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Endometrial wave-like activity in the non-pregnant uterus

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The non-pregnant uterus shows wave-like activity throughout the menstrual cycle. This uterine activity was first detected using intra-uterine pressure recordings. The use of ultrasound has made it possible to study the movements of the uterus in a non-invasive manner. Throughout the menstrual cycle, several wavelike activity patterns have been described; these patterns change throughout the menstrual cycle and are governed by steroid hormones. An adequate wave pattern seems to be related to successful reproduction in spontaneous cycles and assisted reproduction. Further insight into the phenomenon of endometrial wave-like activity might offer an opportunity to correct abnormal wave patterns and thereby improve pregnancy rates.

Key words: endometrial waves/endometrial wave classification system/non-pregnant uterus/transvaginal ultrasound/uterine contractions

Introduction

The non-pregnant uterus is not a quiescent organ. Its contractility has been described with the help of various methods. One of the first scientific reports on this subject was published in 1937 by Dickinson, who described the possibility of registering uterine contractions by bimanual palpation (Dickinson, 1937).

Contractions and their characteristics, such as frequency, amplitude and basal pressure, have been examined for the various phases of the menstrual cycle with the aid of intra-uterine pressure transducers. Ultrasound has made it possible to study various aspects of uterine activity in a non-invasive manner, by visualization of endometrial wave-like activity resulting from sequential segmental contractions in the subendometrial myometrium.

Intra-uterine pressure recordings

While Heinricius (1889) was the first to describe a method to record activity in the non-pregnant uterus with a balloon system, several other authors have subsequently used closed-tip intra-uterine catheters to measure uterine activity (Knaus, 1933; Moir, 1944; Csapo and Pino-Dantas, 1966). The results of the various studies applying this method were highly variable, mostly because of calibration problems due to variations in the size of the balloons, the volume of fluid introduced in the balloons, and the amount of pressure in the balloons at the onset of the recording period. The large volume of the balloon also acted as a potential uterine irritant.

The intra-uterine open-tip catheter, which was introduced by Hendricks (1964), theoretically affected the contractility of the uterus less than the closed catheters. Almost all authors who studied uterine contractility by this method produced similar qualitative assessments of the different contraction types throughout the cycle. During menstruation, regular labour-like contractions with a high intensity, high amplitude, low frequency and low basal pressure were described. In the proliferative phase, the pressure and frequency increased while amplitude and intensity decreased. In the peri-ovulatory phase, the intensity was found to be low and the frequency high, while at ovulation, small, high-frequency contractions with high pressure were seen. In the second half of the cycle, towards menstruation, the intensity and amplitude increased and the frequency decreased (Hendricks, 1965; 1966; Cibils, 1967; Bengtsson, 1968; Eskes *et al*., 1969; 1970; Braaksma, 1970; Yoshida and Hendricks, 1970; Hein, 1972). However, the absolute values measured by the various investigators often differed (Table I).

Ultrasound studies

Since 1984, when Birnholz first used the transabdominal ultrasound technique to study movements in the non-pregnant uterus, ultrasound has been used to study uterine activity in a non-invasive manner.

Intra-uterine pressure recordings provide information about frequency, amplitude and basal pressure tone. Ultrasound can also record contraction frequency, but its major asset is that it adds another dimension to the recordings, namely direction. This allows observation of the contractions that travel through the uterus in waves to be made, and their direction, frequency and velocity to be ascertained. It has been suggested recently that

Table I. Results of intra-uterine pressure recordings, using an open-tip catheter, in the non-pregnant uterus

