Amniotic Fluid and the Clinical Relevance of the Sonographically Estimated Amniotic Fluid Volume

Oligohydramnios

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The amniotic fluid volume (AFV) is regulated by several systems, including the intramembranous pathway, fetal production (fetal urine and lung fluid) and uptake (fetal swallowing), and the balance of fluid movement via osmotic gradients. The normal AFV across gestation has not been clearly defined; consequently, abnormal volumes are also poorly defined. Actual AFVs can be measured by dye dilution techniques and directly measured at cesarean delivery; however, these techniques are time-consuming, are invasive, and require laboratory support, and direct measurement can only be done at cesarean delivery. As a result of these limitations, the AFV is estimated by the amniotic fluid index (AFI), the single deepest pocket, and subjective assessment of the AFV. Unfortunately, sonographic estimates of the AFV correlate poorly with dye-determined or directly measured amniotic fluid. The recent use of color Doppler sonography has not improved the diagnostic accuracy of sonographic estimates of the AFV but instead has led to overdiagnosis of oligohydramnios. The relationship between the fixed cutoffs of an AFI of 5 cm or less and a single deepest pocket of 2 cm or less for identifying adverse pregnancy outcomes is uncertain. The use of the single deepest pocket compared to the AFI to identify oligohydramnios in at-risk pregnancies seems to be a better choice because the use of the AFI leads to an increase in the diagnosis of oligohydramnios, resulting in more labor inductions and cesarean deliveries without any improvement in peripartum outcomes.

Key Words—amniotic fluid; amniotic fluid index; oligohydramnios; single deepest pocket

Dynamics of the Amniotic Fluid Volume

Amniotic fluid provides an ideal environment for normal fetal growth and development. It provides the fetus with a source of water, protects the fetus from trauma, allows for normal movements critical for anatomic development, and contributes to the development of the fetal lungs. The physiologic characteristics of the dynamics influencing the amniotic fluid volume (AFV) are complex and not clearly understood. To understand the AFV, knowledge of the pathways for potential amniotic fluid movement and the regulatory mechanisms involved must be taken into consideration. There are several potential sources influencing AFV: fetal urine production, fetal swallowing, secretion of fetal lung fluid, the intramembranous pathway (movement of water and solutes between amniotic fluid and fetal blood and the placenta), the transmembra-
Amniotic fluid consists of 98% to 99% water. Early in human pregnancy, the AFV is isotonic with maternal or fetal plasma and contains minimal amounts of proteins. In early gestation, substantial amounts of amniotic fluid are present before the establishment of fetal urine production. Little is known about the dynamics of amniotic fluid early in gestation, but a likely scenario is the active transport of solutes across the amnion into the amniotic space with water moving passively down the chemical gradient. Fluid may also arise as a transudate of plasma across fetal nonkeratinized skin or from the mother across the uterine decidua and/or the placental surface.

Much more is known about the dynamics of the AFV in the second half of pregnancy after fetal skin keratinizes at 22 to 25 weeks’ gestation, resulting in the prevention of further water movement across skin. As the gestational age increases, amniotic fluid osmolality and sodium concentrations decrease, which is thought to be due to the increasing production of dilute fetal urine. Amniotic fluid osmolality ultimately reaches 250 to 260 mOsm/mL at term. Fetal osmolality (≈278 mOsm/mL) remains close to maternal osmolality (280 mOsm/mL), which limits the amount of water transfer between the fetal and maternal circulations under normal conditions.

Fetal Urination
Fetal urine production is the predominant source of amniotic fluid in the second half of pregnancy, as evidenced by the almost complete absence of amniotic fluid with renal agenesis or fetal urinary tract obstruction. Fetal urine first enters the amniotic space at 8 to 11 weeks’ gestation and constantly increases throughout gestation. Fetal urine production per kilogram of fetal body weight at 25 weeks is approximately 110 mL/kg per 24 hours, and it is approximately 190 mL/kg per 24 hours at 39 weeks. Estimates of human fetal urine output are served that fetal ovine hypoxia was associated with increased urine flow, as opposed to the often-associated chronic fetal hypoxia and low AFV. This finding suggests that human regulation of the AFV is also likely mediated by other mechanisms such as intramembranous absorption in addition to changes in fetal urine production at times of fetal hypoxia. Similarly, Gagnon et al found that the reduction in the AFV seen with chronic severe placental insufficiency in sheep was not due to a decrease in fetal urinary production but due to an increase in the intramembranous absorption of amniotic fluid, resulting in an overall decrease in the AFV.

Fetal Swallowing
Fetal swallowing plays a vital role in the maintenance of the AFV, as evidenced by the association of hydramnios with disturbances in fetal swallowing. The human fetus begins to swallow at the same time that fetal urine begins to enter the amniotic cavity, around 8 to 11 weeks’ gestation. Near term, the human fetus swallows an estimated average of 210 to 760 mL per day.

There are few human studies evaluating fetal swallowing; thus, our current knowledge is based primarily on observations using the ovine model, which is well established in evaluating human fetal physiologic development. Studies have shown many similarities between the ovine fetus and the human fetus with regard to fetal swallowing behavior and the rates of ingested fluid in utero. Studies in fetal sheep, as well as humans, show that the fetus usually swallows during episodes of fetal breathing activity.

