Cubical Anatomy of Several Ducts and Vessels by Injection Method of Acrylic Resin.

II. Spiral structures on the inside wall of the hepatic venous system in dog.

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(With 12 figures in 2 plates)

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1. Preface

Pfuhl (1922, 1932) noted, in his thesis, that Hering (1867) had suggested existence of sphincteral valves in the hepatic venous system of dog. Brissaud and Sabourin (1888) observed strengthened valves, which formed peculiar spiral triangular protuberances, were composed of smooth muscle fibres on the inside wall of the hepatic venous system in seal and dog. Later, much works have been done by Mall (1906), Gilbert and Villaret (1909), Arey and Simonds (1920), Zimmermann (1923), Jaffé (1924), Walter (1925), Miyake (1929), Popper (1931), Elias and Feller (1931), Takahashi (1935), Arey (1941) Tomonari (1953), Makiura (1954). These seniors studied, chiefly in carnivora, on an arrangement of smooth muscle fibers at the junction of the branches of the hepatic veins, at the pouring portion of the hepatic veins into v. cava caudalis, and on the sphincteral structures of the fine venous branches. For these researches,

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non-injected or coloured gelatin injected serial sections, wax-reconstruction and celluloid corrosions were employed.

We have made observations on the corrosion specimens of the vascular system and the bile duct of the liver injected with acrylic resin. In this experiment, the spiral vulves projecting on the inside wall of the hepatic venous system appeared remarkable constrictions on the corrosions. Consequently, the authors studied on the central veins up to the branches of the hepatic veins below 1 mm in thickness, laying emphasis on the corrosions of them.

2. Materials and Methods

Authors studied on the resin injected livers of 48 adult dogs, which injected acrylic resin into the hepatic venous system alone, or into the portal vein, the hepatic artery proper, the bile duct and the hepatic vein respectively. In injecting acrylic resin and producing a cubical corrosion specimen, the method published by Taniguchi, Ohta and Tajiri (1952) and its supplement (1955), was adopted. In each case, before preparing the corrosions, we always fixed part of the resin injected liver in 10% formalin, or sometimes Zenker's fluid, and made it celloidin sections and then stained them with hematoxylin-eosin or van Gieson. Taking the artificial products of injection pressure and viscosity of the resin into consideration, non-injected sections stained with Azan were used as control.

Observations were performed under binocular magnifier, and further fine portions under microscope. Moreover, a drawing-reconstruction was performed by serial resin injected sections.

Micrometry was carried out on the corrosions, resin injected serial sections and non-injected serial, respectively. In measuring, though it was difficult to settle a basis of calibration in case of the venous branches which had remarkable and frequent vulves, the whole hepatic venous system was divided into 4 parts as follows:—

Central veins below $49\ \mu$ in thickness;

Fine portions of the sublobular veins $50\text{--}229\ \mu$;

The larger of the sublobular veins $300\text{--}499\ \mu$;

Branches after the sublobular veins $500\ \mu\text{--}1\text{ mm}$.

Then, about each division, the following points were measured; interval of the constrictions caused by spiral vulves, thickness at the constricted portions and the interconstricted (expanded by injection) portions and frequency of the constrictions at a certain distance of

each branch in various sizes.

3. Observations

Under a general observation of the hepatic venous system, spiral vulves appear distinctly all the way from the central veins, the sublobular veins and the branches of the hepatic vein up to about 1 mm in thickness. But in the larger than that, the vulves appear as only cricoid wrinkles (Fig. 10), furthermore in the branches have a thickness of about 3 mm, even the wrinkles entirely disappear and there are no sphincteral vulves, namely constrictions on the corrosions as a counter die, worthy of the name. Then, the degree of the conspicuousness of the spiral vulves is similar irrespective of the portions within liver provided the venous branches have the same thickness.

It will be described in order of the views of the central veins, the sublobular veins and the branches of the hepatic veins after the sublobular.

1. Central veins

In the central veins, almost of the vulves are not in the shape of spiral. So on the corrosions, they are single file spindle or rosary shape (Figs. 1, 2, 3, 11). Thickness at the constricted portions, which correspond to the triangular protuberances as the vulves, is mean 17.5μ , but it is found some of them only 6μ ; that at the expanded portions, correspond to the intervals of the vulves, is mean 41.1μ . On the non-injected sections, that at the former is mean 12.3μ , at the latter mean 22.2μ . In the course of the central vein, full length about 500μ , 5-9 constrictions are observed (Fig. 1). (The venous sinusoids always flow into the intervals of the constrictions, the expanded portions.)