Reference	Menses	Pre-ovulatory phase	Post-ovulatory phase
Hendricks (1964; 1966)	Labour-like contractions F: 1 per 1–3 min I: 50–200 mmHg	Early follicular: F: 1 per 30–60 s, I: 20–50 mmHg Peri-ovulatory: F: 1 per 15–20 s, I: 5–29 mmHg (small, frequent contractions)	Mid-luteal: slow and complex contractions Towards menstruation: pre-labour-like
Cibils (1967)	End of menstruation: F: 1 per 3 min D: 1 min Moderate intensity	Mid-follicular: F: 1 per 25–40 s, D: ⩽20 s Late follicular: F: 1 per 10–15 s, brief, irregular-shaped contractions	Early luteal: F: 1 per 20–40 s; low intensity Mid-luteal: slow fluctuating contractions, D: ⩾1 min Late luteal: slow strong contractions
Bengtsson (1968)	Pre-labour-like	Early follicular: 2–3 small contractions per min	Large contractions with high amplitude and low frequency
Eskes *et al*. (1969; 1970)	Low frequency, low basal pressure, considerable intensity	Follicular: ↑ frequency and basal pressure, ↓ intensity Peri-ovulatory: high frequency, low intensity, high basal pressure (⩾20 mmHg)	Luteal: ↓ basal pressure and frequency, ↑ intensity
Braaksma (1970)	B: 4.9 mmHg, I: 18.6 mmHg, A: 13.6 mmHg D: 35 s, high interval	Mid-follicular/late follicular: B: 22.9 mmHg/15.8 mmHg I: 28.7 mmHg/18.7 mmHg A: 5.2 mmHg/2.9 mmHg D: 18 s/11 s	Luteal: lowest amplitude, shortest duration Pre-menstrual: strongest change in amplitude, duration and interval
Yoshida and Hendricks (1970)	CD 1–3: Labour-like pattern, low resting pressure	CD 11: small contractions, high frequency, resting pressure 15.4 mmHg CD 13: ↑ intensity, resting pressure 26.9 mmHg	CD 15: slightly decreased frequency CD ⩾18: contractile pattern forms complexes, ↓ resting pressure CD 23: pre-labour-like contractions
Hein (1972)	Strong labour-like contractions	Early follicular: frequent small contractions, ↑ basal pressure, ↓ duration Mid-follicular: ↑ basal pressure and frequency, ↓ duration, intensity and amplitude Late follicular: high basal pressure, wandering baseline, ↑ frequency, low intensity	Early luteal: ↓ basal pressure, frequency and amplitude, ↑ duration Late luteal: ↑ intensity and amplitude, ↓ basal pressure and duration
Bulletti *et al*. (2000)		↑ frequency towards mid-cycle	↓ frequency and further ↑ of amplitude, with maximum in late luteal phase
Bulletti *et al*. (2002)	Patients with endometriosis: higher frequency, amplitude and basal pressure		

A = amplitude of contractions; B = basal pressure of contractions; CD = cycle day; D = duration of contractions; F = frequency of contractions; I = intensity of contractions.

ultrasound is as effective as intra-uterine pressure recordings for measuring the frequency of uterine activity (Bulletti *et al*., 2000).

The composition of the patient groups used in ultrasound studies has varied widely, and the moments of measurement have not always been standardized (Table II). In addition, the measuring methods used have also been variable. Some authors did not use taped video recordings and there has been no uniformity in recording and playback times (Table II). Classification of the movements has also differed, in terms of the tissue movement and the direction (Table III), as well as in the characteristics of the movements (Table IV).

The results of several ultrasound studies are summarized in Table V. In general, the ultrasound findings of the studies performed show movements from fundus to cervix during the early follicular phase. Movements from cervix to fundus have been described in the late follicular and peri-ovulatory phases, and most investigators have also described an increased intensity of movements towards ovulation.

A classification system for describing the different activity types has also been proposed (IJland *et al*., 1996).

Endometrial wave classification system

One group (IJland *et al*., 1996) carried out transvaginal ultrasound examinations using a 7.5 mHz transducer. At each examination, between 3 and 15 min of video images were recorded of the uterus in the mid-sagittal plane. If no uterine activity was observed over a period of 3–5 min, the recording was discontinued. Off-line

Table II. Ultrasound studies of movements in the non-pregnant human uterus. [Adapted from IJland (2000), with permission.]

