A Systematic Review of Amniotic Fluid Assessments in Twin Pregnancies

Danielle L. Ippolito, PhD, Jennifer E. Bergstrom, MD, Monica A. Lutgendorf, MD, Shannon K. Flood-Nichols, DO, Everett F. Magann, MD

The objectives of this systematic review were to examine the reproducibility of sonographic estimates of amniotic fluid volume (AFV) in twin pregnancies, compare the association of sonographic estimates of AFV with dye-determined AFV, and correlate AFV with antepartum, intrapartum, and perinatal outcomes in twin pregnancies. Studies were included if they were adequately powered and investigated antepartum, intrapartum, and/or perinatal adverse outcome parameters in twin gestations. Studies with comparable populations and exclusion criteria were merged into forest plots. Data comparing the accuracy of AFV assessment, correlation of AFV with gestational age, and adverse outcomes were tabulated. Five of the 6 studies investigating AFV by the amniotic fluid index as a function of gestational age reported data fitting a quadratic equation, with fluid volumes peaking at mid gestation and then declining. This trend was less pronounced when AFV was assessed by the single deepest pocket (2 of 4 studies reporting a quadratic fit). Polyhydramnios was associated with prematurity in 2 of 4 studies (1 amniotic fluid index and 1 single deepest pocket), and oligohydramnios was associated with prematurity in 1 single deepest pocket study. Stillbirth was the only intrapartum outcome reported in more than 1 study. Perinatal outcomes associated with polyhydramnios included neonatal death ($P < .05$ in 1 of 2 studies), low Apgar scores (1 of 2 studies), neonatal intensive care unit admission (1 of 2 studies), and low birth weight (2 of 3 studies).

Key Words—amniotic fluid volume; obstetric ultrasound; sonography; twin pregnancies

Amniotic fluid volume (AFV) is normally estimated by sonographic assessment as part of routine obstetric care. In singleton gestations, deviations from normal AFV (eg, oligohydramnios and polyhydramnios) have been associated with complications, including fetal anomalies, postmaturity syndrome, fetal growth restriction, congenital abnormalities, and diabetes.[1,2] Singleton pregnancies complicated by oligohydramnios may present with comorbid fetal renal anomalies, central nervous system anomalies, or infections. Pregnancies with severe oligohydramnios are at high risk for fetal or neonatal death.[3] In twins, substantial fluid volume discordance between sacs can be a clinical indicator of twin-twin transfusion syndrome (TTTS).[4–6] Twin pregnancies are at a significantly higher risk for perinatal morbidity and mortality.[7,8] However, few studies have directly investigated whether an abnormal AFV has predictive value in twin gestations outside TTTS.

Received October 10, 2013, from the Department of Clinical Investigation (D.L.I.) and Division of Maternal-Fetal Medicine, Department of Obstetrics and Gynecology (M.A.L., S.K.F.-N.), Madigan Army Medical Center, Tacoma, Washington USA; Department of Obstetrics and Gynecology, Naval Medical Center, Portsmouth, Virginia USA (J.E.B.); and Department of Obstetrics and Gynecology, University of Arkansas for the Medical Sciences, Little Rock, Arkansas USA (E.F.M.). Revision requested October 28, 2013. Revised manuscript accepted for publication November 25, 2013.

We thank Cindy Kirker of Madigan Army Medical Center's Medical Library for article procurement and library support on this project and Donna Eastham, BA, of the University of Arkansas for Medical Sciences for help with manuscript preparation and submission. The views expressed herein are those of the authors and do not reflect the official policy of the Department of the Army, the Department of the Navy, or the Department of Defense.

Address correspondence to Everett F. Magann, MD, Department of Obstetrics and Gynecology, University of Arkansas for the Medical Sciences, 4301 W Markham St, Slot 518, Little Rock, AR 72205-7199 USA.

E-mail: efmagann@uams.edu

Abbreviations

AFI, amniotic fluid index; AFV, amniotic fluid volume; GA, gestational age; NICU, neonatal intensive care unit; SDP, single deepest pocket; 2DP, 2-diameter pocket; TTTS, twin-twin transfusion syndrome

doi:10.7863/ultra.33.8.1353

Subjective scales have been developed and used to diagnose changes in fluid volume over gestational time.[9,10] The most accurate methods for quantitatively assessing AFV are measuring the fluid volume at the time of delivery and calculating the AFV by the dye dilution technique of Charles and Jacoby.[11] Concordance has been demonstrated between dye-determined AFV and direct measurement of AFV at the time of cesarean delivery ($r = 0.99$).[12] However, AFV measurement at delivery cannot be used to serially monitor antepartum fluid volumes, and the dye dilution technique is time-consuming and invasive, and it requires specialized laboratory support after hysterotomy. These limitations have led to use of sonography to estimate the AFV. Sonographic measurements of AFV include amniotic fluid index (AFI), single deepest pocket (SDP), and 2-diameter pocket (2DP) techniques.[13] The AFI was first described in 1987 by Phelan et al,[14] and the SDP was introduced in 1980.[15] In singleton pregnancies, these methods are used routinely as part of biophysical tests for monitoring fetal well-being in the second and third trimesters of pregnancy.[16] The use of sonographic measurements in twin gestations is complicated by the dividing membrane in diamniotic twins. This membrane can compromise the accuracy of sonographic volume assessment in twin pregnancies.[7] The accuracy of sonographic methods in making longitudinal assessments of AFV over time is also unclear in twin pregnancies. Furthermore, it is unclear whether AFV abnormalities are also associated with adverse outcomes in twins, as has been observed in singleton pregnancies.

The objective of this study was to conduct a systematic review of the literature describing the sonographic estimates of AFV, their correlation with dye-determined AFV, and the association of twin AFV with antepartum, intrapartum, and perinatal outcomes.

