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# LOOKING BACKWARD AND LOOKING FORWARD: REVISITING "CLINICAL USEFULNESS OF THORACIC DUCT CANNULATION"

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ABSTRACT

*Over the past decade, there has been a resurgence of interest in the thoracic duct and central lymphatic system and its disorders, stimulated by advances in interventional magnetic resonance imaging techniques and urgent challenges in the clinical management of lymphatic malformations and lymphatic complications from congenital heart disease. The following chapter reprinted here written shortly after the formal founding of the discipline of lymphology and the International Society of Lymphology, describes early efforts, and also suggests future directions now being revisited and others yet to be explored (1).*

**Keywords:** thoracic duct, lymph drainage, lymphatic cannulation, lymphatic disorders, applications

*CONFLICT OF INTEREST AND DISCLOSURE*

The author declares no competing financial interests exist.

*REFERENCES*

1. Dumont, AE, MH Witte: "Clinical Usefulness of Thoracic Duct Cannulation" In: *Advances in Internal Medicine*, Vol. XV. Stollerman, GH (Ed.), Year Book Medical Publ., Inc., 1969, 51-72.

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# Clinical Usefulness of Thoracic Duct Cannulation*

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UNTIL THE PAST DECADE, the thoracic duct interested clinicians only when it was wounded or leaking. After the difficulties in collecting and analyzing lymph in animals were overcome, cannulation of the thoracic duct was initiated in man in order to gain direct access to cell-bathing fluid. This technique has uncovered previously unrecognized disturbances in the *milieu interieur* in a variety of disease states. In this paper, the present and future applications of thoracic duct cannulation to clinical medicine are considered.

The mammalian lymphatic system is an extensive network of distensible channels which resemble and develop from veins. Lymphatics from the abdominal viscera and lower half of the body converge just below the diaphragm to form the cisterna chyli. From the cisterna, the thoracic duct ascends as a single major channel through the mediastinum into the left side of the neck where it empties into the angle of the jugular and subclavian veins. From its origin at the diaphragm to its termination in the neck, the thoracic duct receives no important tributaries and is uninterrupted by the interposition of nodes. It is generally recognized that under normal circumstances surgical ligation of the

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duct at any point in its course is harmless and entirely without sequelae.

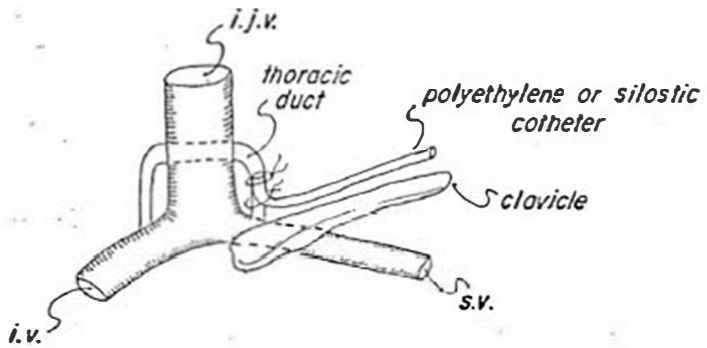
The lymph circulation performs the vital function of collecting and transporting excess tissue fluid and extravasated plasma proteins, absorbed lipids, and other large molecules from the interstitial space back to the blood stream. In normal mammals, approximately 40% of the total plasma protein pool and a volume of fluid equivalent to the total plasma volume are returned to the blood via the thoracic duct every 24 hours.

Lymph nodes are an important subdivision of the lymphatic system but one which is functionally distinct. Lymphocyte and antibody production are prominent functions of this component, and immunologically active cells and proteins reach the blood predominantly via the thoracic duct.

Cannulation of the thoracic duct is a simple surgical maneuver that can be carried out under local anesthesia (Fig. 1). The approach in the neck is similar to that used for scalene node biopsy (31, 39). If the venous end of the duct is not ligated at the time of the original procedure, the cannula is simply removed at the bedside and a pressure dressing applied. Reoperation and lymphangiography confirm that the duct usually remains patent after removal of the cannula (11, 46). If leakage of lymph persists, the incision in the duct is repaired directly with fine silk sutures. Rarely is it necessary to obliterate the lumen by ligation.

During short periods of external lymph drainage when lymph flows at the normal rate of about 1 cc/min, losses of water and electrolytes are replaced by increasing the intake of salt-containing fluids by mouth. If the patient is unable to take adequate amounts of fluid by this route,

FIG. 1.—Technique for cannulation of the thoracic duct in the neck. i.v. = innominate vein; i.j.v. = internal jugular vein; s.v. = subclavian vein. (From Witte, C. L., *et al.* [49].)



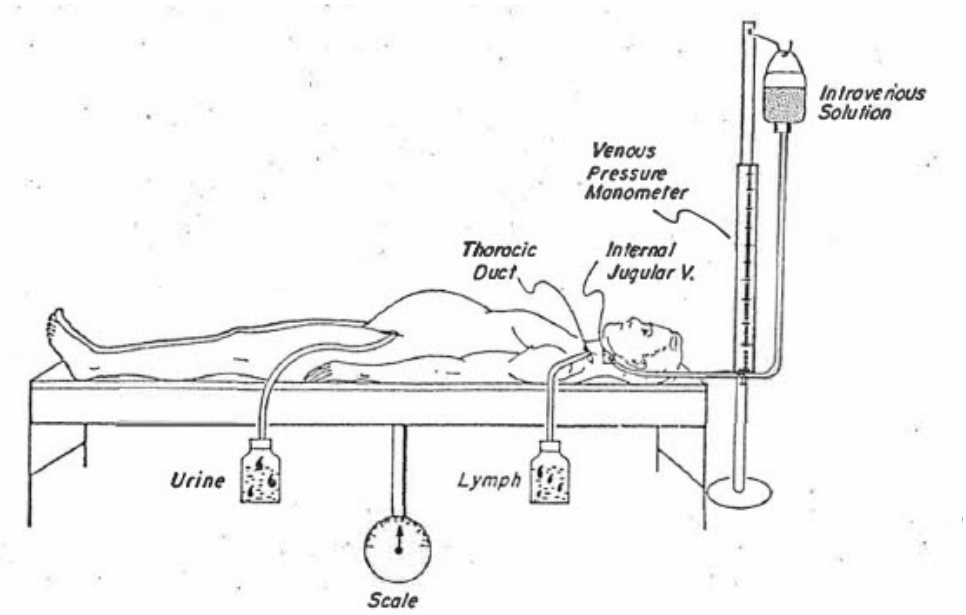



FIG. 2.—Methods for monitoring the patient during prolonged drainage of thoracic duct lymph.

salt-containing solutions (Ringer's lactate, isotonic saline, or plasma) are administered intravenously. Intravenous infusion of albumin is usually not required. Determinations of blood hematocrit are performed 2–3 times daily as a guide to fluid replacement. When lymph flow is increased and a negative fluid balance is desired, however, replacement must be more carefully monitored, preferably with the patient on a "metabolic bed" in a clinical research or intensive care unit (Fig. 2). Volume and composition of the replacement fluid is determined by vital signs, central venous pressure, urinary output and by frequent determinations of blood hematocrit, urea nitrogen, electrolytes and protein content. When large volumes of lymph are drained, excessive loss of protein is avoided by intravenous administration of albumin, plasma or anticoagulated lymph in amounts sufficient to maintain plasma protein levels (usually considerably less than the total amount of protein lost). Once the therapeutic aim is accomplished the cannula is promptly removed.

