ANALYSIS OF CHANGES IN PRESSURE IN THE PANCREATIC DUCTS

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UDC 612.34.014-41-087.78

The maximal pressure in the ducts of the pancreas is 25-45 cm water [3, 6, 8]. In the ducts of the salivary glands, on the other hand, the pressure is much higher and may even exceed the arterial level [5]. The reasons for the relatively low pressure in the pancreatic ducts have been inadequately studied. Some authors have explained it by inhibition of secretion when the pressure in the ducts of the gland is maximal [6], while others attach great importance to the outflow of juice through the lymphatic vessels of the pancreas [2].

The object of the present investigation was to analyze the factors determining the level of the pressure in the pancreatic ducts.

EXPERIMENTAL METHOD

Experiments were carried out on 19 cats anesthetized with chloralose (80 mg/kh), intravenously).

The secretion of the pancreas was evoked by the introduction of 2-5 ml of a 0.25-0.5% solution of hydrochloric acid into the duodenum or by intravenous injection of 3-6 ml of secretion prepared by the method of Bayliss and Starling [1].

A polyethylene cannula was introduced into the pancreatic duct through an incision in its walls. A thin measuring tube was connected to the cannula and could be placed in either the vertical or the horizontal position without disturbing its connection with the duct. In the vertical position of the tube, the pressure was recorded in the ducts of the gland in millimeters of juice. The increase in pressure per min in millimeters of the scale was counted as the rate of secretion ("vertical" secretion). With the tube in the horizontal position the rate and volume of secretion in the conditions of the free outflow of juice were measured in millimeters of the scale ("horizontal" secretion).

EXPERIMENTAL RESULTS AND DISCUSSION

The secretion of juice by the pancreas in response to the intravenous injection of secretion followed a peak-like course with a maximum at 2-5 min. As a rule, the acid solution was more prolonged but less intensive.

The pressure in the pancreatic ducts was determined by the intensity of the secretion. After injection of secretion, the pressure in the ducts reached 170-260 mm in the course of 6-10 min. During acid secretion, the pressure in the ducts rose only to 93-155 mm. In these cases, as Fig. 1 shows, the pressure remained for a long time (up to 30 min) at a maximal level.

The rate of "vertical" secretion gradually fell to 0 with an increase in the pressure in the duct, and this could be interpreted as inhibition of secretion. However, when the manometer was moved into the horizontal position an intensive additional outflow of juice from the duct was observed (Fig. 1). On comparing the volume of secretion obtained in response to the same dose of stimulus in the conditions of a free outflow of juice, and when the pressure in the ducts was raised, closely similar values were found. As Table 1 shows, the total volume of secretion in the conditions of increasing pressure within the pancreatic ducts not only was not reduced below the level of the volume of juice secreted in the conditions of free outflow, but in some experiments it actually exceeded this level.

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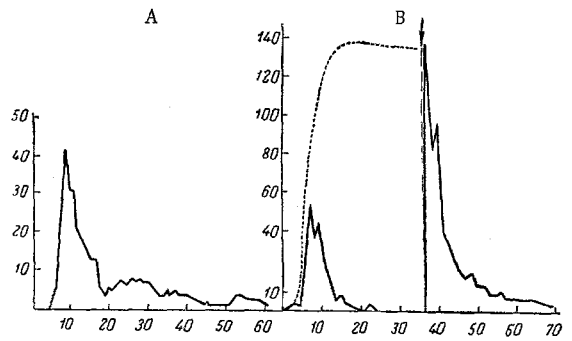

Fig. 1. Dynamics of juice secretion by the pancreas in the conditions of the free outflow of juice (A) and increased pressure in the pancreatic ducts (B) in response to the introduction of 5 ml of 0.25% hydrochloric acid solution into the duodenum. Each point on the continuous line represents the volume of juice secreted every minute (in mm of the scale). The broken line gives the pressure in the duct (in mm juice). The arrow indicates the moment when the manometer was moved into the horizontal position. Abscissa — time (in min); ordinate — volume of juice (in mm of the scale; A); pressure (in mm juice; B).

