Effects of Increased Ureteropelvic Pressure on Fluid and NaCl Absorption Across the Jejunum

Shunji SUZUKI, Nobuhisa UEMURA, Hironobu MORITA, and Hiroshi HOSOMI

Department of Physiology, Kagawa Medical School, Kagawa, 761-07 Japan

Abstract The aim of the present study was to elucidate the effects of an increased ureteropelvic pressure (UPP) on the net jejunal fluid, Na⁺, and Cl⁻ absorption in anesthetized dogs. UPP was changed under hydrostatic pressure with warmed Ringer’s solution. At a UPP of 0 mmHg, the net jejunal fluid, Na⁺, and Cl⁻ absorption were 10.1 ± 0.5 ml, 2.4 ± 0.1, and 2.0 ± 0.1 mEq, and were significantly reduced to 5.9 ± 0.4 ml, 2.0 ± 0.1, and 1.6 ± 0.1 mEq, respectively, by an increase in UPP to 60 mmHg. After lowering the UPP to 0 mmHg, the net absorption recovered to the control values. The same experiments were performed after ipsilateral renal denervation. Ipsilateral renal denervation completely abolished this response. This result suggests that the afferent pathway of this response is the renal nerves. We also assessed the validity of the method using a jejunal loop by examining the effects of repetition of the absorption experiment on the net absorption. The net absorption was not altered by 6 times repetition of the absorption experiment. To determine the collection ratio, phenol red was used in the first and sixth absorption experiments. The collection ratios were 92.2 ± 1.1 and 90.3 ± 0.9%, respectively. There was no significant difference in collection ratio between the first and sixth values. This is the first report in which an increased UPP was found to inhibit the net jejunal fluid, Na⁺, and Cl⁻ absorption.

Key words: increased ureteropelvic pressure, jejunal loop, jejunal fluid absorption, jejunal NaCl absorption, renal denervation.

The ureteral obstruction induces the increase of ureteropelvic pressure (UPP) and impairment of urinary production, which causes the increase of body fluid. This might be compensated by many mechanisms in the kidney. Francisco et al. [1] reported that ureteral occlusion produced reflex vasoconstriction in the contralateral kidney. Kopp et al. [2] demonstrated that raising the ureteral pressure
increased the ipsilateral renal blood flow and renin secretion rate, and decreased the contralateral renal blood flow. The increases of ipsilateral renal blood flow and renin secretion rate may contribute to the increase of filtrate pressure in the glomerulus and excretion of urine, then decrease body fluid to the normal level. The intestine as well as the kidney is an important organ for maintaining body fluid homeostasis. The kidney excretes water and electrolytes, whereas the intestine absorbs and/or secretes them. Because body fluid homeostasis is mainly controlled by the kidney and intestine, there is a possibility that the increased UPP influences intestinal absorption. To test this hypothesis, the jejunal net fluid, Na\(^+\), and Cl\(^-\) absorption were examined under conditions of an increased UPP.

METHODS

The experiments were conducted on 19 mongrel adult dogs of both sexes weighing 8–12 kg. The dogs were fed on commercial dog food at 30 g/(kg body wt. · day) (Oriental Yeast, type DS) and water ad libitum. They were deprived of food for 24 h prior to the experiments but had continued free access to water. The dogs were anesthetized with pentobarbital sodium (25 mg/kg, i.v.), and supplemental doses were added throughout the experiments to maintain anesthetic level. The animals were intubated with an endotracheal tube and mechanically ventilated to maintain the arterial pH at between 7.35 and 7.45. Catheters were inserted into the femoral artery for monitoring the systemic arterial pressure, the femoral vein for blood sampling and infusion of solutions. Through the left side thoracotomy, the left atrial catheter was inserted for monitoring the left atrial pressure. After making a retroperitoneal flank incision, a catheter was inserted into the ureter to a position 5 cm from the inferior extremity of the kidney in order to change the UPP under hydrostatic pressure with warmed Ringer's solution. Through a midline laparotomy, a 30-cm jejunal loop, of which the oral end was 10 cm distal from the duodenal fossa, was cannulated at the oral and anal ends. The proximal tube was used for the injection of test fluid, and the distal tube for fluid collection. Each loop cavity had been rinsed with warmed test fluid. After the implantations, the chest, abdomen, and flank incision were closed, and the catheters and cannulas were exteriorized. The systemic arterial pressure and left atrial pressure were continuously monitored by connecting the previously implanted catheters to the Statham P23 ID transducers. Heart rate was monitored by cardiographometer (San-ei, N4778) triggered by arterial pressure wave. Throughout the experiments, the left atrial pressure was maintained at the preoperative level by intravenous infusion of saline.