## Diagnostic and Investigative Uses

Characteristic alterations in the flow, pressure and composition of thoracic duct lymph aid in the differential diagnosis of various dis-

orders. Usually scalene lymph node biopsy is performed concomitantly, and the cannula is left in place for about an hour or the time necessary to collect the required volume of lymph.

Flow rate of thoracic duct lymph (normal = 0.82 ± 0.27 cc/min) depends largely on the rate of formation of capillary filtrate in the liver and extrahepatic splanchnic bed. Lymph end pressure, that is, the level to which lymph rises in a cannula positioned above the neck (normal = 11.6 ± 6.6 cm $H_2O$ above the right atrium) is governed by a variety of propulsive forces, including filtration pressure, tissue turgor, volume capacity and distensibility of the lymph vessels. Extensive obliteration of hepatic hilar and/or mesenteric lymphatics (e.g., metastatic cancer [50], intestinal tuberculosis [51] or Whipple's disease [43]) reduces the flow of thoracic duct lymph (Fig. 3). On the other hand, obstruction to venous outflow from the splanchnic bed is associated with greatly increased flow and end pressure in the cannulated thoracic duct, an abnormality which occurs early in hepatic cirrhosis (12) and congestive heart failure (13), even before ascites and peripheral edema appear (Fig. 3). Consideration of thoracic duct lymph flow and pressure is helpful in the differential diagnosis of ascites and of obstructive jaundice (50).

Thoracic duct lymph collected during the fasting state is normally clear and straw colored. However, in hepatic cirrhosis, it is grossly bloody. In this disorder, intact red cells appear to gain access to the thoracic duct at some point above the cisterna chyli, perhaps through periesophageal lymphatic-venous communications (14).

The cellular population of thoracic duct lymph consists predominantly of lymphocytes (15). Thoracic duct lymphocytes differ qualitatively and quantitatively from peripheral blood lymphocytes in their reactivity to antigenic stimulation and their ability to synthesize immunoglobulins in vitro (6, 30). Occasionally, abnormal cells appear in thoracic duct lymph. Leukemic cells and gastrointestinal carcinoma cells (26, 45) have been identified in thoracic duct lymph. Wandering macrophages carrying specific storage materials (e.g., Whipple cells [43]) also migrate through the thoracic duct.

Pathogenic microorganisms are transported in thoracic duct lymph, particularly when the infection arises within the abdominal cavity (table). Bacteria have been isolated from thoracic duct lymph when central venous blood cultures were negative in patients with inflammatory disease of the small bowel (tubercle bacilli), peritonitis and cholangitis (7, 51). Further search for parasites, fungi, rickettsiae and viruses in thoracic duct lymph is under way. In patients with "fever of

