienced sonographers have significantly better intraobserver correlation scores (Kappa index = 0.94 vs 0.63) than those with less experience (8). However, ultrasound evaluations of AFV are more likely to identify normal AFV, regardless of the experience of the examiner or the type of ultrasonic measurement utilized (9). When pathological AFV changes are present, especially if the examination is performed by a not so expert sonographer, biometric measurements with their respective reference ranges might be helpful in confirming the diagnosis of oligohydramnios or hydramnios.

Semiquantitative criteria

Many different approaches have been proposed in the literature to assess AFV using methods that imply objective biometric measurement of amniotic fluid pockets. A large number of reference texts used in fetal medicine contain definitions that are often in conflict with the cited reference (10). Therefore, the methods used should be accurately chosen and their respective limitations carefully considered.

Single Deepest Pocket (SDP)

In 1981, Manning et al. (11) introduced the concept of AFV determination using the depth of the maximum vertical pocket (MVP) visible on ultrasound. They defined "oligohydramnios" as an MVP <1 cm and "reduced" AFV as a pocket 1 to 2 cm in depth. Chamberlain et al. (11) later defined as normal an MVP of 2 to 8 cm. Measurements below 2 cm would suggest oligohydramnios; those above 8 cm should be classified as hydramnios. When associated with a normal MVP, perinatal mortality is 2-4/1000; it increases 13-fold when AFV is reduced (MVP between >1 cm and <2 cm) and 47-fold when severe oligohydramnios (MVP <1 cm) is present.

However, as there is unquestionable evidence proving that pregnancies with MVP <1 cm are extremely rare (<1% of normal pregnancies), it is doubtful that the procedure has a good sensitivity for poor fetal outcome (12). Therefore, Manning et al. (12) suggested that oligohydramnios should be defined as MVP <2 cm in both the vertical and the horizontal plane, while Halperin et al. and Crowley et al. used a 3 cm single pocket of amniotic fluid as cut-off between normal AFV and oligohydramnios (13). Although the definitions used by Chamberlain were derived from a population with an elevated incidence of high-risk, postdate pregnancies, the MPV technique is a simple and reproducibile procedure that has proved to be one of the most widely used and probably the best methods for estimating AFV in multifetal pregnancies. In the latter case, the most common reference intervals are comprised between 3 and 8 cm.

Amniotic Fluid Index (AFI)

Originally proposed by Phelan et al. (14) in 1987, this method is based on the sum total of the deepest vertical pockets in each of the four quadrants into which the uterus is divided by using the umbilicus and the linea nigra as reference points for the upper and lower halves and for the left and right halves, respectively. The ultrasound transducer must be in a perpendicular plane to the patient table and in a sagittal plane to the patient herself, but it should never be angled to follow the maternal abdomen's curvature. Each amniotic pocket must be free of fetal extremities and the umbilical cord, and must have a ≥5 mm width. The AFI is considered normal between 8.1and 18 cm, low between 5.1 and 8.0 cm, very low ≤5 cm, and high >18 cm. Moore and Cayle (15) investigated the distribution of AFI measurements in a population of patients with normal pregnancies. Unlike the definition of oligohydramnios by Phelan et al. (AFI <5 cm), these authors claimed that a ≤5 cm AFI was present only in 1% of the normal population (14). Intraobserver variability varies approximately between 0.5 and 1 cm; interobserver variability is comprised between 1 and 2 cm. For optimum accuracy, it is recommended that the mean of three AFI measurements be calculated, especially when the AFI is <10 cm. In pregnancies between 15 and 24 weeks, it is advisable to divide the uterus into two halves only – those split by the linea nigra – and to measure the MVP in each quadrant without an aggregate of cord or fetal extremities (16). Using color flow Doppler ultrasound, loops of the umbilical cord that were not apparent on gray-scale imaging may become visible and excluding these areas would lead to higher AFI values in the gray-scale image. Consequently, AFI measurement by color flow Doppler imaging overestimates oligohydramnios and underestimates polyhydramnios when a standard AFI table is used (17). The abdominal pressure exerted by the ultrasound transducer may also induce changes in the AFI and in the SDP. Indeed, low pressure results in a 13% increase in AFI, while high pressure could lead to a 21% AFI decrease (18).

