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Ultrasound instead of last menstrual period as the basis of gestational age assignment

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Since the beginning of modern obstetric practice in the 19th century, the question of how to determine accurately the expected date of delivery has been a central issue in both clinical practice and research into almost any aspect of fetal wellbeing, fetal growth, events at delivery and in the neonatal period. The last menstrual period (LMP), when it is known, has been the accepted basis for assigning gestational age. Where the LMP is unknown, ultrasound is used, but where a discrepancy is found between scanning and LMP dates, clear guidelines on when to choose one or the other method for estimating gestational age have been lacking.

In 10–45% of pregnant women[1–4], useful information about the LMP is missing. In an unselected population, the true practical figure is around one-third of women attending for antenatal care. The other two-thirds have what is often called 'certain dates', i.e. they report regular menstrual cyclicity and say that they know the date of their LMP. In order to use the LMP in these women, normal menstrual cyclicity should be a reliable biological phenomenon with a constant relation to ovulation and conception, and methods used by women to determine their LMP must, in general, be accurate. If ultrasound scanning is offered to every woman early in pregnancy, some methods of handling differences between gestational age by LMP and ultrasound are needed. Uniform use of only one of these methods may be desirable, since otherwise two or three types of data will be created, depending on what reference point is used for dating the pregnancy.

Other methods for assigning gestational age have either proven too imprecise to be of use (quickening, detection of fetal heart sounds, early uterine size or fundal height, epiphyseal appearance on X-ray films)[5,6], not widely available or of unproven value (biochemical or immunological methods)[2], or imprecise and retrospective (neonatal assessment)[7].

The two methods that must be contrasted for their validity in estimating gestational age are use of the last menstrual period and ultrasound measurement of fetal size in the first half of pregnancy, neither of which are equal, but both of which are related to gestational age. These are the only two methods of potentially sufficient accuracy and availability to be of real use for research and clinical purposes. Clinical or X-ray data may on occasion have to be used to create the 'best corroborated evidence'[5] when the woman presents late in pregnancy with uncertain gestational length.

CYCLE LENGTHS AND CYCLE REGULARITY

Since the middle of the last century, many studies in several parts of the world have repeatedly addressed the issue of normal cycle lengths and their regularity[8–13]. All have shown that there is no solid evidence for the old idea of a lunar month. Arey summarized 50 years of such studies in 1939[9] and showed, using data from around 2600 women and 32 500 calendar records, that there was great variation in cycle lengths, not only between women, but also from one cycle to the next in any one woman. Cycles varied with age, being longer on average in the young (34 days just after puberty) and shortening with increasing age. In the first few years after puberty, the cycles could be extremely variable with women rarely experiencing their own average cycle length. Individual fluctuations of ±2.5 days with respect to the mean corresponded to limits of variability which contained two-thirds of all cycles (approximately one standard deviation (SD)). Gunn and co-workers[8] studied 479 women by asking them to mail record cards on a month-to-month basis. In 30% of the women, the cycles varied by more than 13 days. Goldzieher and co-workers[10] found the same wide variation, showing a constant skewness towards longer and anovulatory cycles. A recent large study[11] of 30 655 concurrently recorded cycles from 2316 women showed a mean cycle length of 29.1 days (SD 7.46), while cycles between 15 and 45 days (95% of all cycles) showed a mean of 28.1 days and a smaller SD of 3.95 days. Cycles of 25–31 days were exhibited by only 77%. Variability in cycle lengths was greatest for women under 25 years of age and then

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declined steadily to the age of 35–39 years, increasing slightly thereafter; these trends were confirmed in another longer term study[12].

The adult woman must, therefore, expect at least a third of all her cycles to depart for more than 2–3 days from her mean cycle length.

The maximum departures of individuals from their own means have been found to extend from 1 to 69 days in adults and 6 to 211 days in pubertal girls. The existence of some favored subordinate types of cycle length in addition to the 4-week modal type, such as 3, 5, 6 or 7 weeks is not true, in sharp contrast to conclusions built on the women's own oral testimony[9].

The smooth frequency distribution, which can be obtained by combining all cycles of a group into one curve, is the result of overlapping individual irregularities and not of closely spaced, regular individual performances, and is observed in all populations[9]. Times of perfect regularity occur only in relatively short observation time-spans, often interspersed between more irregular cycles.

The menstrual cycle in a large proportion of women does not commence at very regularly predetermined intervals of 28 days and every woman has a relatively large degree of variation in her own cyclicity, which is more pronounced during the younger childbearing years. Regularity may be a relative phenomenon that depends upon personal standards of interpretation.

LMP AND CONCEPTION TIME

Careful studies on women with '4-week' cycles whose husbands were allowed home on short leave from the front in the First World War showed a large variation in both supposed time of conception and delivery relative to the LMP. Summarizing his own and previous studies, Pryll found that intercourse resulting in conception covered a 42-day period (Figure 1)[14]. There was a skewness in timing of the intercourse presumed to result in conception, which extended well into the second month, with 36.4% of conceptions taking place after the 15th day of the cycle[15]. Weinstock[16] investigated 416 women, who claimed that pregnancy had resulted from a single act of intercourse for which the date was known, and summarized a large number of earlier studies, including studies performed to devise a safe-period method for contraception, by saying that women could become pregnant on any day of the cycle, including the first. There was an optimal time for conception from day 10 to day 15 after the beginning of menstruation, but with a definite skewness towards later dates. A quarter of the cases became pregnant after the 19th day of the cycle. The same skewness has later been shown in a carefully collected set of data on women with certain LMP and conception times[17,18].