A 30-min equilibration period was observed before commencing the experiments. To examine the net fluid, Na\(^+\), and Cl\(^-\) absorption, test fluid (30 ml, 37°C) was injected into the jejunal loop from the proximal tube and allowed to remain in the loop for 15 min (stop-flow absorption experiments). It was then collected from the distal tube over the following 10 min by gravity drainage. The test fluid had the
following composition (in mEq/l): Na\(^+\), 130; K\(^+\), 4; Ca\(^{2+}\), 3; Cl\(^-\), 109; CH\(_3\)COO\(^-\), 28; and glucose, 50 g/l. The Na\(^+\) and Cl\(^-\) concentrations of the injected and collected fluids were measured with a flame photometer and Cl counter (Hitachi, No. 750, Tokyo). The volume of collected fluid was also measured. The net absorption of fluid, Na\(^+\), and Cl\(^-\) was calculated as the difference between the absolute values for the injected fluid and the absolute values for the collected fluid.

Protocols. The dogs were divided into 3 groups. In the first group \((n = 8)\), absorption experiments were repeated 4 times. The interval between each successive experiment was 10 min. The first absorption experiment was performed under the condition of UPP at 0 mmHg. In the second absorption experiment, the UPP was increased from 0 to 60 mmHg for 25 min. In the first 15 min of this period, the test fluid was poured into and kept within the jejunal loop, and in the last 10 min the fluid was drained from the jejunal loop. After decreasing the UPP from 60 to 0 mmHg, we repeated the absorption experiment 2 more times. Before and after each absorption experiment, the blood samples were taken for measurement of the plasma Na\(^+\), K\(^+\), Cl\(^-\) concentrations and osmolality. The plasma osmolality was determined by an osmometer (FISKE, OTTM OSMOMETER).

In the second group \((n = 5)\), the absorption experiments were performed when unilateral UPP was maintained at 0 then 60 mmHg. After unilateral renal denervation, the absorption experiments were repeated when denervated-side UPP was maintained at 0 and 60 mmHg.

In the third group \((n = 6)\), the absorption experiment was repeated 6 times in order to examine the effects of repetition of the absorption experiment on the net absorption of fluid, Na\(^+\), and Cl\(^-\). In the first and last absorption experiments, the test fluid with phenol red (25 mg/l) as an unabsorbable volume marker was used to examine the accuracy of fluid collection. We compared the collection ratios of the fluid between the first and last absorption experiments. The collection ratio of fluid was calculated by dividing the measured drained volume by the estimated drained volume. The estimated drained volume was calculated as follows:

Estimated drained volume

\[= \text{poured volume (30 ml)} \times \text{phenol red concentration in poured solution/phenol red concentration in drained solution.}\]

The phenol red concentration was determined with a spectrophotometer (558 nm, pH 8.4). The pH of the drained fluid was corrected to 8.4 using 0.1 M tris-(hydroxymethyl)aminomethane buffer. The estimated drained values for Na\(^+\) and Cl\(^-\) were also calculated from the estimated drained volume multiplied by the Na\(^+\) and Cl\(^-\) concentrations in the drained fluid.

Statistical analysis. All values presented here are reported as means±S.E. All data from each experiment were analyzed by two-way analysis of variance for repeated measurements. When the \(F\) ratio exceeded the critical value, Dunnett's multiple testing procedure was applied to determine the significance of the differences between the data. A \(p < 0.05\) was taken as the criterion for the significance of difference.