Two-diameter Pocket (2-DP)

Introduced by Magann et al. in 1992, this method multiplies the vertical depth of the MVP by its largest horizontal diameter (19). In this case, too, the pocket must be free of the umbilical cord or fetal extremities. Normal AFV is defined as 15.1 to 50 cm^2, hydramnios as more than 50 cm^2, and oligohydramnios as 0 to 15 cm^2. In fact, these reference intervals are not reliable, especially before the 24^{th} week of gestation, when the amount of amniotic fluid increases from 10 ml per week at 8 weeks to 60 ml per week at 21 weeks. When the increase in AFV is so sudden, it is better to use normal values calculated on a week-by-week basis (20). A comparison between the largest vertical pocket (LVP), the largest transverse pocket (LTP), and the mean amniotic fluid diameter (MAFD) indicates that up through the second trimester, MAFD is the parameter that shows the highest correlation coefficient (r = 0.99) and the lowest intra- and interobserver variability (0.21 and 0.36 cm, respectively) (21).

Correlation of ultrasound evaluation with actual amniotic fluid volume

The use of invasive methods for quantitating AFV involves the instillation of either colored or inert solute markers into the amniotic cavity. Through a spectrophotometric determination of marker dilution, it is possible to compare directly these methods with non-invasive methods, such as ultrasound. Based on such comparisons, Croom et al. (22) were able to demonstrate that quantitative AFV is positively correlated with both the AFI and MVP (r = 0.75 and 0.60, respectively), and with overall test accuracy for oligo- and polyhydramnios of 84% (AFI) and 72% (MVP). Magann et al. (19) reviewed three ultrasound measurements (AFI, LVP, and 2-DP) in 40 patients undergoing amniocentesis and demonstrated a moderate accuracy in identifying normal AFV (AFI = 50%; LVP = 52%; 2-DP = 65%), oligohydramnios (AFI = 65%; LVP = 62%; 2-DP = 75%), and polyhydramnios (AFI = 85%; LVP = 90%; 2-DP = 90%). In a later case series, the same authors confirmed that the AFI and the SDP are similarly inadequate in identifying dye-determined low AFV (sensitivity = 10% and 5%, respectively) and high abnormal AFV (sensitivity = 29% and 29%, respectively). The summated AFI in normal diamniotic twin pregnancies has a sensitivity of only 13% in predicting AFV.

Correlation of ultrasound evaluation with perinatal outcome

Also in 1987, the same group of authors who proposed that AFV should be assessed by the AFI method (23), reviewed data on 330 high-risk pregnancies and reported an inverse relationship between the AFI and adverse perinatal outcome: when the AFI is <5 cm, the risk of an Apgar score of <7 at 5 minutes increases dramatically (RR = 6.7) and so does the risk of Cesarean delivery for fetal distress (RR = 4.8). In a meta-analysis of 10,551 patients from 18 selected studies, Chauhan et al. (24) reported that an antepartum AFI of <5 cm is associated with an increased risk of Cesarean delivery for fetal distress (RR = 2.2) and an Apgar score of <7 at 5 minutes (RR = 5.2). An intrapartum AFI of <5 cm is also associated with an increased risk of Cesarean delivery for fetal distress (RR = 1.7) and an Apgar score of <7 at 5 minutes (RR = 1.8). However, no clear correlation can be found between the AFI and neonatal acidosis (pH <7.00), which is the only objective measure of fetal well-being. In the past, these findings greatly influenced the conduct of obstetricians faced with ultrasound-verified AFV reductions, but more recently investigators have begun to assume that intrapartum/neonatal outcomes are not affected by AFV. A study on AFV measured by AFI, SDP and dye-determined volume did not show any correlation between these parameters and decelerations in labor, late decelerations, Cesarean deliveries for fetal distress, and umbilical cord pH <7.2; neither was there a correlation with AFV distribution, predominantly upper or lower (25). Casey et al. (26) came to similar conclusions. After a review of 6,423 pregnancies, they hypothesized the need for a power calculation that would require more than 2 million patients in order to unquestionably demonstrate a 20% difference in the stillborn rate with oligohydramnios. Although perinatal morbidity and mortality may demonstrably increase with a low AFI, further prospective studies are certainly needed to demonstrate that routine induction of labor reduces overall maternal and perinatal mortality and morbidity (27).

