The Lymphatic Pathways from the Peritoneal Cavity:
A Lymphangiographic Study in the Rat

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SUMMARY

The lymphatic drainage from the peritoneal cavity was studied radiographically following intraperitoneal injection of Thorotrast. The lymphatics of the diaphragm were filled first, draining both cranially and caudally. The most important pathways from the peritoneal cavity were the parasternal lymphatics. Only a small amount of Thorotrast was found in the lymph of the thoracic duct.

Tumors in the peritoneal cavity often spread via the lymphatics. A thorough knowledge of the lymphatic pathways from the peritoneal cavity is therefore of importance. In studies of the absorption from the peritoneal cavity into the lymphatics, different tracer substances have been used, such as erythrocytes (8, 12), small particles (5, 12, 13, 18), colored substances (10), and roentgen-contrast media (2—4, 7, 16, 22, 24, 25). The lymphatics of the diaphragm have been shown to be the only route for this drainage in man (4), and in many other species such as dog (4, 5, 7, 18), cat (9), rabbit (2—4, 6, 13, 16, 25), rat (2, 3, 10, 22), and mouse (24).

The rat is one of the most frequently used animals for tumor experiments. The lymphatic pathways from the peritoneal cavity have been previously examined in the rat by means of lymphangiography by Menville and Ané (22). They injected 0.5 ml. Thorotrast intraperitoneally into three rats and radiographed the animals at 24 hours and again 2 weeks later. The lymphatics of the diaphragm were shown to be the only route for this drainage in man (4), and in many other species such as dog (4, 5, 7, 18), cat (9), rabbit (2—4, 6, 13, 16, 25), rat (2, 3, 10, 22), and mouse (24).

Bennet and Shivas (3) injected 1 ml. Angiopac (an aqueous emulsion of ethyl iodostearate, Union Chimique Belge) intraperitoneally into ten rats. Each day one rat was sacrificed and radiographed. On lateral chest films a large lymph trunk was seen behind the upper part of the sternum. Furthermore, some mediastinal lymph nodes were opacified.

Barer (2) injected 2—4 cc. of radiopaque materials (Thorotrast, Angiopac, Micropaque, Pyelosil, or Urografin) into fifteen rats. The substances rapidly entered the diaphragmatic lymphatics and passed up by an anterior route through the thorax to the anterior mediastinal glands.

More detailed information was desired, however, and this investigation was therefore performed.

Job (17) described the anatomy of the lymphatic system in the rat but did not go into detail concerning the lymphatic drainage of the peritoneal cavity. As far as possible his terminology has been used.

MATERIALS AND METHODS

Sixty Sprague-Dawley rats weighing 150—200 gm. were used. Five ml. of 20 per cent Thorotrast (Testagar & Co., USA) were injected intraperitoneally, and the rats were sacrificed and radiographed 10 hours later by a 4-valve roentgen-apparatus (Scandia Optimatic, Elema, Sweden). This interval seemed to be optimal—2 hours was often too short a period. Film focus distance was 1 m. and the focal spot, 0.6 × 0.6 mm. No intensifying screens or grids were used. The film, Microcard (Gaevera), was exposed with 1000 mAs and 70—80 kv. The rats were radiographed in three different positions: lateral, anteroposterior, and oblique. Before the exposure the peritoneal cavity was rinsed, clearing away residual Thorotrast solution. In some cases the liver and spleen were removed. To estimate the lowest concentration at which an average-sized lymphatic would be visible in radiographs, polyethylene tubes (PE 10, 0.28 mm.) were filled with Thorotrast solutions of different concentrations. These tubes were placed in a rat and radiographed. The lowest concentration at which a tube could be identified on the radiograms was about 1.2 per cent.

In seven animals the thoracic duct was catheterized in the neck with a polyethylene tube, PE 10, according to a method described by Saldeen and Linder (28). This catheterization was performed prior to the intraperitoneal injection. The lymph from the duct was sampled at 1, 2, and 10 hours following the injection. The concentration of Thorotrast in the lymph was analyzed in a scintillation-counter with a well-crystal, in the energy ranges from 50 to 400 keV. A 20 per cent Thorotrast solution was used as a standard. Following the 10-hour sampling the animals were sacrificed. Thorotrast (0.05 ml.) was injected into the thoracic duct in a retrograde direction, and the animals were radiographed.
The dead animals were autopsied, and organs of special interest—i.e., lymph nodes, liver, spleen, kidneys, and adrenals—were studied microscopically. The sections were stained with haematoxylin-eosin and Best’s carmin (13).