Materials and Methods

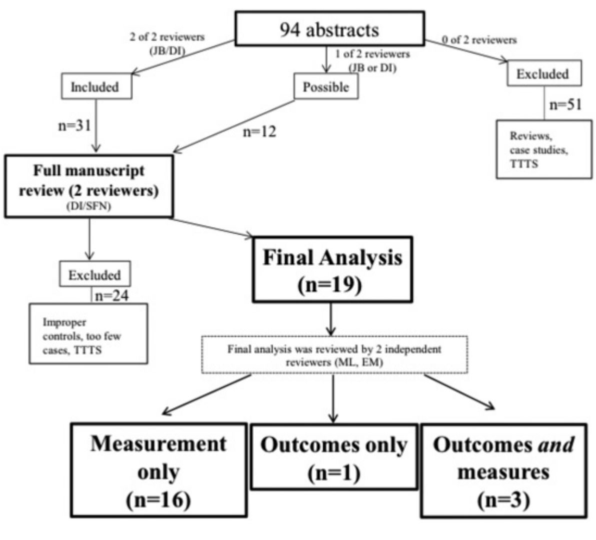
Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2009 guidelines were used to assess available articles for inclusion eligibility and to construct this systematic review.[17] Both PubMed and the Web of Science were searched between January 1, 1980, and December 31, 2012, for search terms including "amniotic fluid," "volume," "cc," "mL," "twin," "twins," and "multiple birth." During the review process, an additional study was added from June 2013.[18] Study eligibility characteristics were twin pregnancies evaluated for AFV by either sonography or the dye exclusion method and AFV assessment throughout pregnancy. Case reports and case series were excluded (>10 patients enrolled in the study). All reports were written in English. Any relevant data summarized in review articles were evaluated by accessing the pertinent manuscripts. End points for data assessment included comparison of sonographic methods (AFI versus SDP versus subjective assessment) in twins compared to singleton pregnancies, changes in fluid volume with advancing gestational age (GA) in twin pregnancies, and differences in AFV throughout pregnancy in monochorionic diamniotic and dichorionic diamniotic twins. Amniotic fluid volumes were segregated according to published criteria for oligohydramnios, polyhydramnios, or normal fluid volumes. The review process is summarized in Figure 1.

Results

Study Selection

Figure 1 illustrates the final schematic for selecting studies for inclusion. A total of 94 studies were retrieved from PubMed as described in "Materials and Methods." Eleven duplicate records were identified on the Web of Science. Duplicate records were removed. Two of the authors (J.E.B. and D.L.I.) reviewed all of the abstracts for the resulting 94 studies (Figure 1). Full articles were reviewed for all abstracts selected for inclusion by 1 or both of the reviewers (n = 43 articles) by 2 authors (J.E.B. and S.K.F.-N.). Of the 43 reports, 24 were excluded because of improper controls, TTTS, too few cases, review articles, and case studies. If there was a discrepancy among authors on an article, a third reviewer (M.A.L.) also reviewed the article

Figure 1. Schematic of the abstract and article screening selection process.



and determined whether it was to be included. The reports proceeding to the final analysis and inclusion in the systematic review were subdivided into categories: measurement, outcomes, both, and exclude. Two more reviewers (S.K.F.-N. and E.F.M.) evaluated the articles designated for the final analysis. The final analysis included reports powered to investigate the following end points: measurements only (n = 16), outcomes only (n = 1), and outcomes and measurements (n = 3). Table 1 lists the parameters of the studies included in the final analysis and whether they were used to assess measurements, outcomes, or both.[1–3,9,18–32] Table 2 lists the studies included for abnormal AFV and adverse outcomes in twins.[3,31–33]

Measurement Methods in Normal Twins

The studies used to assess methods of amniotic fluid measurement in normal twins are listed in Table 1. Studies were grouped according to the type of comparison tested in twins: (1) association between the dye dilution and sonographic estimate; (2) association between AFV and GA; (3) incidence of oligohydramnios or polyhydramnios; (4) intra- and inter-amniotic fluid measurements in each sac; (5) discordance; and (6) comparison between singleton and twin pregnancies.

Table 1. Longitudinal Studies on AFV

Study	Study Period	Type of Twin	Study Design	GA Range, wk	Pregnancies, n	AFV Assessment: Method	Criteria: Oligohydramnios	Criteria: Normal	Criteria: Polyhydramnios
Fluid discordance over gestational time									
Schneider, 1985	1979–1983	MC	Case series	23–30	9	Subjective	NA	NA	NA
Chescheir, 1988	1982–1987	DA	Case series	2-delivery	7	Subjective	NA	NA	NA
Lange, 1989	1983	DA	Intervention	22–37	6	SDP	≤2 cm	2.1–8.0 cm	>10 cm
Patten, 1989	1979–1987	MCDA	Prospective	17–28	52	Subjective	NA	NA	NA
Rådestad, 1990	1980–1987	MCDA	Retrospective	21–35	36	Not stated	NA	NA	>3-cm change in 1 wk
Absolute amniotic sac volume over gestational time									
Magann, 1995 (*OBGYN*)	Not stated	DA	Prospective	27–38	45	Dye dilution	<318 mL	318–2100 mL	>2100 mL
Magann, 1995 (*JSGI*)	Not stated	DA	Prospective	27–38	45	2DP SDP AFI Dye dilution	<15 cm² <2 cm <5 cm <500 mL	15–20 cm² 2–8 cm 15–19 cm 500–2000 mL	>50 cm² >8 cm ≥20 cm >2000 mL
Watson, 1995	Not stated	DA	Prospective	17–39	210	SDP	NA	NA	NA
Chau, 1996	1992–1993	DA	Prospective	15-40	91	AFI, SDP, 2DP	NA	NA	NA
Hill, 1996	Not stated	Not stated	Case series	27–delivery	9	AFI	≤5 cm	>5–<24 cm	≥24 cm
Porter, 1996	1985–1993	MCDA	Retrospective	26–41	288	AFI	NA	NA	NA
Magann, 1997	1993–1994	DA	Prospective	27–38	62	SDP, dye dilution	NA	NA	NA
Magann, 1998	Not stated	DA	Prospective	27–38	39	Dye dilution	155–404 mL	405–807 mL	808–5430 mL
Hill, 2000	1991-1997	DA	Cross-sectional	14–40	488	AFI, SDP	NA	NA	NA
Magann, 2000	1998–1999	DA	Prospective	27–37	23	AFI, SDP, 2DP, dye dilution	SDP 0–2 cm AFI 0–5 cm 2DP 0–15 cm²	SDP 2–8 cm AFI 5–20 cm 2DP 15–50 cm²	SDP >8 cm AFI >20 cm 2DP >50 cm²
Magann, 2007	2004–2006	MCDA	Prospective observational	17–37	299	SDP	<2.2 cm	2.2–7.5 cm	>7.5 cm
Sfakianaki, 2008	2004–2006	Not stated	Longitudinal	≤13–38	92	SDP	NA	NA	NA
Hernandez, 2012	1997–2010	MCDA	Retrospective cohort	Not stated	1951	SDP	NA	<8 cm	Mild 8–9.9 cm Moderate 10–11.9 cm Severe ≥12 cm
Dekoninck, 2013	2004–2011	MCDA	Retrospective	11–37	23	SDP	<2 cm	2.8–8.0 cm	>8 cm

