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Lymphatic Transport of Bacteria in Surgical Infection*

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The lymphatics have often been considered the final common pathway to the systemic circulation for tissue fluids and protein. Little significance has been placed on the system as the common pathway for delivery of bacteria to the systemic circulation and the reticuloendothelial system from an infection site or even from the normally contaminated organ manipulated at the time of a surgical procedure. In-

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fectious complications following surgical manipulation constitute one of the major causes of postoperative morbidity and mortality. The recovery of viable bacteria from thoracic duct lymph of patients undergoing thoracic duct cannulation for investigation of the etiology of jaundice, enteritis and peritonitis caused us to further investigate this route of dissemination of organisms in surgical inflammatory diseases of the abdomen.

Material and Methods

A group of mongrel dogs immunized for distemper and rabies was observed for a quarantine period of seven days to rule out, as nearly as possible, preexisting disease. The animals were divided into groups 1 through 8 and subjected to an operation known to produce inflammatory disease in the abdomen.

Group 1: Ten animals had 1 ml of duodenal contents or irrigation fluid injected into the common bile duct followed immediately by ligation of the common duct.

Group 2: Ten animals had ligation of the base of the cecum and its blood supply.

Group 3: Five animals had ligation of a loop of colon and its blood supply (volvulus).

Group 4: Three animals had ligation of the ileum and its blood supply (volvulus).

Group 5: Four animals underwent ligation of the superior mesenteric artery at its origin.

Group 6: Five animals had ligation of the small bowel lumen without interference with the blood supply.

Group 7: Four animals were subjected to ligation of the common bile duct.

One to four days later, under nembutal anesthesia, lying on its back on a level table, each animal was subjected to thoracic duct cannulation, right atrial catheterization, and exploratory laparotomy. Progression of the lesion was confirmed and serial cultures were taken of thoracic duct lymph and central venous blood during the entire period of the operation. The local inflammatory process was cultured in groups 1 and 2.

Four animals were used as controls. They had thoracic duct cannulation and right atrial catheterization with exploratory laparotomy without a previous lesion being produced. Serial blood and lymph cultures were obtained in a manner exactly similar to that in experimental animals.

All animals of the experimental and control groups were sacrificed after cultures were taken.

All material for culture was placed immediately in deep cooked meat broth and on blood agar plates incubated both aerobically and anaerobically in the hydrogen jar.

Anaerobic cultures were all observed for at least seven days to allow time for growth of gram negative anaerobes. Quantitative bacterial counts were not made.

Results

None of the control animals subjected to sham operation and thoracic duct and right atrial cannulation had organisms recovered from their central venous blood or thoracic duct lymph. Thirty-seven of 38 animals with an experimentally produced lesion associated with inflammation had viable organisms recovered from their lymph. Twelve of the 38 animals in the experimental group had viable organisms recovered

from their blood. Tables 1 through 3 give the organisms and the frequency of recovery from animals in each group. In all groups the lymph cultures were productive of a wider variety of organisms than central vein cultures. The organisms recovered from lymph and blood were also recovered from the site of intraabdominal infection in most cases from which these cultures were obtained. In the other groups organisms recovered from lymph and blood were those that could be expected to be present, although a number of other organisms which are frequently involved in such lesions were not recovered from lymph and blood.

Tab. 1 Cultures 72–96 hours following contamination and ligation of the common bile duct in 10 dogs.

Organisms	Lymph	Blood	Bile
Escherichia coli	5	3	9
Micrococcus sp.	8	2	8
Alpha hemolytic streptococcus	1	1	2
Beta hemolytic streptococcus	1	1	1
Nonhemolytic streptococcus	5	2	6
Corynebacterium sp.	4	–	2
Clostridium sp.	5	–	6
Bacteroides sp.	1	–	–
Proteus mirabilis	–	–	1
Klebsiella sp.	1	–	–
Bacillus sp.	1	–	1
Pseudomonas sp.	–	–	1
Paracolon bacilli	–	–	1
Herellea	1	–	1

Tab. 2 Cultures 24 hours following ligation of the cecum and its blood supply in 10 dogs.

Organisms	Lymph	Blood	Abscess
Escherichia coli	3	–	6
Micrococcus	9	1	4
Alpha hemolytic streptococcus	2	–	1
Beta hemolitic streptococcus	2	–	–
Nonhemolytic streptococcus	3	1	5
Corynebacterium sp.	4	–	3
Clostridium sp.	4	1	6
Bacteroides sp.	2	1	1
Proteus mirabilis	–	–	4

Discussion

Infectious complications constitute the major postoperative hazard to surgical patients. In the past investigators have concentrated on the exogenous sources of bacteria involved in postoperative complications. It has been our experience that the important sources of operative contamination reside within the patient himself. We have specifically identified and documented the gastrointestinal tract and biliary tree as major sources of organisms contaminating abdominal wounds (1, 2). We have also