Fetal hypoxia has been shown to suppress fetal swallowing in the ovine fetus, whereas decreases in amniotic fluid osmolality and increases in fetal plasma osmolality will increase fetal swallowing. In 1976, Minei and Suzuki reported that esophageal ligation in primate fetuses resulted in the development of hydramnios; however, the AFV returned to normal before delivery. It is thought that fetal sheep maintain a constant AFV after esophageal ligation with continued urine flow by increasing intramembranous absorption. These studies suggest that the human fetus is able to modulate swallowing under various conditions similar to that which has been observed in the ovine model; however, it is not likely the major regulatory mechanism by which the human fetus maintains its AFV.

Fetal Lung Fluid
Secretion of fetal lung fluid into the amniotic fluid cavity is well established and accepted. This idea is supported by the measured amount of phospholipids in the amniotic fluid as tests for fetal lung maturity, which are of pulmonary
returns to a homeostatic state even after large quantities of animal species, studies have demonstrated that the AFV between the fetal circulation and the amniotic fluid. In other face of the placenta is driven by the osmotic difference between amniotic fluid and fetal plasma in the lung because the fetal glottis serves to prevent backflow of amniotic fluid into the trachea. This concept is evident by the observation that meconium staining is common, whereas meconium aspiration is rare and often occurs in the setting of severe fetal hypoxia. In 1972, Liley reported that after intra-amniotic injection of contrast media, in only 4 of more than 800 patients was there evidence either radiologically or histologically of contrast medium detectable in the fetal or neonatal lung and noted that these 4 pregnancies were “highly pathological.” An outflow of approximately 200 to 400 mL per day has been shown in near-term fetal sheep. Brace et al demonstrated that in fetal sheep, approximately 50% of the secreted lung fluid entered the amniotic fluid, and the remainder was swallowed as it exited the trachea. This process results in a net secretion of 100 to 200 mL per day.

Secretion flow is thought to be due to the active transport of chloride ions across the epithelial lining of the developing fetal lungs. It has been shown that in utero ligation of the trachea in other animal species results in expansion of the fetal lung, thought to be due to the continued production of fetal lung fluid. It is generally accepted that fetal lung secretion allows for pulmonary lung expansion. Thus, secretion of lung fluid into the amniotic fluid is likely a substantial contributor to the AFV, although factors regulating fetal lung fluid secretion are poorly described, and the exact amount of lung fluid flowing into the amniotic fluid in the human fetus has not been quantified.

Intramembranous and Transmembranous Pathways

The sum of the fetal urine production plus the secreted fetal lung fluid minus the amount removed via fetal swallowing leaves approximately 400 mL in excess within the amniotic cavity. As gestation progresses and fetal urine production as well as secreted lung fluid increases, there must be a mechanism by which to compensate for this excess and maintain balance. This mechanism is termed the intramembranous pathway. It is estimated that in the near-term ovine fetus, approximately 200 to 500 mL per day is absorbed via the intramembranous route.

Intramembranous movement of water and solutes into the fetal circulation across the fetal vessels on the surface of the placenta is driven by the osmotic difference between the fetal circulation and the amniotic fluid. In other animal species, studies have demonstrated that the AFV returns to a homeostatic state even after large quantities of fluid are infused into the amniotic fluid cavity or after esophageal ligation. This finding suggests that there is a continuous flow of water and solutes from the amniotic fluid into the fetal circulation. Only approximately 35% of intramembranous movement of fluid depends on the osmotic gradient between the amniotic fluid and the fetal circulation, as observed in an ovine study. Therefore, there must be other nonpassive mechanisms that contribute to the intramembranous pathway.

There appears to be membrane asymmetry with regard to the bidirectional flow within the intramembranous pathway. Solutes appear not to cross in the same amounts from the amniotic fluid to the fetal circulation and from the fetal circulation to the amniotic fluid cavity. This finding was demonstrated in 2002 by Faber and Anderson using radiolabeled albumin, which rapidly crossed from amniotic fluid to fetal blood in pregnant sheep, but they saw no movement of radiolabeled albumin from the fetal circulation across to the amniotic fluid. Additionally, intramembranous absorption is increased with ligation of the ovine fetal esophagus, which suggests a mechanism by which intramembranous flow is increased when the ability to swallow is eliminated.

There is a strong relationship between the maternal fluid status and fluid balance between the fetal circulation and the AFV. The intramembranous pathway likely plays a role in correcting the fetal volume status during times of maternal dehydration. Animal studies reflect that during maternal dehydration states, the maternal serum osmolality increases, resulting in water movement from the fetal circulation to the maternal circulation; this resulting fetal dehydration results in increased fetal osmolality and promotes movement of water flow from the amniotic fluid to the fetal circulation to restore the fetal intravascular volume with a resultant decrease in the AFV. The opposite effect is also true. In 2003, Magann et al showed that intravenous maternal hydration with 1 L of fluid increased both the actual and sonographically estimated AFV in the human fetus, with an average increase in the actual AFV of 188 mL. Similarly, Kilpatrick et al showed that maternal hydration with 2 L of water in a patient with a low AFV can increase the human fetal amniotic fluid index (AFI) by up to 31%.

There is little support for movement of fluid via the transmembranous pathway as a major contributor to the AFV in the second half of pregnancy. In sheep, studies suggest that only 10 mL per day in late gestation may be absorbed by the uterus in the setting of normal osmolality. There have been experimental studies that imply that the amniotic membrane may be abnormal when
there is a low or high AFV, ie, thinner in the presence of a low AFV and thicker in the presence of a high AFV. Given the large surface area of the amnion and chorion, it is obvious why membrane permeability has been a proposed regulator of the AFV. However, little is known regarding the permeability and filtration characteristics as they relate to amniotic fluid dynamics. Clearly, our knowledge of intramembranous and transmembranous movement of amniotic fluid remains deficient.