DA indicates diamniotic; *JSGI, Journal of the Society for Gynecological Investigation*; MC, monochorionic; NA, not available; and *OBGYN, Obstetrics and Gynecology.*

Measurement Variability

Studies investigating measurement variability reported good intrasac and intersac reproducibility among measurements and also reported that that sonologist's experience did not significantly alter the results. Chau et al[25] reported that mean intraobserver error ± SEM was 2.87% ± 0.26% for AFI, 2.02% ± 0.07% for SDP, and 3.31% ± 0.12% for 2DP. Interobserver variation was 2% to 7%,[25] which was comparable to singleton variances reported by Moore and Cayle[16] of 2% to 3%. Hill et al[30] reported slightly higher values for AFI measurements, with intraobserver variations of 7.4% and interobserver variations of 12.2%, in 44 to 46 independent measurements of twins. Magann et al[9] also found no significant difference in the level of operator experience and number of correct assignments ($P = .98$). The increased variation in twins may be due to the difficulty in consistently visualizing the dividing membrane in twin pregnancies and ensuring correct sac measurements in a 3-dimensional space.

Correlation Between Measurement Methods

Table 3 summarizes studies evaluating the correlation between the various measurement methods. The AFI correlated well with the SDP in a prospective longitudinal study of diamniotic twins (Table 3).[24] However, when dye dilution was directly compared to sonographic methods (AFI, 2DP, and SDP), the sonographic methods had high specificity (98%) but poor sensitivity (26%) for detecting AFV abnormalities (oligohydramnios and polyhydramnios; Table 3).[34] Overall, the sonographic estimates predicted

Table 2. Studies on Abnormal AFV and Adverse Outcomes in Twins

Study	Study Period	Abnormalities Investigated	Type of Twin	GA Range, wk	Pregnancies, n	AFV Assessment			
						Method	Criteria		
							Oligohydramnios	Normal	Polyhydramnios
Orhan, 2005	1988–2002	Stillbirth, neonatal death, NICU/SCN admission, small for GA	DADC, DAMC	Not stated	13,312	AFI	NA	≤25 cm	>25 cm
Magann, 2007	2004–2006	Nonreassuring fetal heart rate, Apgar score <7, neonatal complications (RDS, TTN)	DADC, DAMC	17–37	300	SDP	<2.2 cm	2.2–7.5 cm	>7.5 cm
Sfakianaki, 2008	2004–2006	Preterm birth	DADC, DAMC	13–38	92	SDP	NA	NA	NA
Hernandez, 2012	1997–2010	Preterm birth, birth weight <10th percentile, Apgar score, NICU admission, neonatal death	DADC, DAMC	Not stated	1,951	SDP	NA	<8 cm	Mild 8–9.9 cm Moderate 10–11.9 cm Severe ≥12 cm

DC indicates dichorionic; RDS, respiratory distress syndrome; SCN, special-care nursery; and TTN, transient tachycardia of the neonate; other abbreviations are as in Table 1.

Table 3. Comparison of Correlations Among AFV Measurement Methods

Study	Method 1	Method 2	*r*	Sensitivity, %	Specificity, %	PPV, %	NPV, %
Magann, 1995 (*JSGI*)	Dye dilution	SDP	0.27		98		
		2DP	0.48		81		
		AFI	0.38		98		
Magann, 1999	Dye dilution	2DP	Not given	6.1 (0.7–20)	98.8 (93.7–99.9)	66.6 (9.4–99.1)	73.5 (63.7–84.2)
Watson, 1995	AFI	SDP	0.71				

Numbers in parentheses are 95% confidence intervals. NPV indicates negative predictive value; and PPV, positive predictive value; other abbreviations are as in Table 1.

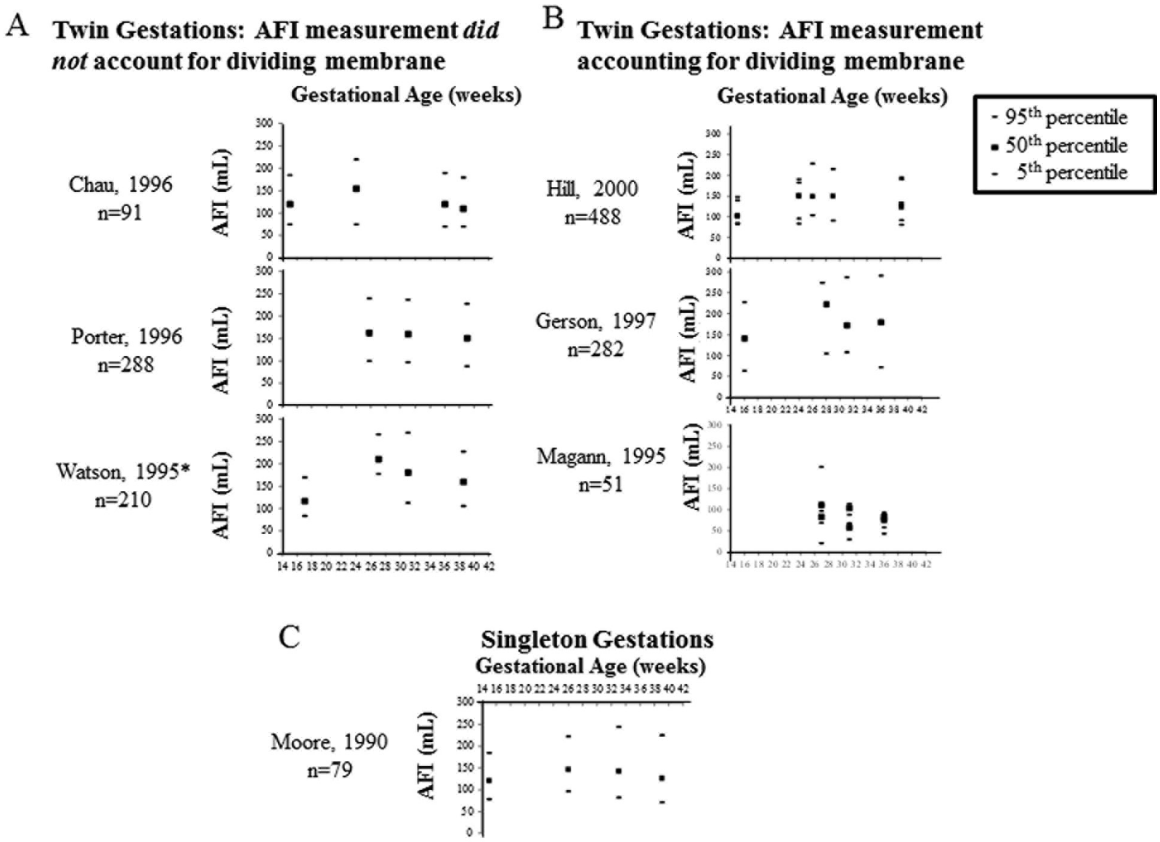
normal fluid volumes with 81% to 98% accuracy (Table 3).[1] However, sonographic methods underpredict oligohydramnios when compared to dye dilution techniques (Table 3).[34] These results were similar in singleton pregnancies: the 2DP had sensitivity of 9.5% (95% confidence interval, 1.1%–30.4%), specificity of 98.2% (90.7%–99.9%), a positive predictive value of 66.7% (9.4%–99.1%), and a negative predictive value of 75.4% (63.7%–84.2%).[34] Based on the discrepancies between the dye dilution techniques and sonographic measurements, the authors urged caution when interpreting AFI results as representative of actual AFV.[35]