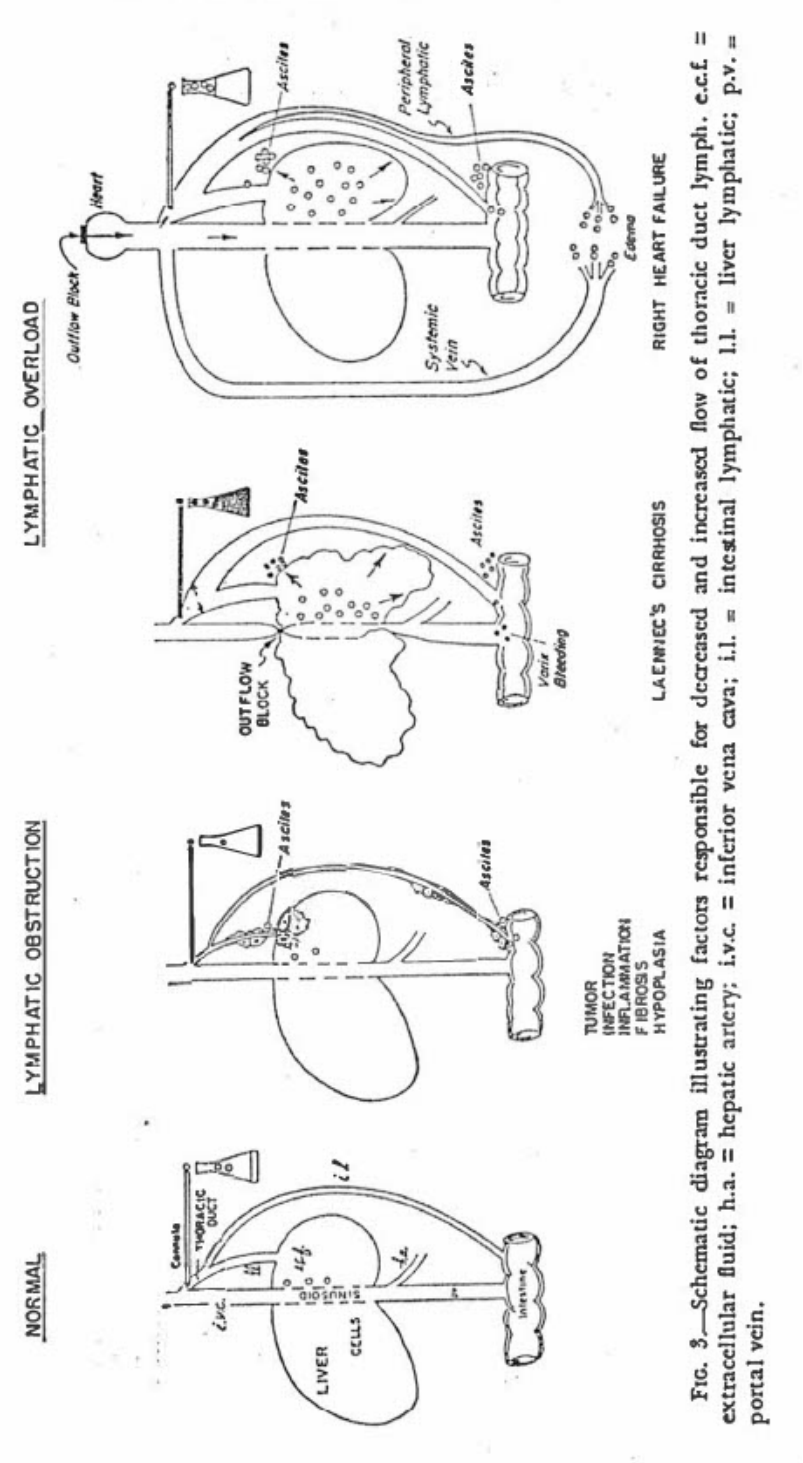



FIG. 3.—Schematic diagram illustrating factors responsible for decreased and increased flow of thoracic duct lymph. e.c.f. = extracellular fluid; h.a. = hepatic artery; i.v.c. = inferior vena cava; i.l. = intestinal lymphatic; l.l. = liver lymphatic; p.v. = portal vein.

POSITIVE CULTURES FOR BACTERIA IN THORACIC DUCT LYMPH AND CENTRAL VENOUS BLOOD AFTER DIFFERENT SURGICAL PROCEDURES*

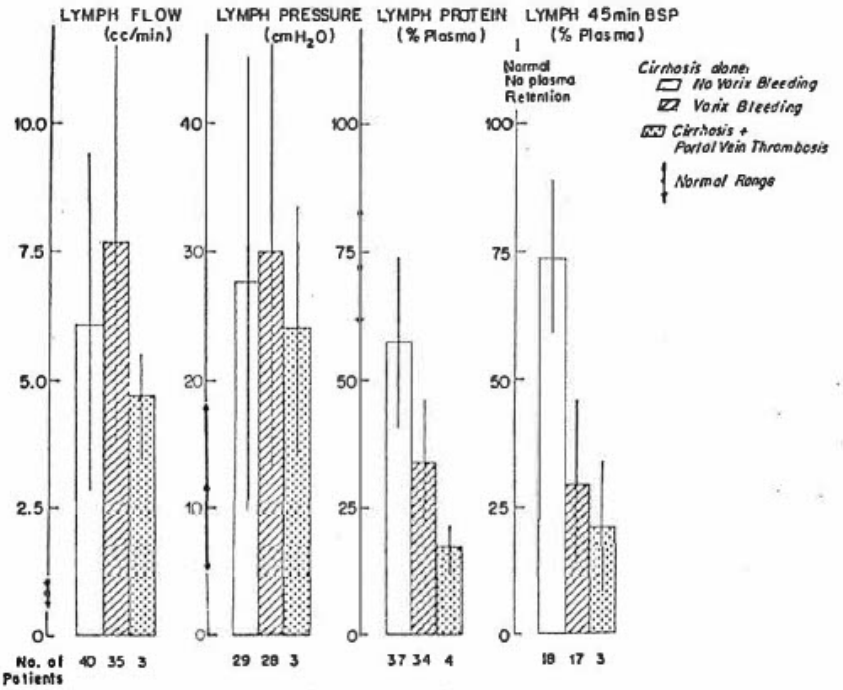
| SURGICAL PROCEDURE | Ligation of loop of colon and its blood supply | | Ligation of loop of ileum and its blood supply | | Mesenteric artery ligation | | Obstruction of terminal ileum | | Obstruction of uncontaminated common duct | |
|---|---|---|---|---|---|---|---|---|---|---|
| TIME BETWEEN SURGERY AND CULTURE | 24 hours | | 24 hours | | 24 hours | | 3 days | | 3 days | |
| NUMBER OF DOGS | 5 | | 3 | | 4 | | 5 | | 4 | |
| BODY FLUID CULTURED | Lymph | Blood | Lymph | Blood | Lymph | Blood | Lymph | Blood | Lymph | Blood |
| ORGANISMS | | | | | | | | | | |
| Escherichia coli | 5 | 0 | 1 | 0 | 2 | 0 | 3 | 0 | 0 | 0 |
| Micrococcus | 4 | 1 | 1 | 0 | 4 | 0 | 3 | 0 | 2 | 0 |
| Alpha hemolytic streptococcus | 1 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 1 | 0 |
| Beta hemolytic streptococcus | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| Nonhemolytic streptococcus | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Corynebacterium sp. | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| Proteus sp. | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| Niesseria sp. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 |
| Klebsiella sp. | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Bacillus sp. | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

* From Cole, W. R., *et al.* (7).

unknown origin," thoracic duct cannulation provides tissue fluid and cells from inaccessible areas in large quantities for concentration and culture, antibody determination and response of lymphocytes to specific antigens associated with pathogenic microorganisms.

Chemical analysis of the fluid portion of thoracic duct lymph is still another source of diagnostic information. Lymph protein (normal = 72% of plasma level) is derived almost entirely from protein that has escaped from the vascular space; newly synthesized proteins appear only in minute amounts. Under normal circumstances about one third to one half of thoracic duct lymph originates in the liver and most of the remainder in the extrahepatic portal bed. As liver sinusoids are freely permeable to protein, liver lymph has a uniquely high protein content (88% of plasma protein) (48, 53). Intestinal capillaries are less permeable, and intestinal lymph, therefore, is lower in protein (69% of plasma), particularly when portal venous flow is impeded (9% of plasma). A small amount of liver lymph arises in the peribiliary

FIG. 4.—Thoracic duct lymph flow, end pressure, total protein and BSP levels in patients with hepatic cirrhosis. Lymph flow and pressure are markedly elevated. Protein and BSP levels are highest in patients who never bled from esophageal varices, much lower in those who bled and lowest in those with superimposed portal vein occlusion (53).



capillary plexus which is in intimate contact with high concentrations of biliary constituents, such as sulfobromophthalein (BSP) in transit from liver cells to biliary radicles (52). Low levels of protein and content of BSP 45 minutes after injection (< 35% of plasma BSP) are found in the lymph of patients with severe presinusoidal obstruction to portal blood flow (advanced hepatic cirrhosis and severe congestive heart failure), particularly when the portal system is occluded (Fig. 4) (48, 53).

Although the normal state of lipids in human thoracic duct lymph has been clarified, little is known about pathologic conditions (28, 29). Alterations in absorption and transport of lipids can be examined directly by chromatographic and other chemical studies of thoracic duct lymph.