From a history of menstrual cyclicity, even when regular, there is, therefore, no certain way of predicting when conception might have taken place.

LMP AND TIME OF DELIVERY

Treolar *et al.* studied prospectively recorded LMP data from 2038 selected women and retrospectively collected LMP data from a similar data set of 882 women[18]. Whereas 85–90% of women delivered at 40 ± 2 weeks' gestation (70% at 280 ± 10 days), there was an expected minority of preterm deliveries, but also a definite skewness towards longer gestations. The limits within which confinement occurred were narrower for women with more secure menstrual cycles and conception dates, but the same skew distribution could be seen. Similar results have also been shown in more recent studies comparing ultrasound and LMP data[3,19–21]. While the gestational age estimates by LMP and ultrasound agree to within ± 7 days for a large majority of women delivering near term, the discrepancies become progressively greater as more pre- or post-term babies are considered. Kramer *et al.* found that using LMP one in four preterm babies and seven of eight among those thought to be post-term were wrongly classified as such[19]. The positive predictive values of the LMP-based estimates of gestational age were found to decrease from 94.9% at term to 77.5% for preterm and only 11.9% for post-term pregnancies[19]. Of women with an optimal menstrual history, 85–89% delivered spontaneously at term ± 2 weeks[3,21].

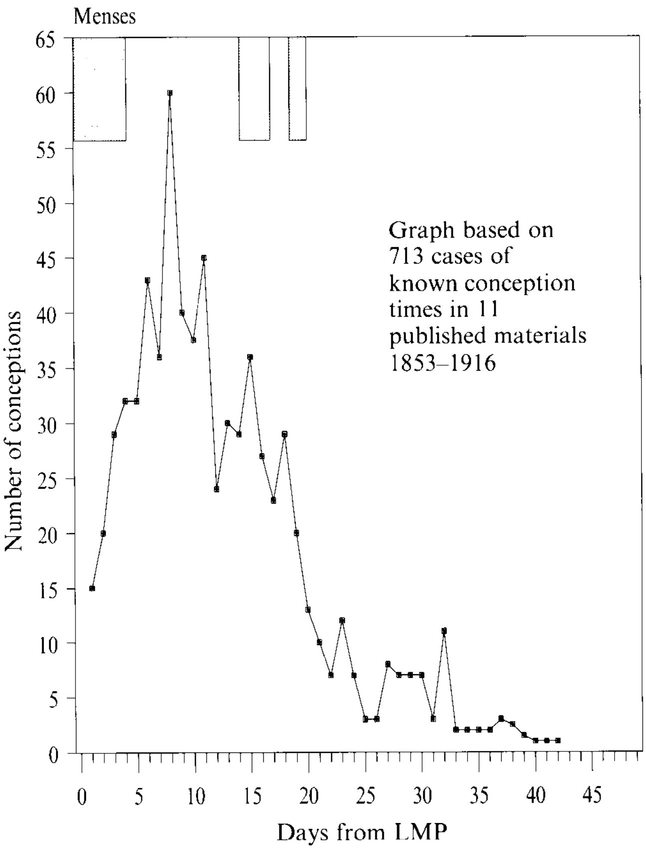

Figure 1 The curve constructed by Pryll in 1916 summarizing day of conception in relation to onset of the LMP based on 713 thoroughly investigated cases of conception after a single act of intercourse found in the literature since 1853[14]. Conception could seemingly occur from the first day of the cycle to 42 days later. A skewness towards late conception is evident. (With kind permission of MMW Verlag, Munich)

In unselected populations, the proportion of women delivering outside 40 ± 2 weeks is high[4,19,22,23]. Bergsjö *et al.*, in reviewing all births in Sweden between 1976 and 1980, thus found that of 427 581 women with a known LMP there were 12.6% who delivered at more than 294 days after their LMP[4]. Even using reliable LMP, about 7–10% of women appear to have pregnancies lasting longer than 42 weeks compared to the figure of 2–4% (the expected in a normal distribution) when ultrasound measurements are used to assign gestational age in whole populations[2,3,19,20,24,25]. This skewness must be based on variability of ovulation in relation to LMP (follicular phase length) and, to a lesser degree, on variable time of fertilization after ovulation. In a substantial proportion of women with a clinical problem situation, the menstrual history fails to predict time of delivery accurately and the limits for this error are wide.

BIOPHYSICAL AND BIOCHEMICAL DATA ON OVULATION IN RELATION TO LMP

The times of the luteinizing hormone (LH) peak and basal body temperature rise provide information of a different nature on the accuracy of using the LMP[26–28].

In a series of 317 women using basal body temperature measurements for family planning reasons, Boyce *et al.*[26] found a skewness towards longer gestations. 'Postmature' cases dropped from 11% to 5% when basal body temperature rise was used to determine onset of gestation compared with LMP, assuming that ovulation and fertilization followed the last day before the temperature surge within 36–44 h. Most (70%) of the variation in those delivering post-term could be ascribed to the LMP–ovulation interval[26].

In a careful study of LH peaks in 327 menstrual cycles of 299 women from two countries, it was found that, even after excluding the oldest women with the greatest differences in cycle length, the time distribution for ovulation was skewed to the right along the x-axis[27]. The mean time until ovulation was 14.63 days. The 95% confidence limits ranged, however, from 8.2 to 20.5 days. Some cycles were excluded because of their excessive length and the shortest follicular phase lasted only 3 days from the first day of the LMP. With longer cycle lengths the timing of LH peaks becomes more variable[28].