Longitudinal Variation in Amniotic Sac Fluid Volume

Longitudinal studies examining AFV over GA supported a nonlinear correlation between GA and fluid volume when the AFI was used to measure AFV (Figure 2). Studies were divided according to whether the authors measured the AFI without accounting for the dividing membrane (Figure 2A) or accounting for the dividing membrane (Figure 2B). Most studies showed a similar trend toward increases in AFI measurements around 24 to 26 weeks of pregnancy and then a slow decline until delivery, whether the dividing membrane was accounted for (Figure 2). Correlation analysis conducted by 2 studies supported a quadratic equation with a significant deviation from 0.[16,24,25,27] A comparable pattern of AFV variation was observed in singleton pregnancies (Figure 2C).[16]

Two of the 3 studies that accounted for the dividing membrane in the AFV measurement reported a nonlinear correlation between the AFI and GA, with a peak AFI measured at 26 to 28 weeks' gestation and then declining linearly until delivery (Figure 2B).[30,36] In contrast to these studies, Magann et al[29] reported no correlation between GA

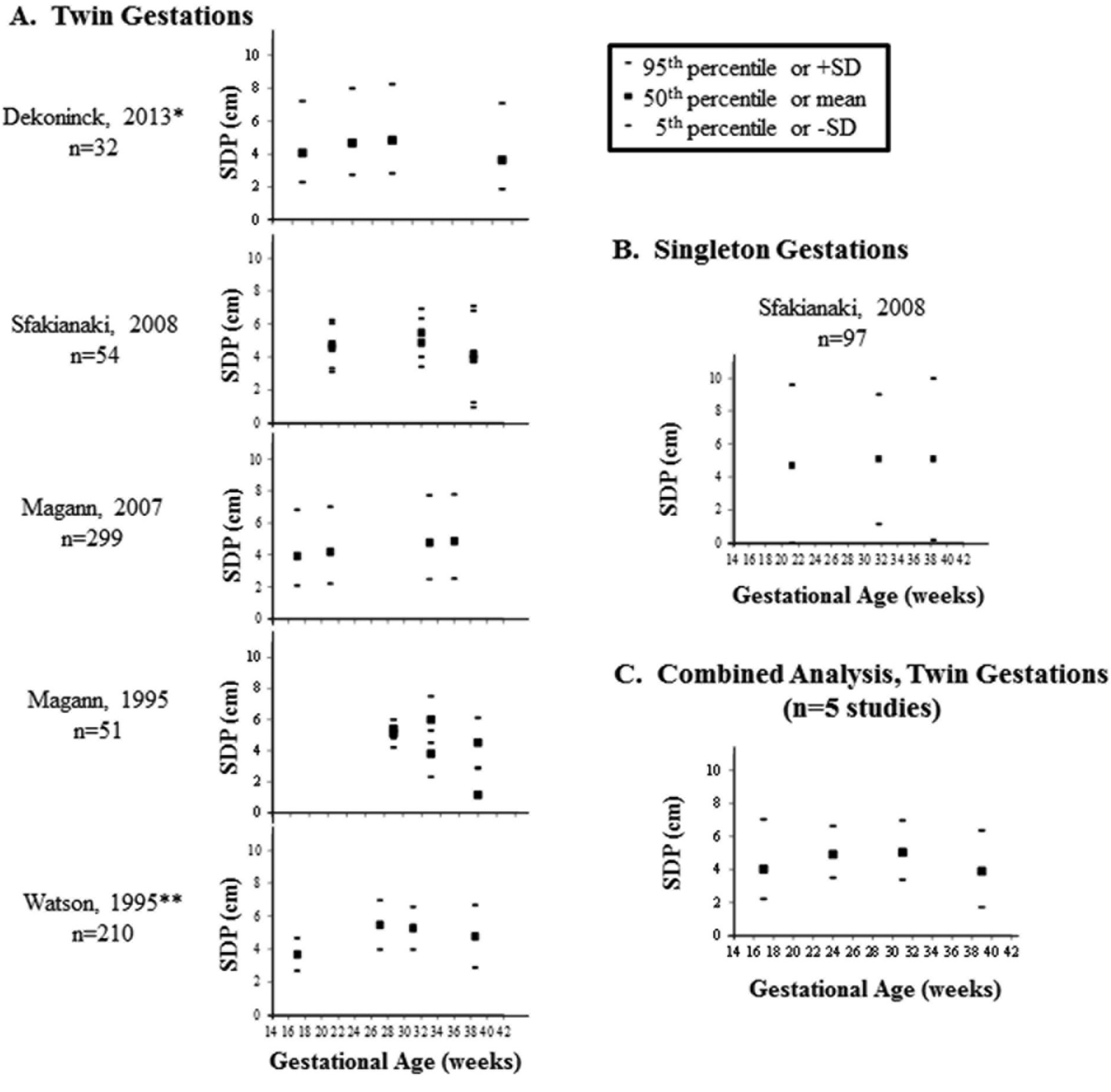
Figure 2. Longitudinal analysis of the AFI in 6 twin studies compared to a singleton-gestation reference study. Reported are the first GA interval in the study, the GA interval at peak fluid volume, the GA interval approximating the plateau point, and the latest GA included in the study. Data are plotted as the mean of the AFIs reported at the 50th percentile. Twin studies are grouped by differences in AFI measurement methods: AFI measurements that did not account for the dividing membrane (**A**) and AFI measurements that accounted for dividing membrane (**B**). **C**, Twin studies were compared to a singleton reference study.[16] *Dashes represent ranges in that study.



and AFV using dye dilution techniques in a longitudinal study of 45 sets of diamniotic twins from 27 to 38 weeks' gestation ($r = 0.134$; $P = .404$; Figure 2B). However, the patients in that study were enrolled between 27 and 38 weeks' gestation. This time point was at or after peak AFV reported by other investigators. Overall, these results support a peak AFI at approximately 24 to 26 weeks, with a steady decline until term.

