Amniotic Fluid Volume Assessment: How to and Why: 19 Years of Studies

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Objectives

- To understand the role of amniotic fluid volume determination in the targeted US and antenatal testing.
- To understand the relationship between an ultrasound estimated amniotic fluid volume and a dye-determine or directly measured amniotic fluid volume.
- To determine which method of estimating the amniotic fluid volume, the AFI or the SDP is a better predictor or pregnancy outcomes.
University of Arkansas for Medical Sciences
What is Amniotic fluid?

Amniotic cavity
Dialysate of maternal and fetal blood
Fetal urine
Fetal swallowing
Fetal respiration
Fetal skin
Amnion – Chorion
When and Why do we Evaluate AF Volume in Pregnancy

Use of AF volume at the time of the anatomic survey
- Oligohydramnios
- Hydramnios

Pregnancies at-risk for an adverse outcome
- Chronically stressed fetus
- BPP
- Modified BPP
AF Volume Assessment

Precise measurement
- Dye-determined volume
- Measurement at the time of cesarean delivery

Estimate of AF volume
- AFI
- SDP
- Subjective assessment
Estimate of AF Volume

**AFI**
- Abdomen divided into 4 quadrants
- LVP of fluid in each of 4 quadrants is summed
- Oligo 0-5, normal 5-20. Hydramnios > 20

**SDP**
- LVP with horizontal measurement of 1 cm
- Oligo \( \leq 2 \), normal 2-8, Hydramnios > 8
Management of High Risk Pregnancies with Low Fluid

> 34 weeks of gestation
  - Induction and delivery

< 34 weeks of gestation
  - Admission, corticosteroids, PO or IV hydration, reassessment with possible induction
Normal AF Volume

Normal AF volume across gestation.

- 705 volumes from 5 studies with direct measurements & 7 with dye-dilution techniques
- Dye-dilution: Coomassie blue, cardiogreen, and para-amino hippurate
- Constant volume from 22 to 39 weeks averaging 777 ml, peaking at 32-34 weeks

Brace, Wolfe AJOG 1989;161:382
Normal AF Volume Across Gestation

Amniotic Fluid Volume During Normal Pregnancy

Normal AF Volume

Normal AF volume across gestation

- 144 singleton pregnancies with all assessments done in single institution using same techniques by the same provider and the same lab for analysis
- Growth curves used rather than polynomial regression model
- AF volume peaked late in third trimester

Magann: Obstet Gynecol 1997;90:524-8
AF Volume in Normal Singleton Pregnancies Growth Curve Modeling
Actual AF Volume Vs Ultrasound
Estimated AF Volume

Moore and Brace: Study on 5 sheep
  – (Abstract SGI #286 1988)
  – Infused saline and AFI \( r = 0.94 \)

Sepulveda: Assessed 16 pregnancies with oligohydramnios at mid-gestation
  – Serial amnioinfusions with AFI measurements
  – Correlation of AFI and SDP with infusion
  – Only 30% of variation in AFI could be explained by the infusion

Sepulveda AJOG 1994;170:1160
AF Volume Determined by Dye-dilution Technique

PAH (Charles and Jacoby 1966)
Nontoxic, physiologically inert, diffuses rapidly, does not cross the membranes or placenta rapidly, can be used in constant dose (400 mg 2 ml)
Mix for 20 minutes
Spectrophotometric reading at 540
Volume determined by dividing the quantity of PAH in 1 ml of undiluted fluid into 400.
Technique validated in the lab
AJOG 1966;95:266-9
AJOG 1992;167:1533-7
Do Dye-determined and Directly Measured AF Volumes Correlate?

Magann: 15 patients undergoing C/S
- Dye-determined volume prior to cesarean
- Directly measured volume at cesarean
- Volumes compared
- Correlation (r = 0.99)

J Mater Fetal Med 2002;11:167
Actual AF Volume Vs Ultrasound

Estimated AF Volume

Croom: Dye-dilution technique (PAH)
- 50 women undergoing C/S, AFI and SDP, amniocentesis, dye-dilution
- 2 with oligohydramnios both identified with AFI and none with hydramnios (AFI overestimates at upper volumes)

Croom AJOG 1992;167:995
Actual AF Volume Vs Ultrasound
Estimated AF Volume

Dildy: 13 US measurements and correlation with dye-dilution (PAH) techniques on 50 patients
- AFI useful for normal AF volumes
- Overestimation by 89% at low volumes
- Underestimation by 54% at high volumes
- 12/50 had oligohydramnios by PAH