Values of $Po_2$, $Pco_2$ and pH in thoracic duct lymph reflect respiratory gas exchange in splanchnic tissues and differ from simultaneous data obtained in arterial and central or splanchnic venous blood (49). These patterns may uncover metabolic and microcirculatory derangements in splanchnic tissues in a wide variety of clinical disorders associated with altered gas exchange, e.g., septic and hemorrhagic shock, hepatic cirrhosis and congestive heart failure.

The following case reports* illustrate the diagnostic uses of thoracic duct cannulation:

CASE 1.—A young man with a history of alcoholism presented with fever, abdominal pain and ascites. Several weeks of hospitalization and an exhaustive work-up failed to provide a specific diagnosis. Thoracic duct cannulation was performed. Grossly hemorrhagic lymph which flowed at a rate of 4.5 cc/min and an end pressure of 20 cm $H_2O$ indicated hepatic cirrhosis. Laparotomy revealed active cirrhosis and granulomatous peritonitis. Cultures of thoracic duct lymph were subsequently positive for Mycobacterium tuberculosis.

CASE 2.—During intensive treatment of acute pancreatitis, a middle-aged man without a history of alcoholic intake developed ascites and bleeding from esophageal varices. Thoracic duct cannulation was performed to control the bleeding, and grossly hemorrhagic lymph flowed at an increased rate (5.5 cc/min) and end pressure (35 cm $H_2O$) favoring a diagnosis of hepatic cirrhosis. Low levels of protein and BSP in lymph reflected increased formation of low-protein lymph in the extrahepatic portal bed from marked presinusoidal obstruction. As hepatocellular function was only mildly disturbed, these findings led to suspicion of isolated portal system occlusion superimposed on cirrhosis. Exploratory laporatomy disclosed nutritional cirrhosis, gastroesophageal and colonic varices and portal hypertension (35 cm $H_2O$). Because of the massive inflammatory reaction secondary to acute pancreatitis, portal decompression could not be performed. At autopsy, the portal vein was patent, but the superior

* Drs. C. L. Witte, W. R. Cole, L. N. Chessin and R. Bopp participated in the study of these patients.

mesenteric vein was almost completely occluded by a large organizing thrombus.

CASE 3.—A middle-aged woman developed pruritus and scleral icterus. Liver function tests, liver scan and liver biopsy were consistent with intrahepatic cholestasis. Thoracic duct cannulation disclosed a decreased flow (0.2 cc/min) of lymph, which suggested widespread obstruction of the splanchnic lymphatics (e.g., by tumor). Extensive carcinoma with metastases to the porta hepatis, liver and splanchnic lymph nodes was found at laparotomy (50).

CASE 4.—An elderly woman presented with massive abdominal swelling and minimally deranged liver function tests. Attempts to distinguish between an ovarian cyst and cirrhosis with ascites were inconclusive. Cannulation of the thoracic duct disclosed a normal flow of clear, straw-colored lymph, and hepatic cirrhosis was thus excluded. At laparotomy, a huge ovarian cyst was found.

CASE 5.—An elderly man was hospitalized for fever, pulmonary infiltrates and anasarca. After several weeks of tests, the diagnosis remained obscure. Thoracic duct cannulation revealed an increased flow of grossly hemorrhagic lymph in the presence of normal central venous pressure, strongly suggesting hepatic cirrhosis. Lymphocytes harvested from thoracic duct lymph and from peripheral blood were exposed in vitro to phytohemagglutinin, tuberculin and Kveim antigens. Thoracic duct lymphocytes, in contrast to peripheral blood lymphocytes, transformed well to Kveim antigen, although the two populations of cells displayed similar good reactivity to phytohemagglutinin and poor reactivity to tuberculin. Open liver biopsy revealed nutritional cirrhosis with many noncaseating granulomata consistent with sarcoidosis. Fever and systemic symptoms failed to respond to antituberculous drugs but did respond to corticosteroid therapy. The patient left the hospital much improved.

CASE 6.—A middle-aged man presented with chronic ulceration of upper and lower extremities. Diagnostic studies were unremarkable, except for hyperglobulinemia (total serum globulins = 7.79 Gm/100 ml). Liver biopsy was normal and bone marrow aspiration revealed 10% plasma cells. Scalene lymph node biopsy showed reticulum cell hyperplasia. Thoracic duct lymph flow was normal, but total protein concentration in lymph was unusually high (88% of plasma protein). Increased amounts of IgG and IgA and a diminished level of IgM were found in both serum and lymph. A cell line isolated from thoracic duct lymph has been in continuous culture for more than a year, and the cells synthesize in vitro IgG molecules manifesting distinctive focal labeling of the precipitant arc. Lymphocytes harvested from simultaneous specimens of peripheral blood and scalene lymph node did not go into continuous culture. Chromosomal analysis of the thoracic duct cell line (Plate 1, *A* and *B*) disclosed prominent secondary chromosomal constriction in 26% of cells, predominantly in *Chromosome 1*. Although the patient's disease has not been specifically labeled, further investigation of the biochemical activities of the thoracic duct cell line suggests that the disorder is a variant of "heavy-chain" disease (6).

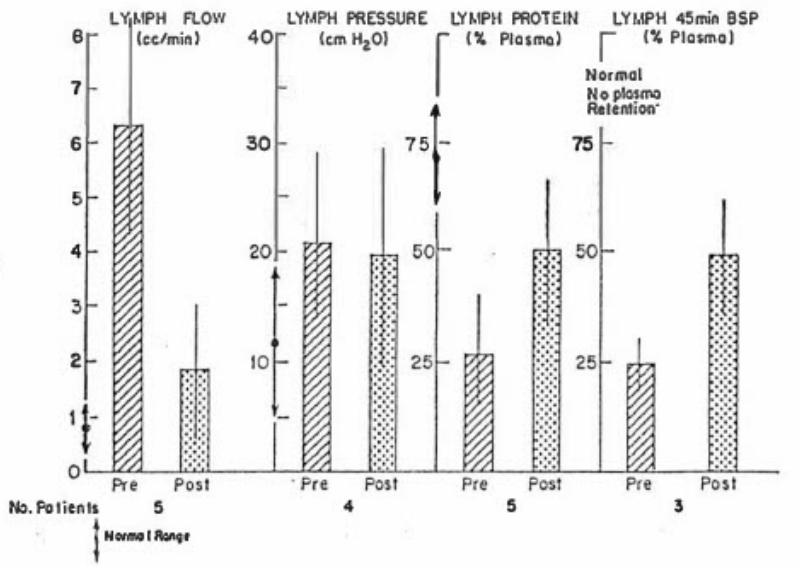
CASE 7.—An elderly man who denied alcoholic intake complained of intense jaundice and abdominal pain. He had been hospitalized 6 months earlier for lower gastrointestinal tract bleeding, and at that time chemical tests of liver function were normal. The liver was enlarged, but spider angiomata and ascites were absent. Laboratory examination revealed a high per cent of direct bilirubin in the blood, clay-colored stools and no urinary urobilinogen, suggesting extrahepatic biliary obstruction. Thoracic duct cannulation, however, disclosed an increased flow of hemorrhagic lymph under pressure. Although cirrhosis was

suspected, laparotomy was performed. Active nutritional cirrhosis and a normal extrahepatic biliary tree were found (50).

