

The correlation between ultrasonic manual and automatic measurements of foetal head and abdominal circumferences

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Abstract

Objective: To assess the correlation between ultrasonic manual and automatic ellipsoid measurements of foetal head and abdominal circumferences.

Methods: This comparative cross-sectional study was conducted at the Ultrasound Clinic, Karachi, from January to July 2004. Seventy two normal pregnant women with gestational ages between 14 to 38 weeks were included. Foetal head and abdominal circumferences were measured by manual method using traditional formulae and by automatic ellipsoid mode incorporated into the real-time ultrasound machines (EcoCee and Power Vision, Toshiba, Japan) using convex probes of 3 and 4.2 MHz frequency. Three readings of each parameter i.e. head circumference (HC) and abdominal circumference (AC) were taken by both methods. Mean values were calculated and compared using paired sample 't' test to assess the correlation between ultrasonic manual and automatic ellipsoid measurements.

Results: The mean HC measured through manual method was found to be 20.11 ± 7.04 cm and was significantly different from that of 19.46 ± 6.82 cm measured through ellipsoid automatic technique. There was, however, a perfect positive correlation ($r = 0.999$) between these measurements. In case of AC, there was no statistical difference between the mean values obtained by the manual technique and those measured automatically (16.79 ± 6.24 vs. 16.74 ± 6.11 ; $p < 0.44$), correlation between these measurements ($r = 0.997$) was also significantly positive.

Conclusion: Correlation was found between the mean measurements of the foetal HC and AC by the manual and the automatic method of calculation; and even stronger for the latter. The automatic mode of measurement is a more rapid method than the manual calculation, and its use may be encouraged (JPMA 57:352:2007).

Introduction

Foetal biometry has been in use for the assessment of gestational age and for monitoring foetal growth since the late 1960s when Campbell's first publication on the subject appeared.¹ The parameters in common use, are the biparietal diameter (BPD), head circumference (HC), abdominal circumference (AC) and femur length (FL).²⁻⁵

Accurate measurements of the head and abdominal circumferences are essential if foetal growth is to be accurately monitored. These can be performed manually by taking two measurements at right angles to each other at an appropriate plane, and the result calculated from the formula for an ellipsoid; it can also be performed on all commercially available ultrasound machines.

Watson and co-workers found a statistically significant difference between the directly measured AC and that of calculated values. The statistical difference was however, not found clinically significant.⁶

Shield JR and co-workers⁷, while working ellipse calculations versus planimetry, expressed that all equations were found to be equally accurate in calculating HC and

AC. Compared to planimetry, the ellipse method is more adequate in calculating circumferences, however, this was not true when calculating their ratios.⁷ Similar author, in another study, working on 122 foetal heads and abdomens, reported that the mean of the cephalic index was $79.1\% \pm 5.21\%$ and that of the abdominal index was $89.1\% (\pm 7.0\%)$, therefore, the simplest equation, $(D1 + D2) \times 1.57$, was recommended for calculating AC and HC except in situations of extreme dolicocephaly.⁸

The objective of this study was to assess the correlation between ultrasonic manual and automatic ellipsoid measurement of foetal head circumference and abdominal circumference.

Subjects and Methods

This comparative cross sectional study was conducted at the Ultrasound Clinic PECHS, Karachi. The study consisted of a convenient sample of 72 uncomplicated singleton pregnant women scanned at the Ultrasound Clinic, Karachi, between 14th to 38th week of gestation. They were part of a research project titled "Sonographic foetal biometry in a cohort of Pakistani population." The

ultrasound machines used were EcoCee and Power Vision, Toshiba, Japan, with convex probes of 3.0 and 4.2 MHz frequencies. Three readings of each parameter, head circumference (HC) and abdominal circumference (AC) were taken using the manual and the automatic modes.

For HC, the mathematical formula used was that for an ellipsoid, viz.

Circumference = $0.5 \pi (D_1 + D_2)$ where $\pi = 3.142$ and D_1, D_2 are the two diameters at right angle to each other, in this case representing the biparietal diameter (BPD) and the occipito-frontal diameter (OFD) respectively. Thus simplified to $(BPD + OFD) \times 1.62$

For the automatic or direct measurements of HC, two calipers were placed on BPD and using trackball to reach the outer margins of skull table from sinciput to the occiput.

In case of abdominal circumference, the same formula was modified to cater for the more circular abdomen, viz.