Five studies conducted prospective longitudinal analyses of AFV in twin pregnancies using the SDP to estimate the AFV. Three of the 5 studies found no statistical correlation with GA (Figure 3).[2,3,25] In twins, there was a trend toward peak AFV at the 31- to 32-week interval, with a decline until delivery, although only 2 of the 5 studies reported statistically significant correlations (Figure 3).[18,24]

Figure 3. Longitudinal analysis of the SDP in 5 twin studies (**A**) compared to singleton gestations (**B**).[31] Reported are the first GA interval in the study, followed by the GAs closest to 21.2, 31.7, and 38.3 weeks' gestation (the intervals plotted by Sfakianaki et al[31]). **C**, Combined analysis of all SDP studies (n = 5). *Dashes represent the 97.5% confidence interval (upper) and 2.5% confidence interval (lower). **Dashes represent standard deviations.



Sac Volume in Normal Twin Versus Singleton Pregnancies
Four studies compared sac volumes in singleton and twin pregnancies.[13,24,30,31] Only 1 study used a direct comparison between singleton and twin pregnancies.[31] The others compared study values to singleton sac volumes reported in the literature.[3,16] Studies using AFI or dye dilution techniques showed a higher AFV in twins than singletons at 35 to 38 weeks' gestation, whereas SDP measurements were lower in twins than singletons (Table 4).

The possible explanations for the discrepancy among techniques include high variation among individual patients, especially in the dye dilution technique (Table 4). The method of AFI measurement further confounds comparisons between studies. The technique of Watson et al[24] in twins used a summated AFI, measuring the deepest pocket in all 4 quadrants and ignoring membrane placement. In contrast, Hill et al[30] identified the dividing membranes in twins and measured the SDP in each of the 4 quadrants of each individual sac. An analysis of the accuracy of the summated AFI technique using dye-determined AFVs of pairs of twin sacs found that if membrane placement was ignored, the summated AFI was a poor predictor of intertwin differences in AFV and did not identify twin pairs at risk for oligohydramnios and polyhydramnios.[28]

Amniotic Fluid Volume Concordance Among Sacs in Diamniotic Dichorionic and Diamniotic Monochorionic Twins
Intersac comparisons were made intratwin (comparing diamniotic sac volumes between twin pairs) and intertwin (monoamniotic sac volume compared to diamniotic sac volume between twin pairs). Only dye dilution techniques supported differences in AFV between twins, suggesting that sonographic methods may underestimate discordance between sacs in twins.

No differences were reported in AFV between the sacs when measured by the AFI, SDP, or 2DP.[25,30] When dye dilution techniques were used to measure AFV in diamniotic twins, 32% of amniotic sacs from diamniotic twins were significantly discordant (AFV normal in one twin with oligohydramnios or polyhydramnios in the other twin). Of the discordant twins, 90% were estimated to be normal when measured by the AFI, which suggests a discrepancy in data based on the measurement technique.[28] The discrepancy between AFI and dye dilution measurements could be due to the use of the summated AFI (ignoring membrane placement).

Sac volumes were compared among monochorionic and dichorionic sets of diamniotic twins in 2 studies.[25,32] Hernandez et al[32] reported no significant differences in SDP measurements among dichorionic and monochorionic twins segregated according to the degree of polyhydramnios (mild, moderate, or severe). Furthermore, Chau et al[25] reported no significant differences in the AFI, SDP, or 2DP among dichorionic and monochorionic twins ($P > .05$). Taken together, these results suggest that sonographic methods do not predict discordances in AFV with the same sensitivity as the dye dilution technique.

Incidence of Oligohydramnios and Polyhydramnios
The incidence of oligohydramnios and polyhydramnios in twin gestations is difficult to assess given fluctuations in AFV over GA, discrepancies among methods, and differences in GAs reported among studies (Table 5). Oligohydramnios incidence in AFV twin studies ranged from 1% to 39%, and polyhydramnios incidence ranged from 0.5% to 18% (Table 5).[1,2,9,24,27,30,32,34]

Table 4. Comparison of AFV in Singletons and Twins by SDP, AFI, and Dye Dilution Techniques

AFV Measurement Method	AFV of Combined Twin Studies, % of Singleton	GA Range, wk	AFV Measurement: Singleton		Twin			
					Sfakianaki, 2008			Magann, 1995
			Sfakianaki, 2008		Twin A	Twin B	Watson, 1995	(*JSGI*)
SDP	89	35–38	5.1 ± 0.5 cm		3.9 ± 0.4 cm	4.2 ± 0.4 cm	5.2 ± 1.5 cm	4.9 cm
					Hill, 2000			
			Moore, 1990	Phelan, 1987	Twin A	Twin B	Watson, 1995	
AFI	125	37–41	11.5 cm	16.2 ± 5.3 cm	13.1 cm	12.3 cm	16.0 ± 5.8 cm	
			Magann, 1997		Magann, 1995 (*JSGI*)			
Dye dilution	113	27–38	777 mL		877 ± 860 mL			

Data are presented as mean ± SE for Sfakianaki and mean ± SD for Watson, Phelan, and Magann where applicable. Abbreviations are as in Table 1.

Adverse Outcomes Associated With Abnormal AFV

The studies that examined a possible association between abnormal AFV and adverse antepartum, intrapartum, and perinatal outcomes are listed in Table 2.

Antepartum Outcomes Associated With AFV

Preterm Birth

Four studies investigating antepartum outcomes in twins showed discordant results when evaluating an association between polyhydramnios and preterm birth (Table 6).[13,31–33] Three of the 4 studies reported a higher incidence of polyhydramnios in fetuses delivered prematurely (Table 6). The discrepancy among studies could be due to the measurement method (AFI versus SDP), the thresholds used for defining polyhydramnios, or failure to adequately exclude TTTS cases from the preterm cohort. One of the studies reported a small but statistically significant increase in placenta previa in the polyhydramnios cohort relative to normal fluid volumes (4.5% versus 1.7%, respectively; $P = .010$).[33] However, none of the other studies commented on this outcome.