RESULTS

After the intraperitoneal injection of Thorotrast, the lymphatics of the diaphragm were generally visualized in all animals by the end of 1 hour. The lymphatics of the anterior part of the diaphragm drained cranially into parasternal lymph vessels, and the lymphatics of the posterior part of the diaphragm drained caudally into retroperitoneal lymph vessels (Fig. 1). Often small, intercostal lymphatics were seen draining the dorsal, lateral part of the diaphragm (Fig. 2). In a few cases mediastinal lymph vessels drained the central part of the diaphragm (Fig. 3).

The paired parasternal lymphatics were always seen, usually as one trunk on each side of the sternum. Sometimes the trunk divided into two vessels on one side. The diameter of the parasternal lymphatics varied between 0.1 and 0.9 mm., with a mean of 0.3. The right paravertebral lymphatic was seen in about three-fourths of the animals. The corresponding vessel on the left side was filled only in one-third of the animals. The paravertebral lymphatics, which were filled from the small intercostal lymphatics (mean diameter, 0.2 mm.), had a diameter between 0.1 and 0.7 mm., with a mean of 0.3 mm. The mediastinal lymphatics, which were seen in about one-fifth of the animals, were usually single and had a diameter of 0.1–0.3 mm., with a mean of 0.2 mm. The retroperitoneal lymphatics were always visualized on the left side but were filled on the right side only in three-fourths of the animals. The diameter of these vessels was 0.2–0.6 mm., with a mean of 0.3 mm.

The parasternal lymphatics, as a rule, show the highest density. In fact, the density was higher in these vessels than in the thoracic duct after retrograde injection of 20 per cent Thorotrast, indicating that the contrast medium had been concentrated in the lymphatics. The mediastinal, paravertebral, and retroperitoneal lymphatics usually seemed to be of lower density than the parasternal lymphatics.

The parasternal, paravertebral, and mediastinal lymphatics emptied into the mediastinal lymph nodes in the upper part of the chest (Fig. 2). These nodes were filled with Thorotrast on both sides in all the animals. The left and right retroperitoneal lymphatics drained into cisternal and intestinal lymph nodes, respectively. These nodes are situated on either side of the cisterna chyli (Fig. 3). The cisternal lymph nodes were usually seen (90 per cent), whereas the intestinal lymph nodes were not seen so frequently (80 per cent). Occasionally, renal lymph nodes were seen situated more caudally on both sides of the aorta. In one-fifth of the rats a mesenteric lymph node in the ileo-cecal region was filled from a small lymphatic from one of the intestinal lymph nodes (Fig. 5).

The thoracic duct was never visualized on the radiograms following intraperitoneal injection of Thorotrast. Most of the lymph in the thoracic duct originates, however, from the intestine, not from the diaphragm. Some rats were placed on a dry diet prior to the experiment to diminish the flow of chyle, but even then the duct was not visible on the radiograms. In the seven rats in which the thoracic duct was catheterized, the amount of lymph collected the 1st hour following the intraperitoneal injection had a mean volume of 3.1 ml. During the 2d hour 3.0 ml. lymph drained, and during the following 8 hours 11.0 ml. lymph was collected. The concentration of Thorotrast in the three samples was 0.5 per cent (range, 0.2–0.9), 0.6 per cent (range, 0.3–1.1), and 0.8 per cent (range, 0.5–1.2), respectively.

The topography of the thoracic duct was then clarified by an injection of Thorotrast in a retrograde direction through the catheter (Figs. 6, 7). The contrast medium easily passed down to the cisterna chyli and also filled some of the intestinal lymphatics. No valves were encountered in the duct, and no connections to the other lymphatics in the thorax were seen. The diameter of the thoracic duct varied between 0.5 and 0.9 mm., with a mean of 0.7 mm.

