Effect of Vagotomy on Dynamics of Mesenteric Lymphatic Vessels in the Rat

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Abstract

The functional modulation of lymphatic vessels may be closely associated with intact structures of the vagus nerve. In the present study, the vagotomy was done in Wistar rat to investigate the effect of vagus nerves on dynamic changes of mesenteric lymphatic vessels. After denervation, the mesenteric lymphatics showed significant decreases in contraction rate, diameter in the static state and overall contractile activity under a microscopic observation. The lymphatic contraction rhythm and valve movement became irregular and inconsistent. These findings indicated that the lymphatic innervation might be an important factor for active lymph formation and transportation.

Key Words: lymphatic vessel, vagotomy, rat

Introduction

The lymphatic system is essential for maintenance of normal fluid balance, draining extracellular fluid from the tissues to blood circulation, and providing an exclusive environment in which immune cells can encounter and respond to foreign antigen in the peripheral lymphoid tissues (10, 11, 18). However, the functional study of lymphatics has been ignored in past years, especially in illustrating how the impairment of lymphatic innervation affects lymph circulation and lymphatic dynamics itself. Furthermore, previous studies on the lymphatic dynamics have mostly focused on the thoracic duct (16, 19), rather than the mesenteric lymphatic vessels that are considered as the most important part for lymph formation and transportation (10, 12). Vagotomy, referred to complete resection of the main body of vagus nerves to reduce acid secretion in the stomach, often causes decrease in peristalsis and lymph absorption (2, 5), although many factors, *e.g.*, substance P, histamine and outflow pressure may affect physiological function of the alimentary tract *via* lymphatic modulation (3, 6, 7, 8). Conversely, the gastrectomy may be complicated by vagotomy-like damages, affecting the function of mesenteric lymphatic vessels (17, 25). In this contet, we studied the possible effects of vagotomy on dynamic changes of mesenteric lymphatic vessels. The findings in the present study provided substantial information regarding the destruction of vagal innervation in affecting lymphatic dynamics.

Materials and Methods

Animals and Experiments

Sixteen Wistar rats, weighing 300-400 g, were intraperitoneally anaesthetized with sodium pentobarbital (30 mg/kg). A median incision was made in the upper abdomen. A part of intestine and mesentery was exposed and spread out on a transparent tray and then kept in Ringer's solution at 37°C. The posterior vagal trunk was resected at the esophageal hiatus of the diaphragm.

Measurements

The contraction rate of mesentery lymphatic vessels was recorded under a vital microscope with a camcorder. The internal diameters at the most dilated or contracted states and in the static state were

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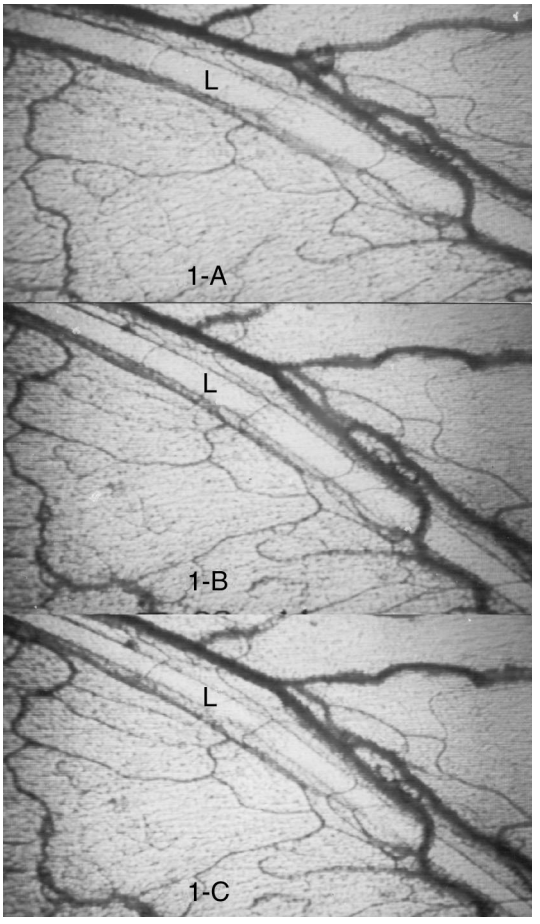