One study reported no correlation between maternal diabetes and the diagnosis of polyhydramnios ($P = .12–.56$)[32]; however, the other studies either excluded diabetic women from study participation or did not report on the incidence. In summary, preterm birth was the only antenatal outcome associated with abnormal AFV in most of the available studies.

Table 5. Incidence of Polyhydramnios and Oligohydramnios in Twin Gestations

Study	Method	GA Range, wk	Incidence of Polyhydramnios	Incidence of Polyhydramnios	Incidence of Oligohydramnios	Incidence of Oligohydramnios
Rådestad, 1990	SDP	21–34	1/200	0.5	Not given	Not given
Hill, 2000	AFI	28–38 (twin A)	19/488 (sac A)	4.0	7/488 (sac A)	2.2
		18–39 (twin B)	20/488 (sac B)		10/488 (sac B)	
Magann, 1999	Dye dilution	Not given	9/120 sacs	7.5	31/120 sacs	26.0
Magann, 1995 (*JSGI*)	Dye dilution	32.6 ± 2.6	7/90 sacs	7.8	35/90 sacs	38.9
Magann, 2000	Dye dilution	Not given	2/46	4.3	14/46	30.4
Porter, 1996	AFI	Not given	127/1,101[a]	11.5	13/1,101a	1.2
Orhan, 2005	AFI	<30?	201/13,111	1.5	Not given	Not given
Magann, 2007	SDP	<17–37	18/518	3.5	22/518	4.2
Hernandez, 2012	SDP	Not given	348/1,951	17.8	Not given	Not given

Data are presented as mean ± SD where applicable. Abbreviations are as in Table 1.
[a]Total number of sonographic examinations; may have overestimated.

Table 6. Antepartum Outcomes: Comparison of Preterm Birth and Abnormal Fluid Volumes (Measured by SDP or AFI)

Study	Pregnancies, n	Preterm GA at Delivery, wk	Type of Twin	AFV Assessment					P
				Oligohydramnios, %	Normal, %	Polyhydramnios, %			
Orhan, 2005[a]	11,947	<35	MCDC	NA	35	49			<.001
		<32	MCDC	NA	11	25			<.001
Magann, 2007	300	<37	MCDC	56	62	86			.04
Sfakianaki, 2008	92	<35	MCDC	NA	NA	NA			.002, .004[b]
					Normal, %	Mild, %[c]	Moderate, %[c]	Severe, %[c]	
Hernandez, 2012	1,951	≤36	DC	NA	43	42	37	25	.53
			MC	NA	46	49	55	67	.53
		≤34	DC	NA	22	21	12	17	.44
			MC	NA	22	22	30	33	.79
		≤32	DC	NA	11	10	2	8	.89
			MC	NA	10	11	15	33	.28

Abbreviations are as in Tables 1 and 2.
[a]Subgroup analysis of preterm birth, removing pregnancies with greater than 25% AFV discordance by AFI.
[b]*P* values are reported for fluid volumes in preterm twins (SDP of 3.7 ± 0.3 cm in fetus A and 4.4 ± 0.3 cm in fetus B) compared to term twins (4.9 ± 0.2 cm in fetus A and 5.5 ± 0.2 cm in fetus B) and term singletons (5.1 ± 0.4 cm); no segregation by polyhydramnios.
[c]Mild, 8 to 9.9 cm; moderate, 10 to 11.9 cm; severe, 12 cm or greater.

Fluid Volume Discordance
Several studies have reported that the risk of preterm labor, preterm delivery, and fetal mortality is significantly increased in cases of fluid discordance.[5,20,22,37–39] The incidence of discordant fluid volume is higher in monochorionic twins (40%–50%) than dichorionic twins (15%).[38] Patten et al[22] reported an association between placental abnormalities/discordant growth and increased mortality in the oligohydramnios twin. Of note, TTTS is the finding most frequently associated with discordant AFV in twins,[4,6] but adverse outcomes associated with TTTS are beyond the scope of this review.

Intrapartum Outcomes Associated With AFV
Associations between stillbirth and polyhydramnios were reported in 2 studies (Table 7).[32,33] None of the other parameters investigated were associated with differences in AFV among cohorts (Table 2).

Perinatal Outcomes Associated With AFV
Perinatal complications investigated included Apgar scores,[3,32] respiratory distress syndrome and tachycardia/bradycardia, nonreassuring fetal heart rate monitoring, abnormal fetal heart rate tracing in labor,[3] admission to the neonatal intensive care unit (NICU),[3,33] neonatal death,[32,33] and anomalous neonates (Table 8).[32] Only 1 of 3 studies reported a significant association between birth weight and AFV (Table 8).[13,32,33]

Adverse perinatal outcomes were more frequent in monochorionic than dichorionic twins (Table 8), with outcomes of a nonreassuring fetal heart rate and neonatal complications reported in the only study that investigated these outcomes (Table 8).[3] Of the 2 studies investigating low Apgar scores, only 1 reported a significant association between elevated AFV and a low Apgar score, but the discrepancy between the studies could be explained by the differences in the threshold selected (Table 8).[13,32]

Both of the studies that investigated associations between NICU admission and AFV reported a higher incidence in hydramnios cases, but in only 1 study did the difference reach statistical significance (Table 8).[32,33]

Neonatal death was only associated with hydramnios in 1 of 2 studies. Differences in the method of AFV assessment (AFI versus SDP), stringency of exclusion criteria for TTTS, and differences in cohort division (dividing monochorionic and dichorionic twins into separate cohorts) are some possible explanations for differences in results among studies.

Summary of Evidence and Recommendations for Clinical Practice

Measurements
As in singleton pregnancies, there are discrepancies among methods that are used to measure AFV: (1) dye dilution techniques consistently report higher incidences of polyhydramnios or oligohydramnios than sonographic techniques and subjective measures[7,10]; (2) AFV by dye dilution techniques does not appear to change significantly in the third trimester of pregnancy, whereas longitudinal analysis appears to follow the nonlinear quadratic regression models proposed for singleton pregnancies, peaking at around 24 to 26 weeks' gestation, plateauing, and then declining until birth in sonographic methods; and (3) measured sac volumes in diamniotic twins appear to be comparable to those in singleton pregnancies. Collectively, these results support the following: (1) assessing AFV in twins by measuring each sac separately; and (2) using defined GA ranges to define oligohydramnios or polyhydramnios when using sonographic methods to clinically assess AFV.