Dildy AJOG 1992;167:986
Actual AF Volume Vs Ultrasound
Estimated AF Volume

Magann: Dye dilution (PAH) and AFI in 40 patients: 15 oligo, 19 normal, 6 hydramnios
  – Good correlation with AFI and normal AFV
  – Oligo, sensitivity of AFI was 6.7%

Magann: Dye dilution (PAH) and AFI in 57 women
  – Good correlation with AFI and normal AFV
  – Oligo, sensitivity of AFI was 8.7%

Magann AJOG 1992;167:1533
Magann Obstet Gynecol 1994;83:959
Actual AF Volume Vs Ultrasound

Estimated AF Volume

Horsager: Directly measured AF volume at C/S and correlate with AFI and SDP
- Sensitivity of AFI was 18% (11/40 with oligohydramnios)

Schiff:
- Used mathematical model, subtracted placental volume and fetal volume = AF volume
- Dye dilution techniques using indigo carmine on 23 pregnancies undergoing termination 16-24 weeks
- Correlation of AF volume and dye dilution was $r = 0.815$)

Horsager Obstet Gynecol 1994;83:955
Schiff Obstet Gynecol 1990;76:44
Magann: Dye-determined AF volume on 79 singleton pregnancies

Presence or absence of a 2X2 pocket of AF

- 21 of the pregnancies had low fluid, 47 had normal fluid and 11 had hydramnios
- Only 3 of the 79 pregnancies did not have a 2X2 pocket

Actual AF Volume Vs Ultrasound
Estimated AF Volume

Chauhan & Magann: Dye determined volume on 144 pregnancies
  - Used ROC curves and regression analysis
    - R Value for the AFI, \( R = 0.34 \)
    - Calculation of prediction limits with 95% CI
    - For oligohydramnios to be absent the AFI would need to be 30

Chauhan: AJOG 1997;177:291
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<tr>
<th>Study (#)</th>
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<tr>
<td>Croom (50)</td>
<td>AFI/SDP</td>
<td>AFI-84% SDP 72%</td>
<td>2 Oligo No Hydram</td>
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<td>Dildy (50)</td>
<td>AFI ++</td>
<td>AFI 71%</td>
<td>87% over 54% under</td>
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<td>Magann (40)</td>
<td>AFI/SDP</td>
<td>AFI 74% 2DP 94%</td>
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<td>AFI/2DP</td>
<td>AFI 87%</td>
<td>AFI 8.7%</td>
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<td>Horsager (45)</td>
<td>AFI/SDP</td>
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<td>AFI 18% SDP 18%</td>
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<td>Sepulved (16)</td>
<td>AFI/SDP</td>
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<td>Only 30%</td>
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<tr>
<td>Magann (79)</td>
<td>2X2</td>
<td>AFI 98%</td>
<td>AFI 9.5%</td>
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<td>Chauha (144)</td>
<td>AFI</td>
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Subjective Vs. Objective Assessment of AF Volume

Magann: 63 singleton pregnancies

- Subjective assessment
  - MFM staff, MFM Fellow, Sonographer, Resident
- Objective assessment
  - AFI and SDP techniques
- Dye determined volume
- Normal fluid similarly identified by subjective evaluation (81-94%) and US techniques (78-98%).
- Abnormal fluid poorly identified
AF Volume and Pregnancy Outcomes

Limitations in obtaining actual volumes
  – Dye determined
  – Direct measurement

Three investigations with actual volumes in singleton pregnancies and perinatal outcomes and one in twin pregnancies.
AF Volume and Pregnancy Outcomes

Magann: dye-determined volume and outcome

- 50 singleton pregnancies with delivery in 48 hours
  - Greater risk of C/S for distress in hydramnios group (P < 0.03) and approached significance in oligohydramnios group (P < 0.056)
  - No difference in risk of meconium stained fluid, variable decelerations or low 5 min Apgar scores

Magann Obstet Gynecol 1994;83:959
AF Volume and Pregnancy Outcomes

Magann: dye-determined volume (74 pregnancies) and 10 intrapartum and perinatal outcomes

- Low vs. normal volumes:
  - Variable decelerations $(p=0.381)$, late decelerations $(p=0.875)$, C/S for distress $(p=0.259)$, IUGR (0.998), Cord pH < 7.2 (0.259)

- Mean AF volume of pregnancies
  - Variable decelerations $(p=0.287)$, late decelerations $(p=0.555)$, C/S for distress $(p=0.310)$, cord pH < 7.2 $(p=0.267)$

Magann J Perinatol 2004;24423-8
How important is the AF Volume as a Predictor of Outcome?

