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A Simple Electrode for Stable Recording of Pacemaker Potentials for Ureteral Peristalsis from the in Vivo Canine Renal Pelvis

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Summary. Pacemaker potentials for ureteral peristalsis were recorded in vivo with a fine, flexible acupuncture needle electrode inserted transparenchymally into the renal pelvis of anesthetized dogs. The recorded pacemaker potentials were quite similar, in every respect, to those shown in vitro, suggesting the availability of this electrode in recording and detailed analysis of the pacemaker activity in studies requiring in vivo preparations.

Key words: Acupuncture needle electrode, Pacemaker potential, Renal pelvis, Ureteral peristalsis, In vivo, Dog.

Introduction

The pacemaker in unicalyceal kidneys controlling ureteral peristalsis is now well known to be located in the proximal end of the pelvis, while in multicalyceal kidneys such a pacemaker exists further proximally in the minor calyces. This is based on recent studies in both types of kidneys from various species (such as the guinea-pig, rat, cat, rabbit, pig and human) which have showed that spontaneous, rhythmic contractions or potential changes (i.e. pacemaker potentials, PPs) were propagated towards the ureter but originated from more proximal areas [2, 4, 5, 7, 9–11, 13, 14, 18]. Most of these studies were performed on immobilized in vitro preparations of the kidneys, in which the renal parenchyma is partially incised or removed for direct positioning of recording electrodes under visual control [4, 5, 7, 9, 10, 18]. Furthermore, the PPs recorded extracellularly with glass microelectrodes from the preparations are small in amplitude and are within a range of 10–20 μV [13, 14]. One of the studies has employed a sophisticated sucrose gap technique for recording the PPs with a large amplitude [18]. The present paper describes the use of a simple electrode for stable, extracellular recording of the PPs in vivo from unicalyceal kidneys of dogs despite respiratory and vascular excursions, without the need to breach the renal parenchyma.

Materials and Methods

Experiments were performed on 11 adult mongrel dogs weighing 8–12 kg. The animals were anesthetized with pentobarbital sodium (initial dose of 30–40 mg/kg, i.m.) during spontaneous respiration. Via an extraperitoneal incision the dorsal surface of the left kidney and the ureter were exposed on the retroperitoneal adipose tissue. A flexible acupuncture needle (No. 2, Asahi-giken), insulated with a cashew paint except for the very tip, was perpendicularly inserted into the proximal end (pacemaker region) of the renal pelvic wall through the parenchyma by manual manipulation (Fig. 1A). This recording electrode was 250 μm in diameter and had a DC resistance of around 50 Kohm. The positioning of the electrode in the pacemaker or other regions of the pelvic wall was not difficult, since a relatively high mechanical resistance could consistently be felt by hand when the electrode reached the regions. The depth of the pacemaker region was 17–23 mm from the dorsal surface of the kidney. The PPS were fed to a single-ended AC amplifier (2 or 0.01 s time constant). Bipolar electrodes made of fine fishhooks (2 mm tip separation, 30–50 Kohm DC resistance) were also embeded into the muscular layer of upper and middle parts of the ureter to record the electroureterograms (EUGs). These electrodes were led to AC differential amplifiers (0.01 s time constant). To measure the intrapelvic pressure (IPP), a small catheter was introduced transparenchymally into the pelvic cavity and connected to a pressure transducer. Via another catheter introduced into the lower ureter, the urine was drained and led to a drop-counter in order to convert individual urine drops (UDs) to electrical pulses. These PPs, EUGs, IPP and UDs were simultaneously recorded on paper with a polygraph (RM-85, Nihon-kohden). The exposed kidney and ureter were immersed in warmed Ringer solution to prevent them from drying. In most animals, intravenous drip infusion was continued throughout the experiment to maintain rhythmic ureteral contractions. After recording PPs, an electrolytic lesion was made at the tip of the recording electrode by passing cathodal DC currents (100 μA for 1 m) through the electrode for later studies of locations of the recording sites (Fig. 1C).

