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Reliability of fetal anthropometry by ultrasound

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1 Introduction

The increasing importance of ultrasound in obstetrical practice requires a sound knowledge of the technique and of the reproducibility and accuracy of the measurements.

In most obstetrical clinics, scanning are not always performed by the same technician and therefore the lack of information about the errors in measurement of the different observers or of one observer may lead to inaccurate procedures.

In this paper, the errors made by one observer in two consecutive scannings (intra-observer errors) and the differences among observers are determined, as well as the accuracy of the echograph for measuring fetal structures.

Curriculum vitae

RICARDO HORACIO FESCINA *was born in Argentina, in 1948. He graduated as Medical Doctor from the School of Medicine, University of Buenos Aires, Argentina, in 1971. 1972–1975 Resident at the Department of Obstetrics and Gynecology, of the Hospital Materno-Infantil Ramón Sardá, Buenos Aires. 1976 Chief Resident at the same Hospital. February–March 1976 Research Fellow in Ultrasounds in Obstetrics and Gynecology at the School of Medicine, Valencia, Spain. 1977–1978 PAHO/WHO Research Fellow at the Latin American Center of Perinatology and Human Development, Montevideo, Uruguay. At present, Dr.* FESCINA *coordinates ultrasound research work at the Latin American Center of Perinatology and Human Development, Montevideo, Uruguay. Current work is centered around fetal growth.*

2 Material and methods

The study population was 14 women at term pregnancy in whom labor had not started and with intact membranes. Elective cesarean section had been indicated in all cases.

The equipment used for the different fetal measurements was an ADR ultrasound B scan real-time, with a 3.5 mega-Hertz transducer which was calibrated at a sound velocity of 1,540 m/sec. The apparatus has an electronic caliper, and a freeze-frame which fixes the selected image on the oscilloscope.

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At each scanning the following parameters were determined: Fetal biparietal diameter (BPD) from outer edge to outer edge; the antero-posterior-abdominal diameter at the ductus venosus of ARANCIO. Both measurements were performed by real-time and using freeze-frame. Furthermore, photographs were taken in which biparietal and abdominal diameters were determined using a VERNIER caliper and the fetal cranial and abdominal perimeters by means of a curvimeter.

Two observers (one more experienced and the other with three months training) carried out the scannings by alternative consecutive turns.

A third observer (a pediatrician) measured the biparietal and abdominal (navel-spine) diameter with steel calipers in the newborns. The cranial perimeters were measured with a flexible and inextensible meter.

Each observer performed all the measurements twice by himself ignoring the results of the other observers until the study was finished. The maximum time elapsing between the echographic measurements and Cesarean section was 12 hours, and between birth and neonatal measurements, 6 hours.

The averages and standard deviation of the differences ($\bar{d}$, SD) among the measurements of the different observers were determined as well as the average and standard deviation of the differences ($\bar{d}$, SD) of intra-observer measurements. The STUDENT "t" test for dependent samples, with a significance level of $p < 0.05$, was used to compare the results.

3 Results

3.1 Intra-observer comparisons

In most scannings, **the echography expert was more accurate in his measurements than the technician** who had 3 months training. This was inferred from a smaller scattering of the measurements (standard deviation).

On Figs. 1, 2 and 3 are shown averages and standard deviation of the differences ($\bar{d}$, SD) of two successive measurements by each observer. **No significant differences between the first and second measurements are found.**

	BIPARIETAL DIAMETER		
	ELECTRONIC CALIPER		VERNIER CALIPER
	Frozen Imaging	Real-Time Imaging	Photography
EXPERT IN ULTRASOUND	n=13 $\bar{d}$=-0.31 mm SD=0.85 mm NS	n=13 $\bar{d}$=0 mm SD=0.71 mm NS	n=13 $\bar{d}$=-0.53 mm SD=1.68 mm NS
PHYSICIAN IN TRAINING	n=13 $\bar{d}$=-0.38 mm SD=0.77 mm NS	n=13 $\bar{d}$=-0.23 mm SD=1.36 mm NS	n=13 $\bar{d}$=-0.38 mm SD=1.44 mm NS

Fig. 1. Fetal anthropometry by ultrasound. Comparison of the differences between first and second measurements of biparietal diameter obtained by the same observer.

