The basal body temperature (BBT) curve and the estimated time of ovulation, defined by the onset of gonadotropin preovulatory discharge, were analyzed in 38 spontaneous cycles. The BBT nadir was usually located at the beginning of the luteinizing hormone surge, and the first high point was 8 hours after ovulation, which was itself usually at the time when the temperature passed 37°C. This temperature rise was related to the increases in plasma progesterone and 17-hydroxyprogesterone with 24 to 36 hours' delay. The BBT was found to be an unreliable technique for precise ovulation timing but would be of use if the clinical precision required for the diagnosis of ovulation were less. Fertil Steril 41:254, 1984

The relationship between the basal body temperature (BBT) curve and ovulation has previously been studied by numerous authors. However, most1-6 used the midcycle luteinizing hormone (LH) peak as a reference for the hypophyseal ovulatory discharge. Some authors7,8 have also used the increase in plasma progesterone (P). Since LH is secreted in a pulsatile manner, and plasma determinations are subject to relatively large daily variations, dependence upon single daily determinations of LH1-5 makes precise determination of the time of ovulation difficult. Furthermore, the LH peak (i.e., the highest LH concentration observed) precedes ovulation by a relatively variable period (12 to 24 hours on average)9,10 and may even follow ovulation,11 although in this latter case the use of histologic criteria for dating would not be very reliable either.

The establishment of an in vitro fertilization program has enabled, from the multiple daily blood samples, the definition of the LH surge-initiating rise (LH-SIR),12 a precise threshold corresponding to the start of the LH surge occurring 38 ± 1 hours before ovulation.13 This improvement in the precision of dating ovulation has permitted refinement of the study of the relationships between the BBT and ovulation.

**MATERIALS AND METHODS**

Between May 1979 and April 1981, 62 women between 24 and 40 years of age were admitted to the hospital during 77 cycles for either an in vitro fertilization attempt or a sterility evaluation. All were volunteers. Thirty-eight cycles from 33 women were retained for study after selection ac-
according to the following criteria: (1) regular cycles with no hormonal disturbances; (2) no hormonal stimulation in the studied cycle; (3) a sufficient period of hospitalization; (4) complete BBT records; and (5) no hyperthermia of $> 37.5^\circ$C.

During their hospitalization, the women measured their rectal temperatures at 7:00 A.M.; and to enable precise prediction of the estimated time of ovulation (ETO), four blood samples were taken daily. These samples were assayed for LH, follicle-stimulating hormone, 17β-estradiol (E$_2$), P, and 17-hydroxyprogesterone (17-OHP) according to previously described methods.$^{14}$

The LH determinations enabled calculation of the LH-SIR according to previous descriptions.$^{12}$ Briefly, each value is compared with the mean of the four previous values, which are taken as the basal level. The existence of an LH surge is defined as when one value exceeds 180% of the baseline, and the LH-SIR is defined as the point where the LH plot crosses 180% of the baseline limit.

The points of the BBT curve considered were the nadir, defined as the last low point before the temperature rise, and the first high point (FHP), defined as the first point of $\geq 37^\circ$C following the nadir. These points were determined with no prior knowledge of the LH-SIR and, then related to the presumed time of ovulation.

**STATISTICAL ANALYSIS**

Mean values and their associated standard deviations (SDs) were compared using Student’s $t$-test or, in the absence of normal distributions, the Wilcoxon test, if necessary, on paired series of data. The relationships between the timing of the various events were assessed by both simple and partial correlation coefficients. The ETO was used as the time of ovulation (i.e., 38 hours after the LH-SIR), and not the time of follicular puncture.

**RESULTS**

Of the 38 BBT charts studied, 5 (13.2%) were uninterpretable because they were monophasic. The nadir was definable in 27 of the remaining 33 cases; fluctuations prohibited its precise definition in the remaining 6 cases. The nadir occurred between 72 hours before and 12 hours after ovulation (Table 1). In 95% of cases it occurred within 66 hours before ovulation, and in 70.4% within 48 hours. On average, the nadir occurred 33 hours, 41 minutes ± 19 hours, 12 minutes (mean ± SD) before ovulation.

The FHP was definable in 32 of 33 cases, the BBT always being $37^\circ$C in the remaining case, and occurred in the range 36 hours before to 48 hours after ovulation (Table 1), with 95% of cases in the range −30 to +42 hours, and 75% within −24 to +24 hours of ovulation. On average, the FHP occurred 8 hours, 15 minutes ± 16 hours, 30 minutes (mean ± SD) after ovulation.

The ETO occurred, on average, at 15.17 ± 1.99 (SD) days after the first day of the menstrual cycle. Figure 1 shows the temperatures observed grouped into 12-hour periods in relation to time 0,
corresponding to the ETO. From this figure it may be concluded that the BBT is very stable until 12 hours before ovulation and then rises, this increase becoming significant in the first 12 hours after ovulation. The BBT plateau then remained very stable for at least 2 days after ovulation. The rise to 37°C occurred at the time of ovulation, with the ETO occurring in 90% of cases (28 of 31) during the temperature rise, in only two cases after the BBT had reached its highest point, and in only one case before this rise (during the preceding 12 hours).