Circumference = $D_1 + D_2 \times 1.57$, where 1.57 is the correction factor for a circle.

The automatic or direct AC measurements was taken by placing two calipers on the periphery of the abdominal wall using the trackball to adjust calipers to the outer margins.

The data was entered and analyzed on SPSS version 10. Continuous variables including HC and AC were represented by mean and standard deviation. Paired 't' test was applied to compare the difference in measurements of these variables by manual and automatic methods. The correlation between manual and automatic measurements was determined through the correlation coefficient (r) and coefficient of determination r^2 .

Results

A total of 72 subjects were enrolled in the study. Three readings of each parameter, head circumference (HC) and abdominal circumference (AC) were taken using manual and automatic methods.

Mean HC calculated by the manual method for the fetuses of different gestational ages (14-38 weeks) was found to be $20.11 (\pm 7.04)$ cm, whereas that measured by the automatic method was $19.46 (\pm 6.82)$ cm; this difference was statistically significant ($p < 0.001$, 95% C.I of difference = 0.559, 0.731) as shown in table 1. There was a positive correlation ($r = 0.999$) between these measurements (Figure-1) showing that the differences were constant. Only two observations of manual HC measurements were found higher than the automatic measurements with a difference

Table 1. Comparison of Mean $\pm$ SD values (in cm) by manual and automatic modes of measurement.

Ultrasonic parameters	Number (n)	Manual measurement Mean $\pm$ SD (in cm)	Automatic measurement Mean $\pm$ SD (in cm)	Level of significance
Level of significance	72	20.10 $\pm$ 7.0	19.46 $\pm$ 6.8	p = 0.44
Abdominal circumference (AC)	72	16.79 $\pm$ 9.62	16.74 $\pm$ 6.1	p< 0.001

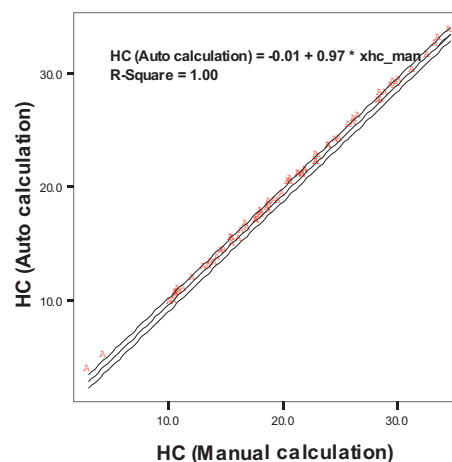


Figure 1. Correlation between manual and auto measurements of head circumference.

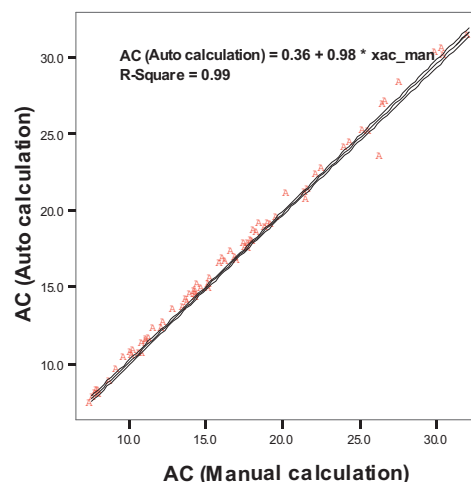


Figure 2. Correlation between manual and auto measurements of abdominal circumference.

of 0.7 and 0.8 cm respectively. Sixteen observations were found equivocal with a difference of 0 to <0.5 cm. While in all remaining 54 observations, automatic HC measurements were found higher than manual HC measurements with a difference of 0.5 to <1.5 cm.

The mean AC calculated by manual technique was $16.79 (\pm 6.24)$ cm, and that measured by automatic technique

was 16.74 (± 6.11) cm. This was not statistically significant ($p = 0.44$, 95% C.I = 0.07, 0.161) as shown in table 1; correlation between these measurements ($r = 0.997$) was positive (Figure-2). In case of AC, 31 manual observations were found less than automatic measurements with a difference ranging from 0.1 to 0.6 cm. Thirty three observations were equivocal where the difference was 0 to < 0.5 cm and in the remaining 8 observations, the automatic AC was found higher than the manual AC measurements with a difference of 0.5 to 3.0 cm.