Fig. 1 Photographs of lymphatic vessels in the preoperative mesentery at the most dilated state (A), in the static state (B), and at the most contracted state (C), respectively. The rhythm of lymphatic contraction is clearly seen. L: lymphatic vessel. × 40

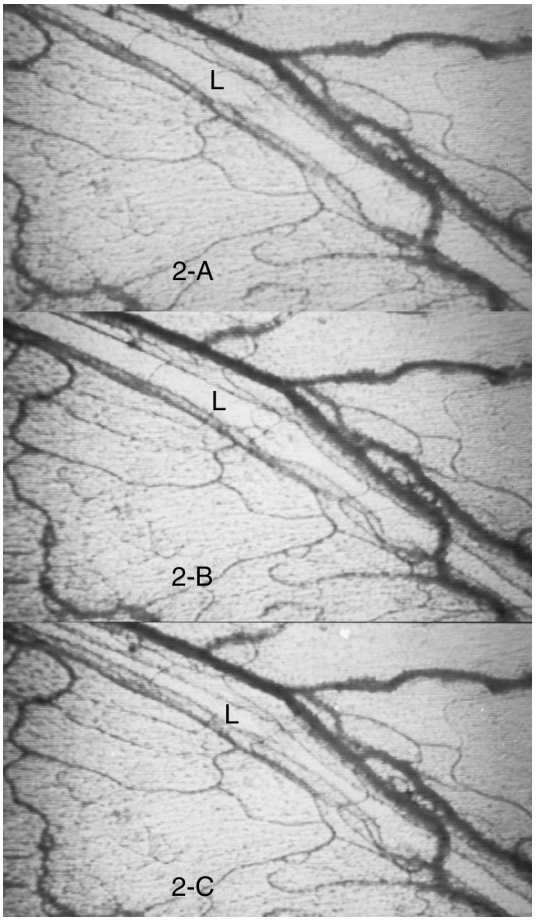

Fig. 2 Photographs of lymphatic vessels in the postoperative mesentery at the most dilated state (A), in the static state (B), and at the most contracted state (C), respectively. The lymphatic internal diameters decreased after denervation and the contraction of lymphatic vessels becomes irregular postoperatively. L: lymphatic vessel. × 40

measured before nerve resection, and at 10, 30 and 60 min after denervation.

The lymphatic contraction rhythm and valve movement were compared before and after denervation. The lymphatic contraction indices were analyzed according to the formulae of Yasuda and Goto (9, 24). The formulae are Index I = $(b^2 - c^2)/b^2$; Index II = $(b^2 - c^2)a/b^2$; L.D. Index = $(b - c)\,100a/d^2$.

Four indices were used in the present study to indicate the lymphatic vessel contractility. '*a*' represents contraction rate and index I represents lymphatic fractional contraction. Index II is produced both from index I and the contraction rate that shows overall lymphatic contractile activity. L.D. index represents peristalsis dynamics of lymphatic vessel. In addition, '*b*,*c*,*d*' are referred to internal diameters at the most dilated, contracted states, and in the static state in the formulae, respectively.

Statistical Analysis

The statistical analysis was made by one-way analysis of variance (ANOVA) followed by Student's *t*-test using SPSS 10.0. Differences were considered statistically significant for *P* values less than or equal to 0.05.

