Ultrasonic prediction of fetal mass

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Summary

A clinically accurate method for estimating fetal mass from fetal body parameters is reviewed. The abdominal circumference is first calculated from the anteroposterior and transverse diameters. This is used as an extra indicator of fetal age. By adding the biparietal diameter, these measurements are converted into fetal mass. From percentile tables the fetal mass at different stages of pregnancy and at term can then be predicted. This method was used on 101 private patients and the average error between actual and predicted mass was 210 g (6,5% of the birth mass).

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Fig. 1. Early gestational age — 15 mm crown-rump length at 8 weeks. The arrows point to the bright acoustic shadow of an intra-uterine contraceptive device close to the gestational sac.

The assessment of gestational age and fetal weight forms an integral part of present-day antenatal care. Birth mass has a major influence on perinatal well-being, and perinatal mortality could be significantly reduced if growth retardation is recognized at 34 weeks.[1] Furthermore, birth weight is an important consideration in the timing of induction or elective caesarean section. In a prospective study Sabbagha[2] found that 28% of patients were uncertain as to dates and an additional 15% had provided inaccurate dates.

A reliable and cost-effective method of establishing fetal maturity would therefore be of great help, especially if it could be used at any time during the second half of pregnancy. In breech presentation the size and maturity of the fetus become of vital importance in deciding the method of delivery. Palpation of fundal height is so inaccurate that it should be discarded. A more reliable clinical parameter is the impression of uterine volume, amount of amniotic fluid and fetal size. It is surprising how closely an experienced obstetrician can judge fetal weight by careful palpation. Lind[3] found that guesswork alone would give an error of about 440 g. Of the 24 clinical estimations in this series 15 were on average 422 g too high and 9 were 310 g too low. The overall average error was 380 g.

Unfortunately clinical estimation is too subjective in critical conditions such as growth retardation and the upper and lower extremes of normal.[4] With the technical improvements in real-time obstetric ultrasonography a number of investigators have published different techniques for estimating fetal age and weight.[1,5-9] These include determination of the fetal heart volume, biparietal diameter (BPD), BPD with body length, and BPD with thoracic circumference. Many of these are too cumbersome for clinical application.

In early gestation from 6 to 14 weeks, the crown-rump length gives the most accurate indication of gestational age (Fig. 1).[10] Care must be taken to obtain precise measurements, because a small error at this stage can make a difference of a few weeks later. Good resolution is therefore necessary to recognize the exact longitudinal plane. This may require repeated 180° rotations of the transducer head until the entire length of the fetus is identified. The size of the gestational sac and dimensions of the uterus are at best only rough guides to gestational age.

From about 14 - 23 weeks the length of the long bones is a useful extra indicator of gestational age and can be read off directly from Campbell's tables (S. Campbell — personal communication).

The BPD (Fig. 2) is reasonably reliable from 12 to 26 weeks although individual variations in head size even at an early stage must be taken into account. Hayashi *et al.*[11] found the BPD to be accurate in 95% of cases if measured between 20 and 28 weeks. This is the optimal time since during this period the rate of growth is constant, the biological variation is still relatively small and the overall likelihood of error in the calculation of age and weight is at a minimum.[1,12] However, after 26 weeks these variables become clinically significant so that a single BPD measurement of 88 mm may indicate a gestational age from 31 to 36 weeks.[2,13] Although a BPD of 90 mm usually signifies a fetal weight of 2 500 g or more, the variation in maturity can still be 4

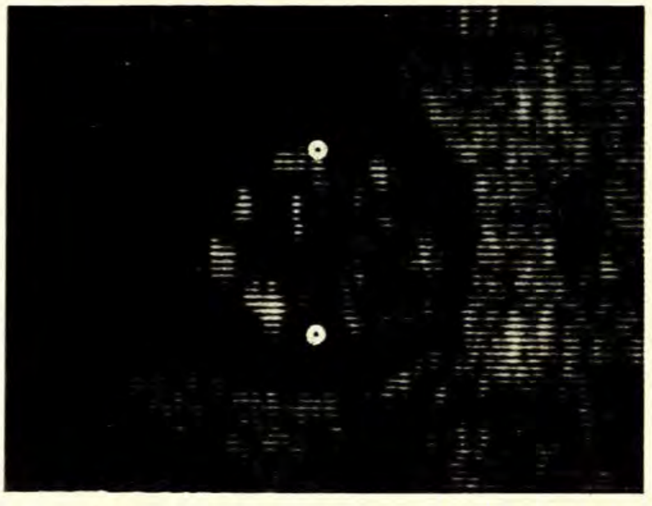

Fig. 2. As early as 12 weeks and 2 days the BPD can indicate fetal age in spite of the fact that the skull tables are not yet clearly defined.