Secretions by the Fetal Oral-Nasal Cavities and Other Influences

Studies of late-gestation sheep have shown that approximately 25 mL per day is secreted by the fetal oral-nasal cavities.22 This amount is small and is not considered a main source of amniotic fluid. On the basis of information about transepidermal water loss in the preterm infant, it is generally accepted that there is movement of water across the highly permeable fetal skin before 22 to 25 weeks' gestation, which contributes to the AFV in the first half of pregnancy. It is also reasonable to assume that there is a relationship between fetal weight and the AFV. Fetal urine production seems to be influenced by weight, with more fetal urine produced as the fetus becomes larger, which is evident as fetal urine production increases with the growing fetus across gestation. However, Magann et al23 showed that the neonatal birth weight was not correlated with a dye-determined or sonographically estimated AFV. Likewise, Owen et al24 showed that there was no clinical correlation between the AFI and estimated human fetal weight.

Clinical Correlation of AFV Dynamics

What was once thought to be a stagnant pool of fluid with turnover once per day, the AFV, is now considered to be a complex system involving numerous forces and pathways that influence the influx and efflux of fluid and solutes within the amniotic fluid cavity and regulating mechanisms of each that are yet to be completely understood. The regulatory balance seems to be focused at 3 levels: first, the intramembranous pathway involving control of the movement of fluid and solutes between fetal blood within the placenta and membranes; second, regulation of the inflows and outflows from the fetus in terms of fetal urine production, which is influenced by hormones such as arginine, aldosterone, angiotensin II, atrial natriuretic peptide, and vasopressin in a similar fashion as in adults; and last, regulation by the maternal-fetal relationship, which influences the fluid balance driven primarily by osmotic gradients.

To a certain extent, the AFV correlates with the status of the fetus and the placenta. A knowledge and understanding of the interplay that takes place to maintain balance within the amniotic fluid cavity are crucial, allowing the practitioner to more readily identify abnormalities in this process, which may be the result of maternal or fetal disease states.

What Is a Normal AFV in Singleton Pregnancies?

The issue of what is considered a normal AFV during pregnancy is vital to the practice of the general obstetrician, family practice physician, and maternal-fetal medicine specialist alike. The AFV is the summation of influx and efflux of fluid within the amniotic space. Abnormalities of the AFV have been associated with adverse pregnancy outcomes.

To label a volume of amniotic fluid as abnormal, the normal volumes of amniotic fluid across gestation must be defined. By convention, on the basis of definitions and cutoff values used in studies of the AFV in the literature and the definitions given by several major texts, there are multiple accepted definitions of an abnormal AFV. A low AFV (oligohydramnios) has been defined as follows: less than 200 mL,27 less than 500 mL total volume,28,29 below the 5th percentile for gestational age,30 a single deepest pocket of less than 2 cm,31–33 an AFI of less than 5 cm,23,26,33–35 and a subjectively low AFV.36 An increased AFV (polyhydramnios) can be defined as follows: greater than 2000 mL total volume,37 above the 95th percentile for gestational age,34 a single deepest pocket of greater than 8 cm,38 an AFI of greater than 24 cm27,39 or greater than 25 cm40 and a subjectively increased AFV.36

Changes in the AFV Across Gestation

Several studies have attempted to define “normal” AFVs across gestation. When discussing the AFV, it is important to point out that there are multiple studies published in the literature that provide reference curves reflecting the changes in the AFV across gestation in normal pregnancies. The volume defined as a normal AFV changes depending on the gestational age at which the AFV is measured.

In 1972, Queenan, et al41 used dye-determined methods with para-aminohippurate to directly measure the AFV of 187 patients across gestation from 15 to 16 weeks to 41 to 42 weeks. They showed a wide range of fluid volumes across gestation and observed that the AFV increased as pregnancy advanced from the 15th to the 20th week and then remained relatively constant from the 20th through the 41st week.41 Their study showed...
that the AFV peaked at 33 to 34 weeks’ gestation, gradually decreased to term, and then decreased at a greater rate after 41 weeks.

In 1989, Brace and Wolf defined normal amniotic fluid changes across gestation. They derived “normal” values from a compilation of 705 pregnancies from 12 previously published studies ranging from 8 to 43.2 weeks. A normal pregnancy was defined as a pregnancy without evidence of fetal anomalies, fetal death, spontaneous abortion, preclampsia, or maternal or fetal disease. Fetuses with “oligohydramnios” and “polyhydramnios” were included in the analysis if the outcome was “good.” Brace and Wolf reported a peak AFV of 931 mL at 33.8 weeks with a decrease in the AFV thereafter. Initially, a polynomial regression was used for the analysis, and the data were then log transformed to overcome statistical “problems” that arose using polynomial regression. Once the data were log transformed, analysis of variance was used to analyze the data, and the authors found no statistically significant change in the AFV from 22 to 39 weeks’ gestation, with an average volume of 777 mL and a range of 630 to 817 mL. Brace and Wolf reported a peak AFV of 931 mL at 33.8 weeks with a decrease in the AFV thereafter. Initially, a polynomial regression was used for the analysis, and the data were then log transformed to overcome statistical “problems” that arose using polynomial regression. Once the data were log transformed, analysis of variance was used to analyze the data, and the authors found no statistically significant change in the AFV from 22 to 39 weeks’ gestation, with an average volume of 777 mL and a range of 630 to 817 mL. Brace and Wolf reported a peak AFV of 931 mL at 33.8 weeks with a decrease in the AFV thereafter. Initially, a polynomial regression was used for the analysis, and the data were then log transformed to overcome statistical “problems” that arose using polynomial regression. Once the data were log transformed, analysis of variance was used to analyze the data, and the authors found no statistically significant change in the AFV from 22 to 39 weeks’ gestation, with an average volume of 777 mL and a range of 630 to 817 mL.

