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Relationship between Autonomic Innervation and Hemodynamics of the Gastric Tube for Esophageal Reconstruction, Especially the Effect of Thoracic Sympathectomy on the Microcirculatory Disturbance in the Gastric Tube

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Introduction

The stomach is being most widely used nowadays for reconstructive surgery after the resection of esophageal cancer. Among many operative methods, the antethoracic esophagogastrostomy with the KIRSCHNER-NAKAYAMA type of gastric tube is found to be the simplest and safest procedure. However, in this procedure, anastomotic breakdown at the esophagogastrostomic region is not infrequent. This complication is not fatal but the patient is prevented from per os feeding for a long time and the anastomotic region tends to be stenotic after its healing. There are two factors in regard to this suture disruption. These are systemic factors caused by cardiopulmonary complication and metabolic disorders, and other local factors induced by anastomotic condition have been considered. It is accepted that the anastomotic procedure is performed under the abnormal environment in the antethoracic subcutaneous space and other causes are microcirculatory disturbance in the gastrointestinal tube for esophageal reconstruction and the longitudinal tension imposed on the suture line. It is thought that the spasm of the nutritional arteries occurs under the predominant sympathetic innervation due to bilateral vagotomy and preservation of sympathetic nerve fibers along the right gastric and the right gastroepiploic arteries and the opening of arteriovenous anastomosis (AVA) should take part in this circulatory disturbance. Experimental studies were performed to clarify this problem.

Method

1) Preparation of animals (Fig. 1)

Adult mongel dogs weighing about 10 kg were used. The animals were deprived of food for at least 24 hours prior to the experiment and anesthetized by intravenous Nembutal injection

Key words: Gastric tube, Autonomic innervation, Vagotomy, Thoracic sympathectomy, Arteriovenous anastomosis.
索引語：食道再建用胃管，自律神経支配，迷切，胸部交感神経切除術，動静脈吻合.
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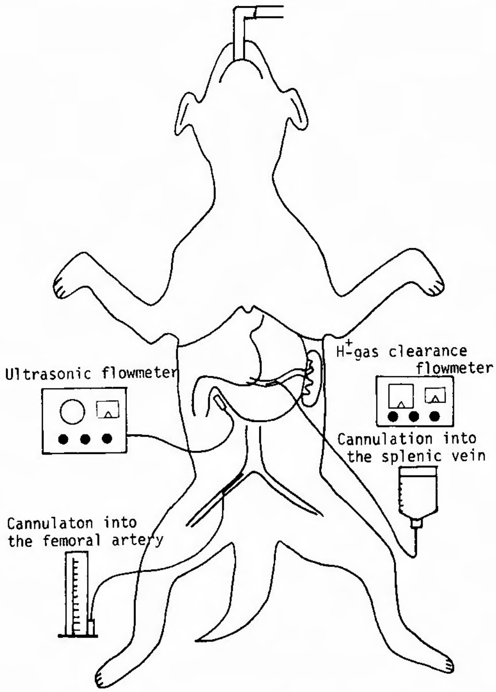

Fig. 1. Experimental method

at a dose of 25 mg/kg. During experiment, air way was secured by intratracheal intubation and ventilated by respiratory apparatus. Following laparotomy, a pedunculated gastric tube was mobilized according to the procedure of KIRSCHNER-NAKAYAMA. Thoracic sympathectomy performed by 7th intercostal thoracotomy and the 5–10 thoracic sympathetics were completely removed.

2) Observation of the microcirculation

a) Dry ice methanol wintergreen method (D.M.W. method)[39]

After construction of the gastric tube, India ink was injected into the common hepatic artery. Biopsy samples were excised from the tip of the gastric tube. The samples were immediately frozen in methanol cooled by dry ice and gradually (over 4 days period) returned to room temperature. Then they were dipped into oil of wintergreen (Methyl salicylate) to make them transparent, were carefully sectioned and without staining, were observed microscopically.

b) Evans blue albumine complex method.[29]

A stock solution of an Evans blue albumine complex (E-A complex) was prepared which was shown by NICOLYSEN and STAUB. E-A complex was injected into the hepatic artery and tissue sample was excised by the same method as D.M.W. method. Tissue sample was frozen in dry ice acetone and then freeze-dried at −35°C for 4 days. The freeze-dried- tissues were then prepared, and examined with fluorescence microscope with filters was used for the observation. (excitation filter: B 2, Barrier filter: Y 52) Vascular changes were recorded photographically on 35 mm film using a Nikon F camera.

3) Fluorescence histochemical studies on the adrenergic innervation of the right gastroepiploic artery. Noradrenaline is the vasoactive substance which induces the contraction of the right gastroepiploic artery and was observed its existence and alteration by FALCK-HILLARP method.[15] Excised specimen was frozen in Isopenthane cooled by dry ice acetone and then freeze-dried at −40°C for 2–3 days, treated in Entellan for fluorescence microscopy. An Olympus F.L.H. fluorescence microscope with filters was used for the observation.

4) Measurement of gastric blood flow.

a) The right gastroepiploic artery

Ultrasonic doppler flowmeter (Parks Electronics Laboratory, MODEL 806) was used for measurement of the right gastroepiploic arterial flow. A measuring probe was placed at the point where the first branch was ramified for determination.

b) Tissue blood flow of the gastric tube.

Hydrogen gas clearance flowmeter (Unique Medical Co. LTD PHG-201) was used for measurement of mucosal and submucosal blood flow of the gastric tube. Measuring points are placed at the portion 2 cm distal to the tip and 2 cm distant from the greater curvature. A platinum electrode was placed at the submucosal layer and not mobilized throughout the experiment.

5) Determination of oxygen pressure difference between the arterial and venous blood supplying the stomach.

a) Venous return from the stomach pours into the splenic vein mostly, therefore, splenectomy was performed and the elastic tube was cannulated into the splenic vein and venous return from the stomach was only collected (Fig. 2).

b) Collection of blood sample from artery.

An elaster needle was cannulated into the femoral artery and arterial blood was collected for analysis. Blood samples were immediately analyzed for PaO_2, PCO_2 and pH.