Vol. 42, No. 1, 1992
RESULTS

Effects of an increased UPP on net jejunal absorption

When the UPP was 0 mmHg in the first absorption experiment (control experiment), the net fluid absorption was 10.1 ± 0.5 ml (Fig. 1). The Na⁺ concentration in the drained fluid was significantly decreased from 130 to 75.0 ± 3.2 mEq/l, and the Cl⁻ concentration from 109 to 65.3 ± 2.9 mEq/l. When the UPP was increased to 60 mmHg in the second absorption experiment, the net fluid absorption was significantly decreased by 41.4 ± 3.5% of the control (Fig. 1). The Na⁺ and Cl⁻ concentrations in the drained fluid decreased to the same extent as in the first absorption experiment. The net absorption of Na⁺ and Cl⁻ was significantly depressed by the increase in UPP to 60 mmHg. After the UPP had again been lowered to 0 mmHg, the net fluid, Na⁺, and Cl⁻ absorption recovered to the control values. Throughout the experiments, no significant changes in mean arterial pressure, left atrial pressure, heart rate, plasma Na⁺, K⁺, Cl⁻ concentrations, and plasma osmolality were observed (Fig. 2).

Effect of ipsilateral renal denervation on the decreased net jejunal absorption induced by the increased UPP

Unilateral renal denervation itself increased the net fluid, Na⁺, and Cl⁻ absorption (Fig. 3). Before unilateral renal denervation, the increased UPP elicited the decreases in net fluid, Na⁺, and Cl⁻ absorption, which were comparable to the responses in Fig. 1. After unilateral renal denervation, the decrease in the net fluid,

![Image of bar graphs showing net fluid, Na⁺, and Cl⁻ absorption across the jejunum while the UPP was changed. Data are expressed as the means ± S.E. (n = 8). *p < 0.05, compared to the control.]

Fig. 1. Net fluid, Na⁺, and Cl⁻ absorption across the jejunum while the UPP was changed. Data are expressed as the means ± S.E. (n = 8). *p < 0.05, as compared to the control.

*Japanese Journal of Physiology*
JEJUNAL ABSORPTION AND PELVIC PRESSURE

Fig. 2. Effects of an increased UPP on the mean systemic arterial pressure (mSAP), heart rate (HR), left atrial pressure (LAP), plasma Na\(^+\) concentration, plasma K\(^+\) concentration, plasma Cl\(^-\) concentration, and plasma osmolality. Data are expressed as the means±S.E. (n = 8).

Fig. 3. Effect of ipsilateral renal denervation on the decreased net jejunal absorption induced by the increased UPP. Data are expressed as the means±S.E. (n = 5). *p < 0.05, as compared to the control.

Vol. 42, No. 1, 1992
Na\(^+\), and Cl\(^-\) absorption induced by the increased UPP was completely abolished.

**Effects of repetition of the absorption experiment on jejunal absorption**

Figure 4 summarizes the effects of repeated experiments on the fluid, Na\(^+\), and Cl\(^-\) absorption. There was no significant effect of the repetition on the net absorption of fluid, Na\(^+\), and Cl\(^-\). The collection ratio was 92.2±1.0% for the first absorption experiment and 90.3±0.9% for the sixth absorption experiment. There was no significant difference in collection ratio between the first and sixth values.

**DISCUSSION**

The major findings of the present study are that an increase in UPP decreases the net jejunal absorption of fluid, Na\(^+\), and Cl\(^-\) and the afferent pathways of this response are the renal nerves.

Stop-flow absorption experiments employing a jejunal loop represent an effective method for evaluating the net jejunal absorption. We were able to estimate the net absorption across the jejunum with an intact innervation and intact blood supply. In the present study, we repeated the absorption experiment 6 times and found that the net absorption of fluid, Na\(^+\), and Cl\(^-\) was constant. In addition, there was no significant difference in collection ratio examined with phenol red between the first and sixth values. These results imply that absorption experiments can be repeated at least 6 times.

The ureteral obstruction induces the increase of UPP and the decrease of glomerular filtration rate (GFR) [3]. The decrease of GFR causes increase of body fluid. When the UPP was increased to 60 mmHg, the net jejunal absorption

*Japanese Journal of Physiology*
of fluid, Na\(^+\), and Cl\(^-\) was significantly reduced. After decreasing the UPP to 0 mmHg, the net jejunal absorption of fluid, Na\(^+\), and Cl\(^-\) recovered to the control values. This suggests that there is an interaction between the kidney and jejunum, which may compensate the increase of body fluid.