Each of the points on the BBT curve appeared to be closely related to ovulation (Table 2). However, study of the partial correlations showed that only the FHP was significantly related to the ETO, and that the relationship between the nadir and FHP explained that existing a priori between the nadir and ovulation.

The length of the follicular phase is related neither to the intervals between the nadir and FHP and ovulation, (respective correlation coefficients: \( r = -0.17 \) [not significant (NS)] and \( r = -0.29 \) [NS]) nor to the duration or extent of the thermal rise (respective correlation coefficients: \( r = 0.09 \) [NS] and \( r = -0.10 \) [NS]).

Plasma P (Fig. 1) was practically undetectable until 36 hours before ovulation when its concentration increased, becoming significant during the 24-hour period before ovulation. The plasma concentration of 17-OHP increased earlier, having already reached 0.6 ng/ml at 60 hours before ovulation. Plasma E2 concentrations increased up until 36 hours before ovulation, the rise becoming significant between 72 and 48 hours before ovulation (two-way analysis of variance) before decreasing.

No endocrine data were available after ovulation, because the subjects were hospitalized for therapeutic reasons: the daily multiple blood samples, necessary for the prediction of ovulation, could not be continued after the laparoscopy.

Table 3 shows the correlations between the hormonal data and the BBT from 0 to 60 hours later. There were never any correlations between the BBT and E2, although significant correlations were found between the P and 17-OHP concentrations and the BBT for 24 and 36 hours (correlation coefficients, 0.49 and 0.42 for P and 0.32 and 0.49 for 17-OHP, respectively).

**DISCUSSION**

Determination of the onset of the LH surge as possible by using the LH-SIR is the sole means whereby the precise time of ovulation may be predicted well in advance. Its use has permitted accurate study of the relationships between the BBT and biologic phenomena associated with ovulation.

The relationship between the BBT nadir and the preovulatory LH surge has already been demonstrated by numerous authors: the LH peak is most frequently detected either on the day of the nadir\(^1\), \(^{15}\) or during the subsequent 24 hours.\(^3\), \(^4\) However, most authors used only single daily blood samples for determining the LH peak; and, furthermore, all used the actual peak, which is known to occur at a fairly variable time before ovulation.\(^9\), \(^10\) Hilgers and Bailey\(^7\) found that the nadir only preceded ovulation by 0.32 days, but they used as their criterion of ovulation the early rise in P concentration. Use of the LH-SIR has enabled a reduction in the variability of the BBT/ovulation relationship by precisely locating the latter aspect, while the former has remained subject to a 24-hour variability. The present study has also permitted better confirmation that the nadir occurs at the time of the LH surge, because it precedes ovulation by 33 hours and the LH-SIR precedes it by 38 hours. The nadir occurs in the 48 hours preceding the ETO in 71% of cases. These figures are close to those produced by the World Health Organization.\(^11\)

The rise in BBT has long been related with ovulation itself.\(^16\) However, Moghissi et al.,\(^4\) using single daily samples, showed that the rise in BBT commenced close to the time of the LH peak, becoming significant only 48 hours later, i.e., shortly after ovulation. Hilgers and Bailey\(^7\) reported that the BBT point preceding that at which the temperature exceeded the upper limit of the follicular phase values was located 0.5 days before ovulation (defined by the increase in P concentration). Furthermore, the use of a precise threshold has enabled clear demonstration that ovulation occurs, on average, 2 hours before the BBT reaches 37°C, and that only the FHP is significantly correlated with ovulation when the partial correlations are considered. Admittedly, ovulation detected by ultrasonography has been shown to occur before the BBT rise in 78% of cases,\(^17\) but ultrasonography performed shortly before ovulation appears to be capable of provoking precocious follicular rupture.\(^18\)

The rise in BBT is probably related to the action of P, as has been demonstrated experimental-
Table 2. Correlation Coefficients Between the Days of Ovulation, Nadir, and FHP

<table>
<thead>
<tr>
<th></th>
<th>Day of ovulation</th>
<th>Day of nadir</th>
<th>Day of FHP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SC</td>
<td>PC</td>
<td>SC</td>
</tr>
<tr>
<td>Day of ovulation</td>
<td>1</td>
<td>1</td>
<td>0.88</td>
</tr>
<tr>
<td>Day of nadir</td>
<td>1</td>
<td>1</td>
<td>0.92</td>
</tr>
<tr>
<td>Day of FHP</td>
<td>1</td>
<td>1</td>
<td>0.92</td>
</tr>
</tbody>
</table>

*Days are referred to as the first day of the last menstrual cycle; SC, simple correlation coefficient; PC, partial correlation coefficient; n = 22.