Magann: Prospective observational trial
- 100 women, unlabored undergoing C/S
- Dye determined low, normal and high volumes had similar number of fetuses with UapH < 7.2 (P = 0.371) and < 7 (P = 0.614)
- ROC from 100 – 1900 could not identify volumes to differentiate the newborns with pH < 7 from the normal 98 newborns

Which AF Estimation Should be Used?

Chamberlain, Hill, and Mercer
- SDP < .5 cm, < 1cm, < 2cm

Manning introduced the BPP in 1980

Phelan introduced the AFI in 1987

Moore claimed the AFI is superior to the SDP for the identification of oligohydramnios and this became the most widely used method

PUBMED 1987 – 2000: 3230 AFI vs. < 100 SDP or LVP or AFV

Phelan: J Reprod Med 1987;32:601
Moore: AJOG 1990;163:762-7
Modified BPP

AFI > 5 and reactive NST is associated with fetal well being within 1 week of testing

Clark: AJOG 1989;160:694-7
BPP

Fetal tone
Fetal movement
Fetal breathing movement
Nonstress Test
AF Pocket (2X1)

Manning AJOG 1980;136:787-95
Is the US estimate of AF volume using the BPP a 2X2 pocket of fluid or a 2X1 pocket of fluid.

## 2X2 vs. 2X1

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<td>Chamberlain</td>
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<td>Manning</td>
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Is the AFI Superior to the SDP?

Magann: challenged this concept in 2000

- The AFI was compared to the SDP to determine which is a better predictor of oligohydramnios but the end point or gold standard with the AFI, not an actual volume.

Comparison of the AFI and SDP to a dye-determined volume (179 pregnancies) both techniques are unreliable in the identification of abnormal AF volumes.

Are the AFI and the SDP Equivalent?

Some authors suggested that this 2 US estimates were interchangeable and either could be use.

Magann: 72% of the time when the AFI is $\leq 5$, there is still a 2X1 pocket of fluid present.

Magann: AJOG 1999;180:1354-9
AFI and SDP Across Gestation in Normal Pregnancies.

Moore: 791 pregnancies
- No fetal anomalies, normal pregnancies
- 5 minute Apgar > 6 and a birth weight between the 10-90%

Nwosu: Questioned Moore’s reference ranges

Follow up study from China and Japan also questioned Moore’s AFI

Moore: AJOG 1990;162:1168-73
Nwosu: Br J Obstet Gynecol 1993;100:816-9
Salahuddin J Matern Fetal Invest 1998;8:1-4
Lei: Obstet Gynecol 1998;92:237
AFI and SDP Across Gestation in Normal Pregnancies

Magann: 1400 women evaluated with normal pregnancies, 50 at each gestational age from 14-41 weeks

- No anomalies, pregnancy complications, birth weight between the 10-90%, Apgar > 6 at 5 minutes
- If we used Moore and Cayle reference ranges on out patients 1/3 would be labeled with an abnormal AF volume
- The SDP identified the fewest number of these normal women as having an abnormal AF volume.

Magann: AJOG 2000;182:1581-88
Color Doppler and the US Estimate of AF Volume

Magann: 67 singleton pregnancies

- US estimate of AF volume with AFI and SDP without color Doppler and with color Doppler followed by dye-determined volumes
- AFI: 11.6 w/o color 9.3 w/color
- SDP: 4.5 w/o color 3.7 w/color
- Use of color did not identify any more women with oligo, but did reclassify 9 normal volumes as oligo
- Use of color Doppler leads to over-diagnosis of oligo

Obstet Gynecol 2001;98:71-4
Measure to the Cord or Through the Cord

Measurement of the AFI and SDP to the cord and through the cord

AF volume was dye-determined by amnio
28 of 100 with oligohydramnios
- AFI to the cord identified 7/28 (25%)
- AFI through the cord identified 2/28(7%) [p=0.025]
- SDP 7% to and 0% through

Ultrasound Obstet Gynecol 2002;20:464-7
Predictability of the AFI for an Adverse Pregnancy Outcome

Rutherford: 330 high risk pregnancies
- Increased risk of FHR decelerations in labor
- Meconium stained AF
- C/S for fetal distress
- Low Apgar scores