Walker *et al.*[29] studied 75 ovulatory cycles in 38 women of proven fertility who were attempting to conceive (25 conceived). Using daily urinary LH and human chorionic gonadotropin (hCG) radioimmunoassays, they showed that ovulation occurred in a range of 8–35 days after the LMP with a mean LH surge occurring at 16.4 days. In nearly one-third of the cycles, ovulation occurred after day 18 and in half of these cases, late ovulation would not have been expected on the basis of menstrual cycle length.

Biochemical and biophysical data reflect cycle and ovulation irregularity as well as skewness towards late ovulation in healthy women, and confirm the poor relation of the LMP to the time of conception.

ARE CERTAIN DATES RELIABLE?

When a woman says that she is certain of the date of her LMP, this is usually accepted and no further evidence may be sought. Hall and co-workers[1] studied a large population where gestational age was corrected retrospectively on the basis of the LMP and any other corroborated evidence. Ultrasound was performed in 46.7% of the women and largely confined to those with uncertain dates, half of whom presented after 20 weeks. In 11% of cases the LMP followed pill withdrawal. Of the women, 78% had their LMP recorded as certain in the case notes by the criteria used. Whether gestational age was deemed certain, approximate or uncertain, the discrepancy between the LMP and the retrospective best estimate of gestational length was always skewed towards longer gestations by LMP. Campbell *et al.*[3] found that only 55% of their investigated population had a reliable menstrual history. Of the 45% with suspect menstrual histories, half were unsure of the exact date of their LMP, one-third had been on the oral contraceptive pill within 2 months of conceiving, and 9.1% could not volunteer any meaningful information on their LMP.

Treolar *et al.*[18] found that prospectively recorded and retrospectively collected LMP data were virtually identical, with a small difference towards more prolonged gestations of between 40 and 43 postmenstrual weeks in the retrospective material. These differences were well within sampling error expectancy, showing that concurrent recording of LMP was not very different from careful retrospective recollection in predicting the date of delivery.

Geirsson and Busby-Earle found that, of 315 women coming consecutively to an antenatal booking clinic, 24% were unsure of their dates on routine history taking[30]. Of the 76% with 'certain' dates, 6% had, however, used the last day of their LMP instead of the first as a reference. Just under half of all the women had written down the date of the LMP. Various life events (visits by relatives, birthdays, holidays, attending a doctor) were used by 18% to aid memory and some were sure of their LMP because their menstrual pattern was 'always regular', while others admitted that they had just made a good guess. Another 10% counted backwards to a likely date from the day they had expected menstruation to start. If only women with regular cycles of 28 ± 2 days were considered, then these were 46% of the total. In this group, some had been on the oral contraceptive pill or had an abnormal LMP, leaving only 102 or 32% out of the total of 315 with regular monthly cycles and certain dates. However, within this group, closer questioning revealed that one-third had used various memory aids and guessing to date their LMP. In reality, only an approximate quarter of the women were sufficiently accurate and regular to allow the deduction that mid-cycle ovulation was reasonably likely. In 12% of this smallest group of women, considered to have very reliable dates, there was a difference of over 1 week between early ultrasound and LMP and this difference ranged from being 24 days further on to 33 days less far on than the certain dates implied. Similar discrepancies have been reported elsewhere[21].

Use of the LMP appears to involve an in-built inexactness, which even for women with certain dates and regular 28-day cycles is unpredictable, because the day of ovulation may vary considerably. There is a chance of inaccuracy of more than 7 days in one of ten women with very certain dates.

CONSISTENCY OF ULTRASOUND FOR ESTIMATING GESTATIONAL AGE

Ultrasonic fetal biometry can be used to estimate gestational age if performed before mid-pregnancy with an upper limit of about 22–24 weeks' gestation. After that time, increasing fetal weight accumulation is associated with wider confidence intervals for all such measurements and therefore decreasing precision in estimating gestational length[20,31,32]. Growth of several fetal bony and soft tissue landmarks has been shown to be of use in determining gestational age, singly or in combination. The most commonly used measurements at present are fetal crown–rump length, biparietal diameter and femur length. These measurements are also best researched with respect to normal values, predictive accuracy and reproducibility.

Crown–rump length can be measured from 6 to around 14 weeks' menstrual age and a number of subsequent studies have shown virtually identical mean values to those described originally by Robinson and Fleming[33]. All the main reference studies appear to have consisted of mixed longitudinal and cross-sectional data. The studies do, therefore, show population variability, not measurement variability for individual fetuses. No appreciable race or sex differences appear to exist[32]. The accuracy of single crown–rump length measurements has consistently been found to be from ± 4.7 to ± 6 days with a 95% probability. This means that a given measurement has a predictive value corresponding to a timespan of 9–12 days[32]. Accuracy lessens after approximately 11 weeks. Transvaginal ultrasound may improve accuracy of early crown–rump length measurements.

A large number of studies are available on the biparietal diameter. The concept of a relation between gestational age and size in the second trimester was first described by Campbell in 1969[34]. He showed that biparietal diameter values were confined to within narrow limits for a certain week of gestation and that such measurements might be used to predict gestational age with an accuracy of ± 8.4 days (95% confidence limits). The measurement technique, machine settings and machine calibration can all introduce an error, but in studies of normal values care is usually taken to ensure average machine settings and correct calibration for speed of sound in tissue. The error potential is ≤ 1 mm in midgestation for a single trained observer (intra-observer error) which equals the growth during 1 day (slope of the biparietal diameter growth curve), and a similar magnitude of error is present when comparing measurements between observers (reproducibility, inter-observer error)[20,32]. Increased accuracy in obtaining consistent measurement planes has evolved in recent years because of much improved imaging and easier recognition of intracranial structures. Measurements of biparietal diameter at between 15 and 24 weeks have been shown to have comparable or better accuracy than measurements of crown–rump length[2,3,32] and they are also more reproducible[3]. The mean values are closely similar in all populations, in older and newer reference materials (Table 1). There is no marked sex or race difference during the first half of pregnancy, although this is the case to a minor degree towards the end of pregnancy[31,32,35–37]. Moore *et al.* demonstrated that the difference between a mean biparietal diameter for a male fetus and a female fetus at 18 weeks is 0.8 mm, which is within the range of measurement error and is less than one-third of the standard deviation at that time[38] (Table 1). Gender differentiation is difficult in the majority of cases and is devoid of practical value at the time of pregnancy when it is best to perform ultrasound dating.

