Study of the electromechanical activity of the uterus

Experimental study

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Summary: The uterine electromechanical activity was studied in 12 mongrel bitches. The uterus was exposed under general anesthesia, and 2 electrodes were sutured to its serosa. The electric activity was recorded for 30 minutes/day for 10 days. Simultaneous electric and mechanical activity (registered by a 4 F catheter connected to a pressure transducer) was also studied without and with uterine distension by a balloon. The electric activity was further recorded after performing uterine annular myotomy proximal and distal to the electrodes and between them.

Pacesetter potentials (PPs) were registered from the 2 electrodes, having identical frequency and regular rhythm by the 2 electrodes, and were consistent in the individual dog on all test days. Action potentials (APs) followed PPs randomly and were associated with increase in uterine pressure. Balloon distension of the uterus effected increased PP and AP frequency. Annular uterine myotomy led to PP and AP disappearance distally but not proximally to myotomy.

In conclusion, the study demonstrates that the uterus possesses electric activity represented by PPs which spread caudally. APs seem to be contractile waves. Recording of the electromechanical activity of the uterus may be of diagnostic significance in uterine disorders.

Key words: Uterus; Electric activity; Uterine motility; Electrophysiology.

The uterus is a contractile organ. Its wall contains smooth muscle fibers which contract to expel a foreign body from its cavity ([1, 2]). Like the smooth muscles in the gut ([3–12]) the uterus, too, presumably has electrical activity. Recent studies have demonstrated a discharge of electric waves by the rectal detrusor ([13, 14]). Electrorectograms were recorded and showed characteristic patterns for the different rectal pathologic conditions ([15, 16]).

The uterus may be involved in various pathologic processes. It is suggested that such conditions may affect uterine electric activity. Meanwhile, available investigative tools may fail to diagnose some of these disorders, in particular the neuropathic or dysfunctional ones. In such conditions, the characterization of an electrouterogram (EUG) may be helpful especially in utero-motor disorders.

The purpose of this investigation was to study the electromechanical activity of the uterus in the canine model aiming at defining a normal electriuterogram that may act as a diagnostic method in the investigation of uterine disorders. The study was approved by our Faculty Review Board.

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MATERIALS AND METHODS

12 healthy mongrel bitches with a mean weight of 19.4±4.6 SD kg (range from 15 to 23 kg) were studied. The dogs were put in cages and given access to water ad libitum. They were maintained on a standard diet of meat dog chow in the morning and dry chow throughout the day. The animals were allowed a 1-week period to acclimate to the facilities prior to inclusion in the study.

Dogs were premedicated with acepromazine (0.15 mg/kg body weight) subcutaneously. They were anesthetized with intravenous sodium pentobarbital (35 mg/kg body weight) with a bolus injection of 20 to 25 mg per hour to maintain adequate anesthesia with spontaneous respiration. All dogs were intubated to assist ventilation. Fluid maintenance consisted of intravenous infusion of normal saline solution (2 ml/kg body weight per hour).

The animal was placed supine on the operating table. The abdomen was opened by a midline incision and the uterus was exposed. Monopolar silver-silver chloride electrodes, 0.8 mm in diameter and covered with an insulating vinyl sheath sparing its tip (Smith Kline-Beckman, Los Angeles, CA, USA) were used. Two electrodes were sutured to the serosa of the anterior uterine wall: one near the fundus and the other in the lower part of the uterine corpus. A metal cannula containing the 2-pinsocket to which the electrodes were attached, was sutured to the anterior abdominal wall.

Recordings were started 2 weeks post-operatively. Insulated wire leads were attached to the pins in the cannula and connected to a Brush Mark 200 rectilinear pen recorder. The electrical activity, including the frequency, amplitude and velocity of conduction of the wave forms, was recorded from the electrodes in each dog for periods of 30 minutes daily on 10 different days.

The uterine mechanical activity in the 12 dogs was recorded simultaneously with the electrical activity. It was performed by measuring the uterine pressure by means of a 4 F catheter with 2 lateral 1 mm side ports and a closed distal end. The catheter was introduced, via the vagina, into the uterine cavity, and was infused with 37° C sterile saline at a rate of 2 ml/min. It was connected to a strain gauge pressure transducer (Statham 230 b, Oxnard, Calif., USA).

Balloon distension of the uterus. The effect of uterine distension on electrical and mechanical activity of the uterus was studied. A balloon-ended 4 F catheter (London Rubber Industries Limited, London) was introduced into the uterus. The balloon was left in place for 15 nutes prior to registration in order to allow for uterine adaptation. It was then infused with 10 ml carbon dioxide (CO_2). The controlled CO_2 source was the Heyer-Schulte CO_2 cystometer (Hayer-Schulte Corp., Goleta, Calif. USA) which has a self-contained CO_2 system that uses disposable CO_2 cartridges. The CO_2 balloon filling was increased in increments of 2 ml to a total of 10 ml.