Miller: Modified BPP on 15,482 women
- 1790 women had an AFI of $\leq 5$ (728 detailed data)
  - 78 had intrapartum fetal distress, meconium stained amniotic fluid or 5 minute Apgar < 7 for false + rate of 63% (if the 28 IUGR fetuses were considered the false + rate would be higher)
  - 13 stillbirths all had an AFI > 6

Rutherford Obstet Gynecol 1987;87:353-6
Miller: AJOG 1996;174:812-7
Predictability of the AFI for an Adverse Pregnancy Outcome

Baron: intrapartum AFI ≤ 5
- Increased risk of variable decelerations and C/S for fetal distress, but not meconium

Magann: 1001 high risk pregnancies
- No greater risk of amnioinfusion, variable or late decelerations, low Apgar scores or UapH < 7 for AFI ≤ 5 vs. > 5

Baron: AJOG 1995;173:167-74
Magann: AJOG 1999;180:1330-36
Predictability of the AFI for an Adverse Pregnancy Outcome

Alfirevic: 500 post-term pregnancies
- NST: AFI vs. SDP
- AFI labeled 10% as oligo, SDP labeled 2%
- More inductions and trend to more C/S without any improvement in perinatal outcome

Alfirevic: BJOG 1997;104:207-11
Predictability of the AFI for an Adverse Pregnancy Outcome

Conway: 183 normal pregnancies AFI ≤5
- No adverse outcome: C/S for distress, meconium, low Apgar scores, low UaPH or NBICU admissions

Schucker: 136 women with severe preeclampsia
- Case control study
- AFI ≤5 vs. > 5
  - No increased risk of C/S for distress or non reassuring fetal heart rate testing

Barrilleaux: 120 women with HELLP
- 26 AFI ≤5 vs. 94 AFI > 5
- No difference severity of HELLP, C/S for distress, variables in labor, low Apgar or cord pH < 7

Schucker:AJOG 1996;175:1018-23
Barrilleaux: J Reprod Med: 2007;52:293-8
Predictability of the AFI for an Adverse Pregnancy Outcome

Chauhan: Meta-analysis 1987-1997
- 18 studies 10,551 patients
- C/S for fetal distress and low Apgar scores more frequently with AFI \( \leq 5 \)
- No difference UapH < 7 (3 studies no difference)
- Importance of UapH vs other parameter assessing perinatal outcome

Chauhan AJOG 1999;181:1473-8
What is the AFI Value Associated with an Adverse Outcome

Baron and Rutherford found an AFI ≤ 5
Dizon-Townsend found ≤ 7, Jeng ≤ 8
Moore suggested the “5 cm rule” is below the 1% for normal AFI across gestation and suggests that 8 cm would be better.
Should we use a % (≤5\textsuperscript{th}) for gestational age?

Predictability of the AFI and SDP < 3rd and 5th % to Detect Oligohydramnios

291 Pregnancies:
- US estimated (AFI & SDP) AF volume
- AFI and SDP < 3rd and 5th % based on this population
- Dye determined AF volume: 75 (26%) with oligo
- AFI and SDP < 3rd and 5th % were no better than fixed cut offs to identify oligo (11-27%)

Magann AJOG 2004;190:164-9
Predictability of the SDP for an Adverse Pregnancy Outcome

Manning: Analysis IV
- Highly significant inverse relationship
  - IUGR, C/S for distress, 5 minute Apgar < 7, NICU admissions, UaPH < 7.2

Vintzileos: Unlabored women undergoing C/S
- As the BPP decreased the cord blood gas decreased

Vintzileos: Unlabored women undergoing C/S
- As the BPP decreased the cord blood gas decreased and 45% with low UaPH had SDP < 2

Manning: AJOG 1990;162:703-9
Vintzileous: Obstet Gynecol 1987;70:196-201
Vintzileous: Obstet Gynecol 1991;77:622-26
Predictability of the SDP for an Adverse Pregnancy Outcome

Manning: BPP and umbilical venous pH

Study at 2 centers: BPP and pH values were obtained by immediate cordocentesis, there were 493 paired observations

- BPP of 0/10 was always associated with pH of < 7.2
- BPP of 10/10 was always associated with pH of > 7.2

Manning AJOG 1993;169:755-63
Predictability of the SDP for an Adverse Pregnancy Outcome as a “Stand Alone Test”

Chamberlain: 7562 High-Risk patients

- SDP > 2 cm the corrected perinatal mortality is 1.9/1000
- SDP 1-2 cm the corrected perinatal mortality is 37/1000
- SDP < 1 cm the corrected perinatal mortality is 109/1000

