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AFFERENT DISCHARGES FROM ARTERIAL MECHANORECEPTORS IN THE KIDNEY OF THE RABBIT

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SUMMARY

1. Afferent discharges were observed in dissected filaments or single nerve fibres of renal nerves in the rabbit.

2. Increasing the arterial perfusion pressure in excised kidney preparations caused an increase in afferent discharge rate. Increasing the venous pressure was without effect. Receptor discharge patterns were compatible with those of the slowly adapting type.

3. *In vivo*, increasing the systemic blood pressure by means of the sinus reflex caused an increase in afferent discharge rate. Afferent discharge patterns showed no synchronicity with heart beat, irrespective of the blood pressure levels.

4. It is suggested that mechanoreceptors are present around the arterial walls in the kidney and that they send information about blood pressure levels in the renal artery to the central nervous system.

INTRODUCTION

It is well known that the kidney is abundantly supplied with autonomic nerves from thoracolumbar sympathetics. The possibility that the kidney might contain afferent fibres has been considered by many workers. In 1967, Åström & Crafoord observed an increase in afferent discharge rates recorded from the renal nerve in rats when the renal vein pressure was elevated or when I.V. infusion of saline solution was given. They concluded that an adequate stimulus for the mechanoreceptors responsible for this activity was increased kidney tension and, perhaps, also distension of the intrarenal veins. The same results were also reported on cats (Åström & Crafoord, 1968; Beacham & Kunze, 1969) and on dogs (Ueda, Uchida & Kamisaka, 1967).

On the other hand, Ábrahám (1953 and 1969) presents histological

evidence for the presence of baroreceptors in the wall of the renal arteries. His reports suggest the possibility that mechanoreceptors may exist in arterial wall in the kidney, in addition to those reported by Åström & Crafoord (1967, 1968), Beacham & Kunze (1969) and Ueda *et al.* (1967).

The present paper is concerned with afferent impulse discharges from renal arterial mechanoreceptors.

METHODS

Experiments were performed on thirty-eight rabbits. Adult animals of either sex were used. The animals were anaesthetized with urethane (1 g/kg) injected subcutaneously. Two different types of experiments were conducted; perfusion experiments on excised preparations, and experiments *in vivo*. In the perfusion experiments, both kidneys along with the renal nerve trunks were excised from the body. Oxygenated Locke's solution was delivered by catheter from a temperature controlled (25° C) reservoir into the renal artery. The perfusion pressure was controlled by a pump connected to the reservoir and was recorded on a kymograph camera along with the afferent discharges. The solution entered through the renal artery, circulated in the kidney, and exited through the renal vein. During the experiments *in vivo*, arterial pressure was recorded from a catheter placed in the cardiac end of right common carotid artery. Injections were made from a catheter in right jugular vein.

Afferent impulse discharges were recorded from filaments of renal nerves. However, in many experiments they were recorded from single afferent fibres which were dissected from the peripheral cut end of renal nerve trunks by the technique described by Tasaki (1953). All dissected single nerve fibres were examined by a high power microscope and in some cases photomicrographs were taken to measure the diameters. To localize the receptive fields, a pressure stimulus (nylon hair) was used.

After placing the dissected nerve fibre or a renal nerve filament on the bipolar silver–silver chloride wire electrodes, afferent impulse discharges were recorded with conventional electrophysiological equipment.

RESULTS

Afferent impulse discharges from the renal nerve trunk. When a renal nerve trunk of an excised kidney preparation was placed on the recording electrodes and perfusion pressure was kept at 0 mm Hg, no resting discharge could be detected. As the perfusion pressure was raised progressively, afferent impulse activity steadily increased suggesting the presence of mechanoreceptors within the kidney.

Unitary afferent discharges from renal nerve fibres. Unitary afferent discharges were recorded from a small number of nerve fibres dissected from renal nerve trunks. While recording the afferent discharges, all fibres which showed no response to an increase in arterial perfusion pressure were discarded. Some of these showed a burst of discharge after manual compression of the pelvic area of the kidney. In the first experi-

ment, the effects of an increase in perfusion pressure in the renal artery and vein on the afferent discharge rate were compared. As shown in Fig. 1, when the perfusion pressure was increased in the renal artery, frequent unitary discharges were observed. However, no afferent discharge accompanied an increase in perfusion pressure in the renal vein. This experiment demonstrated that the receptors activated by the increase in perfusion pressure were situated in the renal arterial side.

