

COMPARISON BETWEEN ULTRASONIC MANUAL AND WAVELET BASED AUTOMATIC MEASUREMENTS OF FOETAL BIOMETRY

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Abstract: In this article our objective is to verify the automatic and manual measurement of biparietal diameter and femur in foetal age prediction in the second and third trimester of pregnancy. The study consisted of 72 pregnant Indian women and manual measurement of fetal biometry was carried out by experienced sonographers. The automatic wavelet based measurement method of fetal biometry had already discussed in our previous paper. We verify that the difference between gestational age obtained for FL (femur length) and BPD (biparietal diameter) parameters via automatic wavelet based contour extraction and manual measurement is very close to each other.

The following findings are also revealed:

1. Linearity throughout pregnancy using the femur length measurements (both auto and manual) while that of the biparietal diameter demonstrated poor correlation after 30 weeks of gestation.
2. The standard error for auto femur length estimate was 0.2845 as against 0.2998 for auto BPD. The standard error for manual femur length estimate was 0.2251 as against 0.3009 for manual BPD.

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1. Introduction

Antenatal ultrasound has become one of the clinician's most important tools for assessing fetal age, growth and well-being. Compared with the physical examination of the pregnant uterus, the most accurate method for assessing and tracking fetal size and growth is with the use of ultrasound imaging and measuring of the various fetal parameters. Gestational age is determined by measuring the fetal parameters of interest, such as a long bone, BPD and HC from the frozen ultrasound image. The collection of measurements that are obtained are then compared with fetal measurement charts, which relate the observed value of a fetal parameter to gestational age or growth. The earliest measurement of gestational age taken in pregnancy should usually be accepted as the definitive assessment with subsequent examinations reflecting only fetal growth in the intervening period. Accurate dating is essential for the proper timing of chorionic villi sampling and nuchal translucency assessment in the first trimester, amniocentesis in the second trimester, as well as relating the various maternal blood serum levels to risk factors, and timing for elective caesarean section.

In Tapi et al. [12] we are automatically segmenting the contours of the femur and of cranial cross-sections by using Wavelet, which are indicators of the gestational age (GA). The accuracy of the GA estimate strongly depends upon how close the collected data follow the standard protocols for obstetrics measurements. In our paper we have used wavelet based deformable models which constitute important approach to contour estimation. Here, global models generally described by a small number of parameters are used. The model parameters are then estimated in the presence of the observed image. Deformable models usually do not include a smoothness energy term since the simplicity of the parametrization itself guarantees regularity and smoothness of the represented shape. Seminal work on deformable models was done by Grenander [3], Figueiredo et al. [2], Jain et al. [4], Staib et al. [10] and Yuille et al. [14]. The measurements obtained via the automatically estimated contours in Tapi et al [12] are **FL** = 31 mm ($GA = 19.5$) and **BPD** = 46 mm ($GA = 20.2$). Manual measurement gives **FL** = 31.8 mm ($GA = 20$) and **BPD** = 46.4 mm ($GA = 20$). Automatically obtained measurements which correspond to another fetus are **FL** = 57 mm ($GA = 30.7$) and **BPD** = 75 mm ($GA = 31.8$); parameters values for manual extraction are **FL** = 57 mm ($GA = 30$) and **BPD** = 76. mm ($GA = 30$).

The fetal biparietal diameter measurement in the determination of fetal ges-

tational age before 30 weeks can provide accuracy but the precision decreases thereafter Okonofua et al. [6], Campell [1] and Sabbagha et al. [9]. The measurement of fetal femur length is however easily done with the use of improved technology under the condition in which BPD is difficult to measure Min-neng et al. [5].

2. Method

This comparative cross sectional study was conducted at the Universal Diagnostic Centre, Indore. The study consisted of a convenient sample of 72 uncomplicated singleton pregnant women between 14th to 40th week of gestation. Measurements were repeated until three successive readings and the average was taken.

2.1. Biparietal Diameter (BPD)

This was measured from the leading edge of the echo from the proximal skull surface to the leading edge of the echo from the distal skull surface - "outer to inner" diameter.

2.2. Femur length (FL)

Measured using a straight-line measurement between the two ends of the femoral diaphysis. One of the most fundamental issues is the detection of object boundaries or singularities, Which is often the basis for further processes such as measurement of anatomical and physiological parameters. A wavelet based edge detection algorithm had been developed based on the theory of multi-resolution. Through the use of matching wavelet algorithm, we can find the wavelet that is closely correlated with the edge signal [11].