TABLE 1. Volume of Pancreatic Juice Isolated in Response to the Same Dose of Stimulus in Conditions of Free Outflow of Juice and of Increased Pressure in the Pancreatic Ducts

Stimulus	Volume of secretion (in mm of the scale)	
	with free outflow	with increased pressure
Hydrochloric acid (0.25%, 5 ml, into the duodenum)	374	504
Secretion (3 ml, intravenously)	541	443
Secretion (4 ml, intravenously)	220	240
Secretion (4 ml, intravenously)	260	342

Hence, the decrease in the rate of "vertical" secretion recorded when the pressure in the pancreatic ducts was increased reflected not inhibition of the secretion, but a decrease in the outflow of juice into the manometer. The retention of juice in the gland may have been associated with the reserve capacity of the ducts, i.e., with an increase in the volume of the ducts in response to an increase in pressure within them. If this were so, the pressure in the manometer would be a measure of the difference between the volume of secretion and the reserve capacity of the ducts in the gland and, consequently, the more intensive the secretion, the less the pressure in the ducts would depend on the reserve capacity of the ducts. On this basis it could be assumed that by increasing the volume of secretion, a higher pressure in the ducts could be obtained. In fact, the experimental results showed that against the background of an established pressure repeated injections of secretion produced a fresh increase of pressure to 280-405 mm (Fig. 2). This fact confirms that stabilization of the pressure in the pancreatic ducts after a single stimulation is determined not by the inhibition of secretion, but by the reserve capacity of the ducts.

As mentioned earlier, after a single stimulation the pressure in the ducts remained maximal for a long time. In contrast to this the increase of pressure in response to repeated injections of secretin (during continuous recording) was brief in duration and was followed by a fall of pressure actually below the level observed after the first injection of secretin (Fig. 2). This fact suggests that in certain conditions the outflow of juice from the pancreas is possible in other ways. The experimental results showed that the role

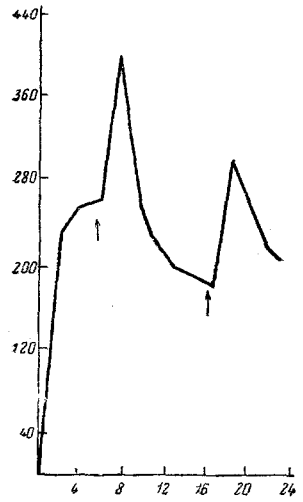

Fig. 2. Pressure in the pancreatic ducts following repeated intravenous injection of 3-5 ml secretin. Abscissa — time (in min); ordinate — pressure in pancreatic ducts (in mm of juice). The time of the first injection of secretin coincides with 0. The arrows indicate the repeated injections of secretin.

of the accessory duct in this phenomenon is small. The entry of a small amount of dye into the duodenum through the accessory ducts was observed in only four cats when 2-5 ml of the dye was injected into the main ducts at the end of each experiment. It is interesting in this connection to note that in chickens an increase of pressure in one duct was not reflected in the rate or volume of secretion in the other ducts of the pancreas [4].

To examine the relationships between the secretory pressure and the system of pancreatic ducts experiments were carried out in which colored physiological saline was injected into the pancreatic ducts under different pressures. The results of these experiments showed that if the pressure was below 300 mm water, the volume of solution entering the glands was determined only by the level of the pressure and was independent of the duration of administration; after injection of the solution ceased the whole of the injected solution flowed back out of the duct. In these conditions the dye was found only in the efferent ducts. When the pressure was above 300 mm water, the volume of solution entering the gland rose in proportion to the pressure and duration of administration, and the more solution was injected, the greater the proportion of it remaining in the gland. In this case, the whole mass of the gland was stained and its lobular structure became clearly apparent, possibly because of the increased permeability of the pancreatic ducts and penetration of the dye outside the ducts into the gland tissue. In this connection important findings were obtained by Dupreez and Godart [2], who showed that when a suspension of ink and fluoroescein was injected into the pancreatic ducts under a pressure of 20-30 mm Hg, spread of these dyes outside the ducts into the tissue spaces, and thereafter into the lymphatic vessels of the gland was observed. Since in the present experiment the maximal secretory pressure was 280-405 mm juice, i.e., 20-30 mm Hg, the possibility of the outflow of juice via the lymphatic vessels must be allowed, and this would account for the fall of pressure in the pancreatic duct.

It may thus be concluded from the results described above that the relatively low values of the pressure in the pancreatic ducts are determined by the reserve capacity of the ducts and the threshold of resistance of the ducts to an increase in pressure within them. When the pressure in the pancreatic ducts is maximal, the possibility of inhibition of secretion cannot be entirely ruled out, but this hypothesis requires experimental proof.

The factors described above may be regarded as protective, for the cells of the parenchyma of the pancreas are highly sensitive to an increase in the pressure in its ducts [7].

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