In the next experiment the relationship between perfusion pressure and afferent discharge rate was studied. Fig. 2 shows the effect of an increase in perfusion pressure on the discharge rate in two separate afferents. An

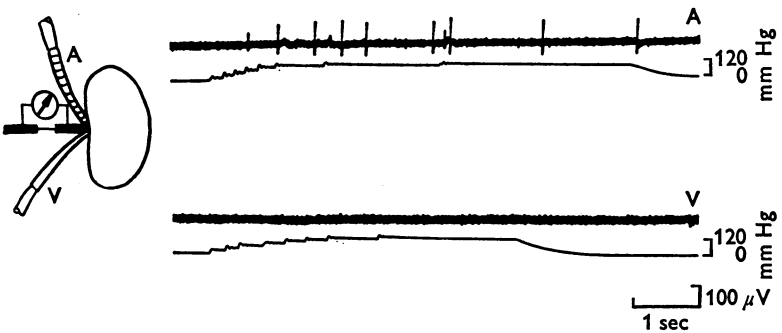

Fig. 1. Effect of an increase in perfusion pressure in renal artery and vein. Rabbit. Isolated kidney. Left: schematic illustration of excised kidney preparation. A, renal artery; V. renal vein. Right: upper trace (A), perfusion through renal artery to renal vein; lower trace (V), perfusion through renal vein to renal artery. Upper trace in each set of tracings shows afferent discharge and lower curve shows perfusion pressure.

increase in perfusion pressure as well as a mechanical stimulus applied on the surface of the kidney in the area of the receptive field elicited an increase in discharge rate. Fig. 3*A* also shows an increase in firing rate of a single myelinated afferent fibre in accordance with an increase in perfusion pressure. The firing pattern of these units indicates that the adaptation of the receptors is slow. For instance, as shown in Fig. 3*A*, when the pressure was increased from 0 to 150 mm Hg, the interspike interval was 270 msec, and 24 sec later it was 300 msec. These are mean values obtained from ten intervals at the beginning and at the end of the increased perfusion pressure. The difference between these two mean intervals is rather small, although a small lengthening was noted in the latter. The time course of firing rate illustrated in Fig. 3*B* also indicates that the receptors belong to the slowly adapting type.

In Fig. 4, the relationship between perfusion pressure and afferent discharge rate was plotted on four different fibres. It was observed that

the higher the intra-arterial pressure, the higher the discharge rate. As the cut end of the renal vein was kept open, it is assumed that the pressure in the renal vein must have been very low throughout the experiment. It is reasonable to assume that the above mentioned activity originated from mechanoreceptors in or near the renal arterial wall.

Localization of renal arterial receptors. To prove the existence of mechanoreceptors around the renal arterial wall, the following experiments were conducted. As shown in Fig. 5*A*, the ventral and dorsal surfaces of the kidney were cut off at the cranial portion. After this procedure, branches

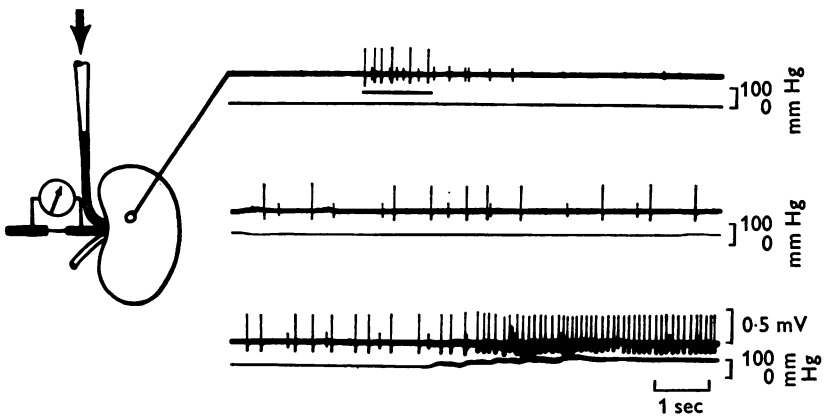

Fig. 2. Effect of an increase in perfusion pressure in renal artery on the afferent discharge rate. Rabbit. Isolated kidney. Left: schematic illustration of excised kidney preparation. Open circle shows area sensitive to mechanical stimulation of the surface of the kidney. Right: top, afferent discharge elicited by mechanical stimulation by a nylon hair applied on the surface of the kidney; middle, afferent discharge recorded while kidney was perfused by 50 mm Hg; bottom, perfusion pressure was increased from 50 to 100 mm Hg. Upper curve in each figure shows afferent discharge and lower curve shows perfusion pressure. Horizontal bar in the top set of tracings shows the time of mechanical stimulation.

