

EXPERIMENTAL STUDIES ON ASCITES *

by

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I. INTRODUCTION

Ascites is one of the most important symptoms found in patients with hepatic cirrhosis or so-called "portal hypertension", the name given by the Spleen Clinic of Presbyterian Hospital.

Since STARLING's paper on ascites, the pathogenesis of ascites has been considered to be an increase in portal venous pressure and a decrease in serum colloidal osmotic pressure. However, some investigators doubt the parallel relationship between production of ascites, portal venous pressure, and serum colloidal osmotic pressure. Others point to the important role of hepatic lymph as an origin of ascites, and others suggest an endocrine change as a factor in ascites formation.

However, many problems pertaining to the pathogenesis of ascites remain unexplained.

In regard to the treatment of ascites there are many methods, such as the TALMA-DRUMMOND's operation, the portacaval shunting, etc.; none of which are very satisfactory.

On an experimental basis, ascites has been produced by constriction of the thoracic inferior vena cava and also, as included in this report, the production of ascites by the addition of plasmapheresis to the constricted portal vein.

This paper deals with the contents of the ascitic fluid produced by the two experimental methods, in addition to the difference in production of ascites and method to control the formation of ascites.

* The outline of this study was reported on at the 56th and 57th Annual Congress of the Japanese Surgical Society, at Sendai City May 1, 1956 and at Tokyo April 3, 1957.

II. THE PRODUCTION OF EXPERIMENTAL ASCITES

1. Experimental materials

Twenty-eight adult mongrel dogs weighing about 10kg were used.

2. Experimental method

Twenty dogs were used for the constriction of the thoracic inferior vena cava. Following adequate exposure of the thoracic inferior vena cava by entering the chest through the sixth right intercostal space, a small cellophane band was applied to the inferior vena cava so that the vein could be constricted to approximately one-half of the original luminal diameter.

Eight dogs were used for the constriction of the portal vein plus plasmapheresis. To constrict the portal vein, a cellophane band, also, was used. After exposure of the vein through a median incision in the upper abdomen, the vein was constricted to approximately one-half or one-third of its former diameter. Seven days after the establishment of portal stenosis, plasmapheresis was started and continued almost every other day for 2 months. The term "plasmapheresis" as used here means the removal of 100 cc of whole blood with subsequent replacement of the red blood cells suspended in 100 cc of 0.9% saline solution.

After ascites formation was well established by these two methods, samples of blood serum, ascitic fluid, and sometimes thoracic duct lymph, hepatic lymph, and the fluid formed on the liver surface (hereafter referred to as "capsular liver fluid"), were obtained for the following examinations; protein concentration (by refractometric determination), A/G ratio (by HOWE's method), cholesterol (by BLOOR's method), sodium and potassium (by BECKMAN's flamephotometer), chlorine (by SCHALES and SCHALES's method) and sugar (by HAGEDORN-JENSEN's method) in blood serum and ascitic fluid were measured to compare the two methods used in production of ascites.

The following function tests were performed to compare the two experimental methods: (1) comparative blood picture to include the number of red blood cells, hemoglobin content and hematocrit, (2) circulating plasma volume by EVANS Blue method and extracellular fluid volume by sodium rhodanate method, (3) bromsulphonphthalein retention after 30 minutes to determine the liver function, (4) phenolsulphonphthalein excretion for the renal function.

Microscopic examination of the liver, spleen, pancreas, intestine and adrenal gland were performed following staining by hematoxylin-eosin.

Samples of hepatic lymph and thoracic duct lymph were obtained by cannulation of one of the extrahepatic lymphatics and the thoracic duct with a fine polyethylene tube. Capsular liver fluid was allowed to drain into polyethylene sheets placed around the liver, and then the fluid samples were removed with a capillary pipette for the examination.

The portal venous pressure was measured by direct puncture of the portal trunk with a needle having a 1 mm. luminal diameter attached to a simple water manometer.

3. Experimental results.

a) Comparison of the components of the two types of experimental ascites.

i) Constriction of the thoracic inferior vena cava caused accumulation of ascites which began to appear in 1 week after the operation and developed to a maximum (about 2,000 cc) within 2 or 3 weeks postoperatively. Extensive venous collateral channels were noted on the abdominal wall. The liver of the dogs was moderately enlarged, turgid, and of purple hue. The surfaces were uneven. Innumerable droplets constantly coalesced and trickled from the liver into the peritoneal cavity. However, other abdominal viscera and peritoneal surfaces showed no pathological changes on gross inspection. The extrahepatic lymphatics located about the portal vein were found to be engorged with clear lymph.

The protein content of the capsular liver fluid was similar to that of the hepatic lymph. The protein contents were found to be the highest, in this order; blood serum, hepatic lymph, thoracic duct lymph and ascites (Table 1.).

Table 1. Total protein value of serum, hepatic lymph, capsular liver fluid, thoracic duct lymph, and ascitic fluid. Protein values are expressed in grams per 100 cc.

No. of dogs	17	21	22	23	24	25	26	27	Average
Blood serum	7.2	3.9	4.7	6.0	3.9	4.8	3.9	6.5	5.11
Hepatic lymph	5.7	3.0	3.7	4.6	3.0	3.9	3.2	5.9	4.13
Capsular liver fluid	5.4	—	3.7	4.7	3.0	3.8	3.2	5.0	4.11
Thoracic duct lymph	5.6	2.5		4.7	2.8	3.6	2.6	4.6	3.77
Ascitic fluid	4.8	2.2	2.6	3.8	1.8	3.0	2.0	5.0	3.15

ii) Constriction of the portal vein did not result in accumulation of ascites unless the procedure was combined with plasmapheresis to reduce the concentration of serum protein. The volume of accumulated ascites by the addition of plasmapheresis to constriction of the portal vein was 20 to 450 cc (Fig. 1). Extensive venous collateral channels were noted on the retroperitoneum and around the cardia and esophagus; however, no submucous varices of the esophagus were recognized. The liver of each dog was fairly pale macroscopically. Other abdominal viscera did not show any noticeable change except for the engorgement of mesenteric veins.

iii) Compared these two ascites, the contents of protein and cholesterol in the ascites of group B were markedly less than those in the ascites of group A (Fig. 2, 3.). (For convenience of comparison, A will be used to denote those dogs with constricted thoracic inferior vena cava and B used to denote that group with constricted portal vein and plasmapheresis.) However, both ascites were similar in sodium, potassium, chlorine and sugar (Fig. 4, 5, 6, 7). A/G ratio and chlorine concentration of both ascites were higher than those of the serum (Fig. 6, 8).

b) Comparison of various function tests.