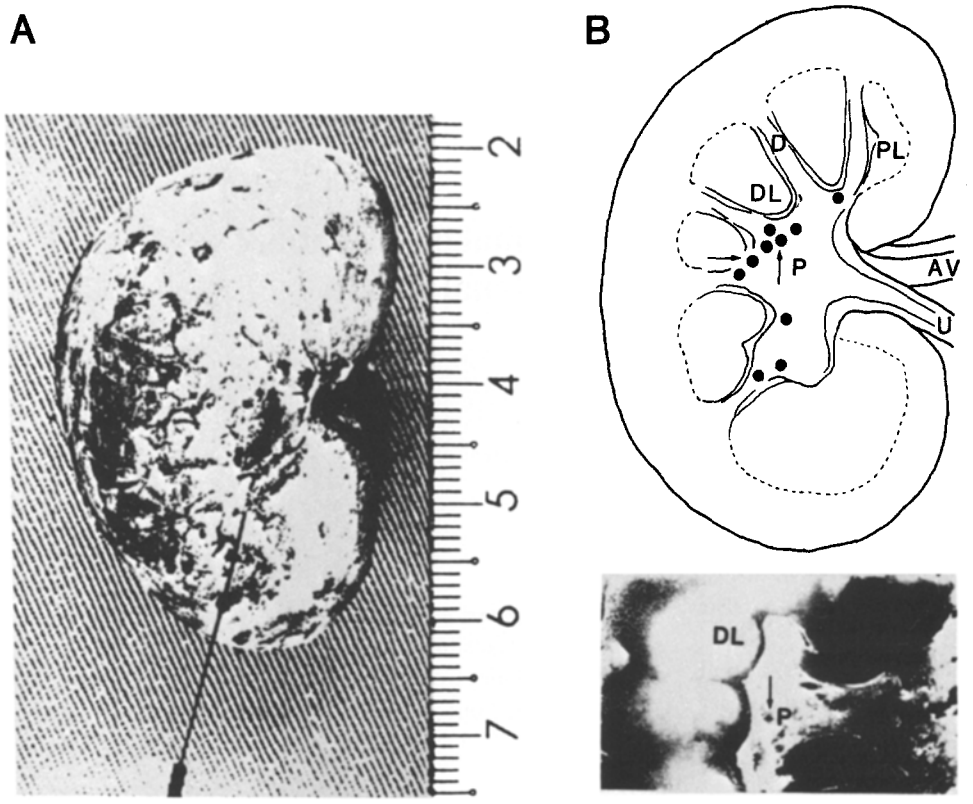

Fig. 1. A acupuncture needle recording electrode inserted transparenchymally into the pacemaker region of the renal pelvis. Numerals on the scale are given in each cm step. B drawing of a mid-sagittal section of the kidney where recording sites of pacemaker potentials were represented by filled circles. The sites of the pacemaker potentials shown in Fig. 2 and 3 are indicated by rightward and upward *arrows*, respectively. *AV*, renal artery and vein; *D*, diverticulum of the pelvis; *DL*, digital lobe; *P*, pelvis; *PL*, polar lobe; *U*, ureter. C photograph of a sagittal section of the kidney showing a recording site of pacemaker potentials (electrolytic lesion indicated by *arrow*)

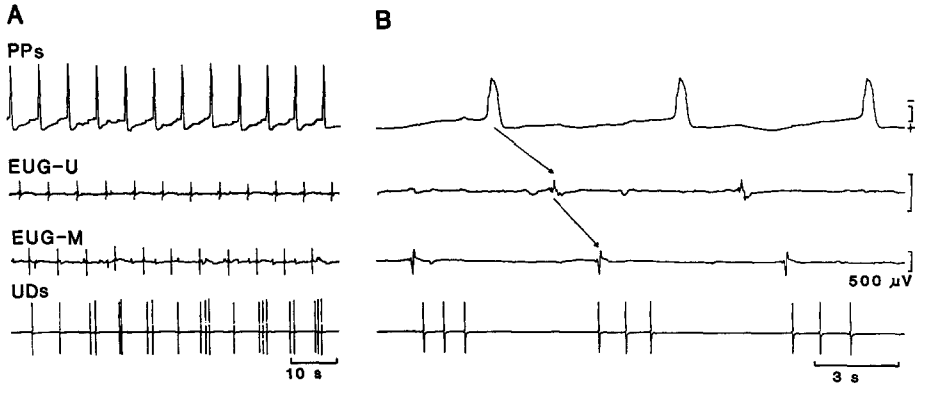

Fig. 2A, B. Simultaneous recording of pacemaker potentials in the renal pelvis (PPs), electroureterograms in the upper (EUG-U) and middle ureter (EUG-M), and urine drops from the lower ureter (UDs) in slow (A) and fast paper speeds (B). For recording the PPs, an AC amplifier with 2 s time contant was used. *Arrows* in B indicate the temporal sequence of propagation of the pacemaker potential to the ureter

Results

Regular potentials were recorded with the monopolar acupuncture needle electrode in the renal pelvis. Of these potentials, those identified by the following characteristics were considered to be PPs: (1) When each of the potentials consisted of an early slow potential and a succeeding spike potential [18]. (2) When the potentials showed an one-to-one relationship with systolic changes of the intrapelvic pressure [13]. (3) When the recording site of the potential was located in the proximal end of the renal pelvis [9, 13, 18].

Figure 2 shows simultaneous recording of, the PP, the EUG from the upper and middle parts of the ureter and the UD. These PPs were recorded from a position marked by an arrow pointing to the right in Fig. 1B using an AC amplifier (2 s time constant). They exhibited an uniform configuration characterized by an initial slow negative potential and a succeding negative spike potential, in spite of the presence of respiratory and vascular artefacts. This configuration is quite similar to that of PPs recorded from in vitro guinea-pig's kidneys with a sucrose gap technique [18]. The amplitude of the PPs were approximately 2.5 mV. They occurred rhythmically at intervalls of 6.5 s. The same intervals were seen between individual polyphasic spikes of the bipolarly recorded EUGs. Simultaneously a corresponding number of UDs emerged from the ureteric orifice. These observations indicated that during a diuresis all PPs originating from the proximal end of the pelvis were propagated toward the lower ureter without any blockade. In some animals which did not receive intravenous infusion, the interval between PPs was usually a multiple of the interspike interval of the EUGs.