Tab. 3 Cultures after several 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 animals	5		3		4		5		4	
Body fluid cultured	Lymph	Blood	Lymph	Blood	Lymph	Blood	Lymph	Blood	Lymph	Blood
Organisms										
Escherichia coli	5	–	1	–	2	–	3	–	–	–
Micrococcus	4	1	1	–	4	–	3	–	2	–
Alpha hemolytic streptococcus	1	–	–	–	–	–	2	–	1	–
Beta hemolytic streptococcus	1	–	1	–	–	–	1	–	–	–
Nonhemolytic streptococcus	–	–	1	–	–	–	–	–	–	–
Corynebacterium sp.	–	–	1	–	1	–	–	–	–	–
Proteus sp.	–	–	–	–	1	–	–	–	–	–
Neisseria sp.	–	–	–	–	–	–	–	3	–	–
Klebsiella sp.	–	–	1	–	–	–	–	–	–	–
Bacillus sp.	–	–	1	–	–	–	–	–	–	–

demonstrated that the patient's skin can be a significant source of wound contamination leading to infection (3). Although we have assumed that these bacteria are transferred by contact at the time of surgical manipulation, it is possible that organisms residing in the nasopharynx, gastrointestinal tract, respiratory tract and urinary tract, either normally or in the presence of inflammation, might migrate through the regional venous or lymphatic system during the surgical procedure, lodge in the lungs, kidneys, wound, or parotid glands, and initiate an infection which would then cause complications in the postoperative course of the patient.

Support for such a hypothesis is gained by the inability of surgeons to completely eliminate infectious complications by means directed at air-bourne and contact contamination (4). We found that two patients out of 75 examined by continuous blood cultures from the superior vena cava during endotracheal intubation had bacteremia of a degree which allowed detection by the methods used. There was rough correlation between the severity of trauma and the detection of organisms in the superior vena cava. Although one of these two patients followed a febrile postoperative course, a definite clinical infection was not identified (5).

Recently the concept of studying lymphogenous dissemination of microorganisms during surgical manipulation attracted our attention when the cultures of thoracic duct lymph taken from patients with cholangitis were positive during surgical correction of biliary obstruction. Although bacteria have been demonstrated in the regional

efferent lymphatics draining burn wounds (6) and stomach during gastrectomy (7), an erroneous impression exists that lymph is filtered effectively by lymph nodes and that the bacteriostatic properties of lymph prevent viable organisms from reaching the blood stream. Wood (8) has stated, to the contrary, that an acute sudden shower of bacteria into the lymph is filtered poorly by normal lymph nodes. Polymorphonuclear leukocytes are not yet present in the peripheral sinus and the absence of antibodies makes phagocytosis inefficient. *Drinker* (9) has stated that increased afferent lymphatic pressure or massage of the nodes decreases their filtering efficiency. The addition of circulatory insufficiency secondary to blood loss has been shown to enhance the movement of organisms from an infected focus into the lymphatics (6). These circumstances occur repeatedly during every intraabdominal surgical operation.

Our observations in experimental animals with intestinal obstruction, ligation of the superior mesenteric artery, gangrene of the cecum, common bile duct obstruction or peritoneal contamination indicate that while bacteria are occasionally recovered from central venous blood during surgical manipulation in these disorders, a variety of viable organisms in large numbers can be isolated from the thoracic duct at the point where it empties into the subclavian vein in almost every case. Moreover, cultures of thoracic duct lymph in patients with pre-existent infections (tuberculous) enteritis (10), peritonitis, and acute suppurative cholangitis (11) during operative manipulation of the gastrointestinal tract and biliary tree have disclosed that large numbers of viable bacteria may be released into the lymphatic system and reach the thoracic duct-venous junction in the neck to be carried by the subclavian vein through the right heart to the lungs and systemic circulation.

The occurrence of disseminated infections from a source of contamination such as the mouth to a diseased heart valve at the time of a tooth extraction is well recognized (12). The predelection of bacterial growth in areas of trauma is also well known to every surgeon. The frequent development of metastatic infections secondary to suppurative infection such as appendicitis (13) and cutaneous burns (14) has been observed for years. Demonstration that showers of bacteria are frequently released into the circulation by way of the lymphatics appears to complete the requirements needed to make the surgical patient undergoing operation on contaminated organs or infected areas an ideal candidate for such disseminated infections.

Although we have not proven a cause and effect relationship between the circulating bacteria recovered in this study and the postoperative complication seen so frequently following surgery on contaminated organs or in the presence of infection, all factors seem to be present to make this a likely occurrence.

Peripheral blood is often sampled, but rarely yields positive cultures in the postoperative general surgical patient. Only under unusual research conditions is central venous blood monitored for bacteria. Cultures of blood from the superior vena cava obtained by us during nasopharyngeal manipulation and tracheal intubation reveal occasional heavy "showers" of bacteria. It is likely that sampling portal venous blood and regional venous blood draining other organs may be even more rewarding in the presence of visceral infection; this blood has not yet passed through reticuloendothelial lined capillaries of lungs, liver and spleen.

Large infectious particles appear to be disseminated primarily by the lymphatics (15) which deliver them to the lymphatic-venous junction in the neck where they are diluted several thousand-fold as they enter the blood. These facts along with ability to collect large quantities of lymph for culture may account for our success in recovering bacteria from this fluid and may also make lymph a more logical fluid for the study of these infectious problems in the future.

Summary

Viable bacteria have been recovered from the thoracic duct lymph of patients undergoing operative manipulation of intraabdominal inflammatory lesions such as cholangitis, peritonitis and tuberculous enteritis. Inflammatory intraabdominal lesions were experimentally produced in dogs. In 37 of 38 animals the lymph cultures were positive during abdominal exploration and manipulation of the inflammatory lesion. Viable organisms were recovered from the central venous blood of 12 of the 38 experimental animals. No viable organisms could be recovered from the lymph or blood of 4 sham operated control animals. It is concluded that lymphatic and hematogenous transport of bacteria may be of some importance in the operative dissemination of bacteria and the production of postoperative infectious complications.

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