Each group showed marked anemia and decrease of hematocrit (Fig. 9). There was an increase of extracellular fluid in both groups, but this was more pronounced in group B. Circulating plasma volume increased in both groups (Fig. 10). There was increased retention of BSP in group A and B showing decreased liver function in each group (Fig. 11). The renal function of group A was found

Fig. 1 Relationship between the appearance of ascites and the decrease of serum protein concentration.

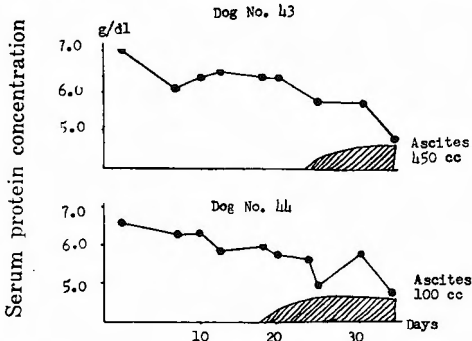
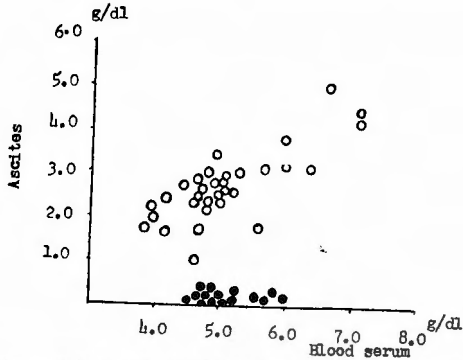


Fig. 2 Comparison of two types of ascites. I. Protein.



From Fig. 2 through Fig. 13:

- ; refers to value in group with constricted thoracic inferior vena cava.
- ; refers to value in group with constricted portal vein plus plasmapheresis.

Fig. 3 Comparison of two types of ascites II. Total cholesterol.

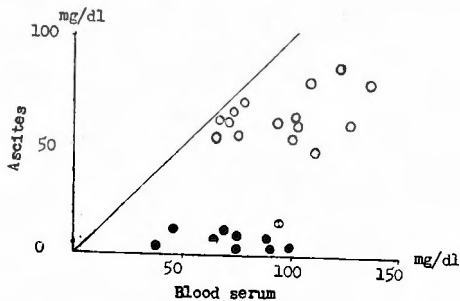


Fig. 4 Comparison of two types of ascites III. Sodium.

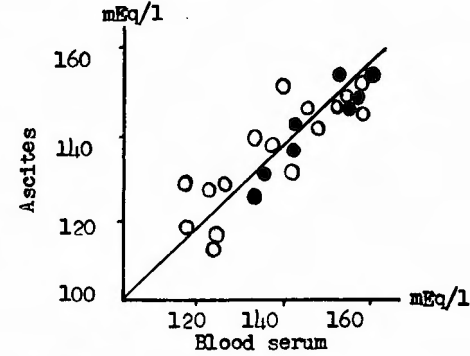


Fig. 5 Comparison of two types of ascites IV. Potassium.

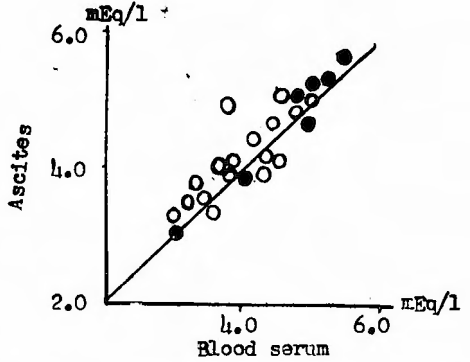


Fig. 6 Comparison of two types of ascites V. Chlorine.

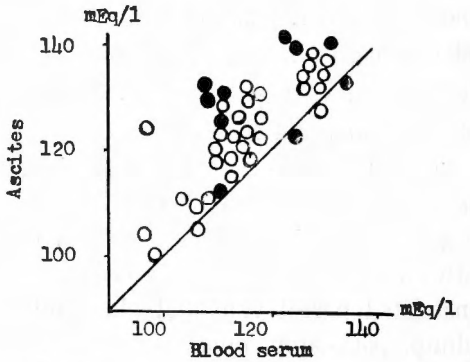


Fig. 7 Comparison of two types of ascites VI. Sugar.

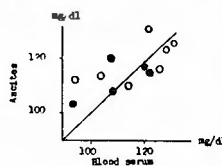


Fig. 8 Comparison of two types of ascites VII. A/G ratio.

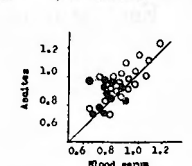


Fig. 9 Comparison of two types of experimental ascitic dogs concerning number of red cells, hemoglobin concentration and hematocrit in blood.

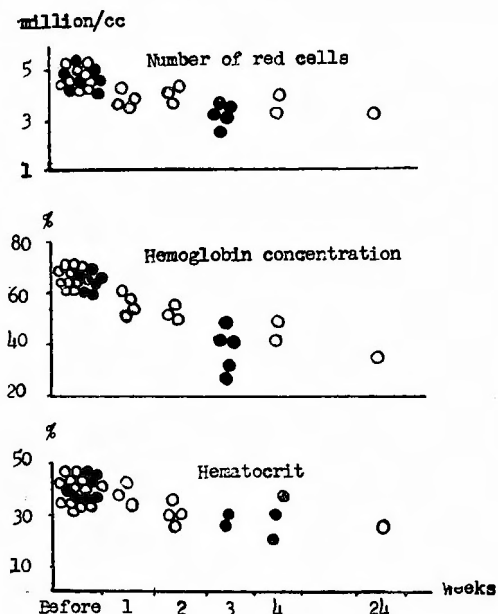


Fig. 10 Comparison of two types of experimental ascitic dogs concerning extracellular fluid and circulating plasma volume.