Outcomes
Associations between adverse outcomes and AFV are inconsistent among studies. However, discordant fluid vol-

Table 7. Intrapartum Outcomes: Comparison of Stillbirth and Abnormal Fluid Volumes

Study	Measurement Method	Type of Twin	Normal Pregnancies, n	Polyhydramnios Pregnancies, n	AFV Assessment: Normal, %	AFV Assessment: Polyhydramnios, %			P
Orhan, 2005[a]	AFI	MCDC	11,817	130	0.3	3.8			<.001
					Normal, %	Mild, %[b]	Moderate, %[b]	Severe, %[b]	
Hernandez, 2012	SDP	DC	1,077	234	1	1	0	0	>.05
		MC	526	114	3	1	0	27	<.001

Abbreviations are as in Tables 1 and 2.
[a]Subgroup analysis of preterm birth, removing pregnancies with greater than 25% AFV discordance by AFI.
[b]Mild, 8 to 9.9 cm; moderate, 10 to 11.9 cm; severe, 12 cm or greater.

umes and polyhydramnios in twin pregnancies may place the affected fetus at elevated risk for adverse outcomes. One or more studies supported elevated risks of preterm birth, stillbirth, and adverse neonatal outcomes (ie, low Apgar scores, small for GA, and admission to the NICU) in polyhydramnios cases. Improving the reliability of sonographic measurement accuracy in twin pregnancies may enhance the predictive power of AFV assessment in risk assessment of adverse outcomes in twin gestations.

Study Limitations

Our study was limited by the discrepancies between sonographic and dye dilution methods, differences among the cohorts (including differences in GA for inclusion among the different studies and differences in measurement types used), differences in sample sizes of the study populations, and differences in GAs at sonographic measurement and delivery. In comparing AFVs in singletons and controls, all studies except the study by Sfakianaki et al[31] compared the AFVs to historical controls rather than directly comparing singletons and twins. Longitudinal studies may be biased by the range of GAs, patient demographics in study populations, and differences in exclusion criteria (with many studies excluding twin pregnancies with fluid discordance >20% as suspicious for TTTS). Furthermore, none of the studies measured the same outcome variables.

Conclusions

Sonographic measurements of AFV in twin pregnancies are reproducible and not dependent on sonographer experience. However, sonographic estimation of AFV (using the AFI, 2DP, or SDP) has high specificity but poor sensitivity for detecting abnormal AFV (oligohydramnios or polyhydramnios). These discrepancies among methods for AFV assessment in identifying abnormal fluid volumes suggest that caution should be exercised when interpreting

Table 8. Perinatal Outcomes and Abnormal Fluid Volumes

Study	Measurement Method	Type of Twin	Normal Pregnancies, n	Polyhydramnios Pregnancies, n	Outcome	AFV Assessment				P
						Normal, %	Polyhydramnios, %			
Orhan, 2005[a]	AFI	MCDC	11,817	130	Neonatal death	0.2	1.5			<.001
					NICU/SCN admission	43.3	54.3			<.001
					Small for GA	5.1	8.7			<.001
Magann, 2007	SDP	MCDC	518	22	Tracing influencing delivery	8	27			.013
					Nonreassuring fetal heart rate	9	27			.023
					Apgar score <7 (1 min)	31	46			.154
					Apgar score <7 (5 min)	27	10			.028
					Neonatal complications (RDS, TTN)	21	55			.002
						Normal, %	Mild, %[b]	Moderate, %[b]	Severe, %[b]	
Hernandez, 2012	SDP	DC	1,077	234	Birth weight <10th percentile	22	15	22	25	.17
					Apgar score ≤3 (5 min)	1	0	0	0	.73
					NICU admission	18	12	15	17	.40
					Neonatal death	1	0	0	0	.63
		MC	526	114	Birth weight <10th percentile	27	16	20	33	.21
					Apgar score ≤3 (5 min)	3	0	0	0	.90
					NICU admission	16	23	15	33	.39
					Neonatal death	3	1	0	0	.78

Abbreviations are as in Tables 1 and 2.
[a]Subgroup analysis of preterm birth, removing pregnancies with greater than 25% AFV discordance by AFI.
[b]Mild, 8 to 9.9 cm; moderate, 10 to 11.9 cm; severe, 12 cm or greater.

data characterizing AFV in normal and complicated pregnancies. Additionally, the studies evaluating antepartum, intrapartum, and perinatal outcomes associated with AFV in twin pregnancies have been limited and have not been consistent in outcomes assessed. Thus, if AFV assessment is to be used for identifying pregnancies at risk for stillbirth, preterm birth, and perinatal complications, more rigorously controlled studies need to be undertaken to verify the optimal sonographic strategy.