Reference	Year	US abd/vag	Patients (*n*)	Observations (*n*)	Patients	Moments in cycle	Record time/video/ replay ×normal speed
Birnholz (1984)	1984	+ / –	26	32	Spont, clomid	?	30 s/ –
Oike *et al*. (1990)	1990	– / +	21	?	Spont	?	
de Vries *et al*. (1990)	1990	+ / +	35	35	Spont	1st and 2nd half cycle	120 s /+/ 5×
Abramowics and Archer (1990)	1990	– / +	a. 15 b. 10 c. 18	21 cycles 15 cycles 18 cycles	Spont Oac IVF	a+b. CD 5/6, 10/11, 13/15, 20/22 c. CD 5/6, hCG, ET+2	? /+and –/ ?
Lyons *et al*. (1991)	1991	– / +	18	328	Spont	Menstrual, follicular Peri-ovulatory, luteal	120 s /+/ 5×
Chalubinski *et al*. (1993)	1993	– / +	53	a. 14 b. 9 c. 20 d. 10	Spont	a. CD 2 b. CD 7/8 c. Ovulatory phase d. CD 20/22	? / +/ ?
Fukuda and Fufuda (1994)	1994	– / +	a. 72 b. 18 c. 11	180 cycles 75 cycles 18 cycles	Spont Clomid Gn	Mid-follicular (1–2 times) Late follicular; daily Luteal (3–4 times)	2 min /+/ ?
Salamanca and Beltran (1995)	1995	– / +	37	37	Endometriosis Spont	CD 1/2	5 min /+/ ?
Kunz *et al*. (1996)	1996	– / +	36	a. 11 b. 17 c. 8	Spont	a. Early follicular b. Mid-follicular c. Late follicular	5 min /+/ ?
Leyendecker *et al*. (1996)	1996	– / +	66	a. 15 b. 27 c. 39 d. 19 e. 18	Endometriosis Spont	a. Menstruation b. Early follicular c. Mid-follicular d. Late follicular e. Luteal	5 min /+/ 5×
IJland *et al*.	1996 1997 1998 1999	– / + – / + – / + – / +	16 47 19 21	23 cycles 59 cycles 35 cycles 21 cycles	a. Spont b. Spont c. Gn d. IVF	a+b. Early, mid- and late follicular; early, mid- and late luteal c. Start, 2× stim period, hCG, hCG+2, hCG+6, hCG+9 d. Start, 3× stim period, hCG, OPU, ET, hCG+7 (d)	3–15 min /+/ 4×
Fanchin *et al*.	1998 2001	– / + – / +	209 43	220 43	IVF IVF	Before ET HCG, hCG+4, hCG+7	5 min /+/ 10× 2 min / – / ?

abd = abdominal; CD = cycle day; clomid = clomiphene citrate; ET = embryo transfer; Gn = gonadotrophins; Oac = oral contraceptives; OPU = ovum pick-up; spont = spontaneous cycles; US = ultrasound; vag = vaginal.

analysis was performed at high speed (four times normal) replay. This method seems comparable with those reported previously (de Vries *et al*., 1990; Lyons *et al*., 1991; Leyendecker *et al*., 1996), in which the analysis was conducted at five times normal speed.

IJland's endometrial wave classification system distinguished five types of wave-like activity (Table VI). Waves from fundus to cervix dominated during the follicular phase, and no fundus-to-cervix waves were seen after ovulation. A putative function of fundus-to-cervix waves is that of cleansing the uterine cavity and creating a barrier to ascending pathogens. Waves from cervix to fundus were recorded predominantly in the late follicular and the luteal phases. The cervix-to-fundus waves are assumed to promote sperm transport (Abramowics and Archer, 1990) and to restrict the implantation of the embryo to the upper uterine cavity (IJland *et al*., 1996). This phenomenon has also been described by others (Lyons *et al*., 1991; Kunz *et al*., 1996). The latter group mimicked sperm transport in the follicular phase by the placement of labelled macrospheres of sperm size at the external cervical os. By using serial hysterosalpingoscintigraphy it was shown that sperm reach the uterine cavity within minutes. The proportion of macrospheres entering the tubes is highest during the late follicular phase, when there is maximum frequency and intensity of the endometrial waves. The transport of the macrospheres was preferably directed into the tube ipsilateral to the dominant follicle (Kunz *et al*., 1996). These authors hypothesized that the direction of the endometrial wave towards the ipsilateral tube might be controlled by a specific myometrial architecture in combination with a asymmetric distribution of myometrial estrogen receptors. Furthermore, human semen contains large amounts of prostaglandins which may also promote the phenomenon of directed endometrial waves and isthmic tubal relaxation (Coutinho and Maia, 1971)