	ABDOMINAL DIAMETER		
	ELECTRONIC CALIPER		VERNIER CALIPER
	Frozen Imaging	Real Time Imaging	Photography
EXPERT IN ULTRASOUND	n=10 $\bar{d}$=0 mm SD=2.92 mm NS	n=10 $\bar{d}$=0.67 mm SD=2.99 mm NS	n=10 $\bar{d}$=0.93 mm SD=3.05 mm NS
PHYSICIAN IN TRAINING	n=10 $\bar{d}$=0.89 mm SD=4.43 mm NS	n=10 $\bar{d}$=1.33 mm SD=3.74 mm NS	n=10 $\bar{d}$=0.78 mm SD=3.91 mm NS

Fig. 2. Fetal anthropometry by ultrasound. Comparison of the differences between the first and second measurements of abdominal diameter obtained by the same observer.

	PERIMETER	
	CRANIAL	ABDOMINAL
EXPERT IN ULTRASOUND	n=13 $\bar{d}$=-0.23 mm SD=3.44 mm NS	n=10 $\bar{d}$=-0.60 mm SD=5.25 mm NS
PHYSICIAN IN TRAINING	n=13 $\bar{d}$=0 mm SD=3.62 mm NS	n=10 $\bar{d}$=-1.40 mm SD=10.41 mm NS

Fig. 3. Fetal anthropometry by ultrasound. Comparison of the differences between the first and second measurements of cranial and abdominal perimeters obtained by the same observer.

	DIAMETER			
	BIPARIETAL		ABDOMINAL	
	Frozen Imaging Vs. Real-Time Imaging	Frozen Imaging Vs Photography	Frozen Imaging Vs Real-Time Imaging	Frozen Imaging Vs Photography
EXPERT IN ULTRASOUND	$n = 27$ $\bar{d} = 0.59$ mm SD = 0.75 mm Sign $p < 0.05$	$n = 27$ $\bar{d} = -2.04$ mm SD = 1.24 mm Sign $p < 0.05$	$n = 20$ $\bar{d} = -0.21$ mm SD = 1.51 mm NS	$n = 20$ $\bar{d} = -0.29$ mm SD = 2.85 mm NS
PHYSICIAN IN TRAINING	$n = 27$ $\bar{d} = -0.07$ mm SD = 1.27 mm NS	$n = 27$ $\bar{d} = -2.37$ mm SD = 2.13 mm Sign $p < 0.05$	$n = 20$ $\bar{d} = 0.45$ mm SD = 2.48 mm NS	$n = 20$ $\bar{d} = -0.65$ mm SD = 2.45 mm NS

Fig. 4. Fetal anthropometry by ultrasound. Intra-observer differences. Comparison between the measurements obtained using different techniques.

Fig. 4 shows the difference found by each observer with the different techniques. The frozen image was considered standard pattern measurement and compared with real-time image and photograph.

No significant differences were found in the measurements of the abdominal diameters made by each observer using different techniques. However, the important variations in these measurements should be pointed out since, as it is well known, these may change due to fetal respiratory movements and to involuntary compression with the transducer.

Regarding biparietal diameter, comparing the frozen image measurement against that obtained with real-time, a significant difference was found in those performed by the experienced observer. **The tendency is to give larger measurements to the frozen image** ($\bar{d} = 0.59$ mm), which may be due to hazing in the contours of the image produced when the freeze-frame is used. This small difference is only spotted by the experienced observer.

When the measurements of the frozen image are compared against that taken from photographs, a systematic tendency to make larger measurements in these last ones was observed for both technicians. Although these differences are significant, it should be noted that the error is 2 to 3%.

DIAMETER		PERIMETER	
BIPARIETAL	ABDOMINAL	CRANIAL	ABDOMINAL
$n = 14$ $\bar{d} = -0.11$ mm SD = 0.92 mm NS	$n = 10$ $\bar{d} = -1.10$ mm SD = 4.56 mm Sign $p < 0.05$	$n = 14$ $\bar{d} = 0$ mm SD = 1.22 mm NS	$n = 10$ $\bar{d} = -0.80$ mm SD = 1.81 mm NS

Fig. 5. Neonatal anthropometry performed by a pediatrician. Comparison of the differences between the first and second measurements of the neonate.

These differences could be due to the aberration of the curvature of the camera lens, especially in its periphery, which was the part where the pictures were taken.