Similarly, Davis and Fugo have shown a relationship between the BBT and urinary pregnanediol concentrations. However, this physiologic process is not immediate, because increases in the plasma P and 17-OHP concentrations are measurable before the BBT rise, 24 to 48 hours before ovulation, or at the time of the LH peak. In addition, Ross et al. also found that the increase in plasma 17-OHP slightly preceded that of P. With the LH-SIR it has been shown that P increases about 24 hours before ovulation, and that 17-OHP, already detectable 60 hours before the ETO, also increases during the last 36 hours before ovulation. This 12-hour difference between these two hormonal changes has been described elsewhere. However, the BBT appears to be related to the concentrations of 17-OHP and P, with delays of 36 and 24 hours, respectively (Table 3), confirming the earlier experimental findings of Israel and Schneller. This difference is certainly related to the indirect nature of the action of P, being mediated by the release of noradrenalin stored in synaptic vesicles in the hypothalamic temperature regulation center (this storage being due to the influence of estrogens during the first half of the cycle).

However, in spite of the physiologic interest of these relationships between biologic data and the BBT, the practical use of the BBT is less simple and is dependent upon the precision with which one needs to define the time of ovulation. If it is necessary to predict an accurate date (e.g., for a mature oocyte recovery), or to be a little less precise (e.g., for an artificial insemination), the BBT is very unreliable for three principal reasons: (1) There is a large variation in the interval between each of the recognizable points on the BBT chart and ovulation, 4 days in the present study, but up to 8 days in some other studies. (2) A 48-hour period is necessary for confirmation of a BBT criterion because of a large proportion of false nadirs and FHPs (27% and 30%, respectively, in the present study). The nadir is a poor predictive criterion: it falls in the peri ovulatory period in only 26% of cases and within 24 hours of ovulation (corresponding to the estimated fertilizability duration) in 37% of cases. Using the FHP, ovulation would have occurred more than 24 hours previously in 94% of cases (78% of cases if the confirmation period was 24 hours only). (3) BBT charts are sometimes difficult to interpret, either because of fluctuations (16% of cases for the nadir in the present study or 18% of cases according to Morris et al.) or because of a monophasic appearance (in 1.7% of cases according to Marshall) which might both be compatible with an ovulatory cycle in 3% to 30% of cases, or because of hyperthermia of alternative causation.

Table 3. Correlation Coefficients Between Plasma P, 17-OHP, and E₂ Levels, Respectively, and BBT Observed from 0 to 60 Hours After Sampling Time

<table>
<thead>
<tr>
<th>Hormone</th>
<th>Time interval from sampling time to basal temperature measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>−6, +6</td>
</tr>
<tr>
<td>17-OHP</td>
<td></td>
</tr>
<tr>
<td>P</td>
<td></td>
</tr>
<tr>
<td>E₂</td>
<td></td>
</tr>
</tbody>
</table>

*Numbers in parentheses represent the numbers of couples hormone level—BBT available for calculation of each correlation coefficient.

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Such poor reliability has been reported by Baumann, who found that only 22% of BBT assessments corresponded to within 1 day of the biologic phenomena, and by Buxton and Engle, who found at laparoscopies performed on the first day of the BBT rise that in one third of cases ovulation had already occurred more than 24 hours earlier. The BBT is therefore a difficult method for the accurate prediction of ovulation.

However, with regard to artificial insemination with donor semen, use of the BBT, in spite of the imprecision of its relationship to ovulation, does provide an acceptable level of success, which falls from 20% when the artificial insemination by donor is performed 3 days before the nadir to 9% 2 days after it. Newill and Katz have reported that of 110 pregnancies ensuing from single inseminations, none occurred when insemination took place more than 48 hours after the achievement of the hyperthermic plateau, and that most pregnancies resulted from inseminations performed on the evening before the BBT rise.

Finally, there is the matter of ovulation confirmation; 2 or 3 days after ovulation, the BBT would seem to be of use. In 80% of cases, diagnosis of an ovulatory cycle is correct, and in the present study the existence of a third point \( \geq 37^\circ C \) indicated, in all cases, that ovulation had occurred at least 12 hours before. The achievement of a BBT of \( 37^\circ C \) might therefore be used in natural family planning for the confirmation of ovulation, although its long-term use by all women would not be practicable without an appreciable number of failures or dropouts.

**REFERENCES**

17. Marinho AO, Sallam HN, Goessens LKV, Collins WP, Rodeck CH, Campbell S: Real time pelvic ultrasonography during the periovulatory period of patients attending an artificial insemination clinic. Fertil Steril 37:633, 1982
20. Rothchild I, Barnes AC: The effects of dosage, and of estrogen, androgen or salicylate administration on the degree of body temperature elevation induced by progesterone. Endocrinology 50:485, 1952
23. Ross GT, Cargille CM, Lipssett MB, Rayford PL, Marshall JR, Strott CA, Rodbard D: Pituitary and gonadal hor-
mones in women during spontaneous and induced ovulatory cycles. Recent Prog Horm Res 26:1, 1970