Then we automatically segmented the contours of the femur and of cranial cross-sections, which are indicators of the gestational age (GA). The accuracy of the GA estimate strongly depends upon how close the collected data follow the standard protocols for obstetrics measurements. Manual segmentation is the most flexible method to obtain obstetric measurements according to the standard protocols, but it requires expert knowledge and it is a time-consuming and error-prone task Powis et al. [8]. On the other hand, automatic localization of the contours is in general less flexible, since such standard protocols are hard to encode in a computationally efficient algorithm, but has the benefit of

increasing the reliability and reproducibility of the obstetric measurements.

Also to deal with the low quality of US images, which makes any contour detection task very difficult, we use low-order parametrization of the contour shapes. This low order parametrization is sufficient to accommodate the expected shape and size variations of the organs, but provides robustness against noise, image artifacts, and regions of missing data. The problem is formulated in a statistical framework, and implementation is carried out by unsupervised deterministic iterative algorithms.

In our paper Tapi et al. [12] we used deformable models which constitute important approach to contour estimation. Here, global models generally described by a small number of parameters are used. The model parameters are then estimated in the presence of the observed image. Deformable models usually do not include a smoothness energy term since the simplicity of the parametrization itself guarantees regularity and smoothness of the represented shape Tapi et al. [12]. Seminal work on deformable models was done by Grenander [3], Figueiredo et al. [2], Jain et al. [4], Staib et al. [10] and Yuille et al. [14].

The measurement was analyzed by the method of least square linear regression. The predicted (both auto and manual) gestational age for both *BPD* and *FL* measurement were determined from the regression result using the following equations respectively:

$$G1 = BPD(b1) + b2, \quad (1)$$

$$G2 = FL(b3) + b4, \quad (2)$$

where:

- G1* is predicted gestational age for *BPD* measurement,
- G2* is predicted gestational age for *FL* measurement,
- BPD* is the mean of biparietal diameter at a particular gestation,
- FL* is the mean of femur length at a particular gestation,
- b1* is regression coefficient of *BPD* (slope),
- b2* is regression constant or intercept of *BPD*,
- b3* is regression coefficient of *FL* (slope),
- b4* is regression constant or intercept of *FL*.

3. Result

The measurements obtained via the automatically estimated contours are **FL** = 31 mm (*GA* = 19.5) and **BPD** = 46 mm (*GA* = 20.2). Manual measurement

Manual FL (mm)	Auto FL (mm)	Manual predicted weeks	Auto pre- dicted weeks	Manual BPD (mm)	Auto BPD (mm)	Manually predicted GA weeks	Auto pre- dicted GA weeks
14.00	13.90	14.00	13.10	26.10	26.00	14.00	13.00
20.21	20.19	16.00	16.30	32.80	32.10	16.00	16.10
26.00	25.90	18.00	18.10	39.70	39.20	18.00	18.50
31.80	31.00	20.00	19.50	46.40	46.00	20.00	20.20
37.30	37.00	22.00	22.70	53.00	52.90	22.00	23.10
42.50	41.90	24.00	24.60	59.30	58.70	24.00	25.20
47.50	47.20	26.00	26.60	65.40	64.00	26.00	27.20
52.30	51.90	28.00	28.80	71.30	70.90	28.00	29.60
57.00	57.00	30.00	30.70	76.50	75.00	30.00	31.80
61.20	61.00	32.00	32.10	80.90	79.80	32.00	32.60
64.90	64.20	34.00	34.10	84.30	83.90	34.00	31.70
68.20	68.00	36.00	35.70	87.20	87.00	36.00	34.10
71.00	71.20	38.00	37.40	89.70	88.00	38.00	35.80
73.39	72.90	40.00	38.50	91.90	90.00	40.00	36.90

Table 1: Comparison between Femur length (FL) and biparietal diameter (BPD) estimate for auto and manual gestational ages.

gives **FL** = 31.8 mm ($GA = 20$) and **BPD** = 46.4 mm ($GA = 20$). Automatically obtained measurements which correspond to another fetus are **FL** = 57 mm ($GA = 30.7$) and **BPD** = 75 mm ($GA = 31.8$); parameters values for manual extraction are **FL** = 57 mm ($GA = 30$) and **BPD** = 76.5 mm ($GA = 30$) Tapi et al [12]. The complete measurements on 72 women are shown in Table 1.

Table 1 shows clearly that the Auto predicted GA using auto femur length were closer to that of the manual predicted GA using manual femur length measurement in both the second and third trimester. The Auto predicted GA using auto BPD , however, varied from that of the manual GA after 30 weeks of gestation.