of the interlobar arteries were easily recognized in the kidney slice. Throughout these procedures the kidney was often soaked by oxygenated Locke's solution. Spontaneous single unit discharges were observed in this preparation. Under the dissection microscope, a light mechanical stimulus by a nylon hair applied to the receptive field evoked a train of afferent discharges. As indicated in Fig. 5*A* (dotted area) a receptive field area 4 mm in length was found along the interlobar artery. No response was observed on application of the stimulus to any other place outside the dotted area. In Fig. 5*B*, additional evidence suggesting the existence of mechanoreceptors in the arterial wall is presented. In this experiment, the renal artery and its branches (interlobar arteries) with the renal vein was

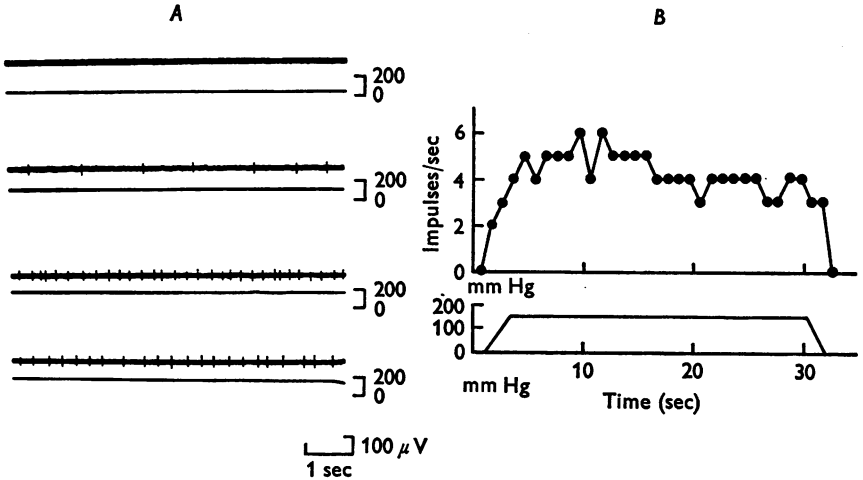

Fig. 3. Effect of an increase in perfusion pressure in renal artery on the afferent discharge rate and its adaptation. Rabbit. Isolated kidney. *A*: top, perfusion pressure at 0 mm Hg; second part, perfusion pressure at 100 mm Hg; third part, immediately after an increase in perfusion pressure to 150 mm Hg; fourth part, 13 sec after the end of third set of tracings. *B*: afferent discharge rate in response to constant perfusion pressure. Upper graph, discharge rate; lower graph, perfusion pressure.

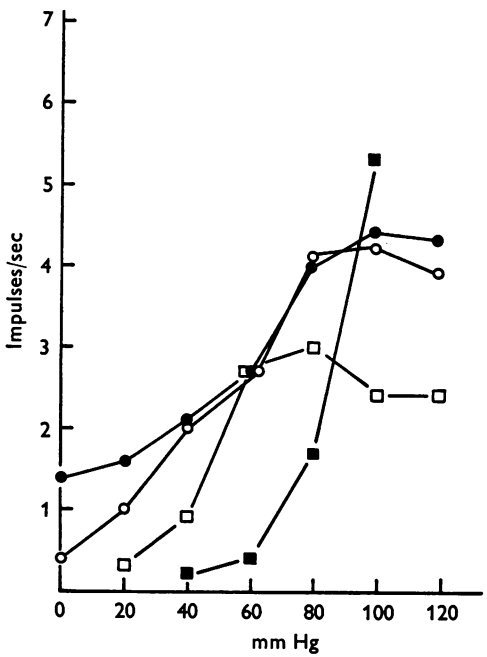

Fig. 4. Relation between afferent discharge rate and perfusion pressure in four different units. Rabbit. Isolated kidney.

excised from the kidney along with a renal nerve trunk. Afferent impulses were recorded from a fine filament dissected from the nerve trunk, and a small area sensitive to mechanical stimuli was found on the wall of the interlobar artery. Further, pressure stimulation by a nylon hair applied to the excised cortex of the kidney also evoked a burst of afferent discharges in the renal nerve (Fig. 5*B*).

