The Accuracy of Ultrasound Evaluation of Amniotic Fluid Volume in Singleton Pregnancies: The Effect of Operator Experience and Ultrasound Interpretative Technique

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Abstract: The objective of this study was to evaluate the effect of operator experience and ultrasound interpretation technique on the accuracy of ultrasound estimates of amniotic fluid volume. Ultrasound evaluation was carried out by an obstetric resident, a nurse sonographer, a maternal-fetal medicine fellow, and a maternal-fetal medicine staff member to subjectively estimate (visual interpretation without sonographic measurements) amniotic fluid volume in 63 pregnancies. Amniotic fluid volume was also evaluated using ultrasound measurements based on the largest vertical pocket technique, the amniotic fluid index, and the two-diameter pocket method. The accuracy of these ultrasound estimates was assessed by comparing the ultrasound results to actual amniotic fluid volume as determined by a dye-dilution technique. For analysis, amniotic fluid volumes were classified as oligohydramnios, normal, or hydramnios using established volumetric criteria for singleton pregnancies. Subjective estimates ranged from 65% to 70% correct and did not differ by operator experience except for the more accurate diagnosis of hydramnios by the maternal-fetal medicine staff. The three sonographic measurements were similar in overall accuracy (59±67%). The two-diameter pocket method was, however, significantly more accurate in identifying oligohydramnios. It appears that neither operator experience nor sonographic technique greatly affects the accuracy of ultrasound estimates of amniotic fluid volume. © 1997 John Wiley & Sons, Inc. J Clin Ultrasound 25:249–253, 1997

Keywords: ultrasound technique; amniotic fluid volume; operator experience

Amniotic fluid (AF) volume serves as an indicator of fetal well-being. Decreased AF volume is associated with congenital anomalies, postmaturity syndrome, intrauterine growth restriction, and increased perinatal morbidity and mortality.1–3 Increased AF volume is associated with other congenital malformations (neural tube defects, gastrointestinal tract obstruction), diabetes, hydrops fetalis, and increased perinatal morbidity and mortality.4–5 The identification and evaluation of abnormal amounts of AF is, therefore, considered an important component of antenatal assessment.

Current sonographic techniques for estimating AF volume range from subjective visual inspection to more elaborate ultrasonically derived indices of AF volume. The latter procedures are based on the measurement of various aspects of the size of the AF cavity. They include the
largest vertical pocket of Chamberlain et al, AF index of Phelan et al, and the two-diameter pocket of Magann et al. It has been suggested that operator experience is an important determinant of the intra- and interobserver variation of subjective estimates of the AF volume. However, since visual inspection is a subjective evaluation while ultrasound measurements are more objective, sonographic measurements are suggested as potentially providing a more accurate estimate of AF volume. Despite the widespread use of these procedures in clinical practice, there is relatively little data directly evaluating the effect of operator experience on subjective ultrasound estimates of AF volume or comparing the relative accuracy of ultrasound measurement techniques and subjective determinations of AF volume. In the present investigation, we used empirically-determined AF volumes as a standard to compare the accuracy of subjective estimates and sonographic measurements of AF volume and evaluate the role of operator experience in achieving this accuracy.

MATERIALS AND METHODS
This prospective study involved 63 singleton pregnancies undergoing an amniocentesis to evaluate fetal lung maturity and/or to detect subclinical chorioamnionitis in women in preterm labor. Exclusion criteria included ruptured membranes, refusal of amniocentesis, or refusal to participate in this study. Those women agreeing to participate were asked to sign a consent form approved by the Investigation Review Board of the University of Mississippi Medical Center.

Ultrasonography was performed on all patients using an Ultramark-4 device (Advanced Technology Laboratories, Bothell, WA). Subjective assessment (visual interpretation without sonographic measurements) using ultrasound was performed by a second-year resident in obstetrics and gynecology credentialed in performing obstetric ultrasound (1 year experience), a nurse sonologist (5 years' obstetric sonographic experience), a second-year maternal-fetal medicine fellow, and a maternal-fetal medicine attending staff (4 years' staff maternal-fetal medicine experience in obstetric ultrasound and co-director of the obstetric ultrasound unit). Using visual interpretation without sonographic measurements, these four sonographers identified the AF volume of these 63 pregnancies as oligohydramnios, normal AF volume, or hydramnios. This assessment by each evaluator was performed alone; none of the examiners knew the AF determinations of the other three examiners.

Following the four subjective assessments and using the same ultrasound equipment, the AF volume was also assessed using sonographic measurements. All measurements were performed by the same sonographer (EFM) who did not participate in the subjective evaluations. Sonographic measurements included the (1) largest vertical pocket, (2) AF index, and (3) two-diameter pocket technique.

In the largest vertical pocket technique, the depth of the largest pocket of AF without an aggregate of cord or fetal extremities at a right angle to the uterine contour was measured. A depth of 0–2 cm was classified as oligohydramnios, 2.1–8 cm as normal, and >8 cm as hydramnios.

