The Time Course of Lymph Drainage from the Peritoneal Cavity in Beagle Dogs

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ABSTRACT. Lymph drainage routes from the abdominal and pelvic cavities in beagle dogs were observed serially by following the time course of India ink administered intraperitoneally. Four systems of lymph drainage routes from the peritoneal cavity were observed in this study. The earliest drainage returned to the cranial mediastinal lymph nodes via the sternal lymph vessels; subsequently, the sternal lymph nodes located along the internal thoracic artery became involved. Then, a drainage route via the lymph vessel along the left vagus nerve was observed. The final drainage route flowed into the lateral lymph vessel through the thoracic duct located on the vertebra. These results show that India ink is absorbed from the peritoneal cavity, and that the lymph drainage first flows mainly towards the cranial mediastinal lymph nodes through the ventral lymphatic channels. Our serial observations suggest that, over time, the lymph drainage routes changed from the ventral abdominal to the dorsal thoracic lymphatic channels in the thorax.

KEY WORDS: beagle dog, lymph drainage, peritoneal cavity.

The lymphatic system establishes a lymphatic circulation and transports lymph containing lipid droplets, immunocytes, and tumor cells. Ultimately, lymphatic drainage routes flow into the systemic circulation. However, parts of the lymphatic system are located in serous cavities. These lymphatic routes have yet to be adequately clarified. Previously, a limited amount of information about the lymphatic drainage from the abdominal cavity was collected by examining the route that drains lymph from the canine peritoneal cavity [6]. Tracing marker administered into the peritoneal cavity was found to travel via the diaphragm to the sternal lymphatics located in the ventral inner-wall of the thoracic cavity. Subsequently, the same drainage pattern was observed in many animals [4, 7, 9]. This lymphatic drainage route may be clinically useful in predicting the course of intraperitoneal cancer dissemination. The present paper provides a detailed description of lymph drainage routes over time following the intraperitoneal administration of India ink in beagle dogs.

MATERIALS AND METHODS

Three adult male beagle dogs (body weight, 8.5 kg) and one adult female beagle dog (body weight, 6.7 kg) were used for this experiment.

Using a fine needle, the male dogs were all injected intraperitoneally with warm India ink dissolved in physiological saline at a dose of 25 m/l per kg body weight; the India ink was injected into the pelvic cavity via the rectum in the female dog. The male dogs were sacrificed by an overdose of Nembutal (0.2 ml/kg) at 30 min, 60 min, and 2.5 hr after injection, respectively. The female dog was sacrificed at 2.5 hr. A fixative solution [24 (ethylene glycol): 8 (phenol): 1 (formaldehyde solution): 16 (methanol)] was immediately injected intraperitoneally and intraperitoneally after the animals were sacrificed. The peritoneal and pelvic cavities were dissected from the carcasses, and these dissected samples were then fixed in the same fixative solution. After complete fixation, the individual absorption fields and pathways of the drainage routes were observed macroscopically and under stereoscopic microscopy. The animal facility at Azabu University has animal care and use programs that are accredited by the Office of Laboratory Animal Welfare.

RESULTS

In the dog that was sacrificed 30 min after intraperitoneal injection, drainage was observed to follow a route that traveled from the diaphragm via the intrathoracic lymph vessels along the internal thoracic artery and vein. The lymph vessels finally returned to the cranial mediastinal lymph nodes (Lymphonodi mediastinales craniales) via the sternal lymph nodes (Lymphonodi sternales craniales) (Figs. 1–1, 1–2, 1–3). In particular, the lymph vessels on the right side of the thoracic cavity were observed to have a greater inflow of marker and to have a greater volume of marker than on the left side of the thoracic cavity. In addition, a large India ink uptake volume was observed on the right half of the diaphragm after intraperitoneal injection (data not shown).

In the dog that was sacrificed 60 min after intraperitoneal injection, the drainage of the India ink was observed to follow a route that traveled via the lymph vessel along the left vagus nerve located on the esophagus. This vessel joined...
Fig. 1–1. Schematic drawing of the drainage routes 30 min after intraperitoneal India ink injection. Drainage was observed to occur via the intrathoracic lymph vessels arising from the diaphragm located along the internal thoracic artery and vein. The lymph vessel finally returned to the lymph nodes of the cranial mediastinal lymph nodes (Lymphonodi mediastinales craniales) via the sternal lymph nodes (Lymphonodi sternales craniales). Note that the lymph vessels on the right side had a greater inflow of India ink than the lymph vessels on the left side.

Fig. 1–2. The dorsal view of the thoracic cavity 30 min after intraperitoneal India ink injection. a; cranial mediastinal lymph node. b, c; sternal lymph nodes.

Fig. 1–3. Schematic drawing of the dorsal view of the thoracic cavity 30 min after intraperitoneal India ink injection. a; cranial mediastinal lymph node. b, c; sternal lymph nodes.

Fig. 2–1. Schematic drawing of the drainage routes 60 min after intraperitoneal India ink injection. In addition to drainage via the right and left intrathoracic lymph vessels, drainage flowed via the lymph vessel along the left vagus nerve located on the esophagus. This vessel inserted into the cranial mediastinal and lymph nodes via the cranial tracheobronchial lymph nodes. Note that uptake of the ink was observed on the right half of the diaphragm.

Fig. 2–2. Dorsal view of the thoracic cavity 60 min after intraperitoneal India ink injection. a; cranial mediastinal lymph node. b; sternal lymph nodes.