Serial changes in the flow and composition of thoracic duct lymph may be used to evaluate progression or reversal of a disease process. The spectrum of hemodynamic disturbances in patients with hepatic cirrhosis includes various degrees of obstruction on either side of liver sinusoids (postsinusoidal and presinusoidal block). Splenoportography, splenic pulp manometry, hepatic venography and wedge pressure, liver blood flow determinations, etc., focus only on specific facets of the hemodynamic disturbance. On the other hand, the flow, pressure, protein and BSP content of thoracic duct lymph represent the net effect of hydrostatic and osmotic forces on capillary filtration in the liver and extrahepatic splanchnic bed (48, 53, 54). This information is useful not only in understanding evolution of the forces and their relation to the clinical manifestations of the disease but also in individualizing treatment of ascites and esophageal varix hemorrhage. The effects of operative treatment, e.g., portacaval shunt, on splanchnic hemodynamics are reflected in pre- and postoperative studies of the flow, pressure and composition of thoracic duct lymph (Fig. 5). The following cases are illustrative:

CASE 8.—A young man with advanced hepatic cirrhosis developed massive bleeding from esophageal varices. Thoracic duct cannulation disclosed a very

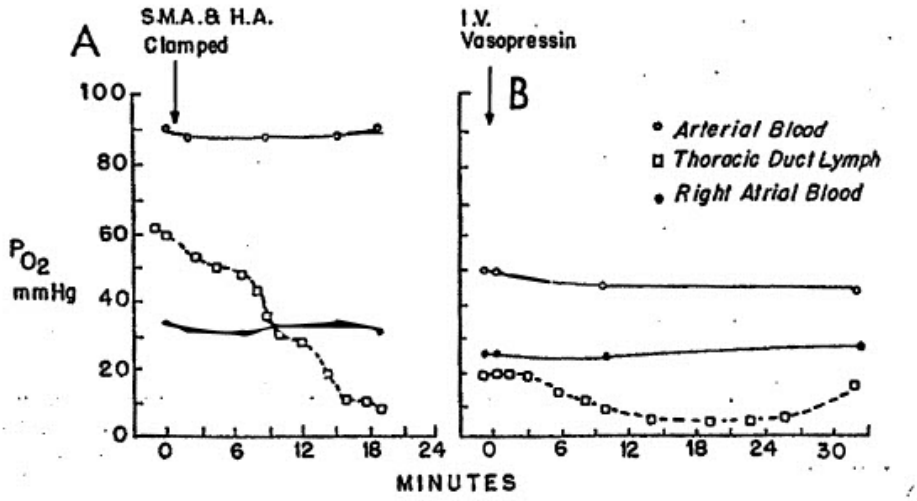
FIG. 5.—Effects of portacaval shunt on flow and composition of thoracic duct lymph. Following shunt, lymph flow decreases and levels of protein and BSP rise. (From Witte, M. H., *et al.* [54].)



rapid flow (12.8 cc/min) of hemorrhagic lymph low in protein (19% of plasma protein). Exploratory laparotomy revealed a shrunken, coarsely nodular liver, portal hypertension (45 cm $H_2O$) and no ascites. Liver lymph protein was 62% of plasma protein, whereas intestinal lymph protein was 9% of plasma protein, suggesting that the bulk of thoracic duct lymph was coming not from the liver but from the congested gastrointestinal tract. After a side-to-side portacaval shunt, portal pressure dropped (25 cm $H_2O$), and within 30 minutes lymph flow decreased to 2.4 cc/min. Postoperatively, the patient developed hepatic coma, severe jaundice and transient ascites. Recannulation of the thoracic duct 3 weeks later showed persistence of a mildly elevated flow (2.3 cc/min) and doubling of lymph protein content (38%). These findings indicated a patent shunt and adequate decompression of the extrahepatic portal bed; thoracic duct lymph now originated predominantly from the liver. The patient left the hospital well but died from liver failure 7 months later. The shunt was patent at postmortem examination.

Case 9.—An elderly man with hepatosplenomegaly of several years' duration bled massively from enormous esophageal varices. Thoracic duct cannulation revealed an increased flow (5.5 cc/min) of grossly hemorrhagic lymph low in protein (17% of plasma protein) and of BSP 45 minutes after administration by vein (31% of plasma BSP). Hepatic cirrhosis with superimposed portal vein occlusion was suspected and confirmed at laparotomy. Thrombectomy and side-to-side portacaval shunt was attempted, but rethrombosis of the anastomosis occurred at the operating table. Lymph flow did not fall and portal pressure, which had transiently dropped, rose to the preoperative level (41 cm $H_2O$) the day after operation. Postoperatively, hepatic precoma and ascites appeared. Recannulation of the thoracic duct 1 month after thrombosis of the portacaval anastomosis showed a further rise in thoracic duct lymph flow (8.0 cc/min) and a further fall in lymph protein (10% of plasma protein) and 45-minute

Fig. 6.—Fall in $Po_2$ of thoracic duct lymph *(A)* in a dog after cross-clamping of the superior mesenteric artery (S.M.A.) and hepatic artery (H.A.) and *(B)* in a patient with cirrhosis after administration of vasopressin. (From Witte, C. L., *et al.* [49].)



BSP (12% of plasma BSP) reflecting the overwhelming preponderance of intestinal lymph in the thoracic duct. The patient died several months later.

The selective action of various therapeutic agents on metabolism and microcirculation in splanchnic tissues can be assessed by their effect on thoracic duct lymph gas tensions. For example, administration of vasopressin, a potent splanchnic arterial vasoconstrictor, to patients with hepatic cirrhosis is followed by an immediate sharp decline in thoracic duct lymph $Po_2$ similar to that seen in experimental animals after ligation of the superior mesenteric and hepatic arteries (Fig. 6) (49). "Lymph gas monitoring" in conjunction with "blood gas monitoring" is helpful in the evaluation of treatment for "clinical shock."

