ABSORPTION OF PARTICULATE MATTER BY THE GREAT OMENTUM

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Past attempts to determine the channels of absorption of particulate matter in the great omentum have depended on the use of suspensions made up of chemically inert, colored particles. The interpretation of results and the conclusions were based on the subsequent microscopic recognition of these particles *in situ*.

Shipley and Cunningham (1) floated the omentum of the cat (decerebrate) in a dish of filtered India ink and found particles of carbon free in the portal vessels soon afterward. They believed the omentum of the adult animal contained few if any lymphatics and that the particles in question were absorbed by the blood capillaries. Poynter (2) confirmed this finding. Higgins and Bain (3) in careful experiments upon cats were unable to find that omental capillaries were in any way concerned in the removal of particles. The problem as to whether non-motile substances of bacterial dimensions must be removed *via* lymphatics or whether they are at least to some degree removed by entrance into blood vessels is of considerable practical importance and bears directly upon the problem of the real function of the lymphatics. We have consequently made observations very similar to those of Shipley and Cunningham but have used a particulate suspension chemically quantitatable so as to render the fact of absorption absolutely final. Even the most careful histological search can cover but a small part of the liver. If, however, the end-point is chemical the whole organ may be examined.

EXPERIMENTAL

A suspension of garnierite, an amorphous silicate of nickel and magnesium, $H_2(NiMg)SiO_4$, was used as particulate matter for the

following reasons: first, after being washed free of soluble nickel, this suspension did not oxidize rapidly to the soluble form in the presence of air, moisture, and living tissue; second, it could be determined quantitatively by Fairhall's (4) potassium di-thio-oxalate method; and, finally, the difference between nickel determinations made before and after treatment with hydrofluoric acid represented not only a very accurate control of the normal nickel content of the sample being analyzed, but also furnished unquestionable evidence that absorption of particulate matter had occurred.

A quantity of garnierite dust, produced by grinding the mineral in a ball mill, was suspended in 2 l. of distilled water and allowed to settle for 15 to 20 minutes in an ordinary laboratory 2 l. cylinder. At the end of this time, the fluid was siphoned off down to the 20 cc. mark, thus eliminating the heavier and larger particles. The suspension collected was first concentrated and then washed by repeated centrifugalization in large centrifuge bottles until the wash water did not give the slightest test for nickel with potassium di-thio-oxalate. The sediment of particles was then resuspended in enough 0.85 per cent salt solution so that 1 cc. contained 12 mg. of nickel. After repeated washing very little adjustment was necessary to bring the hydrogen ion concentration between pH 7.2 and 7.6.

The dogs used were anesthetized by sodium barbital, 0.35 gm. per kilogram intravenously. They were killed by bleeding to death at the close of the experiment. The omentum was drawn out of the abdomen through a linear incision and floated freely in a dish of garnierite suspension kept at body temperature and stirred by an occasional gentle blast of compressed air. The thoracic duct was cannulated in all experiments and in three of the group making Table II, the right lymphatic duct was tied so that all lymphatic entrance into the circulation was blocked. The livers and mediastinal lymph nodes were removed, washed in distilled water, weighed, and analyzed. In every instance the ligamentous attachments of the liver were carefully removed, so that liver tissue alone was analyzed.

Control fresh tissue, except lymph, was secured from dogs recently killed by the officials of the city.

DISCUSSION

In two cases out of five the normal liver contained traces of nickel, too weak to measure accurately. All other normal tissues were negative.

In the six experimental animals in which the omentum was isolated from the peritoneal cavity and exposed to garnierite particles in suspension, the lymph from the thoracic duct was negative in five cases.

TABLE I

Nickel Content of Lymph, Blood, Mediastinal Lymph Nodes, and Liver in Normal Dogs

No. of animal	Nickel content per 1000 gm.			
	Lymph	Blood	Mediastinal lymph nodes	Liver
1	Neg.	Neg.	Neg.	Trace
2	—	Neg.	Neg.	Neg.
3	—	Neg.	Neg.	Neg.
4	—	Neg.	Neg.	Trace
5	—	Neg.	Neg.	Neg.