Opposing waves, which were observed during the first days after ovulation, might help prepare the endometrium for successful nidation and also assist in providing the pre-implantation embryo with nutrients and oxygen (IJland *et al*., 1996).

Table III. Description of uterine movements in the non-pregnant human uterus by ultrasound. [Adapted from IJland (2000), with permission.]

Reference	Description of uterine movement	Direction
Birnholz (1984)	Stripping movements endometrium	–
Oike *et al*. (1990)	Endometrial movements	Towards fundus
de Vries *et al*. (1990)	Inner one-third myometrium contractions	Antegrade/retrograde
Abramowics and Archer (1990)	Endometrial peristalsis	–
Lyons *et al*. (1991)	Subendometrial myometrial contractions	–
Chalubinski *et al*. (1993)	Myometrial contractions	Towards fundus and cervix
Fukuda and Fufuda (1994)	Endometrial echo free space	Horizontal, vertical
Salamanca and Beltran (1995)	Subendometrial contractility	Antegrade, retrograde
Kunz *et al*. (1996)/Leyendecker *et al*. (1996)	Uterine peristalsis	Fundo-cervical, cervico-fundal
IJland *et al*. (1996)	Endometrial waves	Cervix to fundus, fundus to cervix, opposing, random
Fanchin *et al*. (1998a)	Uterine contractions	Antegrade, retrograde, antagonistic, non-propagated

Table IV. Aspects of movements in the non-pregnant human uterus studied by ultrasound. [Adapted from IJland (2000), with permission.]

Reference	Direction	Frequency	Amplitude	Strength (intensity)	Symmetry
Birnholz (1984)	–	+	–	–	–
Oike *et al*. (1990)	+	+	+	+	–
de Vries *et al*. (1990)	+	+	+	–	+
Abramowics and Archer (1990)	–	+	+	+	–
Lyons *et al*. (1991)	+	+	+	–	–
Chalubinski *et al*. (1993)	+	+	–	–	+
Fukuda and Fufuda (1994)	+	–	–	–	–
Salamanca and Beltran (1995)	+	–	–	–	–
Kunz *et al*. (1996)	+	+	–	+	–
Leyendecker *et al*. (1996)	+	+	–	–	–
IJland *et al*. (1996)	+	+	–	–	–
Fanchin *et al*. (1998)	+	+	–	–	–

In spontaneous menstrual cycles and stimulation cycles wave frequency can be analysed according to the presence of unidirectional waves (fundus-to-cervix and cervix-to-fundus). There is an increase in the frequency of fundus-to-cervix waves from the mid-follicular to the late follicular phase, while the frequency of cervix-to-fundus waves also increases from the mid-follicular phase towards the early luteal phase (IJland *et al*., 1996; Kunz *et al*., 1996). After ovulation, there is a reduction in the frequency of contractions, which might optimize the contact between the blastocyst and the endometrium to facilitate implantation (Fanchin *et al*., 1998a; 2001b). Kunz and colleagues reported that during the luteal phase, the upper fundal part of the uterus shows a relative quiescence facilitating embryo implantation (Kunz *et al*., 2000b).

Wave velocity can be calculated for the unidirectional wave types. There is a trend towards increasing wave velocity in fundus-to-cervix waves from the mid-follicular to the late follicular phase (IJland *et al*., 1997b). Cervix-to-fundus waves seem to attain their highest velocity in the peri-ovulatory phase, underlining their putative role in rapid sperm transport, and these findings corroborate the results of other studies (Abramowics and Archer, 1990; Lyons *et al*., 1991). Because of the low inter-observer reproducibility and the complexity of measurements, the wave velocity measurements do not as yet appear to be appropriate for clinical application (IJland *et al*., 1997b).