When comparing the measurements obtained in newborn infants (Fig. 5) no significant differences were found in the cranial and abdominal perimeters or in the biparietal diameter. There were significant differences in the abdominal diameter. These values are not very reliable due to the technical difficulties observed in the measurement of the abdominal diameter.

3.2 Comparisons among observers

No significant differences were found by comparing the echographic measurements made by the ultrasound expert with those taken by the less

	DIAMETER Electronic caliper, frozen imaging		PERIMETER Curvimeter in photography	
	BIPARIETAL	ABDOMINAL	CRANIAL	ABDOMINAL
EXPERT IN ULTRASOUND VS. PHYSICIAN IN TRAINING	n = 14 $\bar{d}$ = 0.82 mm SD = 1.41 mm NS	n = 10 $\bar{d}$ = 2 mm SD = 5.44 mm NS	n = 14 $\bar{d}$ = 4.82 mm SD = 12.95 mm NS	n = 10 $\bar{d}$ = 1.45 mm SD = 14.67 mm NS

Fig. 6. Fetal anthropometry by ultrasound. Comparison of the differences between observers.

experienced technician (Fig. 6). This finding may indicate that both observers make the same measurements.

The echographic measurements by each observer are compared against neonatal measurements in Fig. 7.

The significant difference found by both echographists in the cranial perimeter, with relation to the direct measurement of the neonate may be due to the fact that on the photograph the fetal bone perimeter is determined, and in the measurement of the neonate, the width of the scalp is added. This fact coincides with the smaller perimeter systematically determined by both echographists ($\bar{d} = -10.96$ mm and $\bar{d} = -16$ mm).

If one adds the width of the scalp, 1.2 mm in infants of more than 2,000 g according to WILLOCKS, to the echographically determined perimeter, the differences would be reduced by approximately 8 mm.

Concerning BPD no differences were found, since the thickness of the scalp plays a role only in two parts and not over the whole perimeter, as with the cranial circumferences. Besides, on measuring the neonate's BPD with the steel caliper, a slight compression is exerted, which would reduce the influence of the soft tissues.

Regarding the abdominal diameter and perimeter, the differences found may be accounted for by modifications in these measurements due to environmental changes after birth.

It is well known that the abdominal perimeter assessed by echography in normally growing fetuses [2] is usually greater than the cranial perimeter. On the other hand, in neonates born at term and with normal weight for their gestational age, the cranial perimeter is greater than the abdominal perimeter.

	DIAMETER *		PERIMETER	
	BIPARIETAL	ABDOMINAL	CRANIAL	ABDOMINAL
EXPERT IN ULTRASOUND VS. NEONATOLOGIST	n = 14 $\bar{d}$ = 0.13 mm SD = 2.08 mm NS	n = 10 $\bar{d}$ = 18.28 mm SD = 8.92 mm Sign $p < 0.05$	n = 14 $\bar{d}$ = −10.96 mm SD = 10.74 mm Sign $p < 0.05$	n = 10 $\bar{d}$ = 16.70 mm SD = 14.95 mm Sign $p < 0.05$
PHYSICIAN IN TRAINING VS. NEONATOLOGIST	n = 14 $\bar{d}$ = −0.66 mm SD = 2.66 mm NS	n = 10 $\bar{d}$ = 15.45 mm SD = 7.50 mm Sign $p < 0.05$	n = 14 $\bar{d}$ = −16 mm SD = 15.26 mm Sign $p < 0.05$	n = 10 $\bar{d}$ = 12.10 mm SD = 11.44 mm Sign $p < 0.05$

(*) Fetal diameters were measured with the electronic caliper, frozen imaging.

Fig. 7. Differences among observers. Comparison between echographic and neonatal measurements.

It may, therefore, be concluded that the abdominal diameter and perimeter should not be used to determine ultrasound accuracy.

4 Discussion

When comparing the first and second measurements of each observer, **a standard deviation of the differences for BPD was estimated: 0,85 and 0.71 mm for the expert in ultrasound, and 0.77 and 1.36 mm for the training physician with frozen image and realtime image respectively (Fig. 1).**

This variability is similar to that found by POLL [6] (SD = 0.76 mm) and COOPERBERG et al [3] (SD = 0.77 mm), and somewhat smaller than that found by DOCKER et al [4].