### Therapeutic Uses of Thoracic Duct Cannulation

In general, cannulation of the thoracic duct serves therapeutic purposes in three different ways: (1) by removing excess fluid, (2) by eliminating toxins and other harmful substances dissolved in lymph and (3) by depleting the body of cells circulating in the thoracic duct. Lymph may be removed in bulk and replaced with substitute solutions, or specific fractions of lymph may be removed and the remainder returned to the patient. Thus, thoracic duct cannulation is an alternative to exchange transfusion, peritoneal and hemodialysis, paracentesis, plasmapheresis and leukophoresis; it differs in the nature of the fluid removed and its relation to other body compartments.

## Hepatic Cirrhosis

Alterations in the flow and composition of thoracic duct lymph are linked with circulatory derangements in the portal system in patients with Laennec's cirrhosis (see Fig. 3). Venting the distended thoracic duct is followed by decrease in liver size, diminution in ascites and cessation of bleeding from esophageal varices (16). These striking clinical changes are related to the outlet provided for excess lymph under pressure and implicate impairment to flow of excess lymph as an important feature of this disease. Lymph does not flow freely into the subclavian vein, even under physiologic circumstances, and resistance to flow is exaggerated in patients who produce excessive amounts of lymph.

The effects of thoracic duct cannulation on ascites, hepatomegaly and bleeding from esophageal varices are usually temporary and last only as long as the cannula drains freely. For this reason, cannulation, per-

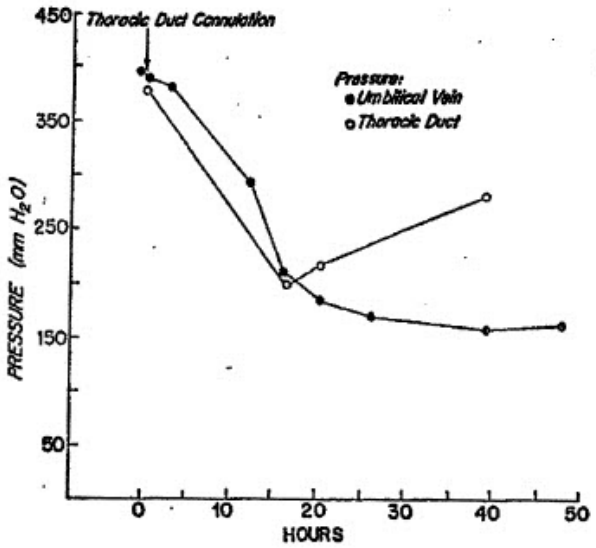



FIG. 7.—Decrease in portal pressure in a patient after thoracic duct cannulation to control varix hemorrhage. (From Witte, C. L., *et al.* [49].)

formed at the bedside if necessary, is most useful in the control of acute esophageal varix hemorrhage (10, 17, 18, 35). In our experience, massive bleeding ceased in 22 of 30 patients with advanced liver disease, and in 5 of these a successful abdominal operation was then carried out. The curious effect of cannulation on varix hemorrhage is unexplained but may be related to facilitation of transhepatic portal flow by decompression of the liver, decompression of varices from lymphatic-venous shunts in which flow is reversed when lymph drains freely, and accommodation of increased capillary filtrate in the extrahepatic portal bed, usually associated with a decrease in portal pressure (Fig. 7).

Lymph losses in patients bleeding from varices may exceed 5–10 L per day, and intravenous replacement therapy is vital. Negative fluid balance is maintained as long as arterial and central venous pressure, urinary output and hematocrit remain stable. Suppression of massive hemorrhage depends on maintenance of high rates of lymph flow. If the cannula becomes dislodged or occluded, or if the tip is raised to levels limiting flow, hemorrhage promptly recurs. The Blakemore tube is not used concomitantly because inflation and traction on this device impedes lymph flow (37). Surgical procedures on the portal circulation designed to prevent recurrent bleeding are carried out within 24–72 hours with the cannula still in place so as to avoid depletion of lymph-borne coagulation factors (42) and derangements in fluid, electrolyte and

protein balance. Lymph drainage promotes collapse of distended hepatic hilar lymph vessels and limits troublesome seepage of lymph into the operative field during a portacaval shunt.

Ascites decreases or disappears, and ascitic fluid fistulae (e.g., after laparotomy or paracentesis) close after thoracic duct cannulation even when "hypovolemia" is prevented by partial replacement of lymph losses. Leakage of excess lymph into the peritoneal cavity from the liver and/or extrahepatic portal capillary bed subsides (19). The considerable time and close supervision required to bring about only short-lived remission has relegated this use of thoracic duct cannulation to patients in whom medical management has failed and portacaval shunt is not feasible.

The lightening of hepatic coma which occasionally occurs after 24–48 hours of external lymph drainage is of particular interest. Circulating toxins (e.g., ammonium salts) from hepatic insufficiency may be cleared in sufficient quantities to account for this effect (25).

CASE 10.—A middle-aged woman with Laennec's cirrhosis developed massive bleeding from esophageal varices and hepatic coma for the third time. Ascites and jaundice were associated with severely deranged liver function tests. The Blakemore tube initially controlled acute bleeding, but after balloon deflation bleeding resumed; however, following thoracic duct cannulation, hemorrhage ceased promptly. After 2 days of lymph drainage, the patient regained consciousness and ascites disappeared. An end-to-side portacaval shunt was performed on the 3d day, and the cannula was removed 24 hours later. One month later the patient was alert and out of bed when she suddenly died.

CASE 11.—A middle-aged man with alcoholic cirrhosis, intractable ascites, and

FIG. 8.—CASE 11. Fluid balance and other data during lymph drainage in a patient with cirrhosis. L = lymph; U = urine.