6) Monitoring of systemic hemodynamics.

Throughout the experimental procedure, blood pressure and pulse rate were watched by polygraph with D-C amplifier continuously. By means of such procedure, the experiment was performed. Measurement of blood flow and oxygen pressure were performed by acute experi-

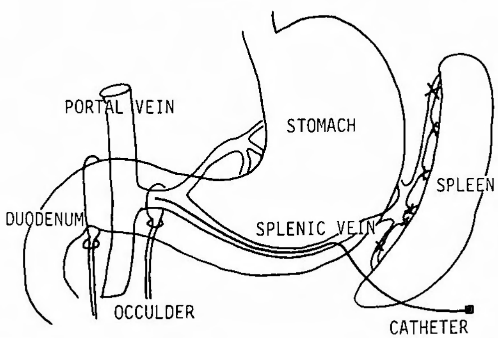

Fig. 2. An elastic needle was cannulated into the splenic vein and venous return from the stomach was only collected.

ment. Observation of microcirculation, fluorescence and histochemical studies were performed by chronic experiment. Blood flow was measured immediately after the laparotomy for the control value and also measured 1–2 hours following the construction of the gastric tube and the thoracic sympathectomy, respectively. Morphologic studies were performed 2–3 days after the construction of the gastric tube. Coloring materials were injected into the common hepatic artery. The thoracic sympathectomy was performed 1–2 weeks prior to the laparotomy for chronic study.

Results

1) Observation of microcirculatory changes in the gastric tube.

In the gastric tube group, injected India ink and Evans blue did not arrive at the mucosal surface sufficiently. Stasis and sludging in the submucosal layer were seen and the opening of arteriovenous anastomosis (AVA) was also observed (Fig. 3, 4). On the other hand, in the group which had undergone right 5-10 thoracic sympathectomy 1–2 weeks prior to the abdominal procedure, such microcirculatory disturbance was not seen or seen slightly (Fig. 5). But in the group which had undergone left 5–10 thoracic sympathectomy, microcirculatory disturbance was seen at the same grade as the control group and not improved in blood circulation.

2) Results of fluorescence histochemical studies on the right gastroepiploic artery.

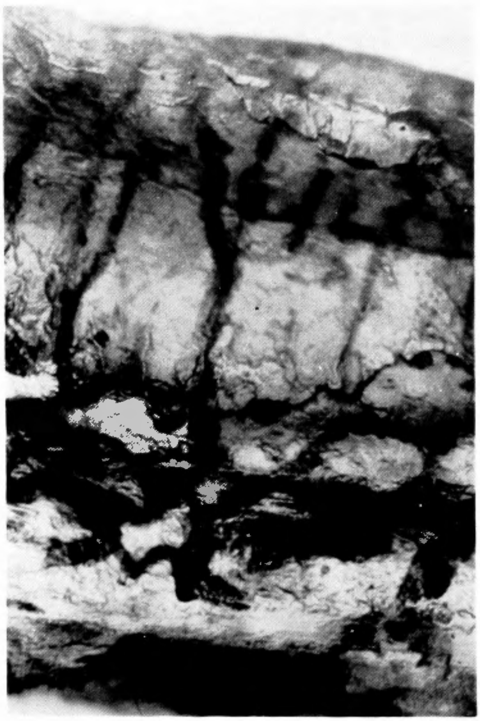

Fig. 3. Cross section of the mucosal and submucosal layer of the gastric tube. Injected India ink did not arrive at mucosal surface sufficiently. Stasis and sludging in the submucosal layer and opening of arteriovenous anastomosis were observed.

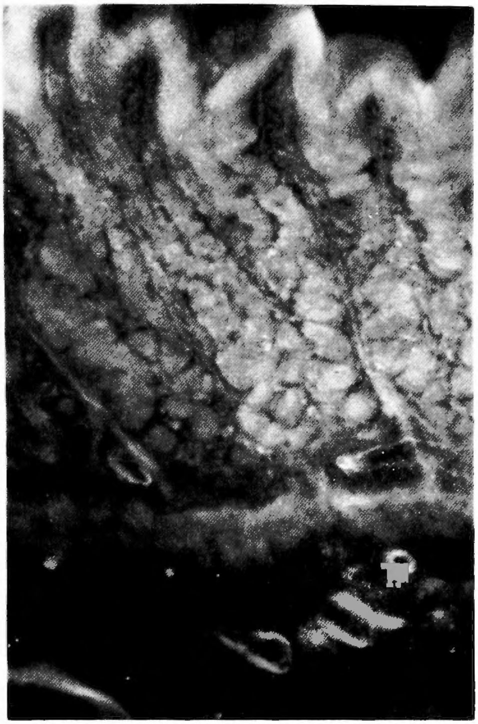

Fig. 4. Evans blue did not arrive at mucosal surface in the same manner as the D.M.W. method. Similar microcirculatory disturbance was seen.

In the control group, fluorescence of catecholamine was seen at the outer layer of the media and the adventitia (Fig. 6). In the group in which the gastric tube was constructed, increased fluorescence of the gastroepiploic artery was observed and it was recognized that sympathetic innervation was predominant (Fig. 7). Hence, in the group in which the right 5–10 thoracic sympathetics were removed previously and the gastric tube was constructed, fluorescence of noradrenaline had almost disappeared (Fig. 8), but in the group in which the left thoracic sympathetics were removed previously and the gastric tube was constructed, fluorescence of noradrenaline was still seen (Fig. 9).

3) Tissue blood flow of the gastric tube.

In the control group, mucosal and submucosal blood flow in the tip of the gastric tube amounted to 64.2±12.6 ml/min/100 g. After the construction of the gastric tube, blood flow at the same point decreased to 32.29±9.6 ml/min/100 g ($P<0.01$) (Table 1, Fig. 10), and after right 5–10 thoracic sympathectomy, increased to 46.5±11.9 ml/min/100 g, showing a 32.2% rise ($P<0.10$) (Table 2, Fig. 11). On the other hand, in the left 5–10 thoracic sympathectomized group, after the construction of the gastric tube, mucosal and submucosal blood flow decreased to 33.0±10.8 ml/min/100 g, the decrement being 48.5% ($P<0.01$), and after left thoracic sympathectomy, it showed 32.18±13.8 ml/min/100 g, without efficient changes (Table 3, Fig. 12).