In 1997, Magann et al performed another study to assess normal AFVs across gestation. This study was undertaken for several reasons: first, the patients in the study by Brace and Wolf were obtained from 12 different studies conducted by 23 different investigators published between 1962 and 1977, and second, the average sample size per study was 60 or fewer patients, and the studies used a combination of techniques to measure the AFV, either by direct measurement at the time of hysterotomy (with the possibility of blood contamination) or a variety of dye dilution techniques (some of which remain unvalidated). As a result, these potential confounding variables may have influenced the AFV determinations in the study by Brace and Wolf. Magann et al measured the AFV of 144 singleton pregnancies between 15 and 40 weeks using the same “normal” pregnancy criteria as Brace and Wolf. One investigator performed all of the amniocenteses using a single dye-dilution technique for measurement with analysis performed in the same laboratory.

Additionally, a formulation derived from the Richards growth curve was used to plot the data across gestation. Using nonlinear regression and logarithmic transformation with the growth curve model, the AFV was found to increase across gestation with a peak at 40 weeks. This finding is contrary to the previously published conclusion of Brace and Wolf, who found that the AFV remained stable from 22 to 39 weeks, but is consistent with some of the conclusions drawn by Queenan et al. Magann et al maintained that although polynomial regression and multivariate analysis can empirically model trends over the range of the observed data, these equations are not accurate when dealing with the physiologic characteristics of the growth process. These equations provide information only over a limited range of the growth cycle and are therefore regarded as less than optimal for studies of the growth process. A growth curve model would therefore be more appropriate because it allows one to incorporate biologically interpretable parameters that apply to a larger range of the growth cycle. A polynomial model, if extrapolated to earlier gestational ages, would actually yield a negative AFV value. Using the growth curve model with time 0 at conception, the AFV is 0, and as gestational age increases, the AFV increases. Thus, this growth model has the ability to fit the data and offer a physiologic basis for that modeling. This model may prove to be superior to the previously published methods of statistical analysis, but further analyses of the various data sets using this model need to be performed. These 3 published normal AFVs across gestation have notable similarities and differences (Figure 1).

Because the actual AFV can only be calculated by amniocentesis and dye dilution techniques or directly measured at the time of cesarean delivery, the AFV is usually estimated by sonography. An often-cited reference to a “normal” AFV in pregnancy is a 1990 article by Moore and Cayle, who attempted to define the normal AFI in pregnancy. They evaluated 791 patients with normal pregnan-
cies. Their definition of normal was as follows: gestation between 16 and 44 weeks, adequate obstetric dating, no structural abnormalities on sonography, normal pregnancy without complications, term delivery with a neonatal birth weight between the 10th and 90th percentiles, and a normal neonatal course. Moore and Cayle measured the AFI according to the criteria established by Rutherford et al and plotted the measurements across gestation. Using polynomial regression and logarithmic transformation, Moore and Cayle found the mean AFI curve to rise starting at 16 weeks, peak at 27 weeks, plateau until 33 weeks, and then decline until 42 weeks. They observed that the AFI decreased by 12% per week after 40 weeks.

In 2007, Machado et al found results similar to those of Brace and Wolf. This prospective study evaluated the AFI of 2868 patients. They analyzed their data using multiple linear regression and quadratic polynomial adjustments and found the AFI across gestation to be practically constant between 20 and 33 weeks’ gestation and then began to decrease after 33 weeks, with the most notable decrease after the 38th week.

In 2000, Magann et al performed a prospective study to determine normal values for the sonographically measured AFI, single deepest pocket, and 2-diameter pocket in normal human pregnancy. Normal pregnancy was defined the same as it was by Moore and Cayle. The exclusion criteria included growth abnormalities, gestational age extremes (<14 or >42 weeks), and a depressed Apgar score of less than 7 at 5 minutes. They recruited 50 patients at every gestational age between 14 and 41 weeks, for a total of 1400 patients. The data were analyzed using linear regression and logarithmic transformation, to be consistent with the work done previously by Moore and Cayle. Magann et al found that when the AFI is used to define the fluid status across gestation, it increases from 14 to 31 weeks and then declines thereafter. When the single deepest pocket 2-diameter pocket is used, the AFV increases from 14 to 20 weeks’ gestation, plateaus between 20 and 37 weeks, and then gradually declines thereafter through the 41st week. How does that study compare to the study by Moore and Cayle with regard to defining a “normal” value for the sonographically estimated AFV? If you were to consider the individual cases in the study by Magann et al and use the curve of Moore and Cayle, you would find that 36% of the patients in the study by Magann et al study who had normal outcomes would have been labeled as having abnormal (either oligohydramnios or polyhydramnios) fluid volumes according to the curve of Moore and Cayle.