References

1. Magann EF, Chauhan SP, Martin JN Jr, Whitworth NS, Morrison JC. Ultrasonic assessment of the amniotic fluid volume in diamniotic twins. *J Soc Gynecol Investig* 1995; 2:609–613.
2. Magann EF, Whitworth NS, Bass JD, Chauhan SP, Martin JN Jr, Morrison JC. Amniotic fluid volume of third-trimester diamniotic twin pregnancies. *Obstet Gynecol* 1995; 85:957–960.
3. Magann EF, Doherty DA, Ennen CS, et al. The ultrasound estimation of amniotic fluid volume in diamniotic twin pregnancies and prediction of peripartum outcomes. *Am J Obstet Gynecol* 2007; 196:570.e1–570.e6.
4. Huber A, Diehl W, Zikulnig L, Bregenzer T, Hackelöer BJ, Hecher K. Perinatal outcome in monochorionic twin pregnancies complicated by amniotic fluid discordance without severe twin-twin transfusion syndrome. *Ultrasound Obstet Gynecol* 2006; 27:48–52.
5. Kaneko M, Sameshima H, Ikeda T, Kodama Y, Ikenoue T. Antepartum evaluation of monochorionic diamniotic (MD) twins: MD-twin score—a new scoring method for perinatal outcome. *J Obstet Gynaecol Res* 2000; 26:111–116.
6. Van Mieghem T, Eixarch E, Gucciardo L, et al. Outcome prediction in monochorionic diamniotic twin pregnancies with moderately discordant amniotic fluid. *Ultrasound Obstet Gynecol* 2011; 37:15–21.
7. Magann EF, Martin JN Jr. Amniotic fluid volume assessment in singleton and twin pregnancies. *Obstet Gynecol Clin North Am* 1999; 26:579–593.
8. Volante E, Gramellini D, Moretti S, Kaihura C, Bevilacqua G. Alteration of the amniotic fluid and neonatal outcome. *Acta Biomed* 2004;75(suppl 1):71–75.
9. Magann EF, Chauhan SP, Whitworth NS, Anfanger P, Rinehart BK, Morrison JC Determination of amniotic fluid volume in twin pregnancies: ultrasonographic evaluation versus operator estimation. *Am J Obstet Gynecol* 2000; 182:1606–1609.
10. Goldstein RB, Filly RA. Sonographic estimation of amniotic fluid volume: subjective assessment versus pocket measurements. *J Ultrasound Med* 1988; 7:363–369.
11. Charles D, Jacoby HE. Preliminary data on the use of sodium aminohippurate to determine amniotic fluid volumes. *Am J Obstet Gynecol* 1966; 95:266–269.
12. Magann EF, Whitworth NS, Files JC, Terrone DA, Chauhan SP, Morrison JC. Dye-dilution techniques using aminohippurate sodium: do they accurately reflect amniotic fluid volume? *J Matern Fetal Neonatal Med* 2002; 11:167–170.
13. Magann EF, Chauhan SP, Doherty DA, Magann MI, Morrison JC. The evidence for abandoning the amniotic fluid index in favor of the single deepest pocket. *Am J Perinatol* 2007; 24:549–555.
14. Phelan JP, Ahn MO, Smith CV, Rutherford SE, Anderson E. Amniotic fluid index measurements during pregnancy. *J Reprod Med* 1987; 32:601–604.
15. Manning FA, Platt LD, Sipos L. Antepartum fetal evaluation: development of a fetal biophysical profile. *Am J Obstet Gynecol* 1980; 136:787–795.
16. Moore TR, Cayle JE. The amniotic fluid index in normal human pregnancy. *Am J Obstet Gynecol* 1990; 162:1168–1173.
17. Moher D, Liberati A, Tetzlaff J, Altman DG; PRISMA Group. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *PLoS Med* 2009; 6:e1000097.
18. Dekoninck P, Deprest J, Lewi P, et al. Gestational age-specific reference ranges for amniotic fluid assessment in monochorionic diamniotic twin pregnancies. *Ultrasound Obstet Gynecol* 2013; 41:649–652.
19. Schneider KT, Vetter K, Huch R, Huch A. Acute polyhydramnios complicating twin pregnancies. *Acta Genet Med Gemellol (Roma)* 1985; 34:179–184.
20. Chescheir NC, Seeds JW. Polyhydramnios and oligohydramnios in twin gestations. *Obstet Gynecol* 1988; 71:882–884.
21. Lange IR, Harman CR, Ash KM, Manning FA, Menticoglou S. Twin with hydramnios: treating premature labor at source. *Am J Obstet Gynecol* 1989; 160:552–557.
22. Patten RM, Mack LA, Harvey D, Cyr DR, Pretorius DH. Disparity of amniotic fluid volume and fetal size: problem of the stuck twin—US studies. *Radiology* 1989; 172:153–157.
23. Rådestad A, Thomassen PA. Acute polyhydramnios in twin pregnancy: a retrospective study with special reference to therapeutic amniocentesis. *Acta Obstet Gynecol Scand* 1990; 69:297–300.
24. Watson WJ, Harlass FE, Menard MK, McCurdy CM, Brady K, Miller RC. Sonographic assessment of amniotic fluid in normal twin pregnancy. *Am J Perinatol* 1995; 12:122–124.
25. Chau AC, Kjos SL, Kovacs BW. Ultrasonographic measurement of amniotic fluid volume in normal diamniotic twin pregnancies. *Am J Obstet Gynecol* 1996; 174:1003–1007.
26. Hill LM, Lazebnik N, Many A. Effect of indomethacin on individual amniotic fluid indices in multiple gestations. *J Ultrasound Med* 1996; 15:395–399.
27. Porter TF, Dildy GA, Blanchard JR, Kochenour NK, Clark SL. Normal values for amniotic fluid index during uncomplicated twin pregnancy. *Obstet Gynecol* 1996; 87:699–702.
28. 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; 177:1041–1045.
29. Magann EF, Whitworth NS, Rhodes PG, Bass JD, Chauhan SP, Morrison JC. Effect of amniotic fluid volume on neonatal outcome in diamniotic twin pregnancies. *South Med J* 1998; 91:942–945.

30. Hill LM, Krohn M, Lazebnik N, Tush B, Boyles D, Ursiny JJ. The amniotic fluid index in normal twin pregnancies. *Am J Obstet Gynecol* 2000; 182:950–954.
31. Sfakianaki AK, Buhimschi IA, Pettker CM, et al. Ultrasonographic evaluation of myometrial thickness in twin pregnancies. *Am J Obstet Gynecol* 2008; 198:530.e1–530.e10.
32. Hernandez JS, Twickler DM, McIntire DD, Dashe JS. Hydramnios in twin gestations. *Obstet Gynecol* 2012; 120:759–765.
33. Orhan A, Kurzel RB, Istwan NB, Rhea D, Burgess E, Stanziano G. The impact of hydramnios on pregnancy outcome in twin gestations. *J Perinatol* 2005; 25:8–10.
34. 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.
35. Magann EF, Chauhan SP, Morrison JC. Amniotic fluid index estimation of amniotic fluid volume must be validated. *Am J Obstet Gynecol* 1996; 175:757–758.
36. Gerson A, Free SM Jr, Russino J, Maenner G, Weitz G, Young L. Amniotic fluid index in twin gestation. *Ultrasound Obstet Gynecol* 1997; 10:98–102.
37. Hashimoto B, Callen PW, Filly RA, Laros RK. Ultrasound evaluation of polyhydramnios and twin pregnancy. *Am J Obstet Gynecol* 1986; 154:1069–1072.
38. Snijder MJ, Wladimiroff JW. Fetal biometry and outcome in monochorionic vs dichorionic twin pregnancies: a retrospective cross-sectional matched-control study. *Ultrasound Med Biol* 1998; 24:197–201.
39. Bromley B, Frigoletto FD, Jr, Estroff JA, Benacerraf BR. The natural history of oligohydramnios/polyhydramnios sequence in monochorionic diamniotic twins. *Ultrasound Obstet Gynecol* 1992; 2:317–320.