4) Blood flow of the right gastroepiploic artery.

Fig. 5. In the group which had undergone right thoracic sympathectomy 1-2 weeks prior to the abdominal procedure, microcirculatory disturbance of the gastric tube was not seen or seen slightly.

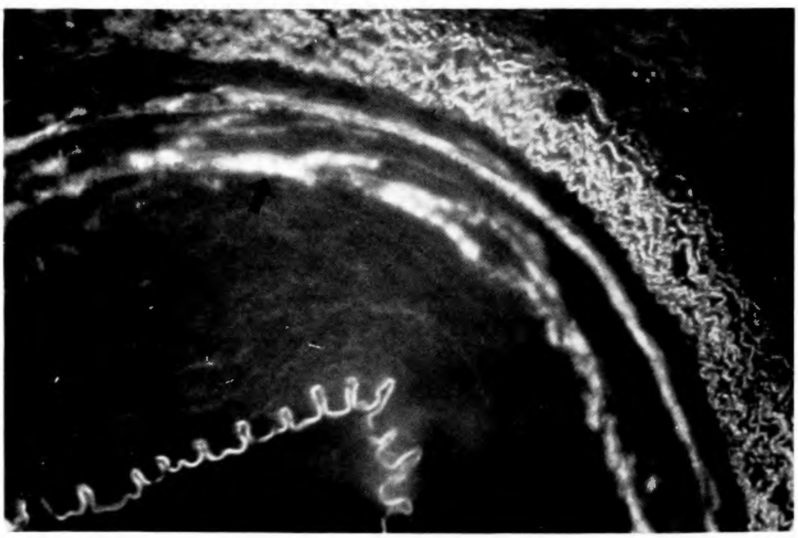

Fig. 6. Fluorescence of noradrenaline was seen at the media and the adventitia of the right gastroepiploic artery in the control group.

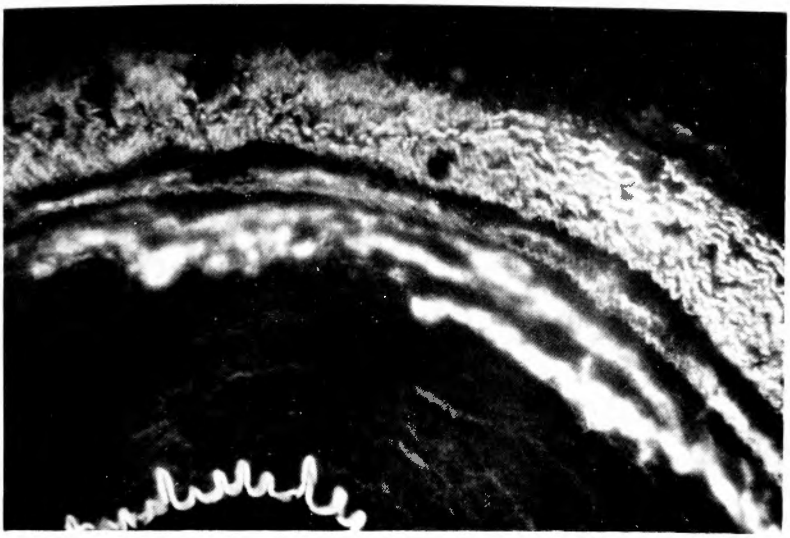

Fig. 7. Fluorescence of noradrenaline of the right gastroepiploic artery increased markedly in the group in which the gastric tube was constructed.

In the control group, the right gastroepiploic arterial blood flow was 10.75±0.625 ml/min and after the construction of the gastric tube, it dropped to 6.75±0.875 ml/min, the decrement being 36.1%. Furthermore, after right 5–10 thoracic sympathectomy, it increased to 11.6±0.937 ml/min, at the increasing rate of 67.9% ($P<0.01$) (Table 4, Fig. 13). On the other hand, in the left thoracic sympathectomized group, before the procedure, blood flow was 10.1±3.75 ml/min, with reduction of 23%. After left thoracic sympathectomy, it did not show reasonable changes, with blood flow of 6.62±3.125 ml/min in value (Table 5, Fig. 14). It was summerized that blood

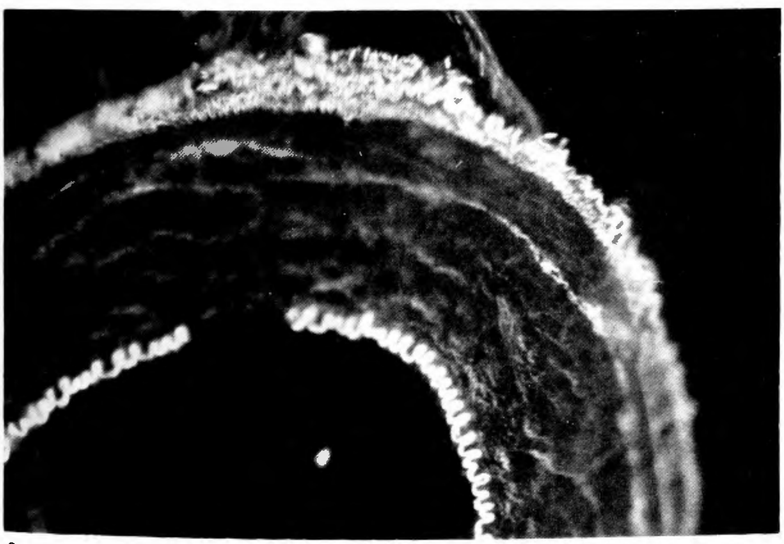

Fig. 8. Fluorescence of noradrenaline was almost disappeared in the group in which the right thoracic sympathetics were removed previously and the gastric tube was constructed.

Fig. 9. Fluorescence of noradrenaline was still seen in the group in which the left thoracic sympathetics were removed previously and the gastric tube was constructed.