Another investigation by Lei and Wen constructed an AFI curve by gestational week in 5496 Chinese women. The 5th, 50th, and 95th percentiles of this study were different from the curves of both Moore and Cayle and Magann et al across gestation (Figure 2). The curves of both Lei and Wen and Magann et al had an AFI that was less at each gestational age than the curve of Moore and Cayle. The curves of Lei and Wen for the 5th and 95th percentiles were greater than those of Magann et al at less than 22 and greater than 36 weeks but less at each gestational age between 22 and 36 weeks. These findings suggest that the “normal” AFV at a point in gestation may be different depending on the population being investigated, and perhaps population-specific curves should be established to better define the normal AFV to prevent increased interventions with no ultimate change in pregnancy outcomes.

In summation, there is yet to be a clearly defined normal value for the AFV or for the estimated AFV at each week across gestation; therefore, “abnormal” cannot be defined. The definitions of oligohydramnios by Queenan et al, Brace and Wolf, and Magann et al differ markedly from widely used fixed cutoffs such as an AFV of less than 200 mL or less than 500 mL. Whether the actual AFV decreases in late gestation, remains steady throughout most of the third trimester, or increases throughout gestation with a peak at term is yet to be clearly established. Ideally, a normal AFV should be defined as a value between defined high and low values, which are linked to adverse pregnancy outcomes at each point across gestation. Importantly, a value defined as a normal AFV cannot in and of itself guarantee a good perinatal outcome.
Measurement of the AFV

Methods of Sonographic Estimation of the AFV (AFI, Single Deepest Pocket, 2-Diameter Pocket, and Subjective Assessment)

The AFV can be measured by dye dilution techniques at the time of amniocentesis or can be directly measured at cesarean delivery. These methods are time-consuming, are invasive (done at the time of amniocentesis), and may require laboratory support (dye dilution techniques), and some can only be done at the time of delivery (direct measurement technique). Because of these limitations, the AFV is estimated by sonography.

There are 4 reported techniques used to estimate the AFV. Two of these are used frequently: the AFI and the single deepest pocket. A third technique is subjective assessment, although how frequently the subjective assessment is used is uncertain. The fourth technique, the 2-diameter pocket technique, is no longer used because it was shown not to be a better predictor of an abnormal AFV than the AFI.

Correlation of a Sonographically Estimated AFV With a Dye-Determined or Directly Measured AFV

The correlation of a sonographic estimate of amniotic fluid with a known fluid volume was suggested by Moore and Brace. The uteri of 5 near-term sheep were exteriorized, with a known fluid volume was suggested by Moore and Brace. The uteri were then filled with normal saline, and at each 100-mL increment of fluid, an AFI was obtained until 2 to 2.5 L of saline had been instilled. The AFI was then compared to infused volumes using curve-fitting formulas. A good correlation (r = 0.94) was observed between the infused saline and the AFI. Both the dye-determined fluid calculation using para-aminohippurate and direct measurement at cesarean delivery have been shown to have good concordance (r = 0.99), and either can be used in determining the actual AFV.

Sepulveda et al amnioinfused 16 pregnancies between 16 and 28 weeks' gestation with severe oligohydramnios or anhydramnios and intact membranes. They observed a linear relationship between the infusion and the AFI, but only 30% of the variation in the AFI could be explained by the infused volume. Croom et al estimated the AFV with sonography (AFI and single deepest pocket) in term pregnancies and correlated those measurements with a dye-determined fluid volume using para-aminohippurate and calculated after amniocentesis. They observed that both the AFI and single deepest pocket reliably identified a normal fluid volume and the 2 pregnancies with oligo-

hydramnios. None of the pregnancies had polyhydramnios, but the authors observed that at high volumes, the AFI overestimated the AFV.

Dildy et al used 13 different sonographic measurements and compared them to a dye-determined volume and observed that the sonographically estimated AFV could lead to an overestimation of the dye-determined AFV by 89% at low volumes and an underestimation of 54% at high volumes. Magann et al assessed the association of a sonographic estimate of the AFV with a dye-determined fluid volume in two investigations and observed that the sensitivity of the AFI for oligohydramnios was 6.7% in one study and 8.7% in the other investigation. Horsager et al estimated the AFV by sonography and directly measured the fluid at cesarean delivery and observed that the sensitivity of sonography for detecting a low AFV was only 18%. Chauhan et al compared the ability of two methods of amniotic fluid assessment (2-diameter amniotic fluid pocket versus AFI) to predict oligohydramnios or polyhydramnios using receiver operating characteristic curves and regression analysis and observed that both sonographic measurements were inaccurate predictors of actual oligohydramnios or polyhydramnios when compared with dye dilution or direct measurements of the actual AFV at cesarean delivery. Another investigation assessed the accuracy of the 2 x 2-cm pocket for identifying a low AFV in singleton pregnancies and noted that more than 90% of dye-determined oligohydramnios was not detected.

An analysis of an AFI and a single deepest pocket below the 3rd and 5th percentiles and above the 95th and 97th percentiles for detecting dye-determined or directly measured oligohydramnios and polyhydramnios in 291 singleton pregnancies identified 11% to 27% with oligohydramnios and 33% to 46% with hydramnios. The overall sensitivities of the AFI and single deepest pocket from these studies for identifying actual normal fluid ranged from 71% to 98%. The sensitivities and specificities for detecting actual oligohydramnios vary among the published studies (Table 1).

