Magnetic field profiles in normal human breast during the menstrual cycle

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Summary

Objective: To investigate the subtle magnetic fields produced by living normal breast tissue during the menstrual cycle.

Methods: The magnetic activity of the breast was recorded in four young women, 26-28 years old; two had regular and two irregular menstrual cycles. The recordings were accomplished with a biomagnetometer and covered two complete menstrual cycles. The results were correlated with estrogen and progesterone levels on days 7, 14 and 21 of the menstrual cycle.

Results: The magnetic breast recordings in the two young women with the regular cycling endometrium showed a biphasic magnetic curve, apparently corresponding to the proliferative and secretory phase of the menstrual cycle. By contrast, the two young women with irregular menstrual cycles showed a monophasic magnetic curve.

Conclusion: It is suggested that a biphasic, but not a monophasic, pattern of magnetic activity in the breast is indicative of an ovulatory endometrial cycle.

Key words: Biomagnetic fields; Normal breast; Menstrual cycle.

Introduction

The female breast is a target tissue for sex steroid hormones and as such it responds to hormonal stimuli [1]. These responses have been correlated with the menstrual cycle [2, 3]. Furthermore, the mammary gland, like all living tissues, emits magnetic fields produced by the continuous ionic movement across the plasma membranes. Interestingly, this activity, although very weak, can be recorded by means of a superconducting quantum interference device (SQUID). SQUID is a non-invasive research tool capable of recording the exceedingly weak biomagnetic signals generated spontaneously by all living tissues; it has been used successfully in recording breast activity in normal [4], benign and malignant breast tissues [5, 6].

In this study, we investigated whether the subtle histological changes observed in normal breast tissues during the menstrual cycle can be recorded magnetically and correlated with the menstrual cycle of young women of the reproductive age.

Methods

Four young healthy females, aged 24-28 years, volunteered to take part in this investigation. Of these, two were married, had children and regular menstrual cycles, while the other two were single and had irregular and rather prolonged menstrual cycles.

Blood measurements for estrogen and progesterone levels were performed on days 7, 14 and 21 of the menstrual cycle. With the exception of the weekends, biomagnetic measurements were taken regularly on an everyday basis, starting from the first day of menstruation; only occasional unexpected circumstances resulted in the loss of some measurements. Informed consent for the study was obtained from all participating women prior to the procedure.

The method used for recording magnetic activity has been described previously [4-7]. In brief a single-channel SQUID was used with a sensitivity of 95 pTesla/volt at 1000 Hz (DC SQUID model 601, Biomagnetic Technologies, San Diego, CA). During the procedure the woman was lying supine on a wooden bed, free of any metallic objects. Recordings were taken from the upper/outer quadrant of the right breast, i.e., the area with the largest proportion of lobular units [8], at a distance of 1 cm from the areola. For each point, 32 recordings of 1-sec duration each were taken, with the SQUID detector placed 3 mm above the recording position which allowed the maximum magnetic flux to pass through the coil with little deviation from the vertical direction. The duration of the recordings was adequate to cancel out all random events, leaving the persistent ones undisturbed. Only measurements in the frequency range between 2-7 Hz were considered. By convention, the maximum value was used when assessing breast recordings. Data conversion of the analog signals into digital recordings was accomplished by means of an AD converter on line with a computer. The average spectral densities from the 32 1-sec recordings were obtained after applying Fourier statistical analysis. In all cases, the signals were related to measurements of background magnetic activity (environmental magnetic noise).

Results

Figure 1A presents the biomagnetic profile of a young woman with a normal menstrual cycle. High intensity waveforms generated by epithelial activity during the second half of the menstrual cycle can be observed. Figure 1B shows the spectral densities of a waveform from one representative day of Figure 1A with a peak value of 110 fT/ $\sqrt{}$Hz at the frequency of 2 Hz. Figure 1C presents the biomagnetic profile of a young woman with