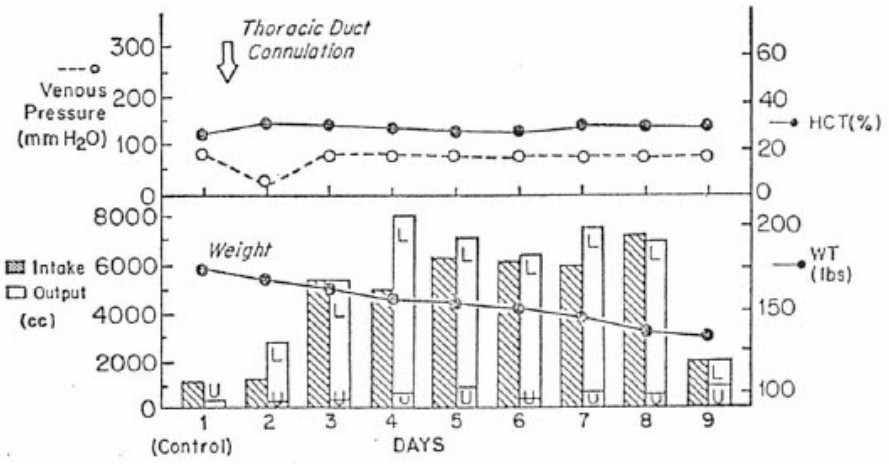


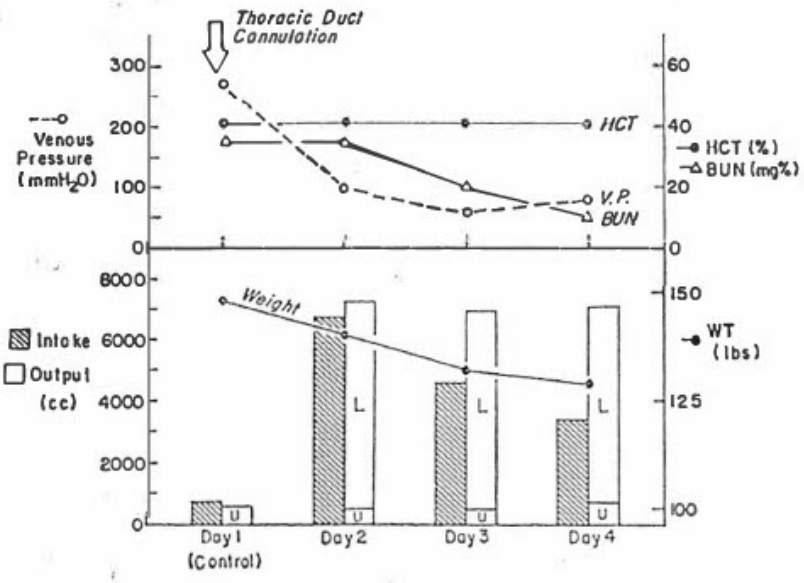

PLATE 1.—Chromosomes of the thoracic duct lymph cell line disclose a predominantly diploid mode *(A)*, with 26% of cells showing prominent secondary chromosomal constrictions *(B)*. (From Chessin, L. N., *et al.* [5].)

scrotal and peripheral edema underwent repeated paracenteses. Ascitic fluid reaccumulated rapidly and hepatic coma appeared. All medications were discontinued, and thoracic duct lymph was drained for 10 days (Fig. 8). He lost 40 lb, and an abdominal fluid wave was no longer detected. On discharge from the hospital, he was controlled on a low-salt diet and diuretics to which he had previously been unresponsive.

## Congestive Heart Failure

External thoracic duct lymph drainage was carried out in 11 patients with severe intractable congestive heart failure (most of these patients were class IV E by the New York Heart Association functional-therapeutic classification) (13). Upon inserting the cannula, the huge, distended thoracic duct collapsed and lymph flowed at an increased rate (mean 8.4 cc/min) under increased pressure approximating central venous pressure (34 cm $H_2O$). Venous pressure fell promptly, and, during the next few days of negative fluid balance, distended neck veins, peripheral edema, ascites and hepatomegaly diminished or disappeared. One patient with massive edema lost 7 L of lymph in the first 24 hours and received only 1 L of fluid replacement, without a rise in the blood hematocrit. Urine flow increased to normal levels in 4 patients with severe oliguria. Hypovolemia as reflected in hematocrit and plasma volume determinations did not occur while central venous pressure was

Fig. 9—Case 12. Fluid balance and other data during lymph drainage in a patient with right heart failure.



normal or elevated and significant edema persisted. The data suggest that when the lymphatic system is vented by thoracic duct cannulation, excess fluid can again be siphoned off from the venous side of the circulation. As a result, venous pressure falls, capillary filtration decreases and edema fluid is reabsorbed. Following removal of the cannula several patients responded to previously unsuccessful medical management. Large volumes of thoracic duct lymph collected during external lymph drainage may be stored for "priming" the pump and for plasma volume expansion during cardiopulmonary bypass.

CASE 12.—A middle-aged white man with rheumatic heart disease involving the mitral, tricuspid and aortic valves, complicated by subacute bacterial endocarditis and systemic embolization had been hospitalized for several months. Treatment for anasarca was unsuccessful, and renal insufficiency and severe hyponatremia developed. Thoracic duct cannulation (Fig. 9) resulted in a 19-lb. weight loss, and the signs and symptoms of circulatory congestion disappeared. Following removal of the cannula, the patient was discharged on low doses of diuretic drugs. He died suddenly at home several months later.

## ACUTE PANCREATITIS

The pancreatic exocrine system normally leaks enzymes and other osmotically active proteins into pancreatic interstitial fluid and lymph (20). When the pancreatic ducts are obstructed in dogs, drainage of thoracic duct lymph limits edema formation by removing excess protein from pancreatic interstitial fluid (21). In experimentally induced pancreatitis, this maneuver lowers the mortality rate (40). Unidentified inflammatory substances are released into pancreatic lymphatics and the thoracic duct in this disorder (22). Intradermal autoinjection of 0.1 cc of thoracic duct lymph in a patient with acute pancreatitis produced a severe local inflammatory reaction (23). Recent clinical studies indicate that thoracic duct cannulation decreases the severity as well as duration of acute pancreatitis in man (2).