Color Doppler Sonography for Estimation of the AFV

The use of color Doppler sonography has been suggested in the evaluation of the AFV to eliminate pockets of fluid containing the umbilical cord not detected by gray scale sonography and thereby increase the detection of oligohydramnios. Bianco et al reported a significant reduction in the measured AFI and a significant increase in the number of pregnancies with a diagnosis of oligohydramnios when color Doppler sonography was used. In all probabili-
ity, this reduction in the estimated AFV was due to the elimination of amniotic fluid pockets when color Doppler sonography showed them to be filled with the umbilical cord.

Magann et al.\(^7\) also observed a reduction in both the AFI and the single deepest pocket by approximately 20% with the use of color Doppler sonography compared to gray scale sonography alone. In their investigation, they compared the AFI and single deepest pocket to a dye-determined AFV using color Doppler versus gray scale sonography and observed that color Doppler sonography led to overdiagnosis of oligohydramnios. Disturbingly, color Doppler sonography not only did not identify any more pregnancies with dye-determined oligohydramnios but also labeled 9 of 42 women with normal AFVs as having oligohydramnios.\(^7\)

**Subjective Evaluation of Amniotic Fluid**

Subjective assessment of the AFV and the quas object (AFI and single deepest pocket) techniques are both currently used to estimate the AFV. Few studies have linked the subjective evaluation of AFV with a dye-determined or directly measured AFV. In an assessment of the AFV at less than 24 weeks, there was no difference in the accuracy of subjective assessment (visual interpretation without sonographic measurements) compared to objective assessment (visual interpretation with sonographic measurements) in the correct identification of dye-determined amniotic fluid.\(^7\) In another investigation of 63 pregnancies in the second and third trimesters of pregnancy comparing subjective assessment (visual interpretation without sonographic measurements) and objective assessment (visual interpretation with sonographic measurements) with dye-determined fluid volumes, neither operator experience nor the sonographic technique was observed to greatly affect the accuracy of sonographic estimates of the AFV.\(^7\)

### Table 1. Comparison of the Predictability of the Sonographically Estimated Amniotic Fluid Volume for Identifying Dye-Determined and Directly Measured Oligohydramnios

<table>
<thead>
<tr>
<th>Study</th>
<th>Define Oligohydramnios</th>
<th>Sample Size</th>
<th>Amniotic Fluid Collection</th>
<th>Sensitivity</th>
<th>Specificity</th>
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<tr>
<td>Horsager et al(^27)</td>
<td>&lt;200 mL</td>
<td>40</td>
<td>AFI &lt;5 cm</td>
<td>0.18</td>
<td>1.00</td>
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<td></td>
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<td>AFI &lt;8 cm</td>
<td>0.36</td>
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<td></td>
<td></td>
<td></td>
<td>Largest vertical pocket &lt;3 cm</td>
<td>0.18</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>AFI ≤5 cm</td>
<td>0.05</td>
<td>0.98</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>2-diameter amniotic pocket volume ≤15 cm(^2)</td>
<td>0.58</td>
<td>0.74</td>
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<tr>
<td>Chauhan et al(^67)</td>
<td>&lt;500 mL</td>
<td>144</td>
<td>AFI ≤5 cm</td>
<td>0.067</td>
<td>1.00</td>
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<tr>
<td></td>
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<td>Largest vertical pocket</td>
<td>0.0</td>
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<tr>
<td></td>
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<td>&lt;500 mL</td>
<td>40</td>
<td>AFI ≤5 cm</td>
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</table>

AFI indicates amniotic fluid index.

### Amniotic Fluid Volume and Pregnancy Outcomes

**Dye-Determined AFV and Pregnancy Outcome**

There are a very limited number of investigations with a dye-determined AFV and intrapartum and perinatal outcomes within 72 hours of the AFV determination. One investigation\(^37\) with a dye-determined AFV from 50 singleton pregnancies and delivery within 48 hours of that AFV calculation observed a greater risk of cesarean delivery for fetal labor intolerance in the hydramnios group compared to the normal group (\(P = .03\)), and the results approached significance in the oligohydramnios group compared to the normal group (\(P = .056\)). No differences were observed between groups (oligohydramnios, normal, and polyhydramnios) for the risk of meconium-stained amniotic fluid, variable decelerations influencing delivery, or low 5-minute Apgar scores.

In another study of 100 unlabored women who had their AFV determined by a dye dilution technique just before elective cesarean delivery, oligohydramnios was not predictive of a low umbilical artery pH at delivery.\(^72\) In a third investigation, 10 intrapartum and perinatal outcomes were evaluated in 74 pregnancies with a dye-determined fluid volume and delivery within 72 hours.\(^73\) The dye-determined fluid volumes labeled as oligohydramnios, normal, and polyhydramnios were not predictive of adverse intrapartum or neonatal outcomes (fetal heart rate variability, variable decelerations, late decelerations, fetal labor intolerance, need for amnioinfusion, intrapartum growth restriction, birth weight, mode of delivery, umbilical artery pH <7.2, or neonatal intensive care unit [NICU] admissions).\(^73\)
Sonographically Estimated AFV Using the AFI and Pregnancy Outcomes

In one of the early studies linking an AFI with an adverse pregnancy outcome, Rutherford et al\(^\text{25}\) observed a greater risk of nonreactive nonstress tests, fetal heart rate decelerations, meconium staining, cesarean delivery for labor intolerance, and low Apgar scores in women with an AFI of 5 cm or less. Other studies have also observed an increased risk of adverse pregnancy and neonatal outcomes in those pregnancies with an AFI of 5 cm or less.\(^{35,74}\) But not all investigators agree that an AFI of 5 cm or less is associated with an adverse pregnancy outcome. In both low-risk patients\(^{75}\) and at-risk patients,\(^{76-79}\) oligohydramnios has not been linked to adverse pregnancy or perinatal outcomes in other studies.