Uterine myotomy. The uterine musculature was interrupted in 8 dogs at a second operation. The uterus was exposed through a midline abdominal incision. An annular myotomy was performed in the uterus ½ cm above electrode 1 in 3 dogs, between electrodes 1 and 2 in 3 dogs, and below electrode 2 in another 2 dogs. The myotomy comprised division of the uterine muscle coat down to, but not including, the mucosa. The electric activity from each dog was recorded, as aforementioned, starting 2 weeks after the operation.

The results of the study were analysed statistically using the Student's t test.

RESULTS

No complications were encountered in the dogs during the period of study. Break of the electrodes did not occur. Slow waves or PPs were recorded from the 2 electrodes in all the dogs. The wave consisted of a negative deflection (Fig. 1). It exhibited in each dog the same frequency and regular rhythm via the 2 electrodes. The shape was constant in all recordings from the same site. The frequency, amplitude and velocity of conduction were consistent in the individual dog on all test days. The frequency varied from 2.9 to 4.8 cycles per minute (cpm) at electrodes 1 and 2 (mean 3.8±1.3 SD cpm), the amplitude from 1 to 1.5 mV (mean 1.2±0.4 SD mV) and the velocity from 3.3 to 5.9 cm/sec. (mean 4.7÷1.3 SD cm/sec.).

Bursts of action potentials (APs), representing fast activity spikes, were recorded (Fig. 1). They followed the PPs randomly, and their frequency was inconsistent in the individual dog. They consisted of negative deflections (Fig. 1).

The uterine pressure showed simultaneous increase with APs (Fig. 2). It increased with the increase of the AP am-

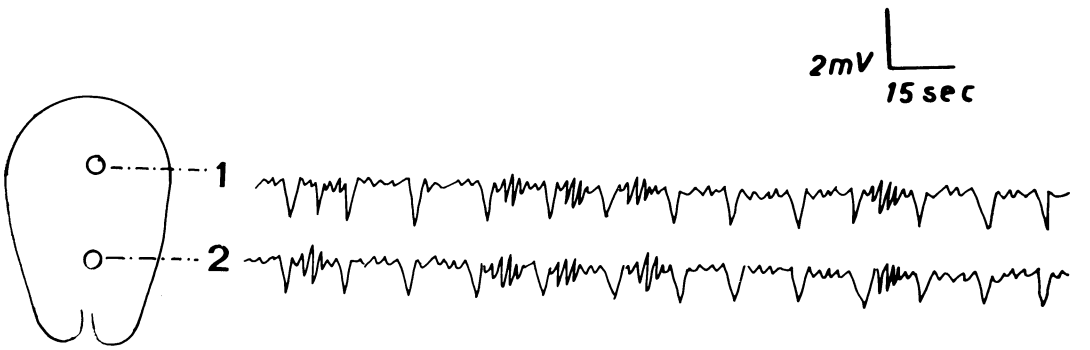

Fig. 1. — Electrouterogram showing pacesetter and action potentials.

plitude. The resting uterine pressure varied from 8 to 14 cm H_2O (mean 11.4 ± 2.6 SD cm H_2O). During bursts of APs, it was elevated to a mean of 20.6 ± 4.2 SD cm H_2O (range from 16 to 27 cm H_2O) ($P < 0.05$).

Balloon distension of the uterus effected increased PP and AP frequency and amplitude (Table 1, Fig. 3). The more uterine distension, the higher PP and AP frequency and amplitude. The PPs showed constant and regular patterns in the individual dog, while the APs did not. With 2 ml uterine distension, the PP frequency and amplitude increased to a mean of $4.6 \div 1.8$ SD cpm and $1.6 \div 0.5$ SD mV, respectively, and at 10 ml distension 10.4 ± 2.3 SD cpm and 2.2 ± 0.9 SD mV, respectively.

Uterine myotomy. No complications were encountered in the 8 dogs in which uterine myotomy was performed. Myotomy done above electrode 1 effected no significant different ($P > 0.05$) against pre-myotomy PP values of frequency, amplitude and velocity recorded by electrodes 1 and 2. APs occurred randomly. Myotomy below either electrodes 1 or 2 led to disappearance of PPs and APs distally to the cut but not proximally (Fig. 4).

The aforementioned results were obtained from all of the studied bitches and were reproducible in the individual animal.

Fig. 2. — Simultaneous recording of the uterine electric activity, action potentials and pressure. The uterine pressure (lower tracing) recorded an increase only with the occurrence of action potentials (upper tracing).