Table 1. Mucosal and submucosal blood flow in the tip of the gastric tube, before and after the construction of the gastric tube. (ml/min/100 g)

No.	Before	After
1	63.4	38.2
2	77.0	60.2
3	63.0	18.9
4	57.7	16.5
5	63.0	36.4
6	99.0	34.6
7	60.2	27.7
8	31.5	19.8
9	85.1	41.9
10	77.0	30.1
11	63.0	49.5
12	31.5	23.1
13	31.5	8.5
14	49.5	31.5
15	99.0	36.4
16	76.0	43.3

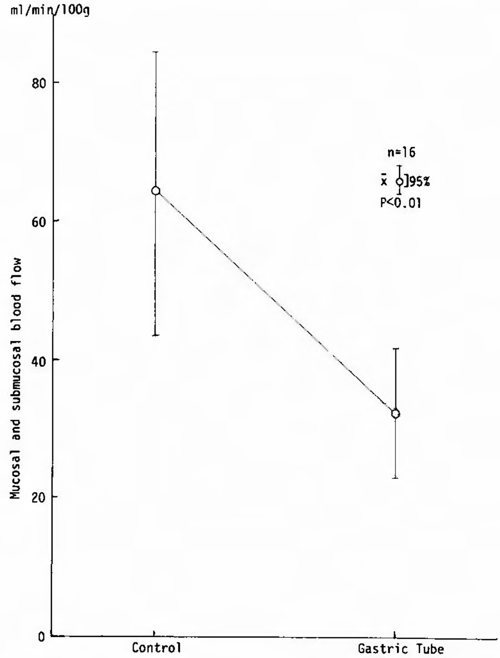

Fig. 10. Mucosal and submucosal blood flow in the tip of the gastric tube, before and after the construction of the gastric tube.

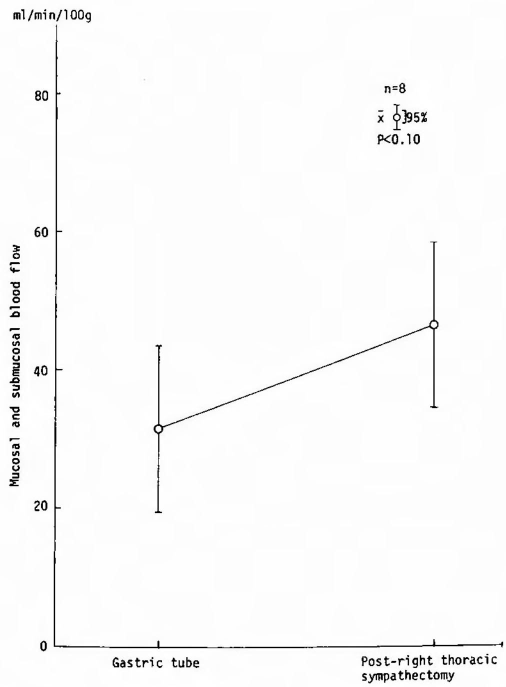

Fig. 11. Tissue blood flow in the tip of the gastric tube after right (5–10) thoracic sympathectomy.

Table 2. Tissue blood flow in the tip of the gastric tube after right (5-10) thoracic sympathectomy. (ml/min/100 g)

No.	Before	After
1	38.2	49.5
2	60.2	69.9
3	18.9	38.5
4	16.5	31.5
5	36.4	46.2
6	34.6	53.3
7	27.7	37.4
8	19.8	25.8

Table 3. Tissue blood flow in the tip of the gastric tube after left (5-10) thoracic sympathectomy. (ml/min/100 g)

No.	Before	After
1	41.9	44.6
2	30.1	5.7
3	49.5	42.3
4	23.1	38.5
5	8.5	15.6
6	31.5	38.5
7	36.4	5.8
8	43.3	36.4

flow of the stomach reduced markedly after the operative procedure of the gastric tube, and right thoracic sympathectomy markedly improved this reduction, but left thoracic sympathectomy was not effective on the impaired blood flow.

5) Differences of the oxygen pressure between the arterial and venous blood supplied the stomach.

Table 4. Blood flow in the right gastroepiploic artery, before and after the construction of the gastric tube and after right thoracic sympathectomy. (ml/min)

No.	Control	Gastric tube	Post-sympathectomy
1	10.8	10.2	11.8
2	12.4	4.6	11.3
3	9.2	6.8	12.5
4	9.4	12.7	13.8
5	9.4	6.5	8.2
6	12.1	6.4	14.1
7	9.6	7.8	12.4
8	11.8	5.6	10.3
9	8.7	6.8	9.8
10	12.8	7.4	12.8

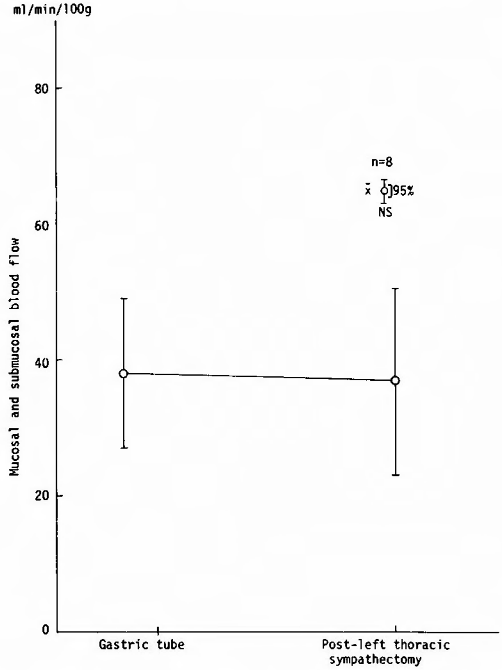

Fig. 12. Tissue blood flow in the tip of the gastric tube after left (5–10) thoracic sympathectomy.