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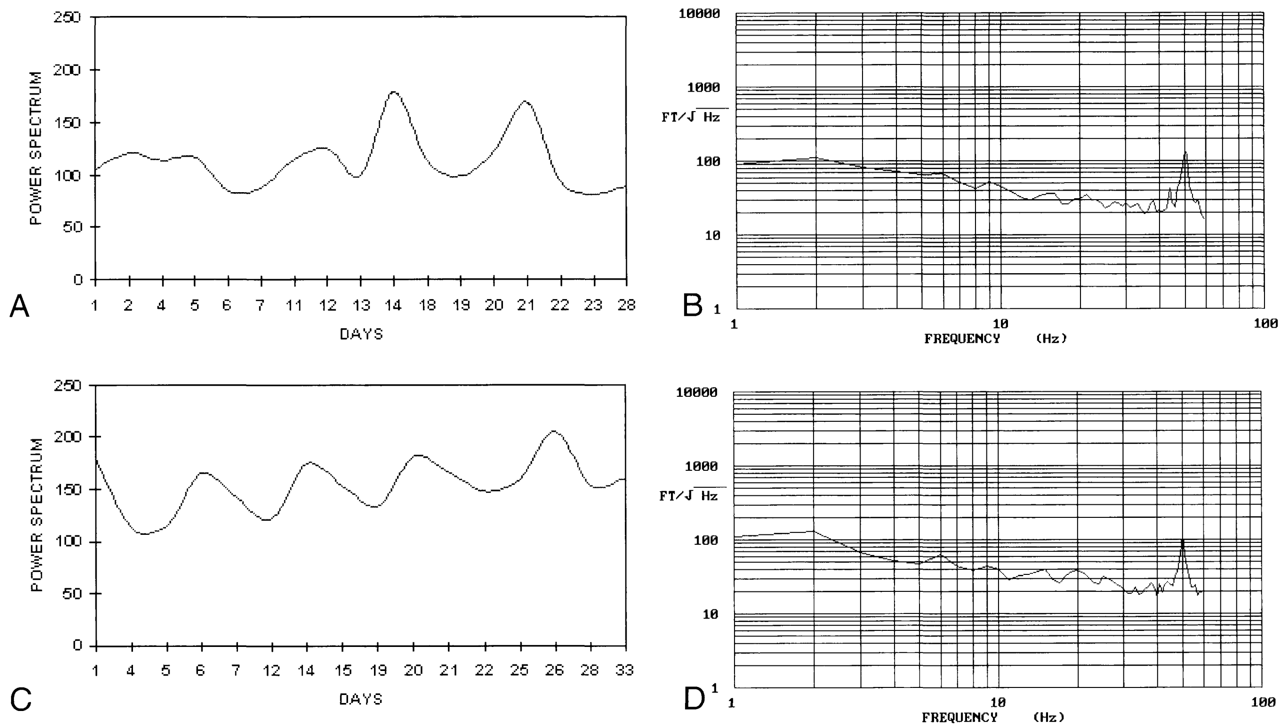

Figure 1 A) — Biomagnetic profile in a young woman with a normal menstrual cycle: high intensity waveforms generated by epithelial activity are noted during the second half of the menstrual cycle. B) The power spectrum of the waveforms, after statistical Fourier analysis, from one representative day of Figure 1A. A peak value of 110 fT/√Hz at the frequency of 2 Hz can be observed. C) Biomagnetic profile in a young woman with a prolonged menstrual cycle: high intensity waveforms generated by epithelial activity throughout the menstrual cycle. D) The power spectrum of the waveforms, after statistical Fourier analysis, from one representative day of Figure 1C. A peak value of 140 fT/√Hz at the frequency of 2 Hz, can be observed.

Table 1. — *Blood sex steroid hormone measurements in the four women in the series during the menstrual cycle – case 1 and 2 with normally cycling endometrium, case 3 and 4 with menstrual irregularities. The second measurements are shown in parentheses.*

Case	Hormone	Day 7	Day 14	Day 21
1	Estradiol	75,8 (67.1) pg/ml	421 (435.7)	247.2 (251.5)
	Progesterone	0.4 (0.45) ng/ml	5.23 (6.01)	19.2 (17.5)
2.	Estradiol	160.1 (145.7) pg/ml	592.2 (610.3)	210 (230.4)
	Progesterone	0.2 (0.39) ng/ml	5.1 (3.7)	9.2 (14.7)
3.	Estradiol	31.8 (28.3) pg/ml	148.3 (139.1)	160.6 (164.4)
	Progesterone	0.05 (0.08) ng/ml	1.45 (1.43)	2.5 (2.1)
4.	Estradiol	42.6 (34) pg/ml	110.9 (121.1)	80.7 (125.5)
	Progesterone	0.04 (0.03) ng/ml	1.2 (1.7)	2.6 (2.4)

Reference values. Estradiol: proliferative phase 30.0-200.0 pg/ml; ovulation 197.6-693.1 pg/ml; secretory phase 189.9-269.7 pg/ml. Progesterone: proliferative phase 0.06-065 ng/mL; ovulation 2.88-7.79 ng/mL; secretory phase 3.00-24.56.

an irregular menstrual cycle. High intensity waveforms generated by epithelial activity throughout the menstrual cycle can be observed. Figure 1D shows the spectral densities of a waveform from one representative day of Figure 1C with a peak value of 140 fT/ √Hz at the frequency of 2 Hz.