Endometrial waves and fecundability

The contractility pattern in the non-pregnant uterus appears to play a role in the reproductive process. In spontaneous cycles, the endometrial wave type is related to fecundability (IJland *et al*., 1997a). Conception cycles show a predominance of waves from cervix to fundus in the peri-ovulatory phase, whereas waves from fundus to cervix are seen only during the late follicular phase and have never been detected after ovulation (IJland *et al*., 1997a; Fanchin *et al*., 1998b). Conception cycles show an overall dampening of endometrial wave activity during the consecutive phases of the cycle. Both dampening of activity and fine-tuning of the activity patterns at mid-cycle appear to be prerequisites for successful embryo implantation (Fanchin *et al*., 1998a).

The endometrial wave pattern is also related to the occurrence of pregnancy in IVF cycles (IJland *et al*., 1999). The relative distribution of the different endometrial wave types in the stimulation period showed more fundus-to-cervix waves in conception cycles than in non-conception cycles. After administration of hCG, fundus-to-cervix waves were no longer detected in either group. Most of the IVF cycles also showed a switch from fundus-to-cervix to cervix-to-fundus waves, referred to as the wave direction switch (WDS). A premature switch from fundus-to-cervix to cervix-to-fundus waves—that is, an early WDS—is associated with a reduced pregnancy prognosis (29%), while a

Table V. Results of ultrasound studies of movements in the non-pregnant uterus. (Adapted from IJland, 2000, with permission)

Author	Year	General	Direction	Frequency (movements per min)	Amplitude/strength/ symmetry
Birnholz	1984	Most movements in first half of cycle			
Oike *et al.*	1990	No movements after ovulation	Towards fundus; late proliferative	Ovulation: 3.9 Late proliferative: 4.5	Increased amplitude to ovulation
de Vries *et al.*	1990	–	Antegrade: menstruation Retrograde: all phases of cycle Antegrade: 2.3 Retrograde: 3.3	First half of cycle: symmetrical Second half of cycle: asymmetrical	
Abramowics and Archer	1990	Gross movements score: average score (1.5) highest at mid-cycle	–	–	Increase in strength from early follicular to mid-cycle
Lyons *et al.*	1991	>80% of the contractions peri-ovulatory	Direction towards fundus	Ovulation: 2.5–3.5	Increase amplitude in follicular phase, decrease after ovulation
Chalubinski *et al.*	1993	–	Toward cervix: menstruation Toward fundus: all phases	CD 2: 1–3 CD 7/8: < 1 Ovulation: 10 CD 20/22: 2–5	Ovulation: symmetrical Mid-follicular and luteal: dysrhythmic
Fukuda and Fufuda	1994	Late follicular most movements	–	–	–
Salamanca and Beltran	1995	Endometriosis patients 87.5% retrograde contractions versus 4.8% in control group	–	–	–
Kunz *et al.*	1996	–	Fundo-cervical contractions decrease in favour of cervico-fundal contractions in the follicular phase (31%, 12%, 1% respectively)	Early follicular: 1.2 Mid-follicular: 1.6 Late follicular: 1.8	Increased intensity in follicular phase
Leyendecker *et al.*	1996	–	–	Early follicular: 1.2 Mid-follicular: >1.5 Late follicular: 2.5	–
IJland *et al.*	1996	Spontaneous cycles	FC waves in follicular phase, not after ovulation; CF waves in peri-ovulatory phase and luteal phase	FC waves: Mid-follicular: 3.35 ± 0.88 Late follicular: 3.90 ± 0.95 CF waves: Mid-follicular: 2.99 ± 0.86 Late follicular: 4.08 ± 1.24 Early luteal: 4.35 ± 1.48	–
Fanchin *et al.*	1998	IVF cycles	Increased retrograde and decreased antagonistic contractions from low (a) to high (d) frequency group	Before ET a. ⩽3.0 (antagonistic) b.1–4.0 c.1–5.0 d. > 5.0 (retrograde)	–
IJland *et al.*	1999	IVF cycles	FC waves before hCG and not after hCG	FC waves: hCG-6: 8.12 ± 4.5 hCG: 7.15 ± 5.2 CF waves: hCG-6: 7.11 ± 4 hCG: 9.4 ± 5.7 ET: 10.1 ± 5.0	–
Bulletti *et al.*	2000	Frequency of uterine contractions comparable in ultrasound and intra-uterine pressure recordings	Retrograde contractions most frequent at mid-cycle Opposing contractions dominant in luteal phase	Early and late luteal 1.8 ± 1.9 contractions/min Early and late luteal 1.4 ± 1.5 contractions/min	–