It is essential that our estimate of the AFV is accurate and correlates with pregnancy outcomes for it to be meaningful in our management of at-risk pregnancies. Why are a number of the studies contradictory in the correlation between fixed cutoffs for oligohydramnios (AFI of ≤5 versus >5 cm) and intrapartum and perinatal outcomes? The conclusions of some of the investigations are easy to understand after the articles are carefully evaluated.

In the study by Casey et al\(^\text{35}\) (adverse pregnancy outcomes after 34 weeks in pregnancies with an AFI of ≤5 versus >5 cm), after the data set was corrected for malformations and congenital syndromes, there was no difference between the pregnancies with an AFI of 5 cm or less versus those with an AFI of greater than 5 cm in the risk of a cesarean delivery for fetal labor intolerance, umbilical cord arterial pH of less than 7, NICU admissions, seizures in the first 24 hours after delivery, or neonatal death. Many intrapartum outcomes evaluated (fetal heart rate tracing, cesarean delivery for fetal labor intolerance, and Apgar scores) by the studies comparing AFIs of 5 cm or less versus those of greater than 5 cm are subjective. The only two objective assessments are the presence of meconium and the umbilical cord arterial pH.

In a meta-analysis, Chauhan et al\(^\text{80}\) observed an increased risk of cesarean deliveries for fetal labor intolerance and an Apgar score of less than 5 minutes in the group with an AFI of 5 cm or less versus women with an AFI of greater than 5 cm but observed no difference in the risk of the objective outcome of neonatal acidosis (umbilical cord arterial pH <7.0) between the two groups. Additionally, investigators group many intrapartum and perinatal outcomes together in their analyses, and perhaps only some of those outcomes are affected by low fluid volumes (eg, fetuses with anomalies, preterm premature rupture of membranes, growth-restricted fetuses below the 5th percentile, and postdate pregnancies).

Estimated AFV Using the Single Deepest Pocket and Subsequent Pregnancy Outcomes

Chamberlain et al\(^\text{31}\) evaluated the relationship of a single deepest pocket, corrected for major congenital anomalies, as a standalone test without any other antenatal testing and perinatal mortality in 7582 high-risk referred patients. The perinatal mortality rates for single deepest pocket measurements were as follows: greater than 2 cm to less than 8 cm, 1.97 per 1000 births; 1 cm or greater to 2 cm or less, 37.74 per 1000; and less than 1 cm, 109.4 per 1000.

Clinical Relevance of the Sonographically Estimated AFV

Should We Use the AFI, the Single Deepest Pocket, or Subjective Assessment to Estimate the AFV?

In a study of 1168 patients, Moore\(^\text{81}\) evaluated the ability of the single deepest pocket compared to the AFI to detect an abnormal AFV. Using the AFI, he labeled 76 women with oligohydramnios compared to 32 using the single deepest pocket. Moore concluded that the AFI was superior to the single deepest pocket because it identified more women with oligohydramnios.\(^\text{81}\) However, the AFI and single deepest pocket were compared only to each other and not to the directly measured or dye-determined AFV.

Magann et al\(^\text{82}\) challenged the concept that the AFI was superior to the single deepest pocket in the identification of abnormal AFVs. They compared the AFI and single deepest pocket with the dye-determined AFV to determine whether either was superior in the detection of abnormal AFVs in 179 singleton pregnancies. They concluded that neither technique was superior to the other, and both techniques were unreliable in the identification of an abnormal AFV.\(^\text{82}\) Subjective assessment of amniotic fluid (visual interpretation without sonographic measurements) has been compared to quasobjective methods (visual interpretation with sonographic measurements), and both techniques were found to be similar, with neither able to independently identify abnormal AFVs.\(^\text{36}\)

How Does the AFI Compare to the Single Deepest Pocket in the Prediction of Adverse Pregnancy Outcomes?

Four recent randomized trials assessed the AFI versus single deepest pocket in the prediction of pregnancy and neonatal outcomes. Alfirevic et al\(^\text{83}\) randomized 500 pregnancies of greater than 290 days to fetal monitoring with either a nonstress test and the AFI or a nonstress test and the single deepest pocket. The AFI labeled 10% of the women as having oligohydramnios versus 2% using the sin-
ingle deepest pocket \((P = .0008)\), resulting in more labor inductions but without any differences in intrapartum or perinatal outcomes except a trend for more cesarean deliveries \((18.8\% \text{ versus } 13.2\%\) in the AFI group.

Chauhan et al\(^8\) evaluated at-risk pregnancies undergoing antenatal testing with a nonstress test and AFV estimation. The patients were randomized to either the AFI or the single deepest pocket. They observed that significantly more patients were identified as having oligohydramnios using the AFI \((17\% \text{ versus } 10\% \text{; } P = .002)\). No differences were noted in the variable decelerations influencing delivery, late decelerations influencing delivery, mode of delivery, number of cesarean or assisted vaginal deliveries for a nonreassuring fetal heart rate tracing, 1- and 5-minute Apgar scores of less than 7, umbilical artery pH of less than 7.1, or NICU admissions between groups.