## TOXINS

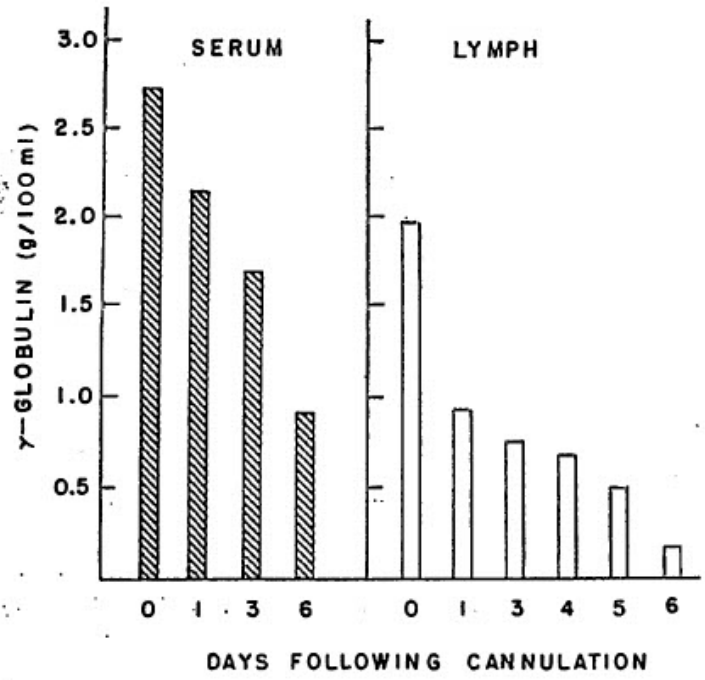
Specific high molecular weight toxins of bacterial and animal origin are transported to blood via lymphatics. In experimental animals, toxins obtained from the venom of certain snakes or from Clostridium tetanus injected into the soft tissues of the lower extremities traverse the thoracic duct before entering the blood stream (1, 36). The lethal toxin of Clostridium botulinus administered orally is transported to the blood exclusively via lacteals and the thoracic duct (32). These

findings suggest that early cannulation of the thoracic duct in patients exposed to these and other similar agents may be a means of limiting their toxic effects.

## Transplantation

The thoracic duct functions as the single major pathway to blood for immunologically active cells and protein (15, 33). External diversion of thoracic duct lymph suppresses immunologic activity (Figs. 10 and 11) and prolongs the survival of transplanted foreign tissue (24, 27, 41, 44). Several preliminary reports in patients undergoing renal homotransplantation indicate that lymph drainage is a useful adjunct to immunosuppressive drug therapy, but the precise nature of the resulting immunologic deficiency is still obscure. It appears that the longer thoracic duct lymph is diverted prior to and after transplantation the more difficult it becomes for the host to recognize and reject the transplant. Overwhelming infection is not prominent in this form of immunosuppression, so that protracted periods of lymph drainage (e.g., many months) are feasible. In patients with renal insufficiency,

Fig. 10.—Decrease in levels of gamma globulin in serum and lymph during 6 days of thoracic duct drainage in a patient with congestive heart failure (flow rate = 5 cc/min). (From Dumont, A. E., *et al.* [15].)



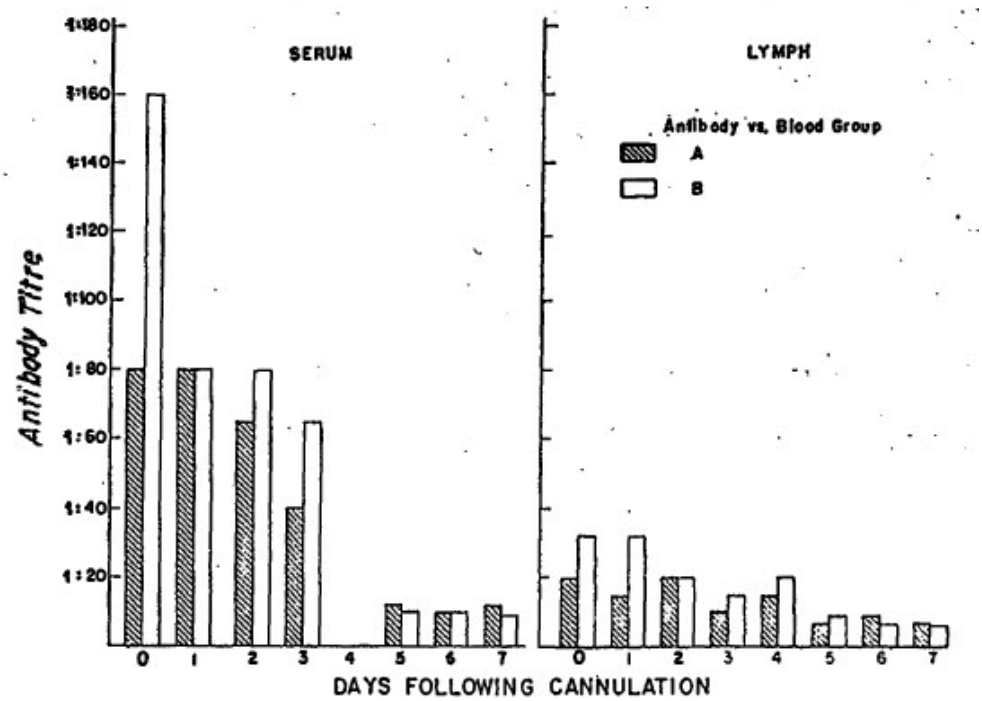



FIG. 11.—Decrease in levels of isoagglutinins to major blood group antigens during 7 days of lymph drainage (flow rate = 1.5 cc/min). (From Dumont, A. E., *et al.* [15].)

removal of nitrogenous waste and elimination of circulatory congestion may be accomplished at the same time (5, 38). Extracorporeal irradiation of lymph suppresses the immune response in experimental animals (9), but the technique has not been applied clinically.

## NEOPLASTIC DISEASES

Operative manipulation of gastrointestinal tract neoplasms releases malignant cells into the thoracic duct (4). Thoracic duct cannulation at the time of operation and for several days thereafter may avert these lymphogenous metastases. Similarly, in leukemia, large numbers of neoplastic cells circulate in the thoracic duct (31). The long-term effect of depleting the numbers of malignant cells on the ultimate course of the disease process is unknown.

In conjunction with endolymphatic chemotherapy, thoracic duct cannulation allows selective destruction of malignant tissue within lymphatics and lymph nodes, without toxic doses to nonlymphatic tissues.

## Miscellaneous Uses

Internal diversion of thoracic duct lymph occasionally fits the clinical situation better than external drainage. In congenital biliary atresia or extrahepatic biliary obstruction unamenable to local surgical decompression, anastomosis between the thoracic duct or hepatic lymphatics and the alimentary tract lowers levels of serum bilirubin and eliminates pruritus (34, 35, 47). The relief of itching may be related to interruption of bile salt recirculation through lymphatic pathways.

In experimental animals with surgically induced right heart failure, anastomosis of the thoracic duct to a pulmonary vein results in diuresis, natruresis, fall in central venous pressure and loss of ascites (8). This procedure may eventually prove useful in patients with isolated right heart failure due to right-sided valvular lesions, chronic pulmonary disease and pulmonary hypertension refractory to other therapeutic measures.

## Conclusion

Thoracic duct lymph is clearly an important key to the understanding and control of various disorders in man. Thoracic duct cannulation has opened up a new frontier in clinical medicine, which holds promise of linking the clinician directly with the site of dysfunction.

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