Femur length had very low inter-data variability during the first half of pregnancy in six studies, with no difference between four races investigated[39,40]. Biparietal diameter and femur length measurements remain the

Table 1 Mean biparietal diameter measurements (mm) in different populations and studies between 13 and 22 weeks' gestation. The sound velocity used was 1540 m/s. Note the close similarity of values in the three longitudinal studies[42,44,45] and the new composite curve of Kurtz and Goldenberg[32]. The male–female means of Moore *et al.*[38] are also shown

	Completed weeks								
Reference	*13*	*14*	*15*	*16*	*17*	*18*	*19*	*20*	*21*
Yagel *et al.*[52]	27.3	29.9	34.0	36.5	39.4	43.4	47.1	50.2	52.8
Okupe *et al.* (o–o)[36]	29.5	30.0	35.0	37.0	40.0	44.0	48.0	51.0	54.0
Watson (o–o)[37]	25	30	35	37	41	45	47	52	53
Sabbagha and Hughey[31†]	28	32	36	39	42	45	48	51	54
Campbell and Newman[41]*	22.5	28.4	33.2	36.9	40.1	43.9	47.2	50.2	53.5
Campbell *et al.*[3]	21.7	27.8	31.4	35.3	38.7	41.5	46	48.2	51.2
Jeanty *et al.*[42]*	24	28	31	35	38	42	45	48	51
Persson and Weldner[45]*	24.6	28.1	31.6	35.5	39.0	42.5	44.3	47.8	51.3
Kurtz and Goldenberg[32†]	23.0	27.0	31.0	34.3	38.0	41.7	44.8	51.2	54.5
Sindberg Eriksen *et al.*[44]*	25.6	28.5	31.5	34.6	37.7	40.9	44.1	47.4	50.6
Moore *et al.*[38]* (female)	24.3	27.7	31.1	34.5	37.9	41.4	44.8	48.2	51.6
Moore *et al.*[38]* (male)	24.3	27.9	31.5	35.1	38.7	42.2	45.8	49.4	53

(o–o) Measurements from outer to outer skull tables; * longitudinal study; † composite mean from several curves most reproducible and practical measurements for estimating gestational age in the early second trimester.

ULTRASOUND REFERENCE STANDARDS

When reference standards for ultrasound measurements are created, the selection of the patients matters as much as the study design. The patients must represent a sample that is not significantly different from the general obstetric population in its main characteristics such as maternal age, height, weight and parity. Predetermined criteria of health during pregnancy may be applied to select a group of healthy women during pregnancy, but these should not include maternal body characteristics or newborn anthropometric requirements. It is controversial whether smokers should be excluded. The study must either use a proper longitudinal design, which is the only accurate way of reflecting growth, or be a true cross-sectional study, with only one value from each patient and with an equal number of randomly selected women in each gestational week (stratified sampling). This avoids unequal weighting being given to some particular times of pregnancy.

Properly constructed fetal biometry studies giving reference data on the early second trimester are relatively few. Most are of the longitudinal variety and include women with a 28-day menstrual cycle (26–31 days in some studies) and 'certain dates'[38,41–44]. Cross-sectional studies depict the range of variability across the population, but they incorporate a time-base uncertainty caused by the same factors that affect the LMP. The standard deviations obtained in cross-sectional, longitudinal and mixed studies are, however, similar during the first half of pregnancy[32,38]. Longitudinal studies have the advantage that variability of measurements in individuals can be compared by adjusting the slopes to the same plane, and the intercept may be projected to a hypothetical common point of origin in order to estimate the true variability of the measurement. Knowledge of the exact time point of fertilization (point 0 of growth) can, however, not be obtained except for fetuses conceived by *in vitro* fertilization.

There is only a small number of published studies where data have been obtained from women with a known date of ovulation, but when this is performed the variation of the biparietal diameter about the mean for each week diminishes. In one of the few longitudinal series of measurements carried out to derive such standards, the population variation of 3.4 mm (one standard deviation) diminished to 1.9–2.2 mm between 17 and 21 weeks' gestation in those women for whom the time of ovulation was known. When in the same study a correction was made for the fetuses that constantly showed values above or below the mean, i.e. the intercepts or starting points of all individual curves were set to be equal, the variation was also lower, at 2.2 mm[20]. Of the variance around the curve 50% was estimated to be due to variation in gestational length (differing times of ovulation and fertilization), 30% to individual fetal differences and 20% to measurement inaccuracy. In a study of 14 women with regular 28-day cycles and known ovulation dates from basal body temperature measurements confirmed by early crown–rump length measurement, the biparietal diameter and femur length were measured on five occasions between 80 and 180 days' menstrual age (assuming ovulation occurred on day 14)[45]. The study was validated in another 44 women who had undergone artificial insemination by donor. The biparietal diameter reflected actual gestational age best with 96% of the estimates based on biparietal diameter being within ± 7 days of the actual conceptional age, followed by femur length at 95%. Both measurements used together enhanced accuracy slightly (by 1 day). A formula combining these two variables (gestational age = biparietal diameter × 1.2 + femur length × 1.0 + 49) gave a small systematic negative error (mean difference of − 0.55 days) from the 'true' gestational age and a standard deviation of the curves of 2.7 days.