Conclusions

Ultrasound determination of AFV plays an important part in ante- and intrapartum monitoring. Although further studies are needed, the AFI is certainly the most widely used parameter of all and is also the one that comes closest to the actual amount of amniotic fluid. It is thought that any AFI centimeter is equivalent to a 30ml volume, indicating that the AFI might account for just 50% of actual AFV (28). When oligohydramnios is suspected, it seems more useful to mediate between three different measurements or use the SVP or the 2-DP method. The color Doppler technique may even be disadvantageous in determining oligohydramnios. When amniotic fluid quantitation is used to monitor term pregnancies, the AFI should be measured weekly in pregnancies under 41 weeks if it exceeds 8 cm, and twice a week in pregnancies over 41weeks or if it is below 8 cm (29).

References

1. Sherer DM, Langer O. Oligohydramnios: use and misure in clinical management. *Ultrasound Obstet Gynecol* 2001; 18: 411-9.

2. Dashe JS, McIntire DD, Ramus RM, Snatos-Ramos R, Twickler DM. Hydramnios: anomaly prevalence and sonographic detection. *Obstet Gynecol* 2002; 100: 134-9.
3. Fuchs F. Volume of amniotic fluid at various stages of pregnancy. *Clin Obstet Gynecol* 1966; 9: 449-60.
4. Queenan JT, Thompson W, Whitefield CR. Amniotic fluid volumes in normal pregnancy. *Am J Obstet Gynecol* 1972; 114: 34-8.
5. Brace RA, Wolf EJ. Normal amniotic fluid volume changes throughout pregnancy. *Am J Obstet Gynecol* 1989; 161: 382-8.
6. Magann EF, Bass JD, Chauhan SP, Young RA, Whithworth NS, Morrison JC. Amniotic fluid volume in normal singleton pregnancies. *Obstet Gynecol* 1997; 90: 524-8.
7. Hill LM. Oligohydramnios: sonographic diagnosis and clinical implications. *Clin Obstet Gynecol* 1997; 40: 314-27.
8. Halperin ME, Fong KW, Zalev AH, Goldsmith CH. Reliability of amniotic fluid volume estimation from ultrasonography: intraobserver and interobserver variation before and after the establishement of criteria. *Am J Obstet Gynecol* 1985; 153: 264-7.
9. Magann EF, Perry KG, Chauhan SP, Anfanger PJ, Whithworth NS, Morrison JC. The accuracy of ultrasound evaluation of amniotic fluid volume in singleton pregnancies: the effect of operator experience and ultrasound interpretative technique. *J Clin Ultrasound* 1997; 25: 249-53.
10. Magann EF, Isler CM, Chauhan SP, Martin JN. Amniotic fluid volume estimation and the biophysical profile: a confusion criteria. *Obstet Gynecol* 2000; 96: 640-2.
11. Chamberlain PF, Manning FA, Morrison I, Harman CR, Lange IR. Ultrasound evaluation of amniotic volume.I. The relationship of marginal and decreased amniotic fluid volume to perinatal outcome. *Am J Obstet Gynecol* 1984; 150: 245-9.
12. Manning FA, Harmon CR, Morrison I. Fetal assessment based on fetal biophysical profile scoring. IV. An analysis of perinatal morbidity and mortality. *Am J Obstet Gynecol* 1990; 162: 703-9.