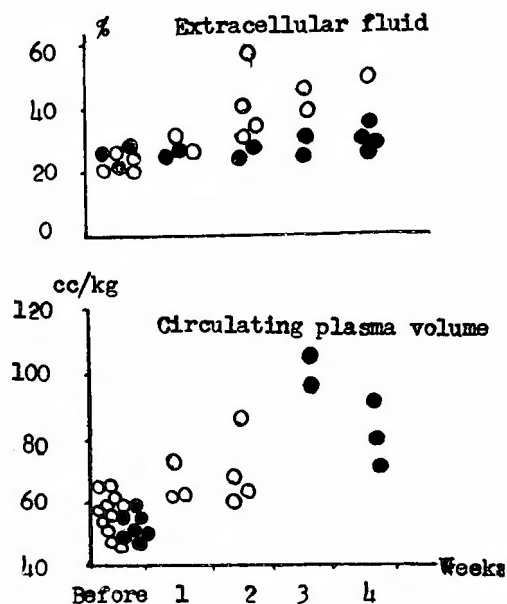


Fig. 11 Comparison of two types of experimental ascitic dogs concerning liver function.

Bromsulphalein retention after 30 minutes

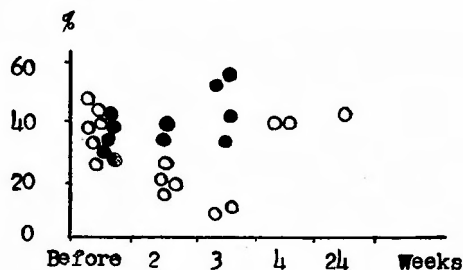


Fig. 12 Comparison of two types of experimental ascitic dogs concerning renal function.

Phenolsulfonphthalein excretion after 15 minutes.

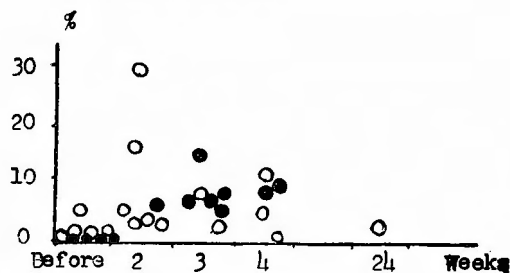


Fig. 13 Comparison of two types of experimental ascitic dogs concerning portal pressure and ascites formation.

□ ; refers to duration of ascites due to constriction of thoracic inferior vena cava.
 ▨ ; refers to duration of ascites due to constriction of portal vein plus plasmapheresis.



to be decreased following the operation by using PSP. This decrease in function was found to be transient and recovery was noted in 2-3 weeks (Fig. 12). The portal venous pressure in group A was not raised very much, but in group B there was a marked elevation immediately after the operation. This elevation of portal venous pressure in group B gradually decreased and returned to normal levels in a four week period (Fig. 13).

c) Comparison of microscopic findings.

i) Liver; In group A, marked congestion, which developed from the central zones of acinus to the peripheral zones with compression-degeneration of hepatic cells, was found within 1 to 2 weeks postoperatively, but the most striking observation was the dilatation of subcapsular sinusoids and lymphatic spaces (Fig. 14). Within 1 to 2 months postoperatively the congestion decreased, and connective tissue began to proliferate from Glisson's capsuls and around the central veins, and finally, the liver developed atrophic cirrhosis about 8 months later (Fig. 15, 16).

In group B, no congestion or distention of sinusoids was recognized, but the hepatic cells, especially in the central zones, showed diffuse degeneration (Fig. 17).

ii) Spleen; In group A, congestion was not found, but atrophy was recognized by the reduction of follicular size, the increase in reticulum cells, and the tortuous trabeculae. Atrophy was also easily recognized macroscopically (Fig. 18). The weight of the spleen was markedly less than that of group B or of normal dogs (Fig. 19). In group B, no pathological change was recognized except for slight congestion.

On examination of the remaining viscera, there was no pathological change found in either group A or B.

4. Summary of chapter II.

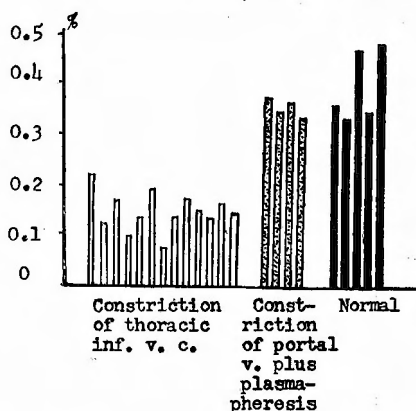
1. Constriction of the thoracic inferior vena cava caused marked extrusion of fluid from the surface of the liver. This fluid had the same amount of protein as hepatic lymph. Dilatation of the liver subcapsular lymphatic spaces was shown microscopically.

2. Constriction of the thoracic inferior vena cava caused the accumulation of ascites in spite of a normal portal venous pressure; however, constriction of the portal vein did not result in accumulation of ascites unless the procedure was combined with plasmapheresis.

3. The protein and cholesterol in the ascitic fluid of group B markedly less than group A. However, there was no difference in sodium, potassium, chlorine and sugar level recognized between the ascitic fluid of group A or B.

4. No difference between the function of comparable organs of group B was noted except for the transient renal dysfunction in group A.

Fig. 19 Spleen weight per body weight



5. There was marked reduction in the size of the spleen recognized in group A.

III. THE REVERSIBILITY OF EXPERIMENTAL ASCITES

1. Experimental materials

Twenty-one adult mongrel dogs weighing about 10 kg were used.

2. Experimental method

i) In 12 normal dogs, the thoracic inferior vena cava was constricted by a tissue-reaction-free polyethylene tube, in which a silver cord was inserted for convenience of manipulation, to produce experimental ascites. After ascites was well established, the constricting tube was removed from animals at periods varying from 21 to 163 days. After removing the constriction, examination was performed daily for one week. The abdominal girth, body weight and components of blood and ascites (protein content, A/G ratio, cholesterol, sodium, potassium and chlorine) were examined. Microscopic examination of the liver and spleen was performed after sacrificing the animals.

ii) On a series of 9 dogs, the portal vein was narrowed to about one-half to one-third its former diameter with a cellophane band at periods of 7 to 47 days after the constriction of the inferior vena cava. Following the addition of portal stenosis, the same examination as above was performed daily for 1 week.