To examine the afferent pathways of the decreased net absorption in response to the increased UPP, the net jejunal absorption was examined before and after unilateral renal denervation. Renal denervation completely blocked the decrease in the net jejunal fluid, Na\(^+\), and Cl\(^-\) absorption induced by increased UPP. This result suggests that the afferent pathways of this response are the renal nerves. There are many reports of the effects of an increased ureteral pressure. Most of these effects appear to be mediated by renal baroreceptors. Niijima [4] found that when the elevation of the intrapelvic pressure was less than 20 mmHg, no change in discharge rate of the renal afferent nerves was observed, but when the elevation was over 30 mmHg, an increase in discharge rate was always observed. Accordingly, the raising of UPP to 60 mmHg employed in this study was sufficient to stimulate the renal baroreceptors.

The afferent signal from the renal baroreceptor is believed to travel via the afferent renal nerves to the spinal cord with central connections above T\(_6\) [1]. Ciriello and Calaresu [5] reported that stimulation of the afferent renal nerves evoked responses bilaterally in the paramedian reticular nucleus and lateral tegmental field of the medulla and in the lateral preoptic nucleus, the lateral hypothalamus, and the paraventricular nucleus of the hypothalamus. Thus, the renal afferent information is related to well-defined regions of the medulla and hypothalamus presumably involved in cardiovascular regulation and body sodium and water balance [6, 7].

Unilateral renal denervation itself increased the net fluid, Na\(^+\), and Cl\(^-\) absorption and the LAP was decreased from 8.4±1.1 to 7.3±1.0 (cmH\(_2\)O) at a UPP of 0 mmHg despite drip infusion of saline. Acute renal denervation is followed by an increase in the excretion of sodium, chloride, and water [8], and the decrease of LAP might be induced by increased excretion. Considering a previous study [9] demonstrating that unloading of the cardiac volume receptor increases the jejunal fluid transport, the increase of net jejunal absorption observed after unilateral renal denervation might depend on the increase on urinary excretion.

There are several candidates for the efferent pathways of the decreased net jejunal absorption induced by the increased UPP. Caverson and Ciriello [10] demonstrated that stimulation of the renal afferent nerves resulted in an increase in the plasma concentration of vasopressin. Dennhardt et al. [11] found that vasopressin decreased the sodium and water absorption across the colon but did not affect the jejunal absorption. In the present study, there were no significant changes in systemic arterial pressure, heart rate, and plasma osmolality during the experiments. Thus, vasopressin may contribute to maintain body fluid homeostasis by inhibiting fluid absorption in the colon, but is unlikely to be involved in the mechanisms of the response in the present study.
Kopp et al. [2] reported that raising the ureteral pressure to 63±3 mmHg increased the ipsilateral renin secretion rate as well as renal blood flow. Levens [12] observed that at low doses, angiotensin II stimulates Na⁺ and water absorption from all intestinal areas, and at high doses, angiotensin II inhibits the absorption. In the present study, no significant changes in systemic arterial pressure, heart rate, and plasma osmolality were noted during the experiments. We can exclude the effect of angiotensin II on inhibition of the jejunal absorption observed in the present study.

Outputs from the central nervous system probably regulate the jejunal absorption via the autonomic nervous system [9, 13–16] or humoral factors [17–19]. It is a well-known fact that inhibition of the α₂-adrenergic effect decreases the intestinal absorption [17, 18], and stimulation of the cholinergic nerves augments the intestinal secretion [13], resulting in inhibition of the net intestinal absorption. The afferent signal from the kidney with a high UPP could thus reflexively inhibit the α₂-adrenergic effect and/or stimulate the cholinergic nerves. Further research on these phenomena is clearly required.

To the best of our knowledge, this is the first report to demonstrate that an increased UPP inhibited the net jejunal absorption of fluid, Na⁺, and Cl⁻. This interaction may be mediated by the renal afferent nerves and play an important role in body fluid homeostasis.

This study was supported in part by The Salt Science Research Foundation (1991), a Grant from Japan Cardiovascular Research Foundation (1991), and a Research Grant from the Ministry of Health and Welfare (1991).

REFERENCES


*Japanese Journal of Physiology*


Vol. 42, No. 1, 1992