In the control group, the difference of the oxygen pressure between arterial and venous blood supplied the stomach showed 47.7±6.2 mmHg and 2 hours after subphrenic bilateral vagotomy, it decreased to 37.4±5.4 mmHg. From this data, it suggested that the opening of submucosal

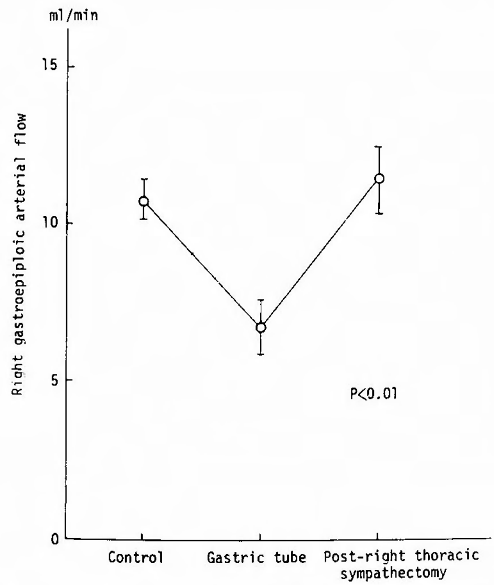

Fig. 13. Blood flow in the right gastroepiploic artery, before and after the construction of the gastric tube and after right thoracic sympathectomy.

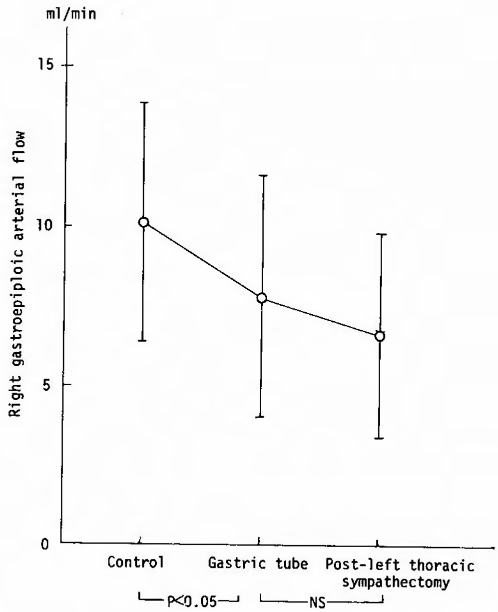

Fig. 14. Blood flow in the right gastroepiploic artery, before and after the construction of the gastric tube and after left thoracic sympathectomy.

AVA brought about this reduction following vagotomy (Table 6, Fig. 15).

6) Hemodynamic changes during experiments.

Systemic blood pressure showed 120–140 mmHg at systolic in the control group. After the surgical procedure of the gastric tube, it decreased slightly and recovered soon. Furthermore following additional thoracic sympathectomy, it decreased slightly during experiment, but sympathectomy did not cause this hypotension.

Table 5. Blood flow in the right gastroepiploic artery, before and after the construction of the gastric tube and after left thoracic sympathectomy. (ml/min)

No.	Control	Gastric tube	Post-sympathectomy
1	14.1	12.9	7.7
2	16.2	9.1	9.1
3	12.7	12.5	9.2
4	6.6	4.0	3.5
5	10.6	4.3	3.3
6	5.3	4.5	4.8
7	10.3	9.9	13.5
8	3.8	1.6	3.7
9	11.4	10.8	4.5
10	10.2	7.8	6.6

Table 6. Differences of the oxygen pressure gradients between the arterial and venous blood of the stomach before and after vagotomy. (mmHg)

No.	Before	After
1	53	43.6
2	39.5	35.3
3	66	43.8
4	31.5	26.7
5	46.9	26.2
6	62.1	47.5
7	32.7	14.0
8	58.5	17.7
9	25.3	13.1
10	47.7	40.1

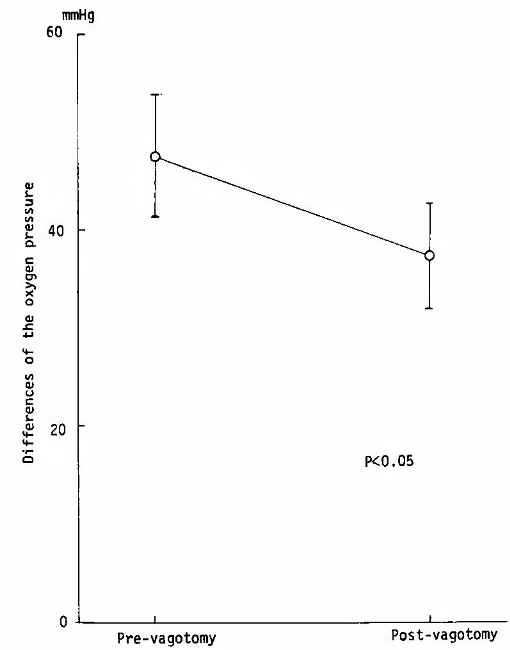

Fig. 15. Differences of the oxygen pressure between the arterial and venous blood of the stomach before and after vagotomy.

Discussion

After the resection of carcinoma of the esophagus, the gastric tube is being widely used in the reconstructive procedure. Among many procedures, the antethoracic esophagogastrostomy is found to be the safest and simplest procedure, in which, however, anastomotic leakage is not rare. To clarify the cause of this serious postoperative complication under the abnormal condition, such as antethoracic subcutaneous space, various studies on this problem have been carried out by many investigators.[19] In regard to esophagogastrostomy, DELANEY and

CUSTER[11] reported in 1965, that tissue perfusion rate of the esophagus was 0.21 ml/min/g and that of the stomach was 0.51 ml/min/g, esophageal blood flow was a half of the stomach. However, the blood supply to the esophagus is meager compared with the reminder of the gastrointestinal tract. The esophagus is not easily movable for anastomosis and have considerable resistance power to hypoxia.[22] Among these factors the most important one is the decrease of blood supply in the tip of the lifted gastric tube due to the impaired blood circulation. In the KIRSCHNER-NAKAYAMA type of gastric tube, blood supply is maintained mainly by the right gastroepiploic and the right gastric arteries. Some causes may reduce the blood flow and result in the suture disruption. ISHIGAMI[20] reported that activation of cathepsin as autolytic enzyme played the most important role in tissue necrosis under hypoxia and the tip of the gastric tube supplied with 70% less of the amount of blood than normal is liable to produce necrosis and it became necrosis completely with 55% less of the normal blood flow. The most significant factors of this circulatory disturbance of the gastric tube are the following:

1) The nutritional blood vessels of the gastric tube is mainly the right gastroepiploic artery and other vessels are divided, except for several branches of the right gastric artery.
2) Bilateral vagotomy is performed following thoracic esophagectomy and construction of the gastric tube.
3) The division of the gastric continuity is additionally performed.
4) A part of the stomach is resected and mechanical stimulus is added to the gastric tube.