3. Experimental results

a) Removal of constriction of the thoracic inferior vena cava.

When a cellophane band was used to constrict the thoracic inferior vena cava, it caused the proliferation of connective tissue in the venous wall; however, the tissue-reaction-free polyethylene tube did not result in such pathological changes and the elasticity of the constricted wall of the vein was not impaired (Fig. 20, 21). It was shown roentgenographically that the constricted venous wall recovered to the pre-constricted state after the removal of the polyethylene tube (Fig. 22, 23). Ascites appeared in one week and reached a maximum (about 2,000 cc) in 2 to 3 weeks after the constriction of the vein by non-irritating polyethylene tubing. This ascitic state was similar to that produced when cellophane is used. After the removal of the constriction, the accumulated ascites disappeared within 1 week showing a decrease in the abdominal girth and body weight (Fig. 24). The protein concentration of blood serum was hypoproteinemic during the accumulation of ascites, but after releasing the constriction it increased to above normal levels reaching maximum within 3 or 4 days, and then recovered to normal within 6 or 7 days. The protein concentration of the ascites increased slightly (Fig. 25). No noticeable change in A/G ratio was recognized in serum or ascitic fluid (Fig. 26). The cholesterol content of blood serum, similarly to protein, increased above normal reaching a maximum in 3 to 4 days and recovered to normal level within 6 to 7 days after removing constriction. The cholesterol content of ascitic fluid slightly increased (Fig. 27). Sodium, potassium and chlorine in the blood serum and ascitic fluid showed no remarkable change (Fig. 28).

Fig. 24 Course of body weight and girth of abdomen after removal of constriction.

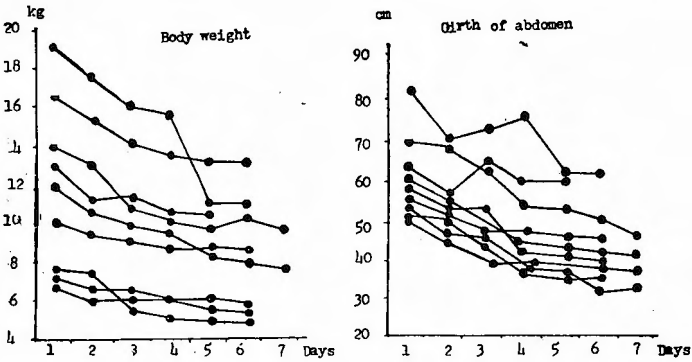


Fig. 25 Course of protein content in blood serum and ascites after removal of constriction.

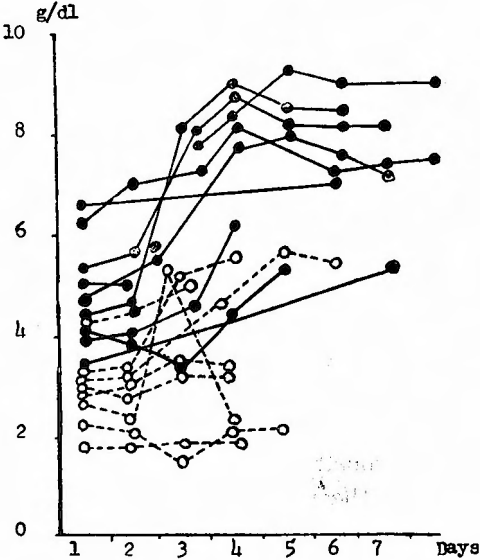


Fig. 27 Course of total cholesterol in blood serum and ascites after removal of constriction.

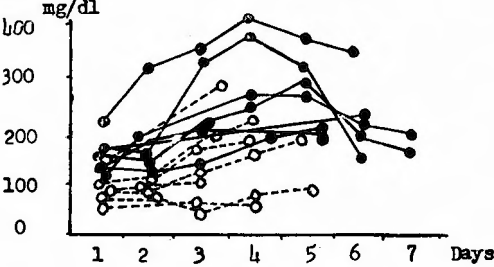
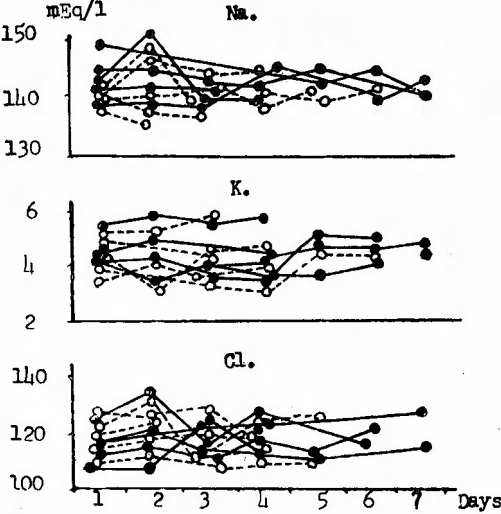
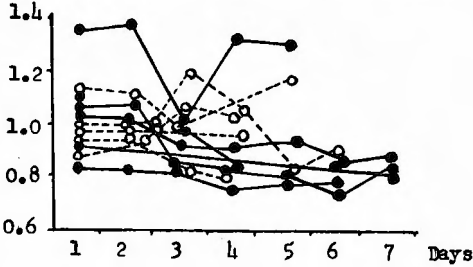


Fig. 28 Course of sodium, potassium and chlorine in blood and ascites after removal of constriction.



From Fig. 25 through Fig. 35:
○—○; refers to value in blood serum.
○---○; refers to value in ascites.

Fig. 26 Course of A/G ratio in blood serum and ascites after removal of constriction.