On the other hand, HUGHEY et al [5] states that when scanning is performed with medium gain (width of skull table: 3–5 mm) and measuring from outer edge to outer edge of the fetal head, the SD is 0.517 mm. Using the same technique, we have found a slightly greater scattering of the measurements.

It should be noted that this intra-observer variability accounts for only 2% of the BPD value.

When BPD measurements were compared among observers, no significant differences were found, this has also been reported by DOCKER et al [4] when both observers used a real-time B scan.

Regarding the comparison between the fetal and neonatal measurements of BPD, no significant differences were found. These results support those found by HUGHEY et al [5] and CAMPBELL [1], who, in 1968, using an A scan and B static scan apparatus, found and average error between the neonatal and ultrasonic measurements of 0.8 mm (SD 1.10 mm). These measurements are slightly smaller than the ones reported here ($\bar{d}$ = 0.13 mm; SD = 2.08 mm) (Fig. 7), probably due to the different equipment used.

In view of these results, it may be concluded that **the real-time apparatuses measure accurately, both when used by expert observers and when used by physicians with a three month training.**

Summary

The biparietal and abdominal diameters and cranial and abdominal perimeters of 14 fetuses were measured a few hours before termination of pregnancy by elective cesarean section.

The same measurements were made in the newborns.

Each observer performed these measurements twice, ignoring the results of the other observers until the study was completed.

The scannings were performed with a real-time ultrasound equipment, by an ultrasound expert and by a technician with three months training.

The average values and standard deviation of the differences ($\bar{d}$, SD) of the measurements among observers and intra-observers, were established. The "t" test for dependent samples was used to compare the results; the significant level was $p < 0.05$.

No significant differences were found between the first and second measurements of each observer (Figs. 1, 2, 3), nor when ultrasound measurements obtained by the expert were compared with those performed by the technician with three months training (Fig. 6).

When different techniques were used (Fig. 4) both observers showed a definite tendency to make larger measurements on the photograph. Regarding biparietal diameter, when comparing the frozen image measurement with real-time scanning, a significant difference was found in those performed by the more experienced observer, probably due to hazing of the contours when the freeze-frame is used.

When comparing the first and second measurement in the newborns (Fig. 5), no significant differences were found in the abdominal and cranial perimeters, nor in biparietal diameter.

In Fig. 7, **the ultrasound measurements of each observer are compared with neonatal measurements. No significant differences were found in the biparietal diameter.** Regarding cranial perimeter, both echographists made smaller measurements than the pediatrician. This could be explained by the fact that in the photograph obtained by ultrasound the bone perimeter of the fetus is determined, whereas in the newborn the thickness of the scalp is added.

The abdominal diameter and perimeter are markedly different in the fetus and neonate, due to environmental changes occurring after birth.

Keywords: Abdominal diameter, abdominal perimeter, biparietal diameter, cranial perimeter, techniques of ultrasound.

Zusammenfassung

Die Reliabilität von fetalen Größenbestimmungen durch Ultraschall

Bei insgesamt 14 Feten wurden wenige Stunden vor Beendigung der Schwangerschaft durch Sectio caesaria der biparietale und abdominale Durchmesser bzw. der craniale und abdominale Umfang gemessen.

Die gleichen Maße wurden bei den Neugeborenen bestimmt.

Jeder Untersucher führte Doppelbestimmungen durch und kannte vor Beendigung der Studie nicht die Ergebnisse der anderen Untersucher.

Für die Aufzeichnungen verwendeten wir das Zeitamplituden-Verfahren. Sie wurden zum einen von einem Ultraschall-Spezialisten durchgeführt, zum anderen von einem Techniker, der nur drei Monate Erfahrung hatte.

Wir bestimmten Mittelwerte und Standardabweichungen der Differenzen ($\bar{d}$, SD) zwischen den Messungen eines Untersuchers und der Untersucher untereinander. Für den Vergleich der Ergebnisse setzten wir den t-Test für abhängige Stichproben ein: das Signifikanzniveau lag bei $p < 0.05$.

Zwischen den ersten und den zweiten Messungen eines jeden Untersuchers gab es keine signifikanten Unterschiede (Abb. 1, 2,und 3). Auch wenn die Meßwerte des Experten mit denen des wenig erfahrenen Technikers verglichen wurden, ließen sich keine signifikanten Unterschiede feststellen (Abb. 6).