The influence of bilateral vagotomy or selective vagotomy on the gastric blood flow has been studied by BALLINGER[3], PADULA[31], Bell[6] and PETER[32]. They have pointed out that subphrenic total vagotomy in dogs decreased the blood flow of the abdominal organ at least for a short period. On the other hand, FOLKOW[16] reported that subphrenic total vagotomy had no effect on the blood flow of the abdominal organ. But generally speaking, the stomach is innervated predominantly by vagal nerves among the other digestive organs. Utilizing ^{32}P, AKAKURA et al[1] made the local clearance study of canine stomach and found that the local disturbance of gastric blood vessels were slight following severance of the gastric blood vessels on the left side alone, but was significantly aggravated when bilateral vagotomy was additionally performed, and pointed out the mutual relation of vagotomy to the reduction of the gastric blood flow. In 1966, SUGIURA[40] et al found that bilateral vagotomy produces significant reduction in the gastric blood flow but the additional division of the gastric blood vessels on the left side does not aggravate the decreased blood flow by utilizing ^{32}P labelled red blood cell. In 1968, BELL and BATHERSBY[6] experimentally showed the influence of intrathoracic vagotomy on the gastric mucosal blood flow and found that vagotomy produced significant reduction in the blood flow by $39\pm20.3\%$. While, quantitative analysis of gastric blood flow was made by PETER[32] et al in 1963, reported that the gastroepiploic arterial flow was decreased due to intrathoracic vagotomy by 30.5% using non-cannulated magnetic flowmeter. BALLINGER[3] has pointed out that subphrenic total vagotomy in dogs decreased the superior mesenteric venous flow by $42\pm11.6\%$ lower than the normal flow. Utilizing non-cannulated magnetic flowmeter, in 1967, SHIMAZU[32] indicated that the gastric venous flow decreased following cervical vagotomy by 55.9% and following subphrenic vagotomy by 49.9% and it remained about 2 weeks after the operation. In 1968, ISHIGAMI[21] and SUGIURA[39] reported that the superior mesenteric venous flow was decreased by 53.2% following subphrenic vagotomy and to relieve this impaired blood flow, periarterial sympathectomy of the right gastric and right gastroepiploic arteries were found to be most effective, the blood flow in the tip of the gastric tube being increased by 42.7%, showed a 9.5% increase even after 2 weeks later. As above mentioned, almost the whole investigators reported that gastric blood flow was decreased following vagotomy. Concerning its mechanism, several factors were studied:

1) Vagotomy produces predominant sympathetic innervation of the vessel antagonistically.
2) Interception of vasodilating fiber in the vagus nerve.
3) Following changes of weaken gastric peristalsis.

But as to the healing course of esophagogastrostomy, anastomotic condition is the most significant subject in 7 to 10 days postoperatively, especially, sufficient blood supply to the tip of the gastric tube is necessary in several days after the operation. Therefore improvement of blood flow in this period is important for successful anastomosis. Some countermeasures against suture distruption were carried out up to date as shown in Table 7. Right thoracic sympathectomy performed in this experiment was found to have a good effect on the blood flow by blockage of sympathetic innervation just the same as lumbal sympathectomy against arterial occulsive disorders in extremities, and had the virtue of being resectable in thoracic procedure for subtotal esophagectomy on the right side. Impaired blood circulation in the tip of the KIRSCHNER-NAKAYAMA type of gastric tube was induced by contraction of the right gastroepiploic artery and mucosal arteriole in the predominant sympathetic innervation following vagotomy. Furthermore, it was suggested that gastric submucosal AVA played a significant role in the gastric blood flow. In the gastric mucosa, it is generally accepted that endarteriole is not present, there are functional AVA with vascular network in the submucosal layer.[4,5,7] Blood distribution of gastric mucosa depend on resistance of mucosal arteriole and AVA located in proximal side. These AVA are closed in physiologic state and open in pathologic state so that blood flow of membrane

Table 7. Countermeasures against anastomotic disruption

1. Improvement of blood circulation of the gastric tube
   a. Revascularization of the divided blood vessels[22]
   b. Blockage of sympathetic nerve[40]
   c. Selection of adequate width of the gastric tube
2. Amelioration of anastomotic procedure
   a. Layer to layer anastomosis[28]
   b. Gambee's method[27]
   c. Olsen's method
3. Release of tension at the suture line
   a. Cross section of sero-muscular layer of the gastric tube[17]
   b. Fixation of the tip of the gastric tube
4. Oxygen therapy
5. Covering of anastomotic portion[17]
6. Others