Microscopically, the marked congestion of the liver following constriction of the thoracic inferior vena cava markedly subsided and the bulk of hepatic cells were normal in arrangement, but size of the acini were slightly smaller than normal (Fig. 29). However, in some parts congestion remained. The connective tissue did not continue to proliferate after the removal of the constriction, but the slight thickening of the wall of the central vein and intrahepatic portal vein remained unchanged (Fig. 30). Splenic atrophy remained unchanged even 153 days following the removal of the constrictive band.

b) Addition of portal stenosis to constriction of the thoracic inferior vena cava.

The portal venous pressure was 160-200 mm. H₂O in experimental ascitic dogs with constricted thoracic inferior vena cava, but immediately after the addition of portal stenosis the pressure became 60-100 mm H₂O in the proximal portion of the stenosis and 240-280 mm H₂O in the distal part. No gross pathological changes were found in the intestinal tracts. The majority of accumulated ascites overflowed from the peritoneal cavity at the time of adding the portal stenosis, but 3-5 days later, ascites was proved by means of paracentesis. After that period, however, even 85 days later, no re-accumulation of ascites was found. There was very little change in abdominal girth and body weight (Fig. 31). The protein concentration of blood serum increased slightly for several days after the addition of portal stenosis, but, on the other hand, that of the ascites markedly decreased (Fig. 32). The A/G ratio of the blood serum and ascitic fluid did not change noticeably (Fig. 33). Blood serum cholesterol content did not show any noticeable change, but, that of ascitic fluid markedly decreased (Fig. 34). Sodium, potassium and chlorine in the blood serum and ascitic fluid showed no remarkable change (Fig. 35).

Histologically the congestion of the liver due to the constriction of the thoracic inferior vena cava disappeared following the addition of portal stenosis. In some instances vacuolic degeneration of hepatic cells was recognized (Fig. 36). No pathological change was detected in the spleen.

4. Summary of chapter III.

1. The application of a cellophane band to constrict the thoracic inferior vena cava resulted in proliferation of connective tissue in the venous wall. Application of a tissue-reaction-free tube of polyethylene was not followed by such pathological changes; the elasticity of the constricted wall of the vein was not damaged; and the constricted wall of the vein reverted to the pre-constricted state following the removal of the polyethylene tube.

2. Upon releasing constriction of the thoracic inferior vena cava, accumulated ascites disappeared within 1 week. This reversibility of ascites was found to take place at the end of three weeks (21 days) and upon release and up to periods of 5 months (163 days) and then release of the constriction.

3. Additional constriction of the portal vein to the experimental ascitic dogs due to the constriction of the thoracic inferior vena cava caused the disappearance of accumulated ascites in a few days.

Fig. 31 Course of body weight and girth of abdomen after addition of portal vein constriction.

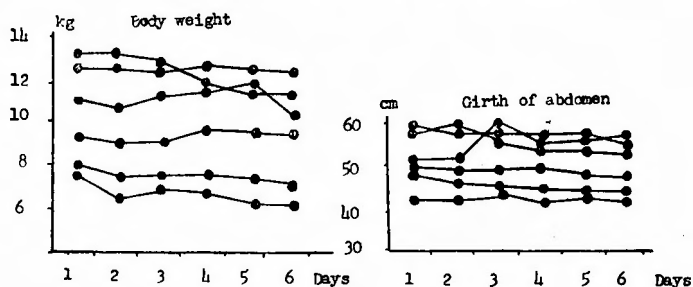


Fig. 32 Course of protein content in blood serum and ascites after addition of portal vein constriction.

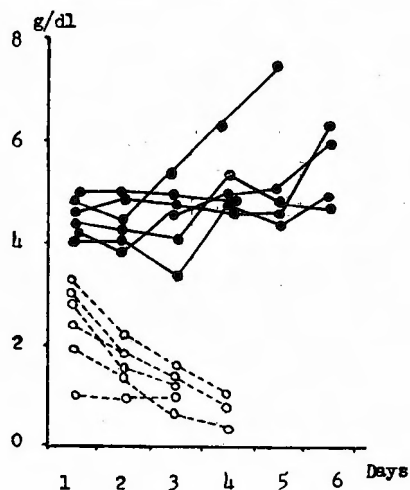


Fig. 33 Course of A/G ratio in blood serum and ascites after addition of portal vein constriction.

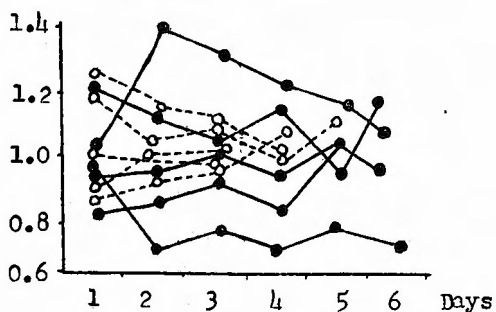


Fig. 34 Course of total cholesterol in blood serum and ascites after addition of portal vein constriction.

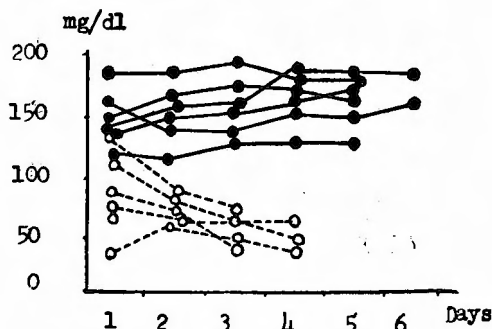
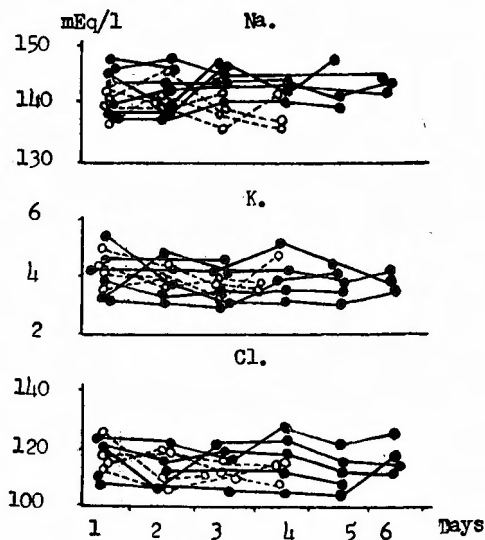


Fig. 35 Course of sodium, potassium and chlorine in blood serum and ascites after addition of portal vein constriction.