CD = cycle day; CF = cervix–fundus; ET = embryo transfer; FC = fundus–cervix.

Table VI. Endometrial wave classification system (IJland *et al.*, 1996)

Fundus-to-cervix waves (FC)	Waves from fundus to cervix
Cervix-to-fundus waves (CF)	Waves from cervix to fundus
Opposing waves (OPP)	Starting simultaneously at fundus and cervix
Random waves (R)	Starting at various foci
No activity	

late WDS is accompanied by a very favourable prognosis of pregnancy (88%). The persistence of fundus-to-cervix waves until the day of hCG administration appears to help a good quality embryo to implant (IJland *et al.*, 1999).

As was the case in controlled ovarian stimulation (COS) cycles, one group (IJland *et al.*, 1998) showed that endometrial wave activity was more pronounced in IVF cycles. A statistically significant difference was found in wave frequency, which was higher in IVF cycles than in spontaneous cycles (Abramowics and Archer, 1990; IJland *et al.*, 1999). Although the latter group could not find any relationship between the frequency of endometrial waves and the occurrence of pregnancy in IVF cycles, others (Fanchin *et al.*, 1998b; 2001b) demonstrated a negative correlation between the frequency of endometrial waves on the day of embryo transfer and pregnancy outcome. High-frequency endometrial waves on the day of embryo transfer appear to affect IVF-embryo transfer outcome in a negative manner, perhaps by expelling embryos from the uterine cavity.

Effect of steroid hormones on endometrial waves

The cycle-dependent pattern of endometrial waves presumes a role for steroid hormones. First, endometrial activity is most pronounced in the peri-ovulatory phase, with high estrogen levels. Also, more endometrial activity is seen in IVF cycles and COS cycles with high estrogen levels, compared with spontaneous cycles. The WDS during the course of the cycle appears to be governed by estrogens and progesterone.

To study this effect of steroids, spontaneous cycles were mimicked in post-menopausal women by giving the patients estradiol (days 1–28) and progesterone (days 14–28) (IJland, 2000). Ultrasound examinations have revealed that the prevalence of spontaneous endometrial wave-like activity is low or absent after menopause. Endometrial waves increase after estrogen administration, with waves from fundus to cervix being recorded in the estradiol-only phase of the cycle and vanishing immediately after the administration of progesterone. Waves from cervix to fundus are seen in both the estradiol-only phase and the estradiol-progesterone phase, with a maximum at the end of the estradiol-only phase.

Besides inducing a WDS, progesterone appears to have a relaxing effect in the non-pregnant uterus (Fanchin *et al.*, 1998b; 2000). The contention that the endometrial wave-like activity is predominantly governed by ovarian steroid hormones has also been supported by others (Knaus, 1933; Bengtsson and Theobald, 1965; Oike *et al.*, 1990; Bulletti *et al.*, 1993; Batra, 1994; Kunz *et al.*, 1998)