A normal range curve based on menstrual data will be subject, even with the best selection of normal women, to the inaccuracies affecting 'certain' dates, and it can be argued that such curves cannot logically be better than certain menstrual data[5]. This is not quite so, for the construction of such reference values does involve data from carefully selected individuals whose range of cycle variability is less than in the average woman presenting at an antenatal clinic with purportedly 'certain' dates. The distribution of such data around a 'true' mean is more likely. The true longitudinal variability of the biparietal diameter and femur length in early second trimester, the range of 2 standard deviations, has been found to correspond to ± 5–6 days[45]. A given biparietal diameter measurement at 15–22 weeks will, therefore, allow fertilization to be pinpointed to a timespan of 11–12 days with a 95% likelihood. Three standard deviations or 99.7% of the population would be contained within 16 days. Measurements in these carefully constructed reference standards have a Gaussian distribution, where the chances are that the true age of a fetus with a given value of biparietal diameter will be close to the mean value for a given gestational length. A biparietal diameter measurement of 37 mm will thus correspond to the mean value at 16 weeks and 3 days. Within a 95% likelihood range, the true age of that fetus might be anything from 15 weeks + 4 days to 17 weeks + 2 days, but is likely to be closest to 16 weeks + 3 days (Figure 2). This accuracy is superior to that which can be obtained with even the most secure menstrual data. The scatter of random variation about the mean caused by measurement error and variation in fetal growth rate is less than variations in the length of the follicular phase. To shift all pregnancies to the mean of the distribution (Figure 3) may, for the individual woman, lead to a potentially small and, for practical purposes, unimportant error of a few days. For the whole population, the error will be much less compared to non-normally distributed LMP data.

There is always a negative skew in the difference between LMP and ultrasound towards longer gestations by LMP[19–21,24,25,30]. Where ultrasound is used to assign gestational age, the birth–anthropometry curves change. For birth weight as an indicator of fetal growth, they will assume linearity[2,24,25]. No amount of enlargement of data or attempts to narrow the data down by stringent criteria of normality will offset the skewness seen when LMP is used. The number of preterm and particularly post-term pregnancies falls with obvious consequences for patient management[3,19,21,24,25].

Ultrasound data relate to size and presume that size is correlated to age. This is, in early pregnancy, a reasonable assumption. Biological development is controlled by biochemical rate processes, where the random variable is rate, not time. Out of about 44 cycles of cell division from conception to adulthood, about 35 occur in the first 12 weeks of gestation[46]. In the protected environment of the early pregnant uterus, the fetus may be subjected to some modulating influences such as smoking, but their overall effects on growth measurements will not be readily detectable. Even powerful modulating factors, such as a diabetic state, seem to have minimal influence on early fetal growth[32], provided fetal anatomy is not disrupted by a teratogenic influence. Growth must, therefore, at least in the first 12 weeks, relate closely to gestational age. In the continued rapid growth phase of the next 6–8 weeks, this will largely still be the case.

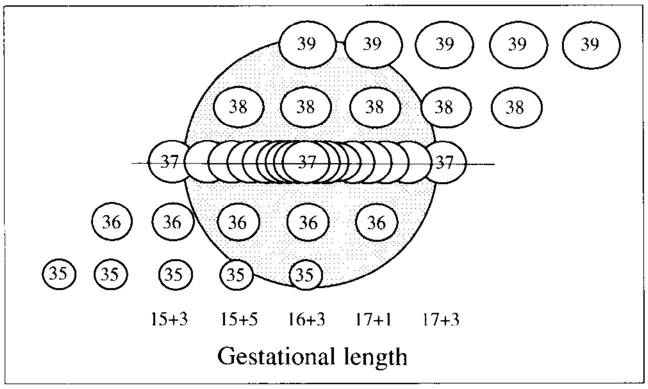

Figure 2 Spatial distribution of fetal biometry measurements shows variation at every point of gestational age (vertically in the figure) and in size over time (horizontally). A fetal head (BPD) measurement of 37 mm is most likely to be close to the mean at 16 weeks + 3 days where the concentration of such measurements is greatest, even though a more varied head size is contained within the 2 standard deviation range (stipled circle)

Individual ultrasound growth-curves later in pregnancy tend to be parallel[47] with a small dispersal, and the observed time-base difference is due to the variability of the time of fertilization in relation to the LMP, i.e. different follicular phase length. As pregnancy progresses into its latter half, genetic influences become more influential as the fetal body mass increases rapidly. Modulating external influences may play a greater part. Variability in fetal measurements, therefore, becomes progressively greater, and dating in late pregnancy is less accurate with ultrasound, although better than with many other methods[3].