The AF index measurement is described as dividing the uterus into four quadrants by the linea nigra into right and left quadrants and by the umbilicus into upper and lower quadrants. The maximum vertical diameter in each quadrant without an aggregate of cord or fetal extremities was measured in centimeters; the sum of these measurements is the AF index. A depth of 0–5 cm was defined as oligohydramnios, 5.1–20 cm as normal, and >20 cm as hydramnios.

The two-diameter pocket technique, which is a variation of the other two techniques, measures the vertical depth multiplied by the horizontal diameter of the largest pocket without an aggregate of cord or fetal extremities identified as the transducer is held at a right angle to the uterine contour. A measurement of 0–15 cm² is oligohydramnios, 15.1–50 cm² is normal, and >50 cm² is hydramnios. To ensure standardization for each measurement technique, the cursor was always placed at the extreme margin of the fluid pocket(s).

An ultrasound-directed amniocentesis was then performed and the actual AF volume determined using a dye-dilution spectrophotometric technique. After 10 mL of AF had been obtained for clinical studies, 2 mL of a 20% aqueous solution of aminohippurate sodium (400 mg; Merck, West Point, PA) was injected into the amniotic cavity. The needle was left in place over the next 20 minutes with continuous ultrasonic monitoring of needle placement and fetal position. Three milliliters of the aminohippurate sodium and AF mixture was withdrawn at 20 minutes. The samples were frozen at −20°C until assayed for aminohippurate sodium concentrations and calculation of AF volume. Each AF volume
AMNIOTIC FLUID VOLUME

was classified as oligohydramnios, normal, or hydramnios based on previously established volumetric criteria at the 95th percentile (2 standard deviations) for normal singleton pregnancies. The volumetric criteria were adjusted for menstrual age.

The sonographic measurements of the AFI were categorized as oligohydramnios, normal, or hydramnios based on previously reported criteria for normal singleton pregnancies at the 95th percentile. The normative data for the sonographic measurements of the largest vertical pocket and the two-diameter pocket technique throughout pregnancy have not been well established. The use of the same criteria for the two-diameter pocket technique throughout pregnancy is suggested by the study evaluating its accuracy in predicting AF volumes in pregnancies between 15 and 24 weeks menstrual age. The published measurements for oligohydramnios, normal, and hydramnios were the same in the 15–24 week evaluation as those used in pregnancies between 29 and 37 weeks. Both studies show measurement accuracies superior to the AF index when compared to dye-determined AF volumes.

The relative accuracy of the subjective assessment and sonographic measurement of AF volume was assessed by comparing these estimates to the dye-determined AF volumes. Intraobserver variability was not evaluated in this study. The author (EFM), who performed all of the ultrasound examinations in this study, has previously determined that his intraobserver variability is 3% to 4% for the sonographic measurements of the largest vertical pocket, AF index, and two-diameter pocket. This is consistent with other reports.

The data were evaluated by chi-square analysis and Fisher’s exact test. Between group differences with \( p < .05 \) were considered statistically significant. The statistical power (\( \alpha = .05 \)) of nonsignificant differences was calculated to determine the probability of detecting a significant difference when group differences were of the magnitude actually observed in the specified comparisons. Because the magnitude of the between group differences in these comparisons was often relatively small, many of the power values were, as expected, low.

RESULTS

The 63 women evaluated in this investigation were predominantly African-American (49 of 63) with a maternal age of 25.1 ± 6.6 years (range: 14–41 years) and a menstrual age of 15–39 weeks (Figure 1, based on initial examination, last menstrual period, and early ultrasound), and 42 of 63 were nulliparous. Using previously reported criteria, 18 of the pregnancies were classified as oligohydramniotic, 36 were normal, and the remaining nine had hydramnios when the dye dilution technique was used to determine AF volume.

Table 1 shows the frequency of correctly estimated AF volumes using either the subjective technique or sonographic measurements. The overall accuracy of subjective estimates of AF volume ranged from 65% to 70%. Between-operator group differences in the total number of correct subjective AF volume estimates were not statistically significant (\( p = .922, \) power < .30). A similar analysis indicated that the overall percentage correct AF volume determinations based on either the AF index (65%), the largest vertical pocket (59%), or the two-diameter pocket (67%) technique were also not significantly different (\( p = .650, \) power < .30).

The overall accuracy of subjective estimates and sonographic measurements of AF volume was compared by combining the total number of correct responses in each group. Subjective estimates of AF volume were correct in 67% (169 of 252) of the evaluations; sonographic measurements were correct in 63% (119 of 189) of the measurements (\( p = .371, \) power = .86). Furthermore, the incidence of correct responses in the most accurate subjective group (nurse sonologist, 70%) was not significantly different from those obtained using the largest vertical pocket technique (59%), the least accurate sonographic measurement (\( p = .193, \) power = .75).