Table 1. – *Frequency and amplitude of pacesetter potentials at different volumes of uterine distension in 12 bitches***.*

Volume of uterine distension (ml)	Pacesetter potentials			
	Frequency (cpm) Range	Mean	Amplitude (mV) Range	Mean
0	2.9–4.8	3.8±1.3	1.0–1.5	1.2±0.4
2	3.4–6.2	4.6±1.8*	1.3–2.1	1.6±0.5*
6	5.7–8.7	7.3±2.2**	1.6–2.4	1.9±0.5*
10	8.2–12.6	10.4±2.3**	1.7–2.8	2.2±0.9**

(*) $P < 0.05$
(**) $P < 0.01$
(***) Values are given as mean ± standard deviations.

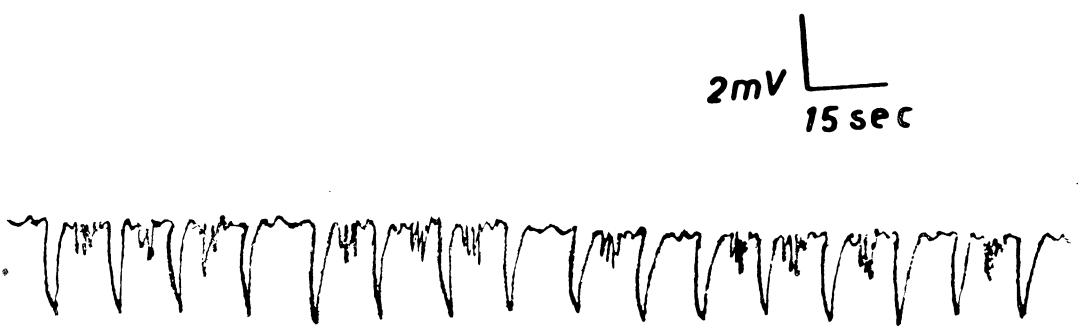

Fig. 3. — Electrouterogram showing increaesed frequency of pacesetter potentials upon uterine distension with 6 ml carbon dioxide.

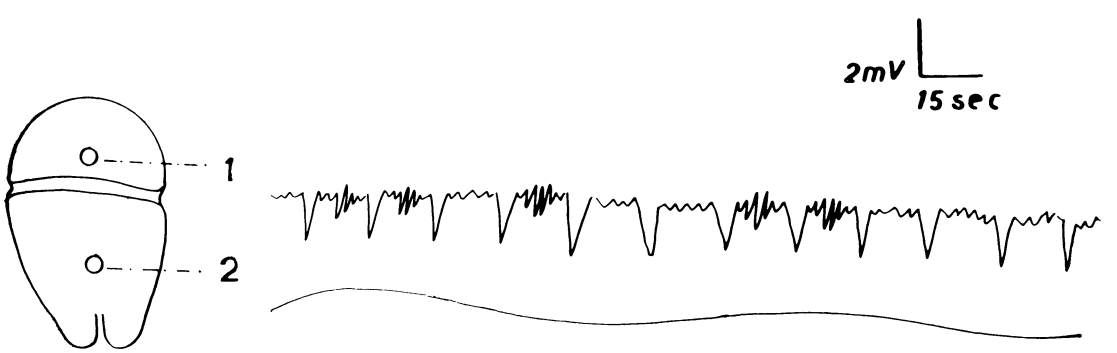

Fig. 4. — Uterine myotomy between electrodes 1 and 2. Electrical activity and action potentials were recorded by electrode 1 (proximal to the cut), but were not recorded by electrode 2 (distal to the cut).

DISCUSSION

The present study demonstrates that the uterus possesses electric activity or PPs. The PPs had a regular and reproducible pattern in the individual dog on all test days. They were followed randomly by APs which were simultaneonsly and consistently accompanied by an increase in uterine pressure. This suggests that the APs are contractile waves which induce nonrhythmic uterine contractions. However, these contractions appear to be too small to be apprehended by the subject.

Uterine distension effected an increase of the frequency and amplitude of both the PPs and APs. The greater the uterine distension by means of the balloon, which simulates a foreign body in the uterus, the higher was the increase of PP and AP amplitude and frequency. As the APs were accompanied by uterine pressure elevation, the increase of their amplitude is suggested to be associated with a greater increase in uterine pressure and contractile activity.

The present study points to the possible direction of propagation of the PPs and APs. The waves seem to spread caudally as shown in uterine myotomy studies. Myotomies performed above the inserted electrodes in the uterus did not influence wave propagation. Meanwhile, cuts below electrodes 1 or 2 interrupted conduction of the waves distally but not proximally to the electrodes. These findings suggest that the PPs start at the uterine fundus and spread caudally. The existence of a pacemaker in the fundus triggering the PPs and maintaining their frequency and direction of conduction is proposed and needs further investigation.

The uterine electric activity may be affected in various uterine disorders and in particular in utero-motor ones. The identifications of a normal EUG may thus prove of value as it represents a control pattern for the study of the different pathologic lesions involving the uterus.

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