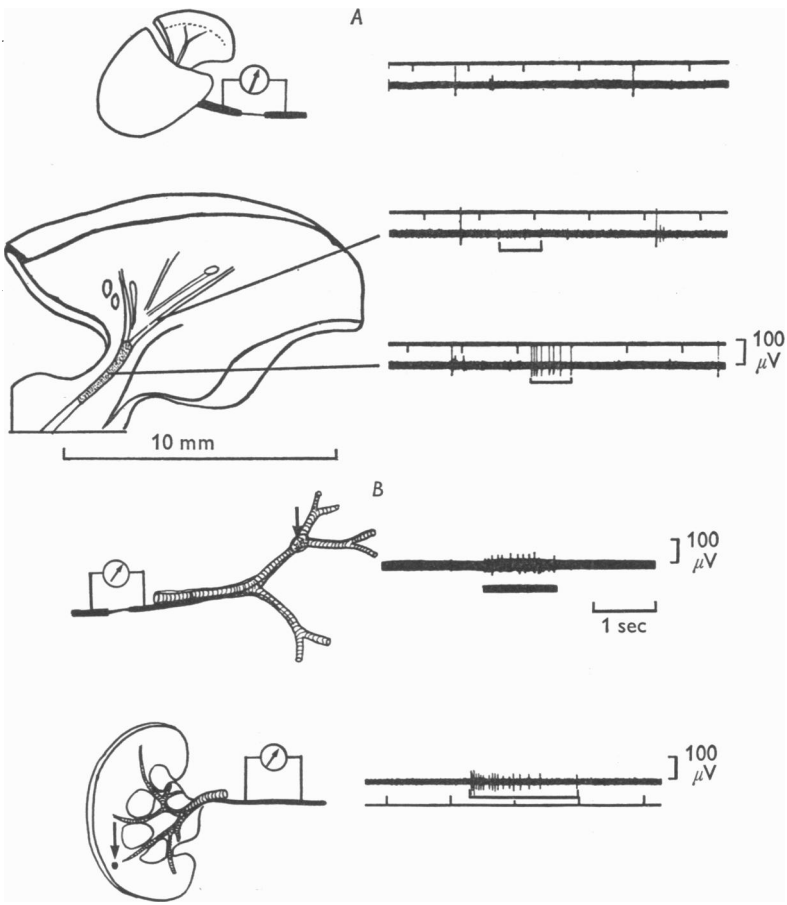

Fig. 5. Location of renal mechanoreceptors. Rabbit. Isolated kidney. *A*: location of receptors on the interlobar artery in excised kidney preparation. Left: schematic illustration of preparation. Dotted area on the interlobar artery shows the area sensitive to mechanical stimulation by a nylon hair. Right tracings show afferent discharge. Top, spontaneous discharge; middle, mechanical stimulation outside the receptive field; bottom, mechanical stimulation delivered to the receptive field. Horizontal bars show the time of stimulation. *B*: upper right part of figure shows location of receptors on the interlobar artery in excised blood vessel preparation; lower tracings, location of receptors in the cortex of the kidney. Arrows indicate the area sensitive for mechanical stimulation.

The effect of anoxia on the afferent discharge rate. The effect of anoxia on the firing rate of arterial mechanoreceptors was tested in the perfused kidney preparation. In four out of five experiments perfusion with anoxic Locke's solution caused a slight increase in the rate of discharge.

Afferent impulse discharges recorded in vivo. To study the relationship between the activity of renal arterial mechanoreceptors and blood pressure, afferent discharges were recorded *in vivo*. Afferent discharges synchronous