Table 2 shows that the standard deviation and the standard error for auto femur length 0.0017 and 0.2845 respectively were smaller than that of the BPD which were 0.0038 and 0.2998, respectively. There was also a stronger significant coefficient of correlation between auto femur length measurement and auto predicted GA ($r = 0.941$) than that of auto BPD ($r = 0.917$). This table also shows that the standard deviation and the standard error for manual femur length 0.0042 and 0.2251 respectively were smaller than that of the BPD which were 0.0045 and 0.3009 respectively. There was also a stronger significant coefficient of correlation between manual femur length measurement and manual predicted GA ($r = 0.992$) than that of manual BPD ($r = 0.985$).

Regression coefficient	0.3292(b1)	0.3493(b1)	0.4008(b3)	0.4129(b3)
Regression constant	1.5997(b2)	1.6033(b2)	6.5156(b4)	6.5398(b4)
Standard deviation	0.0038	0.0045	0.0017	0.0042
Standard error	0.2998	0.3009	0.2845	0.2251
correlation coefficient	0.917	0.985	0.941	0.992

Table 2: Parameters estimates for least squares regression line for relationship between gestational age (Auto and Manual) biparietal diameter and femur length.

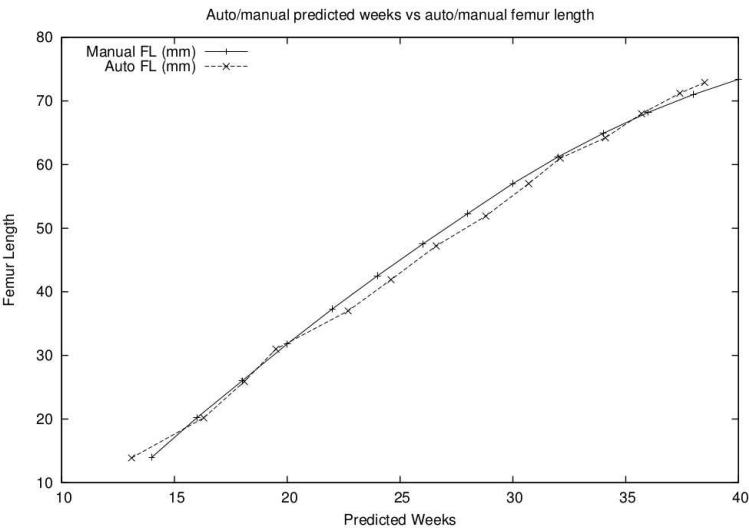


Figure 1: Auto/manual predicted GA weeks vs auto/manual BPD in mm

4. Conclusion

The prediction of gestational age (both auto and manual) by *BPD* measurements before 30 weeks gestation can provide accuracy but its precision declines thereafter Sabbagha et al. [9] and Varma [13]. This study was designed to compare the accuracy of predicting gestational age(both auto and manual) by the measurements of *BPD* and *FL* in the second and third trimester. The

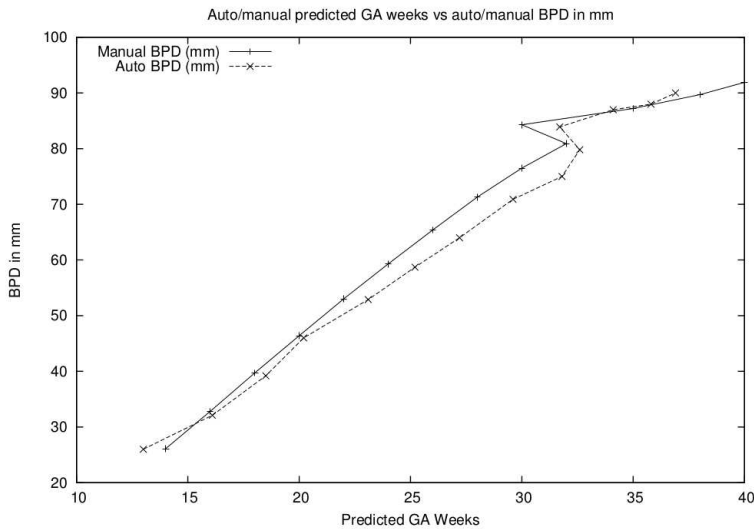


Figure 2: Auto/manual predicted GA weeks vs auto/manual BPD in mm

results demonstrate a linear relationship between the auto and manual gestational ages throughout the second and third trimester using the femur length measurements Figure 1, whereas there was a considerable variation with that of *BPD* measurements after thirty weeks of gestation Figure 2. These findings also reaffirm the fact that the growth rates of *BPD* and *FL* follow a characteristic pattern with maximal growth rate at different gestation Owen et al. [7]. The good correlation between auto and manual measurements also shows the good performance of the approach via contour estimation of fetal biometry by using wavelet based MLE, Tapi et al. [12].

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