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weeks.[14] As a further rough guide a BPD of 93 mm or more at 38 weeks means a low risk of hyaline membrane disease.[11]

It is therefore not surprising that in relating only BPD to birth weight a number of workers found an average error of 400 g and increasing inaccuracy above 4 200 g and below 2 500 g.[15,16] Because of the brain-sparing ability of the growing fetus this is especially true in intra-uterine growth retardation, where there is increased differentiation between the growth of the fetal head and the body.

In 1975 Campbell and Wilkin[5] found the fetal abdominal circumference (AC) at 32 - 34 weeks to have a better correlation with fetal weight than BPD. Then Warsof *et al.*[9] combined these techniques by postulating that birth weight is a logarithmic function of a number of fetal body parameters. After performing a computer-assisted statistical analysis they discarded total intra-uterine volume (TIUV) and found that the two fetal dimensions of AC and BPD had the best correlations with and an acceptable standard deviation from the actual birth weight. For this purpose two formulae were used.[9] Instead of computing the weight of each fetus Warsof has prepared computer-assisted tables from which the weight can be read directly. Because of the simplicity of the method once the calculator had been programmed the measurements of each fetus were computed individually in this series.

Subjects and methods

The majority of the subjects of this report were from a high socio-economic group and were seen in private obstetric consultant practice.

A Toshiba SAL-20 A phased-focus linear array scanner was used for the ultrasound examinations. The 3,5 MHz transducer is calibrated to a velocity of sound in tissue of 1 540 m/s. All examinations and measurements were performed personally by one of the authors (G.H.R.H.).

Measuring the BPD

The BPD was measured with the built-in omnidirectional electronic calipers at the widest diameter of the skull from the outer to the inner table.

There is now no doubt that good real-time measurements are as accurate as those obtained with static scanners.[17] The greater mobility of the transducer head has also made it easier to identify the exact plane of measurement. When the midline echo of the falx cerebri and lateral ventricles have been identified the short twin lines of the septum lucidum indicate the correct angle and position of the transducer (S. Campbell - personal communication) (Fig. 3).

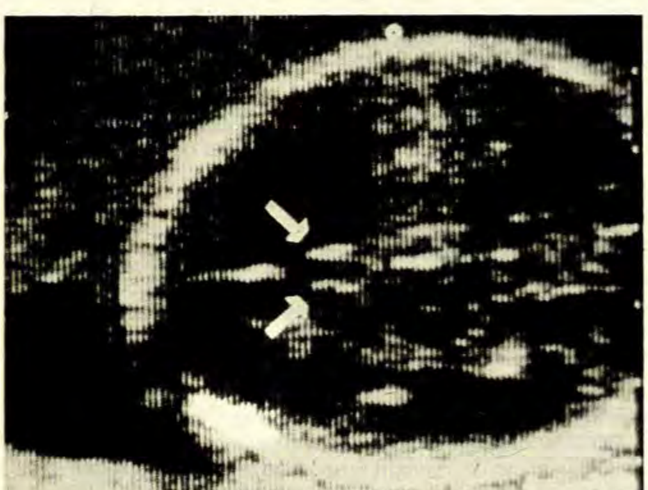

Fig. 3. BPD — midline echoes with the short twin lines of the septum lucidum (arrows) **showing the true plane of measurement.**

Abdominal circumference

The AC was measured by first determining the longitudinal axis of the fetus by locating the vertebral column and a reasonable section of the aorta (Fig. 4). At right angles to this plane the circular and symmetrical abdominal outline can be seen. By moving the probe in a caudal or cephalad direction (keeping it at the same angle to the mother's abdomen) the following landmarks are identified: fetal spine, aorta, umbilical vein, liver, stomach and cardiac echoes (Fig 5).