CONCLUSION

The considerable variability of the length of the follicular phase of the menstrual cycle and the inconstant timing

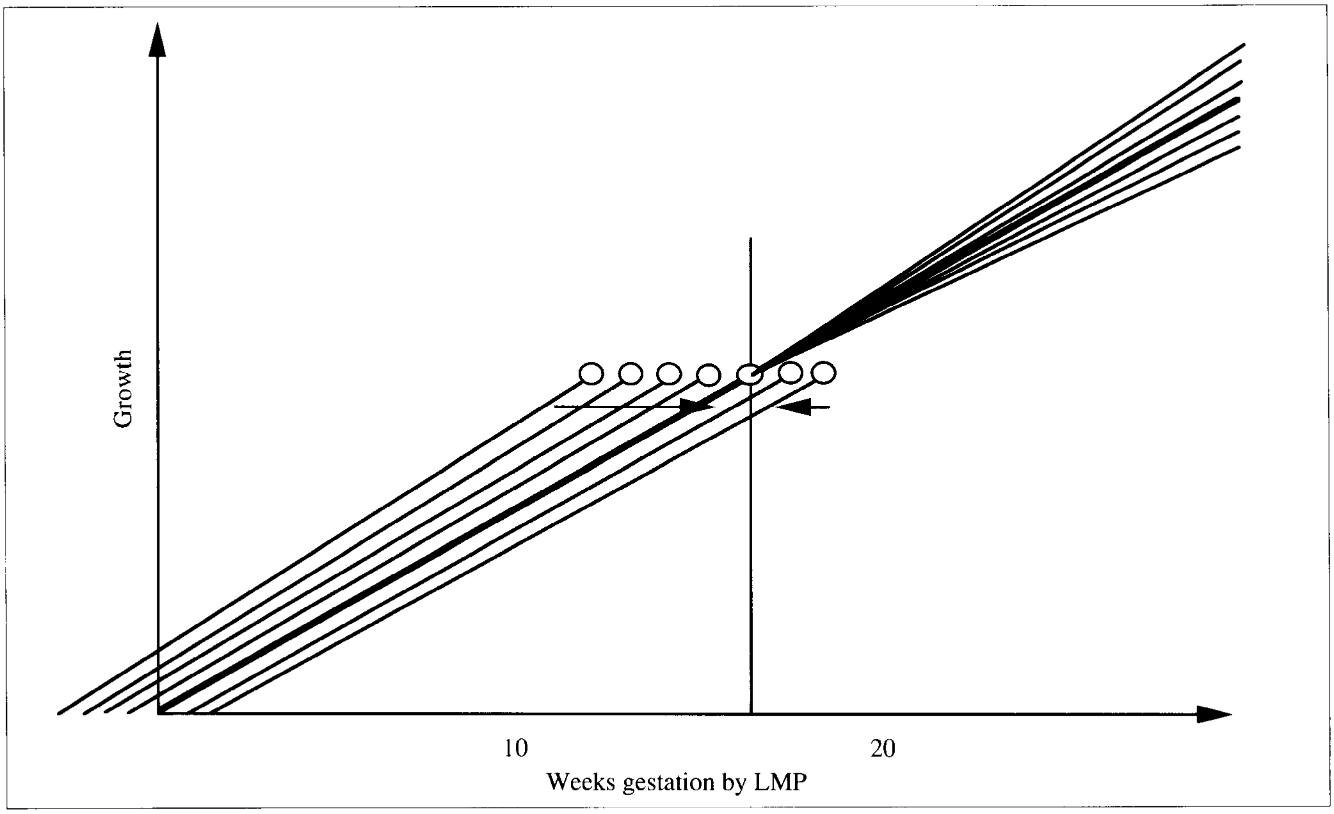

Figure 3 Effect of shifting measurements of the same size to the mean of the reference curve at a particular menstrual age. From the mean a normalized distribution is created to supplant the negatively skewed LMP data. The error in ultrasound random variation, less than the error due to different lengths of the follicular phase, is ignored for practical reasons

of ovulation and fertilization in relation to the LMP, as well as the often inaccurate method whereby the date of the LMP is determined by women, make the LMP a very insecure basis for estimating gestational age. There is a skewness away from modal distribution in both LMP and ovulation data, and the existence of such an error is virtually unpredictable, even in women with a certain or recorded LMP. Such data would not be used as a starting-point for action elsewhere in biology, particularly if some method with a lesser and more predictable error was available. It appears surprising that such an insecure basis can be accepted in an age of electronic technology which makes fetometry available from a very early time in pregnancy. Ultrasound is subject to a certain degree of the same variation as LMP, but that variation is diminished by using reference standards from carefully chosen women, where there is a smaller and more normally distributed variation around the mean. Several such standards exist. The adjustment of dates to ultrasound mean values, which are closely similar in different populations and suggest uniformity of fetal growth in its early stages, may confer slight inaccuracy of no real consequence compared to the true gestational age (usually unknown anyway) in the individual case, but this practice will benefit the population at large. The use of a limit of, for example, ± 7 days difference between LMP and ultrasound estimation as a cut-off mark for using LMP rather than ultrasound, is beneficial but the skew distribution of LMP data will still have an effect and two sets of data are created for perinatal recording. The uniform use of mean ultrasound values for assigning gestational age should be adopted for both clinical and research purposes. This will confer much needed and better credibility to epidemiological and research data involving human gestational length. Most importantly in clinical practice, better knowledge of gestational length at any one time will have significant effects to the benefit of the population, by reducing the chance of unnecessary intervention and by making other procedures more appropriate[48-50]. Fetometry in the third trimester cannot properly be used if it is not put in direct relation to a measurement in the first half of pregnancy, since growth must be assessed between two known points. The LMP should only be used where ultrasound before mid-pregnancy is not available. Corroborated evidence is only called for when a woman presents late in pregnancy and then it is often the corroborated ultrasound evidence which may be best[34,51]. Ultrasound requires knowledge and experience and should be conducted in a laboratory setting, rather than as a technique to be employed anywhere and by anyone.