13. Halperin ME, Fong KW, Zalev AH, et al. Reliability of amniotic fluid volume estimation from ultrasonograms: intraobserver and interobserver variation before and after the establishment of criteria. *Am J Obste Gynecol* 1985; 153: 264-7.
14. Phelan JP, Ahn MO, Smith CV, Rutherford SE, Anderson E. Amniotic fluid index measurements during pregnancy. *J Reprod Med* 1987; 32: 601-4.
15. Moore TR, Cayle JE. The amniotic fluid index in normal human pregnancy. *Am J Obstet Gynecol* 1990; 162: 1168-73.
16. Magann EF, Whithworth NS, Klausen JH, Perry KG, Martin JN, Morrison JC. Accuracy of ultrasonography in evaluating amniotic fluid index at less than 24 weeks' gestation. J Ultrasound Med 1995; 14: 895-7.
17. Zlatnik MG, Olson G, Bukowski R, Saade GR. Amniotic fluid index measured with the aid of color flow Doppler. *J Matern Fetal Med* 2003; 13: 242-5.
18. Flack NJ, Dorè C, Southwell D, et al. The influence of operator transducer pressure on ultrasonographic measurements of amniotic fluid volume. *Am J Obstet Gynecol* 1994; 171: 218-22.
19. Magann EF, Nolan TE, Hess LW, Martin RW, Whitworth NS, Morrison JC. Measurements of amniotic fluid volume: accuracy of ultrasonography techniques. *Am J Obstet Gynecol* 1992; 167: 1533-7.
20. Gramellini D, Delle Chiaie L, Piantelli G, Sansebastiano L, Fieni S, Vadora E. Sonographic assessment of amniotic fluid volume between 11 and 24 weeks of gestation: construction of reference intervals related to gestational age. *Ultrasound Obstet Gynecol* 2001; 17: 410-5.
21. Magann EF, Chauhan SP, Barilleaux PS, Whitworth NS, Martin JN. Amniotic fluid index and single deepest pocket: weak indicators of abnormal amniotic volumes. *Obstet Gynecol* 2000; 96: 737-40.
22. Croom CS, Banias BB, Ramos.Santos E, Devoe LD, Bezhadian A, Hiett AK. Do semiquantitative amniotic fluid indexes reflect actual volume? *Am J Obstet Gynecol* 1992; 167: 995-9.
23. Rutheford 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.
24. 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: 1473-8.
25. Magann EF, Chauhan SP, Doherty DA, Barilleaux PS, Martin JN, Morrison JC. Predictability of intrapartum and neonatal outcomes with the amniotic fluid volume distribution: a reassessment using the amniotic fluid index, single deepest pocket and a dye-determined amniotic fluid volume. *Am J Obstet Gynec* 2003; 188: 1523-8.
26. Casey B, McIntire D, Bloom S, et al. Pregnancies outcomes after antepartum diagnosis of oligohydramnios at or beyond 34 weeks' gestation. *Am J Obstet Gynecol* 2000; 182: 909-12.
27. Schrimmer DB, Moore TR. Sonographic evaluation of amniotic fluid volume. *Clinical Obstet Gynecol* 2002; 45: 1026-38.
28. Grover J, Mentakis EA, Ross M. Threedimensional ultrasonography in obstetrics and gynecology: preliminary experience. *Am J Obstet Gynecol* 1998; 178: 1199-206.
29. Magann EF, Chauhan SP, Whitworth NS, Klausen JH, Nevils BG, Morrison JC. The accuracy of the summated amniotic fluid index in evaluating amniotic fluid volume in twin pregnancies. *Am J Obstet Gynecol* 1997; 177: 1041-5.

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