At first appreciation, it becomes evident that the magnetic fields varied from day to day from as low as 66 fT/ √Hz to as high as 179 fT/ √Hz with a mean value for all days of the cycle of 115 fT/ √Hz. However, a more careful evaluation of the results showed that the young female volunteers with the normally cycling endometrium had a biphasic magnetic curve, with low and almost flat spectral amplitudes during the proliferative phase of the cycle, and with two to three magnetic peaks during the secretory phase of the menstrual cycle (Figures 1A/B). By contrast, the young females with the irregular and prolonged menstrual cycles showed a monophasic magnetic curve with low magnetic peaks uniformly distributed throughout the menstrual cycle (Figures 1C/D).

The plasma estrogen and progesterone levels of the four women under investigation are shown in Table 1.

Discussion

This study exploits the phenomenon of superconductivity to detect the subtle magnetic fields produced by living normal breast tissue during the menstrual cycle. Earlier studies, using light microscopic and electron microscopic techniques, have convincingly shown the existence of cyclic changes in the breast, following those of the endometrium [2, 3]. In addition, differences in magnetic activity between normal, benign and malignant breast tissues have been detected by biomagnetometry [4-6]. This is, however, the first time that such magnetic field changes have been detected in normal mammary tissues during a menstrual cycle. More importantly, minor irregularities of breast responses to hormonal stimuli could be detected by this technique, reflecting analogous disturbances of the endometrial cycle.

It is true that estrogen and progesterone receptors have been identified in both the endometrium and the breast, but it is now becoming apparent that the two-receptor systems share a common course in health and disease. It would be fair, therefore, to say that the biphasic magnetic curve noted in the young women with normal menstrual cycles (as indicated by medical history and blood hormone measurements) is suggestive of an ovulatory endometrial cycle, while the monophasic magnetic field curve observed in the young female volunteers with irregular menstrual cycles may be indicative of a non-ovulatory endometrial cycle. The higher magnetic fields noted in the second half of the breast cycle (secretory phase of the menstrual cycle) relative to the first half (proliferative phase of the menstrual cycle) is in accord with the higher mitotic activity reported at this phase in the adult breast [1, 3, 9].

It is too early to assess the implications of these observations, particularly when they are based on an extremely small sample, but they may offer a new dimension in the investigation of functional endometrial disturbances. Certainly, such an option would be encouraged by the harmless, non-invasiveness and the great precision of the method, which, in addition, is quick and easy to interpret. The cons of the method are, mainly, the unavailability of SQUID technology around the country and, perhaps, the impracticability of regular measurements.

References

[1] Sloane J.P.: "Biopsy Pathology of the Breast" (Biopsy Pathology, Series 24), 2nd edition. London: Arnold, 2001.

[2] Vogel P.M., Georgiade N.G., Fetter B.F., Vogel F.S., McCarty K.S. Jr.: "The correlation of histologic changes in the human breast with the menstrual cycle". *Am. J. Pathol.,* 1981, *104*, 23.

[3] Longacre T.A., Bartow S.A.: "A correlative morphologic study of human breast and endometrium in the menstrual cycle". *Am. J. Surg. Pathol.,* 1986, *10,* 382.

[4] Sivridis E., Anninos P., Giatromanolaki A., Kotini A., Adamopoulos A., Anastasiadis P.: "Biomagnetic activity in the female breast at various physiological states". *Clin. Exp. Obstet. Gynecol.,* 2001, *28,* 196.

[5] Anastasiadis P., Anninos P., Sivridis: "Biomagnetic activity in breast lesions". *Breast,* 1994, *3*, 177.

[6] Anninos P., Kotini A., Koutlaki N., Adamopoulos A., Galazios G., Anastasiadis P.: "Differential diagnosis of breast lesions by use of biomagnetic activity and non-linear analysis". *Eur. J. Gynaecol. Oncol.*, 2000, *21*, 591.

[7] Anninos P., Anogianakis G., Lehnertz K., Pantev Ch., Hoke M.: "Biomagnetic measurements using SQUID". *Int. J. Neurosci*, 1987, *37,* 149.

[8] Hutson S.W., Cowen P.N., Bird C.C.: "Morphometric studies of age related changes in normal human breast and their significance for evolution of mammary cancer". *J. Clin. Pathol.,* 1985, *38*, 281.

[9] Going J.J., Anderson T.J., Battersby S., MacIntyre C.C.A.: "Proliferative and secretory activity in human breast during natural and artificial menstrual cycles". *Am. J. Pathol.,* 1998, *130,* 193.

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