In clinical practice, a compromise is often necessary in the initial reconciliation of a discrepancy between a woman's ideas about her proposed time of conception and expected date of confinement on the one hand and ultrasonic dating on the other. In the author's experience, reason, tact and time resolve nearly all such differences towards acceptance of the expected time of confinement by ultrasound, a scientifically sounder basis for timing pregnancy-related events.

REFERENCES

1. Hall, M. H., Carr-Hill, R. A., Fraser, C., Campbell, D. and Samphier, M. L. (1985). The extent and antecedents of uncertain gestation. *Br. J. Obstet. Gynaecol.*, **92**, 445–51
2. Persson, P-H. (1989). In Sharpe, F., Milner, R. D. G. and Fraser, R. B. (eds.) *Fetal Growth*, pp. 13–25. (London: Royal College of Obstetricians and Gynaecologists)
3. Campbell, S., Warsof, S. L., Little, D. and Cooper, D. J. (1985). Routine ultrasound screening for the prediction of gestational age. *Obstet. Gynecol.*, **65**, 613–20
4. Bergsjö, P., Denman, D. W., Hoffman, H. J. and Meirik, O. (1990). Duration of human singleton pregnancy. A population-based study. *Acta Obstet. Gynecol. Scand.*, **69**, 197–207
5. Hall, M. H. (1990). Definitions used in relation to gestational age. *Paediatr. Perinatal Epidemiol.*, **4**, 123–8
6. Beazley, J. M. and Underhill, R. A. (1970). Fallacy of the fundal height. *Br. Med. J.*, **4**, 404–6
7. Alexander, G. R., Hulsey, T. C., Smeriglio, L. *et al.* (1990). Factors influencing relationship between the new-born assessment of gestational maturity and gestational age. *Paediatr. Perinatal Epidemiol.*, **4**, 135–48
8. Gunn, D. L., Jenkin, P. M. and Gunn, A. L. (1937). Menstrual periodicity; statistical observations on a large sample of normal cases. *J. Obstet. Gynaecol. Br. Commonw.*, **44**, 839–79
9. Arey, L. B. (1939). The degree of normal menstrual irregularity. *Am. J. Obstet. Gynecol.*, **37**, 12–29
10. Goldzieher, J. W., Henkins, A. E. and Hamblen, E. C. (1947). Characteristics of the normal menstrual cycle. *Am. J. Obstet. Gynecol.*, **54**, 668–75
11. Chiazze, L., Brayer, F. T., Macisco, J. J., Parker, M. P. and Duffy, B. J. (1968). The length and variability of the human menstrual cycle. *J. Am. Med. Assoc.*, **203**, 377–80
12. Treolar, A. E., Boynton, R. E., Benn, B. G. and Brown, R. W. (1967). Variation of the human menstrual cycle throughout reproductive life. *Int. J. Fertil.*, **12**, 77–126
13. World Health Organisation (WHO) Task force on methods for the determination of the fertile period. Special programme of Research Training in Human Reproduction (1980). Temporal relationships between ovulation and defined stages in concentration of plasma estradiol-17β, luteinising hormone, follicle-stimulating hormone and progesterone. *Am. J. Obstet. Gynecol.*, **138**, 383–90
14. Pryll, W. (1916). Kohabitationstermin und Kindsgeschlecht. *Muenchener Medizinische Wochenschrift*, **45**, 1579–82
15. Jaeger, F. (1917). Krieg und Geburtshilfe. *Zentralbl. Gynäkol.*, **41**, 857–65
16. Weinstock, F. (1934). Das zeitliche Verhalten von Ovulations- und Konzeptionstermin an Hand von 416 Fällen mit genau bekannter einmaliger Kohabitation und nachfolgender Schwangerschaft. *Zentralbl. Gynäkol.*, **50**, 2947–52
17. Hollenweger-Mayr, B. (1950). Die menschliche Schwangerschaftsdauer. *Geburtsh. Gynäkol.*, **132**, 296–315
18. Treolar, A. E., Behn, B. P. and Cowan, D. W. (1967). Analysis of gestation intervals. *Am. J. Obstet. Gynecol.*, **99**, 34–45
19. Kramer, M. S., McLean, F. H., Boyd, M. and Usher, R. H. (1988). The validity of gestational age estimation by menstrual dating in term, preterm and postterm pregnancies. *J. Am. Med. Assoc.*, **260**, 3306–8
20. Persson, P-H. (1978). *Ultrasonic Studies on Human Fetal Growth.* (Malmö: Thesis, University of Lund)
21. Waldenström, U. Axelsson, O. and Nilsson, S. (1990). A comparison of the ability of a sonographically measured biparietal diameter and the last menstrual period to predict the spontaneous onset of labor. *Obstet. Gynecol.*, **76**, 336–8
22. Bennett, M. J., Little, G., Dewhurst, J. and Chamberlain, G. (1982). Predictive value of ultrasound measurements in