Results

Lymphatic Internal Diameter

The rhythm of lymphatic contraction was clearly seen, and the lymphatic internal diameters were shown at the most dilated or contracted states, and in the static state before vagotomy (Fig. 1). The lymphatic internal diameters decreased significantly in static state and at the most dilated or contracted states after vagotomy (Fig. 2). The decreased alterations in

Table 1. Lymphatic contractility indices in preoperative and postoperative periods

	N	Preoperative	Postoperative		
			10 min	30 min	60 min
a (time/min)	16	10.06 ± 0.88	8.75 ± 1.05	7.06 ± 0.93*	6.31 ± 0.88*
Index I	16	0.58 ± 0.05	0.51 ± 0.05	0.47 ± 0.05	0.45 ± 0.05
Index II	16	5.69 ± 0.73	4.57 ± 0.80	3.59 ± 0.73*	2.82 ± 0.50**
L.D. Index	16	7.07 ± 1.19	6.31 ± 1.03	5.47 ± 1.28	4.69 ± 0.95

1. The data are expressed as Mean ± SD.
2. *$P < 0.05$ or **$P < 0.01$ is analyzed with comparison to preoperative lymphatics.
3. *a* represents contraction rate; Index I represents lymphatic fractional contraction, Index II represents overall lymphatic contractile activity; L.D. Index represents peristalsis dynamics of lymphatic vessel. All these three indices decreased after denervation.

internal diameters and lymphatic contraction were quite irregular after denervation.

Contractility of Lymphatic Vessels

Lymphatic contractility indices were seen in Table 1. All the following three indices decreased after denervation, compared with preoperative indices. '*a*' and Index II showed an obvious decrease at 30 min ($P < 0.05$) and 60 min after denervation ($P < 0.01$). The decrease of Index I and L.D. after denervation did not show a statistical difference compared with preoperative indices ($P > 0.05$).

Lymphatic Contraction Rhythm and Valve Movement

The lymphatic contraction rhythm and valve movement became irregular and inconsistent after vagotomy. The irregular contraction rhythm seemed to be kept in static state, showing continuous spasm and quick contraction. Most quick actions occurred near the valves. The contraction degree of lymphatic vessels differed from various regions and resulted in irregular lymphatic lumen. The valve movement was not consistent with lymphatic contraction. The action frequency of valves was lower than that of the lymphatic contraction. The valve sometimes had too slow movement to fully shut or open, although they were usually kept in continuously open condition.

Discussion

Intramural lymphatics are known to coexist with nerve elements capable of generating powerful muscular contraction, structurally. These nerve varicosities are in close apposition to lymphatic intercellular junctions (13). The automatic contract of lymphatic vessels is the motivation of lymph circulation and accelerates lymph formation (4, 14, 20, 21). The neurogenic activity appears to be an essential prerequisite for normal lymphatic function (1, 13, 15).

Effect of Vagus on Internal Diameter of Lymphatic Vessels

The present finding of decreased internal diameter at three states after denervation indicates that the vagus nerve may inhibit contractility of lymphatic smooth muscles. The lymphatic vessel is dilated, showing an enlarged internal diameter due to regulation of vagus nerves. This function cooperating with other contractility factors for the lymphatic vessel may further result in decreased internal pressure and resistance, therefore accelerate lymph formation and circulation. The normal circulation of lymph is important in maintaining the absorption function in the intestinal cells (22, 23).

Contract Dynamic Effect on Lymphatic Vessel

The lymphatic contraction indices may represent the dynamics of contraction as a quantitative measure. The contraction rate (*a*) and index II significantly decreased after denervation. Although the contraction amplitude of lymphatics did not reduce significantly, the lymphatic motivation decreased with reduced contraction rate (*a*) and contractile activity (index II). The inconsistent contraction rhythm and valve action may decrease effective lymphatic motivation that further interferes in normal lymph circulation (11, 25).

The results in the present study indicated that the vagus nerve is an indispensable factor to maintaining the pump function in lymph circulation. Any destruction or impairment in the vagus nerve will result in the alterations of the rhythm of lymphatic contraction, valve movement, and dynamics of lymphatic vessels.

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