TABLE II

*Nickel Content of Lymph, Blood, Mediastinal Lymph Nodes, and Liver after Floating the Omentum in a Suspension of Nickel Silicate (Garnierite) for Varying Periods of Time**

No. of animal	Length of experiment	Nickel content in mg. per 1000 gm. tissue (before and after treatment with hydrofluoric acid)					
			Control lymph	Experimental lymph	Blood	Mediastinal lymph nodes	Liver
	hrs.						
1	4	Before	Neg.	Neg.	—	—	Neg.
		After	Neg.	Neg.	—	—	0.070
2	2½	Before	Neg.	Neg.	—	—	Neg.
		After	Neg.	Neg.	—	—	0.081
3	5	Before	Neg.	Neg.	Neg.	Neg.	Trace
		After	Neg.	Neg.	Neg.	Neg.	0.097
4	4	Before	Neg.	Neg.	Neg.	Neg.	Neg.
		After	Neg.	Neg.	Neg.	Neg.	0.077
5	5	Before	Neg.	Neg.	Neg.	Neg.	Neg.
		After	Neg.	Neg.	Neg.	Neg.	0.087
6	1	After	Neg.	(0.01)	Neg.	—	0.085

* Thoracic duct cannulated in all cases. Right lymphatic duct tied in Animals 2, 3, and 6.

The lymph from Animal 6 contained a trace of nickel estimated as 0.01 mg. in 1000 gm. lymph.

The liver findings were relatively uniform, ranging between 0.07 and 0.097 mg. of nickel per 1000 gm. of fresh tissue. The blood from four animals and the mediastinal tissue including the lymph nodes from three were all negative. In four of the six liver determinations in which nickel was found in a concentration between 0.07 and 0.09 mg. per 1000 gm. of tissue, no trace of nickel could be found before the material had been treated with hydrofluoric acid. Therefore, the total amount of nickel must have existed as insoluble nickel silicate and must have been absorbed by the omentum as particulate matter. In one other case a trace of nickel could be detected before treatment with hydrofluoric acid. This trace might have represented oxidation of the garnierite during the 5 hour experimental period or, more likely, it represented the normal content of nickel of that particular liver sample.

The results indicate a certain amount of vascular absorption of nickel particles. Since Higgins and Bain failed to find particles histologically, we are inclined to believe the particles removed *via* the blood stream were very small, probably less than 1 micron in diameter. The suspension employed necessarily contained many particles of this degree of fineness. Key (5) considers that in absorption of particles from joints a small amount of material is taken by the blood vessels and that this consists of particles just at the limits of microscopic vision. When the omentum is examined at the close of such an experiment it is laden with particle-containing phagocytes. It would seem that if there had been any considerable migration of these cells into the omental capillaries, the analyses of the liver must have shown far higher figures for nickel than were obtained. The method by which inert particles deposited in the tissues enter closed lymphatic capillaries is unknown, but it is certain such entrance can occur without the aid of free-moving phagocytes. A similar sort of direct entrance into the blood stream is probably involved in the experiments we have described. It is clearly not an important way of getting rid of foreign particles, but it is certainly an existing one.

Field and Drinker (6), in a group of experiments dealing with the paths of absorption of horse serum, found that when the thoracic and

right lymphatic ducts were tied horse serum injected subcutaneously did not reach the blood in periods as long as 7 hours, but that horse serum injected intraperitoneally could be detected in the blood in less than an hour. This result is similar to and confirmatory of that obtained with the nickel suspension.

SUMMARY

When the omentum of the dog is floated in a suspension of insoluble nickel silicate in physiological saline under circumstances precluding the possibility of lymphatic drainage, the liver removed after at least 1 hour contains nickel which must have been brought to it by way of the blood capillaries in particulate form. The blood capillaries are, therefore, a pathway for absorption of solid material but are not important in this respect.

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