Fig. 2–3. Schematic drawing of the dorsal view of the thoracic cavity 60 min after intraperitoneal India ink injection. a; cranial mediastinal lymph node. b; sternal lymph nodes.
3–1
In a case of 2.5 hrs after injection into abdominal cavity.

3–2

Fig. 3–1. Schematic drawing of the drainage routes 2.5 hr after intraperitoneal India ink injection. In addition to the drainage routes seen at 30 and 60 min, yet another route was noted that was located in a more dorsal part of the thoracic cavity and then returned to the thoracic lymphatic trunk and continued to the cranial mediastinal lymph nodes. In the upper most route, the thoracic duct was observed to return by traveling along the right side of the aorta.

Fig. 3–2. A dorsal view of the thoracic cavity 2.5 hr after intraperitoneal India ink injection. a; thoracic duct.

the cranial mediastinal lymph nodes via the cranial tracheobronchial lymph nodes (Figs. 2–1, 2–2, 2–3). The volume of India ink uptake increased over time and, 60 min after the intraperitoneal injection, most of the volume was observed to be located on the right half of the diaphragm.

In the dog that was sacrificed 2.5 hr after intraperitoneal injection, the marker located in the dorsal part of the thoracic cavity had returned into the thoracic lymphatic trunk and drained into the cranial mediastinal lymph nodes (Figs. 3–1, 3–2). Most of the upper lymph route going to the thoracic duct was observed to flow through the cisterna chyli and the lymph nodes (lumbar lymphocenter, celiac lymphocenter, cranial mesenteric lymphocenter) located along the right side of the aorta.

In the female dog that was sacrificed 2.5 hr after injection into the pelvic cavity, 4 lymph drainage routes were observed leaving the peritoneal cavity. The first route drained via the intrathoracic lymph vessels. The second drained via the anterior thoracic inlet located along the vagus nerve and then emptied into the tracheobronchial lymph nodes. The third route drained via the dorsal part of the thoracic cavity into the thoracic lymphatic trunk. The fourth route drained through the cisterna chyli into the thoracic duct located along the right side of the aorta. The fourth route was similar to the route seen after marker had been injected into the abdominal cavity. Of the 4 drainage routes seen after pelvic injection, the fourth route was noted to have the greatest volume of drainage (Figs. 4–1, 4–2).

DISCUSSION

In the present study involving 4 dogs, the lymphatic drainage routes over time were seen after the injection of India ink into the peritoneal or pelvic cavity. The lymphatic channels on the surface of the diaphragm were completely delineated. Thus, the major lymphatic drainage from the peritoneal cavity appeared to be via the diaphragm to the sternal lymphatics. Therefore, the thoracic duct appears to play a relatively insignificant part in the drainage of the peritoneal cavity. Lymph drainage from the cavities largely depended on the 6 branches of lymph vessels that comprise the 4 lymphatic drainage systems. The first drainage route depended on the sternal lymph vessels located along the sternal lymph nodes and transported the lymph into the thoracic lymphatic trunk. The second drainage route drained via the cisterna chyli into the thoracic duct located along the right side of the aorta. The fourth route was similar to the route described by Higgins and Graham [6]. However, as time passed, the India ink was taken up by the thoracic lymph vessels and the lymph vessel route along the left vagus nerve located on the esophagus in the central portion of the thoracic cavity. Lymphatic drainage entered the thoracic duct at the most dorsal part of the cavity. This flow may have been due to
the movement of the ink in the lymph vessels caused by gravity and the passive pressure generated by the thoracic musculature due to respiratory movement [3, 8, 10]. In quadrupeds such as dogs, if no other force affects lymphatic transport, the force of gravity would result in the accumulation of the injected India ink in the ventral peritoneal cavity, as well as drainage of the marker from the inside of the peritoneal cavity via the lymph vessels located along the internal thoracic artery of the ventral chest wall, since the movement of the marker in these lymph vessels is essentially promoted by gravity and passive pressure, such as muscular movement and respiratory movement [3, 10].

Over time, a second drainage route was noted; this route depended on the dorsal thoracic lymph trunk, since India ink was found in the thoracic duct. The drainage route of the thoracic duct was located in the most dorsal part of the thoracic cavity and was the slowest drainage route. The flow in this route may be due to the structure of the thoracic duct itself; the lymph comes from the peritoneal organs and is primarily received through the cisterna chyli located in the peritoneal cavity. Of note, drainage from the pelvic peritoneal cavity flowed primarily into the thoracic duct. This lymph drainage route might reflect changes in the amount of lymph that is accumulated, the location of lymph accumulation, or the retention time of lymph in the body cavity. Therefore, the first lymph drainage route from the abdominal peritoneal cavity differs between quadrupeds and bipeds like humans. However, in quadrupeds, the thoracic duct is a very important drainage route from the peritoneal cavity, as well as from the pelvic cavity.

Finally, in the present study, lateralization of the drainage capacity was observed to occur to the right side of the diaphragm or the right-sided sternal lymph vessel. This may be due to the pressure of the liver on the right surface of the diaphragm. The uptake of lymph from the peritoneal side of the diaphragm’s surface depends on the mesothelial cells of the diaphragm surface[1, 2, 5, 8, 9]. There may be more stomata located in the mesothelium on the surfaces with organ contact than on surfaces with no organ contact.

This study clarified how lymph and cells flow from the peritoneal cavity via the peripheral lymph nodes through the ventral to dorsal lymphatic channels, and it traced the individual routes of each lymph vessel and node that might serve as a route for cancer cell or India ink transport from the peritoneal cavity in dogs.

REFERENCES