Designations of normal AF volume based on subjective ultrasound technique were correct in 81% to 94% of the pregnancies, and these determinations were not significantly influenced
### TABLE 1
Ultrasound Estimates of Amniotic Fluid Volume

<table>
<thead>
<tr>
<th>Type</th>
<th>Total (n = 63)</th>
<th>Oligohydramnios (n = 18)</th>
<th>Normal (n = 36)</th>
<th>Hydramnios (n = 9)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subjective</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Resident</td>
<td>41 (65%)</td>
<td>4 (22%)</td>
<td>33 (92%)</td>
<td>4 (44%)</td>
</tr>
<tr>
<td>Nurse Sonologist</td>
<td>44 (70%)</td>
<td>8 (44%)</td>
<td>34 (94%)</td>
<td>2 (22%)</td>
</tr>
<tr>
<td>MFM Fellow</td>
<td>41 (65%)</td>
<td>8 (44%)</td>
<td>30 (83%)</td>
<td>3 (33%)</td>
</tr>
<tr>
<td>MFM Staff</td>
<td>43 (68%)</td>
<td>7 (39%)</td>
<td>29 (81%)</td>
<td>7 (77%)</td>
</tr>
<tr>
<td>Objective</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AF index</td>
<td>40 (65%)</td>
<td>3 (17%)</td>
<td>35 (97%)</td>
<td>2 (22%)</td>
</tr>
<tr>
<td>LVP</td>
<td>37 (59%)</td>
<td>3 (17%)</td>
<td>32 (89%)</td>
<td>2 (22%)</td>
</tr>
<tr>
<td>2-DP</td>
<td>42 (67%)</td>
<td>13 (72%)</td>
<td>27 (78%)</td>
<td>2 (22%)</td>
</tr>
</tbody>
</table>

MFM, maternal-fetal medicine; AF, amniotic fluid; LVP, largest vertical pocket; 2-DP, two-diameter pocket.

Oligohydramnios, normal, and hydramnios are dye-determined AF fluid volumes. Total refers to the correct number of subjective and objective assessments of the dye-determined AF volume.

by the level of operator experience ($p = .229$, power = .45). In the 36 pregnancies with normal AF volume, four examiners correctly identified the dye-determined volume in 88% (126 of 144) of the cases. The sonographic measurements using the three ultrasound indices correctly identified the dye-determined volume with an 87% (94 of 108) accuracy, which is nearly identical to the subjective assessments ($p = .913$, power < .30). When subjective determinations and sonographic measurements of AF volume were combined, normal volume was correctly detected more often (87%) than either oligohydramnios (36%) or hydramnios (35%; $p < .001$).

Oligohydramnios was recognized significantly more often using the two-diameter pocket technique (72%) than when using the other sonographic measurements (17%) of AF volume ($p < .001$). The determination of hydramnios by maternal-fetal medicine staff was more accurate (77%) than the combined subjective estimates of the other operators (33%; $p = .020$). However, the number of cases in this category was small, and between-group percentage differences represented only 3 to 5 actual patients.

### DISCUSSION

The subjective assessment (visualization without ultrasonic measurements) of AF volume continues to be frequently used to detect AF volume abnormalities. The level of operator experience is often stated as important in obtaining results of AF volume which are in agreement (the least inter- and intraobserver variability). The validity of subjective assessments of AF volume stratified by operator experience is not well documented. In the present study, correct subjective estimations of normal AF volumes ranged from 81% to 94% and were not influenced by the user’s experience. Operator experience also did not improve the diagnostic accuracy of oligohydramnios and hydramnios, which, except for maternal-fetal medicine staff assessment of hydramnios, identified these abnormal AF volumes correctly less than 45% of the time. The similar diagnostic accuracy by individuals with varying experience suggests that AF volume determination is an elementary skill not greatly influenced by ultrasound experience.

The accuracy of ultrasound measurement of normal AF volume ranged from 78% to 97%. The AF index, with an accuracy of 97% in pregnancies with normal AF, was the most accurate assessment. When using the AF index or largest vertical pocket, oligohydramnios and hydramnios were correctly estimated <23% of the time. The AF index has been reported as overestimating low AF volumes by 88% and underestimating high volumes by 54%. The two-diameter pocket was a considerably more accurate (72%) procedure for detecting oligohydramnios. These results are consistent with previous studies of the accuracy of ultrasonic measurement of AF volume.

A comparison of subjective estimates and ultrasound measurements of AF volume indicated no difference in the accuracy of techniques. Subjective assessment was as accurate as ultrasonic measurements in overall AF volume measurements and individually in oligohydramnios, normal AF volumes, and hydramnios. Ultrasound measurements are actually subjective evaluations of AF volume to a considerable degree. Cur-
rently we are unable to standardize the selection of the images in which the measurements are performed or the measurements themselves. Also, both visual inspection and ultrasonic measurements of AF volume are two dimensional and may only partially reflect the three-dimensional characteristics of the more complex shape of the volume containing AF.

The results of this investigation suggest that sonographic assessments of AF volume are more likely to identify normal AF volumes, regardless of the experience of the examiner or the type of ultrasonic measurement utilized. Hydramnios is poorly identified by any technique except subjective assessment by maternal-fetal medicine staff, while oligohydramnios is best recognized by the two-diameter pocket technique.

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REFERENCES