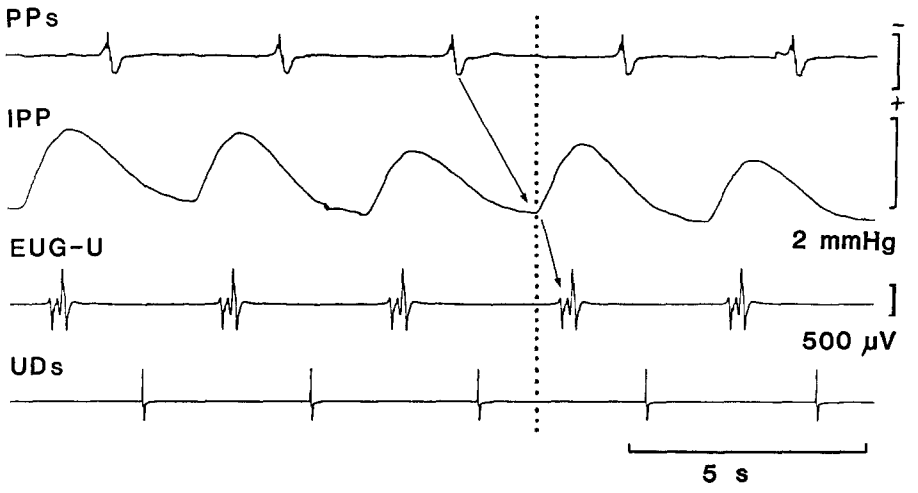

Fig. 3. Simultaneous recording of PPs, intrapelvic pressure (IPP), EUG-U and UDs from another animal. The PPs were recorded with an AC amplifier havings 0.01 s time constant. *Vertical dotted line* indicates the onset of increase of the IPP

The temporal relation between PPs and systolic changes of the IPP is shown in Fig. 3. These PPs (top trace) were recorded from a different animal with another AC mode (0.01 s time constant). The recording site of the PPs is shown by filled circle indicated by upward arrow in Fig. 1B. The PPs thus recorded showed a biphasic negative-positive spike, and occurred regularly. They revealed an one-to-one relationship with rhythmic changes of the IPP consisting of a pressure increase and decrease (second trace). The onset of the spike of the PPs distinctly preceded the onset of an increase in the IPP (dotted line) by approximately 2 s in this instance.

The amplitude of spikes of PPs recorded from different animals with the AC mode (0.01 s time constant) was as large as 77–500 μV (mean = 280.1 μV, SD = 156.0 μV, n = 8). The interval of the PPs was 2.5–6.8 s (mean = 4.22 s, SD = 1.56 s, n = 9). These values are compatible with 1.88–4.73 s of PPs recorded from in vitro kidneys during intrapelvic infusion [13]. The time interval between the preceding PP and the increase of the IPP was 0.3–2.0 s (mean = 1.23 s, SD = 0.75 s, n = 9). Ten recording sites of the PPs were represented by filled circles in Fig. 1B. They were mostly located in the proximal end of the renal pelvis. Some of the sites were also found in the orifice to the pelvic diverticulum. These locations of the recording sites approximately correspond to the distribution of histologically identified pacemaker cells in the pelvis of unicalyceal kidneys including those of dogs [6].

Discussion

We have introduced a simple acupuncture needle electrode for stable recording of PPs for ureteral peristalsis from in vivo kidneys of the dog. The PPs recorded with this electrode, which consisted of initial slow and succeeding spike potentials, were quite similar, in every respect, to those recorded from immobilized in vitro preparations in previous studies.

The use of the electrode for recording such slow and spike potentials from a localized small region of excitable tissues was suggested by a recent study [15], in which extracellular field and spike potentials were recorded in the brainstem of alert animals with the same type of electrodes as used in the present study.

The acupuncture needle electrode allowed more detailed analysis of the effects of changes in the autonomic nerve activity or systemic blood pressure on the pacemaker activity. For instance, stimulation of the renal nerve (splanchnic, hypogastric, pelvic and vagus nerves as well) causes acceleration of ureteral peristalsis [1, 3, 8]. Similar facilitatory effects of the renal nerve on the ureteral pacemaker might be expected, since the nerve fibers terminate in the muscle layer of the calyx and pelvis, besides in upper and middle parts of the ureter and vessels within the kidney [12, 16]. In another study [17] using the same method for recording PPs as in the present study, we observed that renal nerve stimulation induces acceleration of pacemaker discharge and that this acceleration is attributed mainly to steepening and shortening of the initial slow negative potential of the PP.

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