Discussion

Sonographic measurement of foetal ultrasound parameters form the basis of accurate determination of gestational age, monitoring of foetal growth, and detecting growth abnormalities.⁹ Some selected parameters are used to estimate foetal weight.¹⁰⁻¹²

The shape of the foetal head is ovoid, whereas that of the upper abdomen (at the plane where AC is measured) is more circular. Various mathematical formulas are used to measure the circumferences, the one in common use for head circumference being the one for an ellipsoid, is.

$$\text{Circumference} = 0.5 \pi (D_1 + D_2)$$

Where $\pi = 0.3142$, and D_1 and D_2 are the two diameters at right angle to each other and 1.57 is the correction factor for a circle. This equation is commonly used for the calculation of AC. However, the same equation has been claimed to be accurate for the HC, except in situations of extreme dolicocephaly.¹¹

The formula for ovals or ellipses like the head is

$$\text{HC} = \text{BPD} + \text{OFD} \times 1.62$$

Where, 1.62 is the correction factor for ellipses. A more rigorous formula¹³ for ellipses is

$$\text{Circumference} = 0.325 \sqrt{D_1^2 + D_2^2}$$

Systematic errors are common with first two groups; the error further increases near term, as the foetal head becomes more ellipsoid (with a difference of 0.8 weeks in calculation of gestational age). The last group is related to mathematical random error because of its complex nature and applicability.¹⁴ In addition, minor inter-observer biases have been reported while calculating circumferences.¹⁵

The modern ultrasound machines are equipped with the facility to estimate the circumferences technically using calipers and trackball for both circles and ellipses. In this study an attempt was made to find the correlation between manually measured head and abdominal circumferences making use of traditional formulae compared with the automatic mode of ultrasound machine.

There was a statistical difference between the mean values of HC obtained by the two techniques; the difference

being of the order of 0.6 cm (20.11 ± 7.04 cm Vs 19.46 ± 6.82 cm) which forms 3% of the value of 20.1 cm. This may not be clinically significant; i.e. the value of HC at 22 weeks of gestation ranges from 17.4 cm to 22.3 cm (5th and 95th centiles).^{16,17} Therefore, it can be suggested that the difference obtained by two methods, although statistically significant ($p = 0.001$), may not be clinically significant.

This is supported by studies by Zador and W Lu. Zador in 1991¹⁸, who described the highly significant correlation between direct measurements of BPD ($r = 0.986$), OFD ($r = 0.958$) and HC ($r = 0.972$) and those obtained by the operators by planimetry. The mean difference (direct minus planimetry) was 1.87 ± 1.94 mm for BPD, 2.82 ± 4.13 for OFD and -0.36 ± -9.87 mm for AC. These differences were independent of operator's identity, instrument used and gestational age. He recommended the use of direct measurement system that can give the foetal head measurements which correlate highly with manual determination by a skilled operator and which takes a fraction of the time.¹⁸

According to Lu W et al¹⁹, the difference between automatic and sonographer's manual measurements were 0.12% for BPD and - 0.52% for HC. The 95% CI of the agreements were -3.34%, 3.58% for BPD and -5.50%, 4.45% for HC. The results demonstrated that the two measurements were consistent and accurate.¹⁹

In our study, regarding measurement of AC, there was no statistical difference between the values obtained by the two methods ($p = 0.44$). Similar results were obtained by Watson et al¹⁵ who, while working on AC in 235 cases demonstrated that the directly measured AC was found to be greater than the calculated value ($p = 0.00014$). The magnitude of the difference however, was only 1.3 ± 2.2 %, which is smaller than the average inter-observer measurement error. The study further stated that although statistically significant, the difference between these two measurement methods is not clinically significant, suggesting that either method is acceptable to determine foetal AC. This discussion suggests that the automatic measurement is a more rapid method than the manual, and is recommended for the measurement of the head and abdominal circumferences.

Conclusion

The measurements of the head circumference by the manual and the automatic methods were statistically significant; however, the difference may not be clinically significant, as it would fall within the standard deviation of approximately 4 days allowed for the HC. There was strong positive correlation ($r = 0.999$).

As regards the measurement of AC by the two methods, there was no statistical difference between the

two, however, there was strong positive correlation between the two methods ($r = 0.997$)

Automatic measurements are performed more rapidly than the manual ones, and may be routinely used for the measurement of head and abdominal circumferences.

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