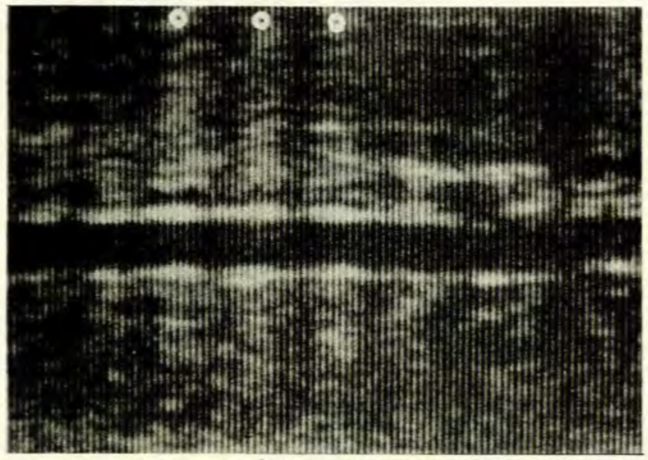

Fig. 4. True longitudinal plane — section of abdominal and thoracic aorta for longitudinal orientation. The markers indicate the rib shadows.

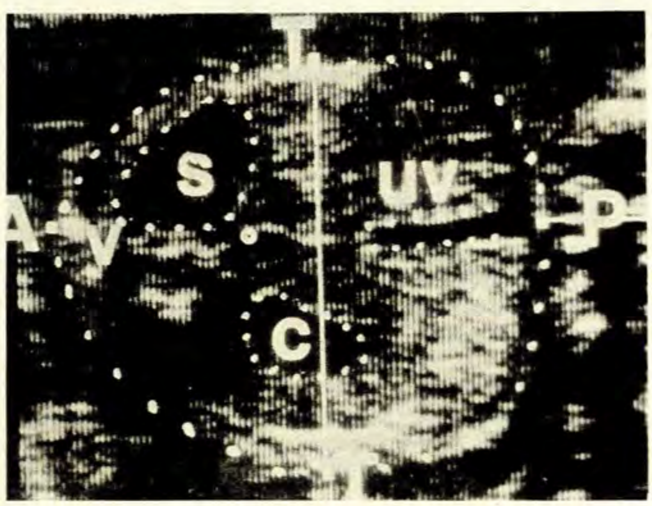

Fig 5. AC landmarks (V = vertebra; C = colon; S = stomach; UV = umbilical vein). Measuring in one step — transverse (T-T) and anteroposterior (A-P).

At the level where the cardiac echoes disappear and the stomach and/or ductus venosus come into view two measurements are recorded: the antero-posterior diameter (AP) through the spine and aorta to the anterior abdominal wall, and the widest transverse diameter at right angles to the AP.

Because of the 11,5 cm width of the probe these measurements often have to be taken in two sections (Fig. 6), from the spine to the aorta and from the aorta to the anterior abdominal wall or from lateral abdominal wall to aorta to lateral wall. A wider probe which can scan the full width of the fetal body even in late pregnancy has now been made available by Toshiba. The accuracy of these dimensions is increased by taking the averages of two or more measurements.

Computing the AC and mass

In a recent publication Ott[18] brings this rather cumbersome calculation within reach of most obstetric ultrasonographers. In

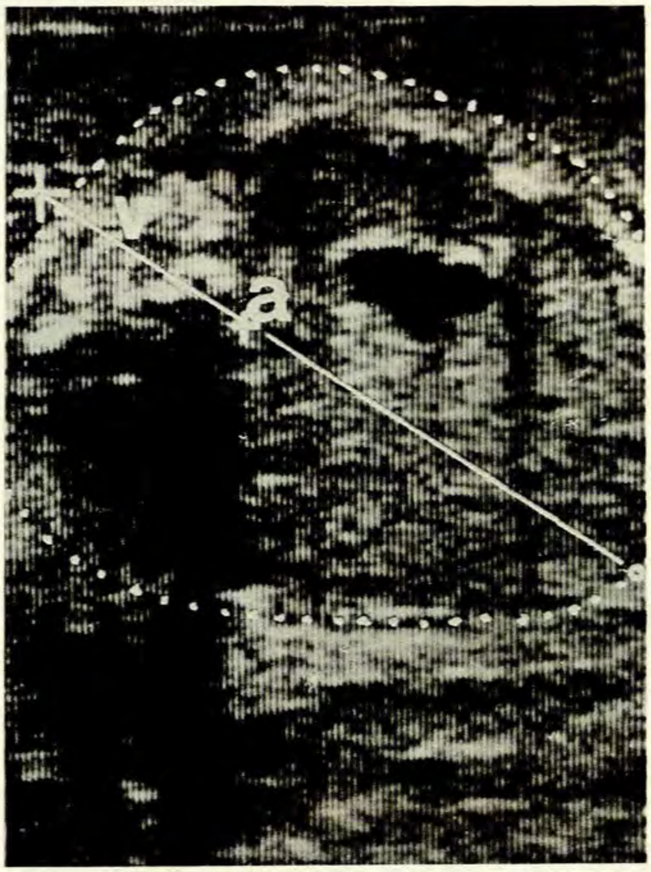

Fig. 6. Measuring in two steps — posterior vertebral column (v) to aorta (a) to anterior abdominal wall.

his series the overall mean error in mass determination was 8,2%. Ott's method was used for the calculations in this series. The AP and transverse dimensions of the fetal abdomen together with the BPD were entered into a calculator programmed to utilize Warsof's formulae. Also in this series an 82nd step was added so that the AC could be calculated and displayed first, irrespective of the BPD. The next sequence of the calculator computes and displays the fetal mass.