is reduced consequently. PETER[33] and SHERMAN[37] reported that the diameter of AVA is 12 to 180 μ in dogs and its opening is caused by adrenaline, hypothermia and stimulation of sympathetic nerve and its closing is caused by histamine[30,33,36,37,43]. To observe AVA in the gastric wall, morphologically, there have been some investigations carried out, for example, dye injection into vessels and photographing by microangiographic technique. But these methods were observed by fixed samples and did not enable evaluation of the functional activity. On the other hand, in order to investigate the function of AVA, the blood volume of arterial inflow and venous outflow were measured and the difference of oxygen pressure was compared with arterial blood to venous blood. Dye dilution method[7] was also carried out previously. Among these methods, they have merits as well as demerits. In the present study, evidence of the opening mechanism of AVA has been provided by indication of increased differences of arteriovenous oxygen pressure following subphrenic vagotomy. Concerning distribution of gastric blood flow, DELANEY[12] observed that the distribution of total gastric blood flow is 72% in mucosal layer, 13% in submucosal layer and 15% in muscle layer, there was remarkable high blood flow in mucosal and submucosal layers as compared to muscle layer. It appeared obvious that the condition and blood flow in the mucosal and submucosal layers were most significant factors for sufficient anastomosis as reported by clinical experimental studies about gastrointestinal anastomosis.[25] BELL[7] has reported the opening of AVA following subphrenic vagotomy utilizing dye dilution technique in dogs. In this experiment, the same result was obtained. Thus, it is clear that as a result of impaired mucosal and submucosal blood flow in the anastomosed portion, the anastomosis will be suffered from suture disruption. In normal dogs, the structure of gastric vessels is formed by thick artery penetrating the proper muscle layer and reaches to the submucosal layer and builds up the high density network. A fine artery runs up to mucosal layer from this network through the submucosal layer obliquely aslant. Mucosal vessels branch out to the surface of the membrane and become fine mucosal capillaries entering collective veins. In this experiment, after the construction of the KIRSCHNER-NAKAYAMA type of gastric tube, it was observed the India ink barely reached the base of the villi capillary networks by D.M.W. method. When there were severe disturbances of microcirculation, the flow disturbance extended not only to the capillary networks of the villi but also to the submucosal plexus and in the submucosal layer, inflow of India ink from artery to vein was observed as a result of the opening of AVA. These results lead to the following conclusion:

Predominant sympathetic nerve innervation following vagotomy during construction of the gastric tube give rise to the opening of submucosal AVA in the tip of the gastric tube morphologically. Table 8 summerizes the methods of measurement of gastric blood flow developed up to date. These methods have merit and demerit. In this study, mucosal and submucosal blood flow in the tip of the gastric tube was measured by clearance technique with hydrogen gas and right gastroepiploic arterial flow was measured by ultrasonic flowmeter. Clearance technique with hydrogen gas has the advantage of obtaining a direct tissue blood flow repeatedly. A platinum electrode was placed in the mucosal and submucosal layers, the dog inhaled room air mixed with 10% hydrogen gas for a few minutes. Electric current was amplified and recorded

Table 8. Measuring methods of gastric blood flow

1. Venous effluent method[10]
2. Pump perfusion[23]
3. Electromagnetic flowmeter
4. Ultrasonic flowmeter[34]
5. Strow-Uhr[9]
6. Vivi-perfusion[26]
7. Measurement of tissue oxygen concentration
8. Measurement of temperature of gastric wall
9. Thermoelectrical method[18]
10. Acetylene uptake method
11. Clearance technique
    - ^{42}K [12]
    - ^{86}Rb[11]
    - ^{131}I [8]
    - Hydrogen gas[2]
    - Aminopyrine[24]

in proportion to gastric blood flow. Blood flow was calculated by a method of computation of KETY's formula. Mucosal and submucosal gastric blood flow determined in this study was 60 ml/min/100 g and similar to that of reported up to now[12,13,35]. Right gastroepiploic arterial flow was measured by ultrasonic flowmeter, it has some merits over the electromagnetic flowmeter. Electromagnetic flowmeters need to be attached to a naked artery or measured in the bypass circuit, so that physiologic data is not obtained by this method. It is very useful in this study that blood flow was measured by ultrasonic flowmeter, without separation of the artery and sympathetic nerve fiber was reserved still for observation of autonomic nervous system. But direct blood flow was not obtained by ultrasonic flowmeter. The diameter of the right gastroepiploic artery was examined in the level of 1 to 100 millimeter and blood flow per minute was calculated with this value.

Histochemical observation of the right gastroepiploic artery.

Attempts to examine autonomic nervous system of the KIRSCHNER-NAKAYAMA type of gastric tube was made by histochemical observation of the right gastroepiploic artery which supplies the blood flow to the gastric tube. The vasomotion is controlled by the smooth muscle of the vessel and noradrenaline is the main substance acted on in this mechanism, so that, dyeing of noradrenaline was made as a conductive particle of the smooth muscle by the method of FALCK-HILLARP[15], and its existence and fluctuation was examined. At first, fluorescence of noradrenaline was recognized in the outer layer of the media and the adventitia of the right gastroepiploic artery and its existence was proved. Next, after the construction of the KIRSCHNER-NAKAYAMA type of gastric tube, fluorescence of noradrenaline increased markedly and it was demonstrated that the right gastroepiploic artery was under the predominant sympathetic innervation. Following right thoracic sympathectomy, fluorescence of noradrenaline of the supplying artery had disappeared completely, finding it freeing from sympathetic predominance.

TSUNEKAWA[41] had observed the vanishing of fluorescence of noradrenaline in the dorsal artery seven days after bilateral lumbal sympathectomy (L_2–L_6). Namely the survey revealed the fact histochemically that by resection of the sympathetic ganglion which innervate the vessels, the vessel is intercepted from sympathetic nerve innervation.

Sympathectomy as a countermeasure against impaired blood flow in the gastric tube for esophageal reconstruction.

Generally speaking, the autonomic nerves supply to the stomach are vagal nerve, splanchnic nerve and enteric nervous system. It is generally accepted that splanchnic nerves act as a contractile nerve to the gastric vessels and stimulation of this nerve decreased the gastric blood flow[13,32,34].