On the radiograms following intraperitoneal injection, the organs containing cells belonging to the reticuloendothelial system—i.e., liver, spleen, and suprarenal glands—were usually filled with Thorotrast (Fig. 1). These organs seemed to be opacified to the same extent, even when the lymph was drained from the thoracic duct. At autopsy large amounts of turbid fluid were usually found in the peritoneal cavity. Otherwise no gross lesions were noted. Microscopic examination of sections revealed large deposits of Thorotrast in the lymph nodes, especially in the mediastinal and cisternal nodes and especially in the cortical sinuses. Large amounts of Thorotrast were also found in the liver, spleen, and adrenals. Small amounts of Thorotrast were found in the kidneys, as a rule in the glomeruli.

DISCUSSION

The only lymphatic pathway from the peritoneal cavity which has been demonstrated by earlier investigators (2, 3, 22) is the parasternal system. Our examination has revealed several other pathways going in a cranial, as well as in a caudal, direction. All the lymphatic pathways which have been revealed are shown in the schematic drawings in Charts 1 and 2. The difference between our examination and the earlier studies might be due to better radiographic technic.

The parasternal lymphatics probably represent the most important drainage of lymph from the peritoneal cavity, since they were filled with highly concentrated Thorotrast in all animals studied. The drainage system through the intercostal and paravertebral lymphatics is mainly right-sided. These lymphatics are not seen in all animals. This is due either to their absence or to the fact that they do not convey enough contrast medium to be visualized. Thus, the intercostal-paravertebral lymphatics are of less importance than the parasternal lymphatics. The same is true for the mediastinal lymphatics.

Since the intercostal-paravertebral system is predominantly right-sided, tumors in the peritoneal cavity should spread predominantly to the mediastinal lymph nodes of
One of us (T.S.) concurrently studied the lymphatic pathways from the peritoneal cavity in the rat following intraperitoneal injection of 2 per cent colloidal silver or of 5 per cent Patent Blue (27). The pattern of the lymphatic system which was obtained agreed well with that found in the present investigation.

In other species the drainage of lymph from the peritoneal cavity is probably not too different from that of rats. Thus, the cranial route, by way of the parasternal lymphatics, dominates over the caudal route and the thoracic duct in man (4), dog (4, 5, 7, 18), rabbit (2—4, 6, 14, 16, 25), cat (9), and mouse (24). The mediastinal, paravertebral, and retroperitoneal lymphatics are usually only secondary pathways.

The role played by the thoracic duct seems however, to differ slightly between various species and for different substances. In the rat only 6 per cent of intraperitoneally injected plasma protein reached the blood by routes other than the thoracic duct, at the same time as 28 per cent...
FIG. 3.—Lateral radiogram following Thorotrast intraperitoneally. The liver and spleen have been removed. The lymphatics of the diaphragm drain predominantly into the parasternal lymphatics (→). The paravertebral lymphatics (←) are also seen. In the middle and posterior part of the chest a small tortuous mediastinal lymphatic (↔) is opacified.

FIG. 4.—Antero-posterior radiogram following Thorotrast intraperitoneally. Same animal as in Fig. 1, but the liver and spleen have been removed for better visualization of the retroperitoneal lymphatics (↔) and the cisternal (↔→) and intestinal (→→) lymph nodes.
Fig. 5.—Lateral radiogram following Thorotrast intraperitoneally. The liver and spleen have been removed. From the intestinal lymph nodes (←→) an ileocecal lymph node (↔) is filled by way of a small lymphatic.

Fig. 6.—Lateral radiogram. Same animal as in Fig. 5. A catheter has been introduced into the thoracic duct (↔), and a small amount of Thorotrast has been injected in a retrograde direction. Some mesenteric lymphatics (↔) are also filled.
FIG. 7.—Radiogram in right posterior oblique position. Same animal as in Figs. 5 and 6. Parasternal lymphatics (←→), paravertebral lymphatics on the right side (←→) and thoracic duct (←→←→) are visualized.
was found in the thoracic duct (1). The corresponding values for red corpuscles were 75 and 25 per cent (27). In the cat 20 per cent of injected plasma protein was demonstrated in the thoracic duct (9) and only a minor portion of a dose of red blood cells (8). This difference may be owing to, e.g., the barrier function of the lymph nodes which the substances have to pass before reaching the thoracic duct.

REFERENCES

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