IV. DISCUSSION

As reported by BOLTON, MCKEE and GRINDLAY, as in this study too, constriction of the thoracic inferior vena cava caused marked extrusion of fluid from the liver surface, which was similar to hepatic lymph as regards protein contents; in addition dilatation of the subcapsular lymphatic spaces of the liver was shown microscopically. Therefore, the origin of proteinous ascites is considered to be from the hepatic lymph. RIENHOFF (1953) noticed exudation of lymph from the hilum of liver in human cirrhosis, and THERON (1955) reported dilatation of the intrahepatic lymphatics. The experimental result following removal of a constriction of the thoracic inferior vena cava suggests that hepatic congestion plays a great role in the production of experimental ascites. It is open to discussion whether such an experimental ascites can be considered to be the same as seen in human cirrhosis. Accordingly, only that experimental ascitic liver which shows cirrhotic change without remaining congestion after the removal of a constriction of the thoracic inferior vena cava can be called a true cirrhosis. But it is well known that there are cases of hepatic cirrhosis without ascites and/or with reversible ascites clinically. MADDEN (1954) stated that reversible ascites of liver cirrhosis is due to the occlusion of the hepatic veins by intrahepatic cellular edema and that the irreversible ascites is due to organic occlusion of the hepatic veins. According to his concept, it might be considered that experimental ascites in dogs with constricted inferior vena cava is due to functional occlusion of the hepatic veins. From the result of these experiments, congestion of the hepatic veins and/or intrahepatic lymph vessels is considered to be an important factor in the production of ascites.

Constriction of the thoracic inferior vena cava caused massive ascites in spite of a normal portal pressure and constriction of the portal vein caused no ascites in spite of high portal pressure. Therefore, as reported by BLAKEMORE, PATTISON and KUNKEL, it is suggested that portal hypertension is not an essential factor in the production of ascites. However, as reported by VOLWILER, GRINDLAY, the addition of hypoproteinemia followed by plasmapheresis caused accumulation of ascites in this experiment. KUNKEL reported that production of ascites in cases of portal hypertension without ascites followed addition of hypoproteinemia caused by hematoemesis due to rupture of esophageal varices; therefore it is considered that the maintenance of ascites would have to be accompanied by decrease of colloidal osmotic pressure and increase of portal venous pressure. In these animals the mesenteric and retroperitoneal veins dilated markedly, but the spleen, pancreas and intestine showed no pathological change. This fluid could be primarily composed of the transudate from the prehepatic portal capillary bed.

Comparing ascites due to the constriction of the thoracic inferior vena cava with ascites due to constriction of the portal vein plus plasmapheresis, the contents of protein and cholesterol in the former were much higher than those of the latter, but the content of sodium, potassium, chlorine and sugar was similar in both cases. Comparing ascites due to constriction of the thoracic inferior vena cava before the addition of portal stenosis with ascites following addition of portal stenosis, the

same results as above mentioned were seen. Accordingly, these results suggest that ascites derived from the liver is rich in protein and cholesterol, but ascites derived from the prehepatic portal vein is poor in these substances.

In the dog with a constricted thoracic inferior vena cava, the protein content of the ascites is much less than that of its hepatic lymph; accordingly, there occurs the problem as to whether the ascites resulted from the dilution of hepatic lymph with other peritoneal transudate or from the selective re-absorption of protein. But according to the comparison of both these types of ascites, it may be derived from the hepatic lymph diluted with the transudate from the prehepatic portal capillary bed.

Comparing the various functions of dogs with constricted thoracic inferior vena cava to those of dogs with constricted portal veins plus plasmapheresis, there was not enough significant difference to suggest a difference of pathogenesis of ascites formation between the two groups of experimental ascitic dogs, except for difference in renal function. The renal dysfunction was found in the former group for 2-3 weeks postoperatively and during that time transient edematous swelling of the legs was recognized. Therefore, it is considered that congestion of the infrahepatic caval system does not have any important significance in the production of ascites.

The reason for high concentration of protein and cholesterol in ascites due to a constricted thoracic inferior vena cava may be due to the special permeability of the hepatic capillaries, as reported by FIELD, LEIGH and DRINKER.

The fact that the A/G ratio of both types of ascites was higher than that of the blood serum might be due to the fact that albumin molecule is more permeable than the globulin molecule, as reported by DRINKER.

Similarly, the content of chlorine in the ascitic fluid was higher than that of the blood serum. This fact may be explained as follows; the decrease of anion due to the reduction of protein in the ascites might be compensated by the chlorine anion, as reported by TAKAHASHI.

The size of the spleen in experimental ascitic dogs with constricted thoracic inferior vena cava markedly reduced in an inverse proportion to the clinical findings of the hepatosplenic syndrome. This fact is of considerable interest, in view of the fact that splenomegaly does not necessarily follow BUDD-CHIARI's syndrome. Therefore it is considered that this disease may be different from common hepatosplenic syndrome.

From the viewpoint of hydrodynamics, it is expected that the reduction of ascites formation may be achieved by the means of diminishing blood inflow to the liver.

In fact, addition of portal stenosis resulted in the disappearance of ascites within a few days. According to LAUFMAN's report, the same procedure caused disappearance of ascites, but this effect was transient and re-accumulation occurred 4 weeks later. On the contrary, re-accumulation of ascites in this experiment was not recognized even 85 days later. MARKOWITZ, RIENHOFF advocated ligation of the hepatic artery as a treatment of ascites. Accordingly, restriction of blood inflow

to the liver might be effective in controlling persistent ascites.

V. CONCLUSION

1) Constriction of the thoracic inferior vena cava caused marked extrusion of fluid from the liver surface, which was similar to hepatic lymph as regards protein contents; in addition dilatation of the subcapsular lymphatic spaces of the liver was shown microscopically. Therefore, the origin of proteinous ascites is considered to be from the hepatic lymph.

2) Removal of a constriction of the thoracic inferior vena cava caused the disappearance of accumulated ascites in a few days. Therefore, it is considered that congestion of the hepatic veins or intrahepatic stagnation of lymph is an important factor in the experimental production of ascites.