Using Campbell's abdominal circumference tables the AC serves as a double check for gestational age, and also identifies early growth retardation. (Sometimes the BPD cannot be measured accurately as in breech presentation, after engagement of the head or with severe lateral flexion.)

Results

On average three ultrasonographic examinations were conducted per patient. The final estimates employed in the statistical analysis were those obtained from the last examination in each case, suitably adjusted to relate to the actual time of birth —if the baby was born at 39 weeks, for example, the mass was projected to that gestational age. The maximum period between the last examination and birth was 10 weeks (1 patient), while 2 examinations were conducted on the day of birth. The average time lapse was 3,3 weeks. In total 75% of the examinations were performed 3 weeks or less before birth. The estimated and actual birth masses of the 101 neonates — including one set of twins —are presented graphically in Fig. 7.

If there was a perfect agreement between the estimated and the true mass, all points would have fallen on the ideal line (a straight line through the origin and with a slope of 45°). Either an upward or a downward deviation of a point from this line is the result of an error in estimation, i.e. a discrepancy between the estimated and the actual birth mass for the case under consideration. From the observations it appeared that the errors varied

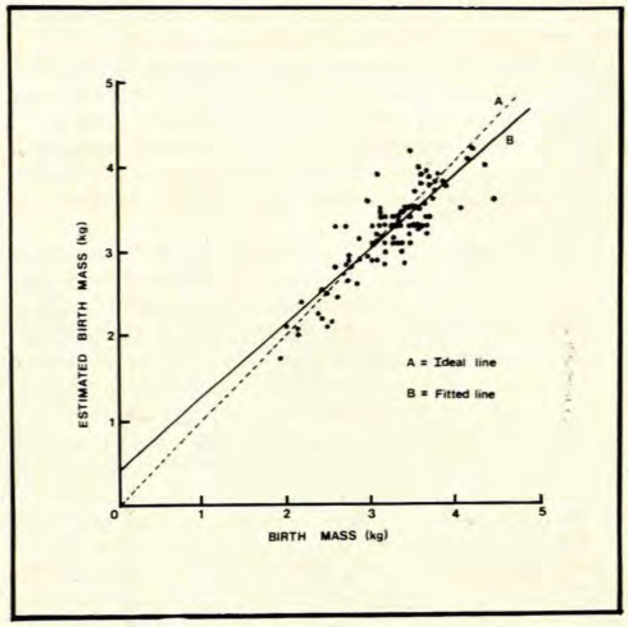

Fig. 7. Relationship between the estimated and actual birth mass of 101 neonates.

from an underestimate of 900 g to an overestimate of 800 g. In total 36% of the estimates were too high, 53% were too low and 11% were correct. The average ultrasonographic error was 210 g, which corresponds to an average percentage error in birth mass of 6,5%.

Out of 20 errors greater than 380 g only 4 applied to infants with a birth mass of less than 3 000 g. The other 16 infants weighed between 3 000 g and 4 500 g at birth. Furthermore, the interval between the last ultrasonographic examination and the birth did not seem to have a bearing on the size of the observed error. Larger errors could not specifically be related to longer intervals. On the contrary, 5 out of the 10 correct estimates were calculated more than 3 weeks before birth.

In 24 cases clinical estimates were recorded immediately before the last ultrasonographic examination. Of these estimates 15 were too high (average +422 g) and 9 too low (average −310 g). The overall average clinical error was 380 g.

For the observed points the line of best fit (B) was calculated by the statistical method of least squares. Its equation was found to be $y = 0{,}45 + 0{,}85\,x$, where y represents the estimated mass and x the birth mass. The fitted line does not differ significantly from the ideal line. The coefficient of correlation between the estimated and actual birth mass was 0,85, which is statistically highly significant ($P < 0{,}005$). The average birth mass was found to be 3 263 g, with a standard deviation of 504 g. The average estimated mass was 3 223 g with a standard deviation of 502 g.