early pregnancy: a randomised controlled trial. *Br. J. Obstet. Gynaecol.*, **89**, 338–42
23. Belfrage, P., Fernström, I. and Hallenberg, G. (1987). Routine or selective ultrasound examinations in early pregnancy. *Obstet. Gynecol.*, **69**, 747–50
24. Lindgren, R., Selbing, A. and Leander, E. (1988). Which fetal growth charts should be used? *Acta Obstet. Gynecol. Scand.*, **67**, 683–7
25. Secher, N. J., Kern Hansen, P., Lenstrup, C. *et al.* (1986). Birthweight for gestational age charts based on early ultrasound estimation of gestational age. *Br. J. Obstet. Gynaecol.*, **93**, 128–34
26. Boyce, A., Mayaux, M. J. and Schwartz, D. (1976). Classical and 'true' gestational postmaturity. *Am. J. Obstet. Gynecol.*, **125**, 911–14
27. Lenton, E. A. and Landgren, B-M. (1985). The normal menstrual cycle. In Shearman, R. P. (ed.) *Clinical Reproductive Endocrinology*, pp. 81–108. (Edinburgh: Churchill Livingstone)
28. McIntosh, J. E. A., Matthews, C. S., Crocker, J. M., Broom, J. J. and Cox, L. W. (1980). Predicting the luteinizing hormone surge: relationship between the duration of the follicular and luteal phases and the length of the human menstrual cycle. *Fertil. Steril.*, **34**, 125–30
29. Walker, E. M., Lewis, M., Cooper, W., Marnie, M. and Howie, P. W. (1988). Occult biochemical pregnancy: fact or fiction? *Br. J. Obstet. Gynaecol.*, **95**, 659–63
30. Geirsson, R. T. and Busby-Earle, C. (1991). Certain dates may not be a reliable estimate of gestational age. *Br. J. Obstet. Gynaecol.*, **98**, 108–9
31. Sabbagha, R. E. and Hughey, M. (1978). Standardization of sonar cephalometry and gestational age. *Obstet. Gynecol.*, **52**, 402–6
32. Kurtz, A. B. and Goldberg, B. B. (1988). *Obstetrical Measurements in Ultrasound.* (Chicago: Year Book Medical Publishers, Inc.)
33. Robinson, H. P. and Fleming, J. E. E. (1975). A critical evaluation of sonar 'crown–rump length' measurements. *Br. J. Obstet. Gynaecol.*, **82**, 702–10
34. Campbell, S. (1969). The prediction of fetal maturity by ultrasonic measurement of the biparietal diameter. *J. Obstet. Gynaecol. Br. Commonw.*, **76**, 605–9
35. Parker, A. J., Davies, P. and Newton, J. R. (1982). Assessment of gestational age of the Asian fetus by the sonar measurement of crown–rump length and biparietal diameter. *Br. J. Obstet. Gynaecol.*, **89**, 836–8
36. Okupe, R. F., Coker, O. O. and Gbajumo, S. A. (1984). Assessment of fetal biparietal diameter during normal pregnancy by ultrasound in Nigerian women. *Br. J. Obstet. Gynaecol.*, **91**, 629–32
37. Watson, D. S. (1986). Biparietal diameter in the Australian Aboriginal fetus. *Br. J. Obstet. Gynaecol.*, **93**, 339–42
38. Moore, W. M. O., Ward, B. S., Jones, V. P. and Bamford, F. N. (1988). Sex difference in fetal head growth. *Br. J. Obstet. Gynaecol.*, **95**, 238–42
39. Schmidt, W. and Hendrik, H. (1985). Fetale Femurlänge im zweiten und dritten Schwangerschaftstrimenon. *Geburtsh. Frauenheilk.*, **45**, 91–7
40. Ruvolo, K. A., Filly, R. A. and Callen, P. W. (1987). Evaluation of fetal femur length for prediction of gestational age in a racially mixed obstetric population. *J. Ultrasound Med.*, **6**, 417–19
41. Campbell, S. and Newman, G. B. (1971). Growth of the fetal biparietal diameter during normal pregnancy. *J. Obstet. Gynaecol. Br. Commonw.*, **78**, 513–19
42. Jeanty, P., Cousaert, E., Hobbins, J. C., Tack, B., Bracken, M. and Cantraine, F. (1984). A longitudinal study of fetal head biometry. *Am. J. Perinatol.*, **1**, 118–28
43. Persson, P-H. and Weldner, B-M. (1986). Normal range curves for fetal biparietal diameter, occipitofrontal diameter, mean abdominal diameter and femur length. *Acta Obstet. Gynecol. Scand.*, **65**, 759–61
44. Sindberg Eriksen, P., Secher, N. J. and Weis-Bentzon, M. (1985). Normal growth of the fetal biparietal diameter, and the abdominal diameter in a longitudinal study. *Acta Obstet. Gynecol. Scand.*, **64**, 65–70
45. Persson, P-H. and Weldner, B-M. (1986). Reliability of ultrasound fetometry in estimating gestational age in the second trimester. *Acta Obstet. Gynecol. Scand.*, **65**, 481–3
46. Hayflick, L. (1980). The cell biology of human ageing. *Sci. Am.*, **242**, 42–9
47. Geirsson, R. T. (1986). Intrauterine volume in pregnancy. *Acta Obstet. Gynecol. Scand. Suppl.*, **136**, 41–2
48. Bennett, M. J., Little, G., Dewhurst, J. and Chamberlain, G. (1982). Predictive value of ultrasound measurement in early pregnancy: a randomized controlled trial. *Br. J. Obstet. Gynaecol.*, **89**, 338–41
49. Persson, P-H. and Kullander, S. (1983). Long-term experience of general ultrasound screening in pregnancy. *Am. J. Obstet. Gynecol.*, **146**, 942–7
50. Saari-Kemppainen, A., Karjalainen, O., Ylöstalo, P. and Heinonen, O. P. (1990). Ultrasound screening and perinatal mortality: controlled trial of systematic one-stage screening in pregnancy. *Lancet*, **336**, 387–91
51. Ott, W. J. (1985). Accurate gestational dating. *Obstet. Gynecol.*, **66**, 311–15
52. Yagel, S., Doni, A., Oman, S., Wax, Y. and Hochner-Celnikier, D. (1986). A statistical examination of the accuracy of combining femoral length and biparietal diameter as an index of fetal gestational age. *Br. J. Obstet. Gynaecol.*, **93**, 109–15