3) The constriction of the thoracic inferior vena cava caused the accumulation of ascites, however, the portal venous pressure was within normal range. On the other hand, constriction of the portal vein alone did not cause the accumulation of ascites, but the addition of plasmapheresis to the constricted portal vein caused the accumulation of ascites. Therefore it is considered that portal hypertension is not an essential factor for the production of ascites, but the association of portal hypertension with a decrease in colloidal osmotic pressure causes the persistent accumulation of ascites.

4) Comparing ascites due to constriction of the thoracic inferior vena cava with ascites due to constriction of the portal vein combined with plasmapheresis, the former was rich in protein and cholesterol, but the latter was poor in protein and cholesterol. These results suggest that ascites derived from the liver is rich in protein and cholesterol, but ascites derived from the prehepatic portal vein is poor in these substances.

5) Addition of a constriction to the portal vein in experimental ascitic dogs with a constricted thoracic inferior vena cava caused the disappearance of accumulated ascites in a few days. Therefore it is considered that restriction of blood inflow to the liver is effective in controlling persistent ascites.

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Fig. 14 Microscopic section of liver 19 days after constriction of thoracic inferior vena cava showing congestion, dilated sinusoid and degeneration of hepatic cells. $\times 100$.

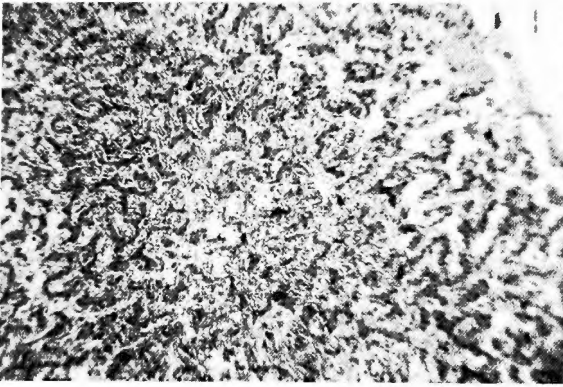


Fig. 15 Microscopic section of liver 56 days after constriction of thoracic inferior vena cava showing dilatation of subcapsular lymphatic spaces and proliferation of connective tissue. $\times 100$.

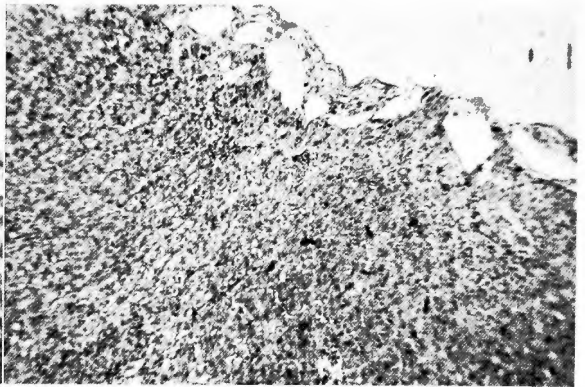


Fig. 16 Microscopic section of liver 222 days after constriction of thoracic inferior vena cava showing atrophic cirrhosis. $\times 100$.

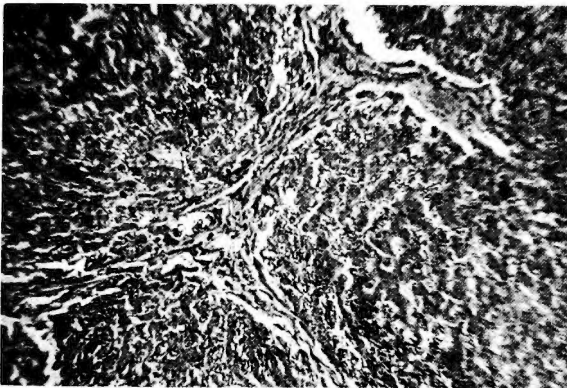


Fig. 17 Microscopic section of 35 days after constriction of portal vein associated plasmapheresis showing diminution of congestion and degeneration of hepatic cells. $\times 100$.

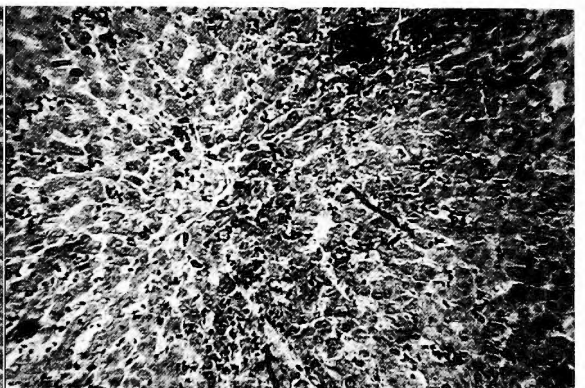


Fig. 18 Microscopic section of spleen 54 days after constriction of thoracic inferior vena cava showing atrophy. $\times 100$.

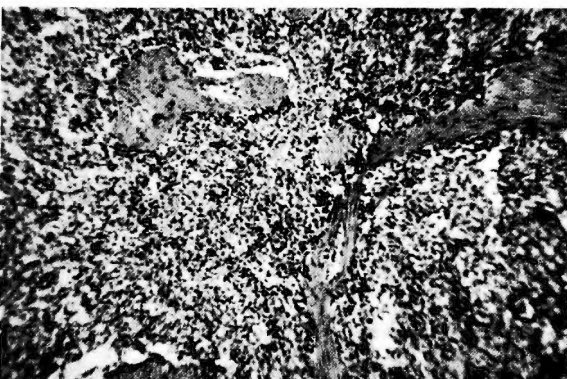


Fig. 20 Microscopic section of thoracic inferior vena cava constricted with cellophane band showing proliferation of connective tissue. $\times 100$.