In summary, it can be stated that the estimates were in close agreement with the true values.

Discussion

By analysis of statistical variation it was found that not only do simple measurement errors occur but there are also normal ranges of BPD and AC for any given maturity.[1,5] The accuracy of any technique therefore depends on a maturity calculated from earlier measurements. That is why early check points are necessary — a crown-rump length before 14 weeks and a basal BPD and AC from 24 to 26 weeks. In this way the growth-adjusted sonographic age can be determined accurately.[19] From the baseline at 30 - 32 weeks a weight estimation can be projected to term or whenever delivery is contemplated. A combination of percentile weight tables are used for this purpose.[20]

The question arises how many ultrasound examinations a normal patient should undergo. It is suggested that every patient

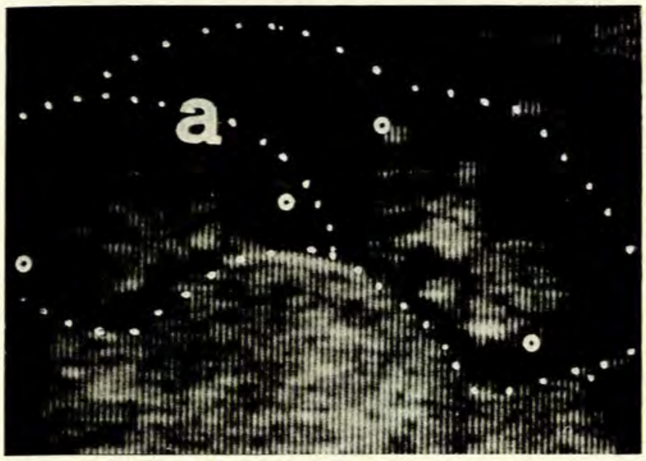

Fig. 8. Multiple gestation at 10 weeks, showing separate gestation sacs, amnions (a) and embryos (between dots).

Fig. 9. Hydrocephalus — BPD of 104 mm at 34 weeks. The ventricular system is grossly distended with cerebrospinal fluid (csf). Note the thin layer of brain tissue (arrows).

is entitled to the many advantages offered by modern real-time ultrasound. The three baseline measurements are: (*i*) prior to 14 weeks; (*ii*) from 24 to 28 weeks; and (*iii*) at 32-33 weeks. Thereafter one more at 36 - 38 weeks is usually sufficient to establish that particular infant's growth curve confidently. These scans also serve to identify other key features such as multiple gestation (Fig. 8), congenital defects (Fig. 9) and placental position (Fig. 10).

It is surprising how reluctant many practising obstetricians in South Africa are to accept the validity of ultrasound, especially in high-risk cases. This probably not only stems from their traditional suspicion of new techniques but might also be due to the

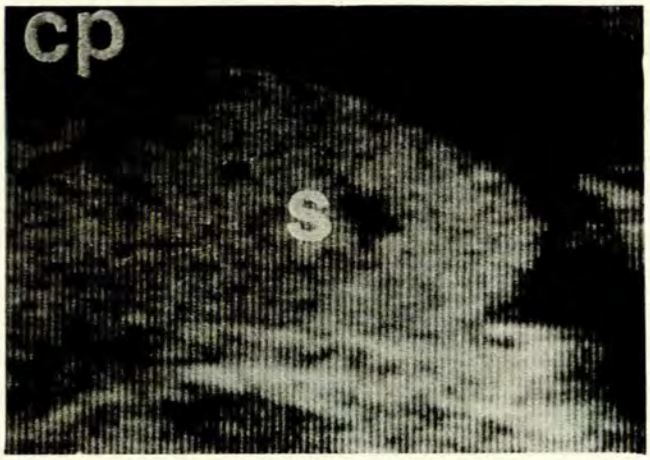

Fig. 10. Placental position — low posterior placenta at 24 weeks. Note the texture of the placental tissue, the chorionic plate (cp) and the sinuses (s).

many bad diagnoses and erroneous reports they have come across. It must be agreed that it is far better to rely on good clinical judgement than to lose a baby because a report had been read wrongly and induction or caesarean section carried out too soon or too late. The need for well-trained obstetrician-ultrasonographers will therefore increase rapidly as the place of ultrasound in South African obstetrics becomes more firmly established.

In conclusion this method seems to be clinically and statistically reliable enough to be used as a basis for important decisions. Data are now being compiled on abdominal circumference and fetal mass in early pregnancy. These will be presented in a future report.

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