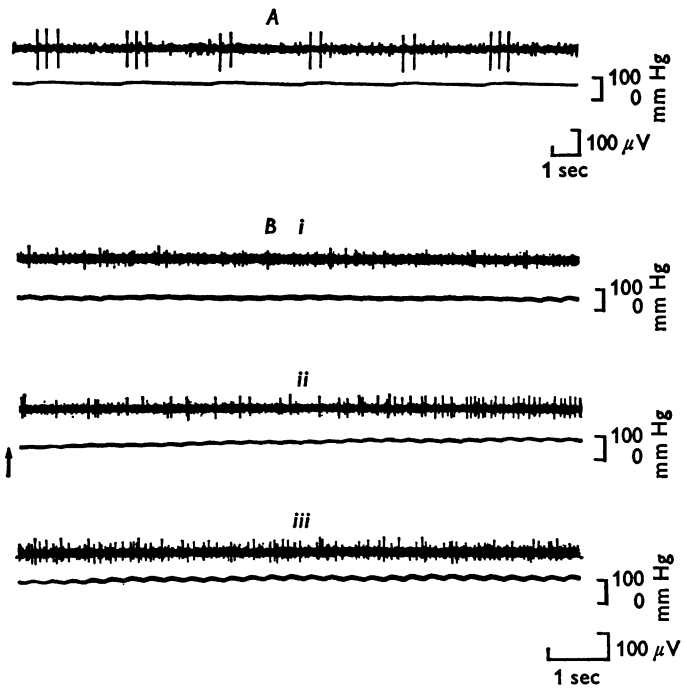

Fig. 6. Afferent discharges from renal arterial mechanoreceptors recorded *in vivo*. Rabbit. Intact kidney. *A*: spontaneous discharge synchronous with heart beats. *B*: effect of increase in blood pressure induced by sinus reflex. (i), control; (ii), arrow shows the time of clamping left common carotid artery; (iii), continued from (ii). Upper curve shows afferent discharge. Lower curve shows blood pressure recorded from cardiac end of right common carotid artery.

with heart beats are presented in Fig. 6*A*. However, this is an exceptional case. Usually, as shown in Fig. 6*B* (top), spontaneous afferent discharges asychronous with the heart beats were observed during normal levels of blood pressure (*ca.* 80 mm Hg). After application of a clamp to the left common carotid artery, an increase in systemic arterial blood pressure and pulse pressure was caused by the sinus reflex. In association with the increase in blood pressure, the units showed an increase in discharge rate.

An increase in systemic blood pressure after the I.V. injection of 10 μg(−)-adrenaline or a large amount of saline (20 ml.) also caused an increase in discharge rate. On the other hand, a decrease in firing rate was observed when the abdominal aorta was clamped above the renal arteries. Throughout these experiments the volleys always remained asynchronous with the heart beats.

DISCUSSION

The records presented in this paper offer physiological evidence that there is a receptor which is sensitive to change in the renal arterial pressure in the kidney. This receptor responded with an increased afferent discharge rate when the arterial pressure in the kidney was increased and did not respond to an increase in venous pressure. The responses in afferent discharge rate not only followed the change in perfusion pressure in the excised kidney, but also followed reflex changes of arterial pressure as elicited by the sinus reflex, *in vivo*.

Further, it was observed that the firing rates recorded from these receptors were approximately proportional to the intrarenal arterial pressure in the excised kidney preparation. In addition, it was found that some mechanoreceptors were actually situated around the interlobar arterial wall. As mechanical stimulation of the renal cortex also evoked afferent discharges, it is possible to suppose that the mechanoreceptors were located not only around the wall of interlobar arteries but also around those of smaller arterioles in the cortex. Although the presence of such receptors has been denied (Ueda & Uchida, 1968), this study offers the first positive evidence supporting the existence of baroreceptors in the renal arterial wall which respond to arterial pressure in the kidney. Ábrahám (1969) described free or encased loose coils which arose from the terminal branching of thick varicose fibres in the adventitia of the human renal artery which he designated baroreceptors, as judged by their structure. He also reported the existence of glomerular formations and some terminal structures somewhat similar to Krause's or the Pacinian corpuscles (1953). His observations support the presented experimental results, and it may be stated that there is a type of baroreceptor located around the renal arterial wall. However, in contrast to the discharges of baroreceptors in the wall of carotid sinus and aortic arch, afferent discharges from these receptors, in general, showed no synchronicity with heart beat.

From observations of the effect of anoxia on the firing rate of these receptors, it is recognized that these receptors are not as sensitive as chemoreceptors in the carotid body. However, anoxia did elicit a slight increase in the firing rate of these receptors.

Apart from sino-aortic and cardio-pulmonary baroreceptors, activity of baroreceptors located elsewhere in the vascular system has been studied by only a few workers (Gammon & Bronk, 1935; Niijima & Winter, 1968). The function of such baroreceptors is unclear.

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