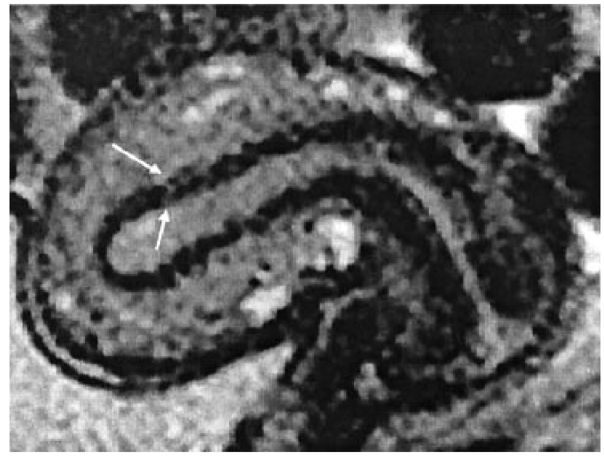

Figure 1. Magnetic resonance image of the uterus in the mid-sagittal plane. The arrows indicate the subendometrial myometrium or junctional zone.

Anatomy

The described endometrial waves are initiated in the subendometrial myometrium or junctional zone, and this can be identified using either magnetic resonance imaging (MRI) (Brosens, 1995) (Figure 1) or ultrasound (Kunz *et al.*, 2000b). Like the endometrium, the subendometrial myometrium exhibits a cyclic pattern of estrogen receptor and progesterone receptor expression (Noe *et al.*, 1999).

The outer layer of the uterus, the non-paramesonephric myometrium, is formed in a later embryological stage and appears to have functions that are predominantly confined to parturition (Noe *et al.*, 1999). This outer portion of the uterine wall does not exhibit a cyclic pattern of estrogen and progesterone receptor expression (Noe *et al.*, 1999).

Conclusions

The endometrium in the non-pregnant uterus shows distinct activity patterns throughout the menstrual cycle, which are called endometrial waves. These waves originate in the subendometrial myometrium and are influenced by steroids. The subendometrial activity might be initiated by pacemakers in the uterine muscle, providing the mechanical phenomenon of endometrial waves. A relative quiescence of the uterus and an adequate wave pattern in certain phases of the cycle are related to successful reproduction (Bulletti *et al.*, 1997; IJland *et al.*, 1997a).

Uterine factors that have so far been implicated in decreased fertility, are the presence of severe intra-uterine adhesions, deformity of the uterine cavity by fibroids, and congenital abnormality of uterus or cervix (Taylor and Collins, 1992). The existence of an abnormal wave pattern in a subfertile patient could be another uterine factor explaining subfertility, and this should be actively sought in future. Other examinations, such as endometrial biopsy, studying the texture of the endometrium by ultrasound, and hysteroscopy to reveal the presence of intra-uterine lesions, contribute little to the understanding of the cause of otherwise unexplained infertility (Taylor and Collins, 1992).

Whilst in assisted reproduction there exists an important role for the pattern and frequency of endometrial waves, more insight is required into the phenomenon of these endometrial waves and the factors which influence them, especially those of a hormonal nature. This might provide an opportunity to correct an abnormal wave pattern or to modulate wave frequency to improve pregnancy rates, for example by exogenously changing hormone levels (Fanchin *et al*., 2001a). Uterine contractility might also be stimulated by the use of prostaglandins (PG), for example the vaginal administration of a PGE_1 analogue (misoprostol) in women undergoing intra-uterine insemination (Brown *et al*., 2001). If a premature WDS should occur in IVF cycles, it could be hypothesized that it would perhaps be better to freeze the embryos and postpone the embryo transfer to another cycle.

Abnormal wave patterns or dysperistalsis have been described by two groups (Salamanca and Beltran, 1995; Bulletti *et al*., 2002), both of which detected abnormal activity patterns in women with endometriosis. Others (Leyendecker *et al*., 1996) identified a relationship between this abnormal activity, endometriosis and impairment of directed sperm transport, resulting in lower pregnancy rates. Furthermore, documentation of the endometrial wave patterns might contribute to an understanding of conditions such as dysmenorrhoea, endometriosis and habitual abortion.

In the near future, MRI techniques might offer another means of detecting endometrial activity and comparing the results with transvaginal ultrasound findings.

Further investigations are important to gain more insight into the phenomenon of endometrial waves. Moreover, improving the uniformity of recording these waves, as well as gathering details of their description and activity, might add to an understanding, diagnosis and treatment of unexplained fertility disorders.

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