Some attempts have made to take the countermeasure against impaired blood flow in the tip of the gastric tube by interception of sympathetic nervous system. SUGIURA and ISHIGAMI[40] have reported that periarterial sympathetomy of the right gastric and right gastroepliploic arteries were found to be most effective, the blood flow being increased by 42.7% in the uppermost tip and 31.2% in the tip, but periarterial sympathectomy of the common hepatic artery had no improving effect on the impaired blood flow, the flow was reduced by 10.8% in the uppermost and 10.4% in the tip, and also reported that right thoracic sympathectomy (Th_{5-10}) significantly raised blood flow of the gastric tube, the increasing being 83.1% in the uppermost tip and 14.9% in the tip. In the present study, following right thoracic sympathectomy, gastric blood flow in the tip of the gastric tube increased by 46.5% and remarkable effect was recognized as a countermeasure against impaired gastric blood flow. But, left thoracic sympathectomy had no effect on impaired blood flow and improvement as a countermeasure was not observed. Anatomically, it is universally admitted that bilateral vagal nerves become two trunks after branching out on the heart and the lung, and each one branch are combined into the esophageal plexus and enter the abdominal cavity as anterior and posterior vagal nerves. Thus, the stomach is innervated by bilateral vagal nerves following intrathoracic intersectional anastomosis. While, according to the sympathetic system of the stomach, the one starting from thoracic sympathetic ganglion and entering the abdominal cavity as greater and lesser splanchnic nerves, terminating in the lesser curvature along the gastric vessels via the celiac plexus. Therefore, it is naturally regarded that there is an interceptional communication in the celiac plexus, but in this experiment, the blood flow in the KIRSCHNER-NAKAYAMA type of gastric tube increased following right thoracic sympathectomy (Th_{5-10}), on the other hand, left thoracic sympathectomy (Th_{5-10}) indicated no effective improvement in the impaired gastric blood flow. Consequently, it was thought that the KIRSCHNER-NAKAYAMA type of gastric tube, which is supplied by the right gastroepiploic artery, receives predominant innervation of the right sympathetic nerve. Difference of opinion concerning this matter has reported by YANO et al[42], they have observed utilizing Horseradish peroxidase method that the stomach was innervated by bilateral sympathetic nerves as a result of study concerning gastrointestinal autonomic nervous system. It is thought that further study is necessary to evaluate this problem.

Conclusion

Factors involved in the development of blood circulatory disturbance in the KIRSCHNER-NAKAYAMA type of gastric tube for esophageal reconstruction are analyzed in experimental dogs. Also the effect of thoracic sympathectomy as a countermeasure against it was studied. The conclusion are as follows:

1) The construction of the gastric tube reduced blood flow in the tip by 49.8% ($P<0.01$), and 36.1% ($P<0.01$) in the right gastroepiploic artery.
2) Right thoracic sympathectomy (Th_{5-10}) significantly raised blood flow in the tip of the gastric tube by 32.2% ($P<0.10$) and 67.9% ($P<0.01$) in the right gastroepiploic artery.
3) As a result of microcirculatory observation of the gastric tube, the occurrence of impaired blood circulation of the gastric tube was prevented by right thoracic sympathectomy (Th_{5-10}) performed previously.
4) The noradrenergic fluorescence of the right gastroepiploic artery which is the main supplying vessel of the gastric tube disappeared following right thoracic sympathectomy (5–10) and the predominant state of sympathetic nerve was observed.
5) Using the same methods as mentioned in 2), 3) and 4), the following conclusion was obtained: The blood flow and microcirculation of the gastric tube and the fluorescence histochemical study of the right gastroepiploic artery showed no significant changes following left thoracic sympathectomy as a countermeasure.
6) The difference of oxygen pressure between the arterial and venous blood of the stomach increased by subphrenic vagotomy and the opening of gastric submucosal AVA was strongly suggested.

Evidences have been presented by these results:

In making of the KIRSCHNER-NAKAYAMA type of gastric tube, both trunks of vagal nerve have to be divided, which subsequently produces predominant sympathetic nerve innervation in the gastric tube. This condition produces the decrease of right gastroepiploic arterial flow and the microcirculatory disturbances and especially the opening of submucosal AVA which are the most significant factors in the development of this circulatory disturbances. This survey revealed the fact that the right thoracic sympathectomy (5–10) was found to have a significant effect on this impaired blood flow.

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和文抄録

食道再建用胃管の自律神経支配とその循環動態および血行改善策としての胸部交感神経切除術

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食道癌切除後の再建に用いられる Kirschner-中山式胃管においてはしばしば血行障害が発生し，吻合部縫合不全の原因となる．この胃管の作成においては両側迷切が伴われるにもかかわらず，右胃動脈や右胃大網動脈周囲の交感神経線維は保存される結果，胃管の自律神経支配は交感神経緊張状態となり，胃管栄養動脈の血流減少，さらに胃粘膜下 A-V シャントの開大をきたし，胃管の血行障害をひきおこすと考えられる．そこで実験犬を用いて水素ガスクリアランス法によって胃管の血流量を測定し，胃管の微小循環動態は瞬間凍結墨汁法（D.M.W. 法），Evans blue albumine complex 法を用いて観察し，さらに右胃大網動脈のカテコールアミン染色，胃灌流動・静脈血酸素分圧較差を測定した．次いでこの血行障害を改善する目的で，胸部交感神経切除術を施行し，その血流改善効果を検討した．以上について次のような結果を得た．

1）胃管の作成に伴い，胃管先端部では49.8％（P<0.01），右胃大網動脈では36.1％（P<0.01）の血流量の減少を認めた．

2）右第5-10胸部交感神経切除術を加えることによって，胃管先端部では32.2％（P<0.10），右胃大網動脈では67.9％（P<0.01）血流量が増加し，著明な血流改善効果を認めた．

3）胃管微小循環動態観察の結果から，胃管作成時にみられた微小循環障害は，あらかじめ右胸部交感神経切除術を施行することによって防止することができた．

4）胃管の栄養動脈である右胃大網動脈のカテコールアミン染色において，右胸部交感神経切除術を加えることによって，ノルアドレナリン螢光が消失し，交感神経遮断効果が確認された．

5）以上について同様の方法で左第5-10胸部交感神経切除術を行い，胃管血流量，微小循環動態，右胃大網動脈カテコールアミン染色について比較・検討したが，有意の変化を認めず，胃管血流改善効果を認めなかった．

6）横隔膜下迷切によって，胃灌流動・静脈血酸素分圧較差は増加し，胃粘膜下 A-V シャントの開大が示唆された．

以上の実験結果より，Kirschner-中山式胃管の血行障害は，胃管作成に伴う迷切を主要因とする交感神経緊張異常に基ずく栄養動脈の血流減少，胃管微小循環障害，とくに胃粘膜下 A-V シャントの開大が大きな原因であり，この血行障害は右第5-10胸部交感神経切除によって著しく改善され得ることを明らかにした．