Chamberlain: AJOG 1984;150:245-9
Predictability of the AFI for an Adverse Pregnancy Outcome as a “Stand Alone Test”

AFI without NST, as a stand alone test of perinatal morbidity and/or mortality, has not been undertaken.
Predictability of the SDP for an Adverse Pregnancy Outcome

Manning: VIII Assessment of 84,947 Cerebral Palsy

- The relationship of the last BPP to the subsequent risk of cerebral palsy is “inverse, exponential and highly significant”

Manning ACOG 1998;178:696-706
BPP: AFI vs. SDP

Magann: Prospective randomized trial of high-risk pregnancies
- 273 AFI vs. 264 SDP
- Oligohydramnios: AFI (38%) vs. SDP (17%)
- Induction of labor for oligo: AFI 30% vs 15% for SDP
- C/S for distress: AFI (16%) vs. SDP (13%)
  - AFI > 5 (12%) vs. SDP (6%)
  - AFI > 5 vs. AFI ≤ 5 (NS)
- No difference in UapH < 7.1, < 7, amnioinfusion, lates or variables influencing delivery

Magann Obstet Gynecol 2004;104:5-10
Intrapartum: AFI vs SDP

Moses

- Intrapartum assessment AF volume identifies a pregnancy at-risk for an adverse outcome: AFI vs. SDP
  - 1023/ transfer to floor (23) AFI 499 vs. SDP 501
  - Oligohydramnios: AFI (25%) vs. SDP (8%)
  - Neither test undertaken as a FAT can identify a pregnancy at-risk for an adverse outcome
  - Both tests of low volumes are no better than their normal volumes to identify a peripartum complication

Moses: AJOG 2004;190:1564-70
Chauhan: Antenatal testing with modified BPP (NST): AFI vs. SDP

- 1080 women: 530 AFI and 558 in SDP
- Oligohydramnios: AFI (17%) vs. 10%
  - Amnioinfusion for distress (P=0.155)
  - Variable decelerations (P=0.279)
  - Late decelerations (P=0.999)
  - C/S for distress (P=0.390)
  - UapH < 7.1 (P=0.688)
NST: AFI vs. SDP

- Apgar score < 7 at 5 minutes (P=0.124)
- NBICU admission (P=0.328)

- AFI will identify more pregnancies as having low fluid volume compared with the SDP but without any difference in outcome.
- For every 20 pregnancies monitored with the AFI instead of the SDP there was an additional patient undergoing an induction of labor.

Chauhan: AJOG 2004;191:661-7
Summary

AFI and SDP poorly identify abnormal AF volumes
AFI and SDP are not equivalent
SDP may be a better test to identify normal AF volume
AFI + NST are associated with increased risk of perinatal morbidity, but not by cord gases, except in post term pregnancies where they may be slightly helpful (compared with SDP)
Summary

AFI + NST has not been linked with cerebral palsy
AFI has not been assessed as a stand alone test for perinatal morbidity or mortality
BPP with SDP has been linked with perinatal morbidity, mortality and UapH
BPP with SDP has been associated with cerebral palsy
Summary

SDP, as stand alone test, has been linked with perinatal mortality.

In prospective evaluations of the US estimate of AF volume, the AFI identifies significantly more pregnancies as having low fluid volume, without any difference in intrapartum or neonatal outcomes.
Amniotic fluid index versus single deepest vertical pocket as a screening test for preventing adverse pregnancy outcome


Primary Outcomes
- NICU admission: No difference
- Perinatal deaths: No difference (2 studies)

Secondary Outcomes
- Diagnosis of Oligohydramnios: AFI > SDP
- Umbilical artery pH < 7.1: No difference
- Apgar score < 7 @ 5 minutes: No difference
- Presence of Meconium: No difference
AFI vs. SDP
Secondary Outcomes


NR FHR tracing: No difference
Rate of induction: AFI > SDP
Assisted vaginal delivery: No difference
Assisted vaginal delivery for NR FHR tracing: No difference
C/S: No difference
C/S for NR FHR: AFI > SDP
Amniotic fluid index versus single deepest vertical pocket as a screening test for preventing adverse pregnancy outcome.

AUTHORS' CONCLUSIONS: The single deepest vertical pocket measurement in the assessment of amniotic fluid volume during fetal surveillance seems a better choice since the use of the amniotic fluid index increases the rate of diagnosis of oligohydramnios and the rate of induction of labor without improvement in peripartum outcomes