Wenn verschiedene Techniken benutzt wurden (Abb. 4), zeigten beide Untersucher bei dem Bildverfahren eine Tendenz, die Maße zu groß zu bestimmen. Betrachtet man z. B. den biparietalen Durchmesser und vergleicht das B-Bild mit dem Zeitamplitudenverfahren, so ergab sich ein signifikanter Unterschied bei den Meßwerten, die der Ultraschallexperte aufgenommen hatte. Dies ist wahrscheinlich auf die durch das B-Bildverfahren bedingten unscharfen Umrisse zurückzuführen.

Vergleicht man die erste und die zweite Messung bei den Neugeborenen (Abb. 5), so traten weder beim abdominalen und cranialen Umfang noch beim biparietalen Durchmesser signifikante Unterschiede auf.

In Abb. 7 werden die Ultraschallgrößen eines jeden Untersuchers mit neonatal bestimmten Maßen verglichen. Beim biparietalen Durchmesser fand sich kein signifikanter Unterschied. Wenn man jedoch den cranialen Umfang betrachtet, so bestimmten beide Ultraschalluntersucher kleinere Größen als der Pädiater. Die Erklärung liegt darin, daß beim Neugeborenen die Dicke der Kopfhaut mit eingeht, während das Ultraschallverfahren nur den Schädelknochenumfang mißt. Der abdominale Durchmesser und auch der Umfang sind deutlich verschieden zwischen Fetus und Neugeborenem, was auf die durch die Geburt bedingten Änderungen der Umgebung zurückzuführen ist.

Schlüsselwörter: Abdominaler Durchmesser, abdominaler Umfang, biparietaler Durchmesser, cranialer Umfang, Ultraschalltechniken.

Résumé

Certitude d'anthropomètrie foetale par ultra-son

Les diamètres bipariétaux et abdominaux ainsi que les périmètres crâniaux et abdominaux de 14 foetus ont été mesurés quelques heures avant l'achèvement de la grossesse par césarienne élective.

Les mêmes mesures ont été effectuées sur les nouveaux-nés.

Chacun des observateurs a pratiqué deux fois ces mesures sans connaître les résultats des autres observateurs jusqu'à la fin de l'étude.

Les scannings ont été réalisés avec un équipment ultra-son de temps réel par un spécialiste de l'ultra-son et par un technicien ayant suivi un entraînement de 3 mois.

Puis on a établi les valeurs moyennes et la déviation standard des différences (d, SD) des mesures entre les observateurs et intra-observateurs. Le test «t» pour les échantillons dépendants a servi à comparer les résultats; le niveau significatif a été de $p < 0{,}05$.

Aucune différence significative n'a été trouvée entre les premières et secondes mesures de chaque observateur (fig. 1, 2 et 3), même lorsque les mesures par ultra-son obtenues par le spécialiste ont été comparées avec celles réalisées par le technician avec 3 mois d'entraînement (fig. 6).

Lorsqu'ils ont utilisé des techniques différentes (fig. 4), les deux observateurs ont montré une tendance précise à marquer des mesures plus grandes sur la photographie. En ce qui concerne le diamètre pariétal, en comparant les mesures des images stockées avec le scanning de temps réel, on a pu observer une différence significative entre celles réalisées par l'observateur plus expérimenté et celles de son collègue, ce qui est dû sans doute à une certaine obscurité des contours résultant de l'emploi du système de stockage.

Lorsqu'on compare les premières et les secondes mesures néonatales (Fig. 5), ne se trouve pas aucune différence ni dans les périmètres abdominal et crânial ni dans le diamètre parietal.

La Fig. 7 présente **une comparaison des mesures à l'ultra-son relevées par les deux observateurs avec celles néonatales. Aucune différence marquée dans le diamètre bipariétal.** En ce qui concerne le périmètre crânial, les deux échographistes ont effectué des mesures plus petites que le pédiâtre. Ceci pourrait s'expliquer du fait que dans la photographie obtenue par ultra-son, le périmètre osseux du foetus se trouve déterminé, tandis que chez le nouveau-né, l'épaisseur de l'épicrâne se trouve ajoutée. Le diamètre et le périmètre abdominaux sont nettement différents chez le foetus et chez le nouveau-né, ce qui est dû aux changements environnants qui surviennent après la naissance.

Mots-clés: Diamètre abdominal, diamètre bipariétal, périmètre abdominal, périmètre crânial, techniques de l'ultra-son.

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