In a randomized trial, Moses et al\(^8\) compared the AFI and the single deepest pocket on admission to labor and delivery to determine whether either was predictive of intrapartum outcomes. Oligohydramnios was diagnosed more frequently \((25\% \text{ versus } 8\%)\) using the AFI compared to the single deepest pocket \((P < .001)\). Both techniques failed to identify patients who subsequently underwent amnioinfusion for fetal distress \((P = .864)\), variable \((P = .208)\) or late \((P = .210)\) decelerations that influenced delivery, fetal distress in labor \((P = .220)\), cesarean delivery for fetal distress \((P = .133)\), or NICU admissions \((P = .686)\). They concluded that neither technique identified a pregnancy that was at risk for an adverse outcome.

Magann et al\(^8\) conducted a randomized trial to compare the AFI and the single deepest pocket in the estimation of the AFV in at-risk pregnancies undergoing antenatal testing with a biophysical profile. The AFI significantly increased the number of pregnancies labeled as oligohydramnios \((38\% \text{ versus } 17\%\) compared to the single deepest pocket \((P < .001)\). There was no difference in the number of women with oligohydramnios in the AFI group undergoing cesarean delivery for fetal intolerance of labor versus the single deepest pocket group \((13\% ; P = .676)\). More women \((12\%)\) with normal fluid by the AFI method \((\text{AFI} > 5 \text{ cm})\) underwent cesarean delivery for fetal distress compared to the women \((6\%)\) with normal fluid by the single deepest pocket technique \((P = .037)\). They concluded that the use of the AFI offers no advantage in detecting adverse outcomes compared to the single deepest pocket measurement with a biophysical profile. In fact, the use of the AFI may result in more interventions by labeling twice as many at-risk pregnancies as having oligohydramnios than with the single deepest pocket technique.

A comparison of the AFI and the single deepest pocket as a screen for preventing adverse pregnancy outcomes was also the focus of a Cochrane review.\(^8\) The review found no differences in the primary outcomes, NICU admissions, or perinatal deaths.\(^8\) There were more women with a diagnosis of oligohydramnios, more labor inductions, and more cesarean deliveries for a nonreassuring fetal heart rate tracing using the AFI but no differences in the number of nonreassuring fetal heart rate tracings, assisted vaginal deliveries with or without a nonreassuring fetal heart rate tracing, umbilical artery pH of less than 7.1, Apgar score of less than 7 at 5 minutes, presence of meconium, or NICU admissions. The authors of the review concluded that the single deepest pocket was a better choice for antenatal testing because the AFI increased the diagnosis of oligohydramnios and labor inductions without any improvement in peripartum outcomes.

Conclusions

In this review, we aimed to provide an overview of the dynamics of the AFV, a synopsis of what is considered in the literature to be a “normal” AFV and a “normal” AFV as it changes across gestation, as well as a look at the various techniques for, and implications of, the sonographically estimated AFV as it relates to the detection of a low AFV. Measurement of the AFV as it relates to polyhydramnios was not specifically addressed in this review, nor was measurement of the AFV in twin gestations.

The dynamics of the AFV are complex and not entirely understood. The regulatory balance of the AFV seems to be focused at 3 main levels: the intramembranous pathway, fetal urine production, which can be influenced by several hormones, and the osmotic fluid gradient provided by the maternal-fetal relationship. As stated previously, there are yet to be clearly defined “normal” values for the AFV and the AFV across gestation. Ideally, a normal AFV should be defined as a value between well-defined high and low values, which is linked to an adverse pregnancy outcome at each point across gestation. However, these values have yet to be clearly established in the literature and are difficult to directly link to adverse pregnancy outcomes.

There are several published curves in the literature attempting to define a “normal” AFV across gestation, each with its own limitations and each differing from the next in what it defines as “normal.” Selection of an AFV curve that is most consistent with the specific population the health care provider is managing should be considered.
There are two main techniques used to estimate AFV via sonography: measurement of the AFI and the single deepest pocket. Both of these techniques can be unreliable in their ability to precisely estimate the actual AFV. Neither the AFI nor the single deepest pocket technique is superior to the other in the detection of oligohydramnios. Both methods have relatively low sensitivity for their detection of a low AFV. Color Doppler sonography does not aid in the detection of oligohydramnios; in fact, it appears to overdiagnose oligohydramnios. Another generally accepted method for evaluating the AFV and one that is widely used by many experienced sonographers is subjective assessment of the AFV. This method has been compared to quasiobjective methods using the AFI and single deepest pocket; neither technique was found to be superior in their ability to precisely estimate the actual AFV. Both methods have relatively low sensitivity for their detection of a low AFV. Color Doppler sonography does not aid in the detection of oligohydramnios; in fact, it appears to overdiagnose oligohydramnios. Another generally accepted method for evaluating the AFV and one that is widely used by many experienced sonographers is subjective assessment of the AFV. This method has been compared to quasiobjective methods using the AFI and single deepest pocket; neither technique was found to be superior to the other, and neither was able to reliably identify abnormal AFVs.

Additional studies are needed to determine whether there is an association between subjective assessment of the AFV and adverse pregnancy outcomes. On the basis of the studies referenced in this review, the use of the AFI compared to the single deepest pocket for estimation of the AFV results in overdiagnosis of oligohydramnios, leading to unnecessary interventions (eg, labor inductions), which often contribute to increased morbidity and mortality without any improvement in perinatal outcomes.

References


68. Magann EF, Nevils BG, Chauhan SP, Whitworth NS, Klausen JH, Morrison JC. Low amniotic fluid volume is poorly identified in singleton and twin pregnancies using the 2 × 2 cm pocket technique of the biophysical profile. *South Med J* 1999; 92:802–805.