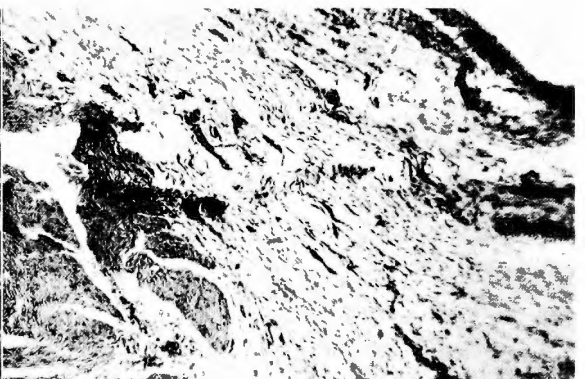


Fig. 21 Microscopic section of thoracic inferior vena cava constricted with non-irritative polyethylene band showing no remarkable proliferation of connective tissue. $\times 100$.

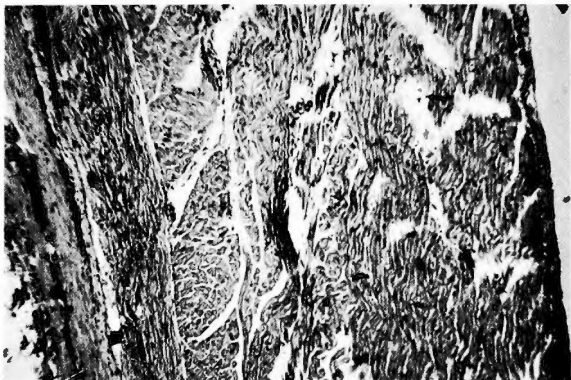


Fig. 23 Roentgenogram of thoracic inferior vena cava 65 days after removal of polyethylene band showing the relief of stenosis. The image shows a clear, unobstructed lumen of the vein.



Fig. 22 Roentgenogram of thoracic inferior vena cava 52 days after constriction with polyethylene band showing stenosis. The image shows a narrowed lumen of the vein.



Fig. 29 Microscopic section of liver 10 days after removal of constriction showing disappearance of congestion. $\times 200$. The image shows a normal liver architecture with no signs of congestion.

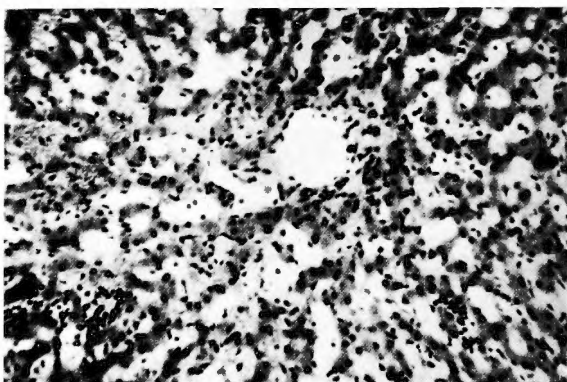


Fig. 30 Microscopic section of liver 76 days after removal of constriction showing remaining proliferated connective tissue. $\times 200$. The image shows a liver with some remaining connective tissue.

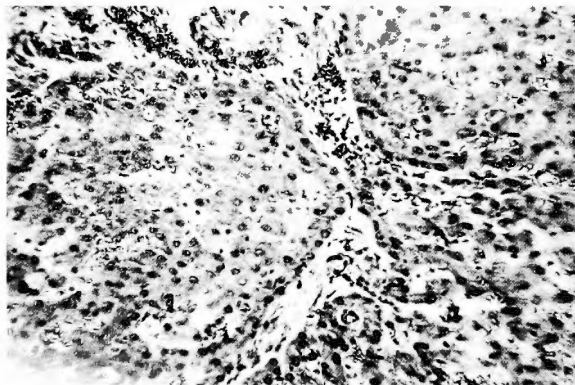
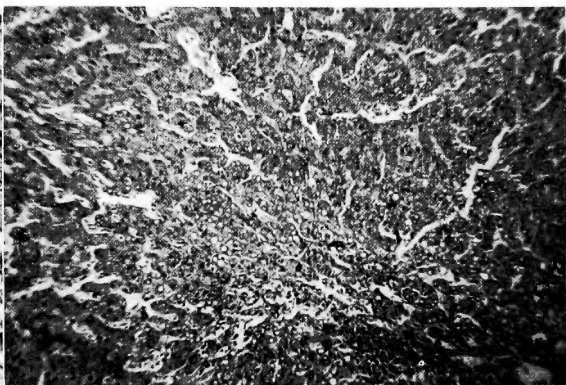


Fig. 36 Microscopic section of liver 10 days after addition of portal stenosis showing disappearance of congestion and degeneration of hepatic cell. $\times 100$. The image shows a liver with some remaining connective tissue.



和 文 抄 録

腹 水 に 関 す る 実 験 的 研 究

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1. 胸部下大静脈狭窄により大量の腹水が貯溜し、此の際肝の表面から著明な液体の漏出を認めた。此の漏出液の蛋白濃度は肝リンパのそれに極めて類似していた。又組織学的に肝被膜下リンパ腔の拡張を認めた。よつて蛋白性腹水の起源として肝被膜よりのリンパ漏出が考えられる。

2. 胸部下大静脈の狭窄を除去すると貯溜していた腹水は数日で消失した。従つて肝内の鬱血或はリンパの鬱積が実験的腹水産生の重要な因子と考えられる。

3. 胸部下大静脈の狭窄により腹水が貯溜するがその際門脈圧はほぼ正常範囲内にあつた。又他方門脈の狭窄のみでは腹水は貯溜せずこれに血漿搬出を追加すると腹水が貯溜して来た。従つて門脈圧の亢進は腹水産生の第一義的因子ではないと考えられる。然し門脈

圧の亢進と血漿膠質滲透圧の低下との共存により持続性の腹水を生ずることが考えられる。

4. 胸部下大静脈狭窄により貯溜した腹水と門脈狭窄加血漿搬出により貯溜した腹水とを比較すると、前者は蛋白、コレステロールに富むが後者はこれらに乏しい、従つて肝に由来する腹水は蛋白、コレステロールに富み肝前部門脈系に由来する腹水はこれらに乏しいと考えられる。又肝よりの漏出液が肝前部門脈系よりの漏出液により稀釈されて腹水が形成され则认为られる。

5. 胸部下大静脈狭窄による実験的腹水犬に門脈狭窄を追加すると貯溜していた腹水は数日で消失した。依つて肝への流入血量を減少させるとたとえ門脈圧亢進があつても腹水の産生が抑制され则认为られる。