2. Sublobular veins

• Almost of vulves in the sublobular veins, are typical spiral shape (Figs. 5, 6, 7, 8, 9, 12). In the branches of $50-299\mu$ in thickness, a series of the spiral vulves with an interval of mean 190μ , are seen. Especially in the fine branches, the vulves, at places, anastomose or bifurcate, and then unite again (Fig. 8). Upon this it is often observed, on the corrosions, that some of the constricted parts make one round of circumference, one half or one third round, or a crescent spot (Fig. 4). In the vein of $300-500\mu$ in thickness, long continued single spirals with an interval of mean 147μ are seen and in this portion the anastomosis between vulves is seldom, so that long series of

tendrils are visible (Figs. 5, 6).

Especially in finer branches of the sublobular vein, the sphincteral vulves are cricoid shape in many cases instead of the spiral. So, in such portion of the corrosions, vulves show single file spindle or rosary shape as in the central vein, but the degree of the constriction is more remarkable than that in the central vein.

3. Branches of the hepatic vein after the sublobular vein

In those branches the sphincteral vulves present spiral up to them of 1 mm or so in thickness, in the thicker than them, vulves become cricoid wrinkles, in the still thicker, the wrinkles become less marked, and in the veins of thickness of several millimeters, the wrinkles disappear even, and the corrosions present only a smooth rod (Fig. 10).

Table

		Corrosion specimen			Resin injected section		Non-injected section	
		Thickness		Interval between each constriction	Thickness		Thickness	
		of constricted part	of expanded part		of constricted part	of expanded part	of constricted part	of expanded part
Central vein	below 49 μ	8.3 $\sim$ 26.7 μ	28.6 $\sim$ 53.6 μ	26.7 $\sim$ 86.7 μ	15.5 $\sim$ 20.5 μ	29.0 $\sim$ 52.8 μ	3.8 $\sim$ 20.8 μ	17.7 $\sim$ 26.7 μ
Sublobular vein	50 $\sim$ 299 μ	70 $\sim$ 123 μ	103 $\sim$ 171 μ	56 $\sim$ 138 μ				
	300 $\sim$ 499 μ	167 $\sim$ 364 μ	255 $\sim$ 452 μ	109 $\sim$ 201 μ				
After the sublobular	500 μ 1 mm	431 $\sim$ 666 μ	535 $\sim$ 768 μ	148 $\sim$ 234 μ				

As it is evident on the table: The interval between the sphincters is mean 56.7μ in the central vein below 49μ in thickness, the interval being larger than its thickness. Consequently, on the corrosions single file spindle shape is numerous. In the vein of about 136μ , the interval is mean 96.9μ , therefore that is smaller than the thickness of the vein. Accordingly, on the corrosions, each expanded part appears spherical compressed mesiodistally. In the vein of about 353μ , the interval becomes mean 155.2μ , so that the intervals turn into a half of its thickness, hence the corrosions present thick discs in file in shape. In the vein of mean 651μ , the interval is mean 190.8μ , and the same appearance is seen.

Examining the rate of the individual constriction in the central vein and the sublobular vein, it is seen that the former is 57.4% and the latter 21.9-27.4%. The degree

is larger in that of the central vein than in that of the sublobular vein. But, in examining the reciprocity of the thickness of the vein in each one and the interval between the constrictions, the interval in the central vein is larger than that in the sublobular vein. Therefore, one is able to mention that the conspicuousness of the constriction in the central vein is smaller than that in the sublobular.

4. Summary and Discussion

The results of author's observations will be now summarized and discussed, that is:—

The average thickness at the constricted portion, vulves, in the central veins, is 12.3μ on the non-injected section, 17.5μ on the corrosions. This shows a dilation of about 42.8% by injection pressure of the resin. And, that at the expanded portion, between the vulves, is 22.2μ on the non-injected sections, 41.1μ on the corrosions, the dilation being about 80.1%. Accordingly, the dilating rate is 1.87 times larger in the portion between the vulves than in that of the vulves. Those matters express an exaggeration of tightening of the constricted portions by encircling smooth muscle fibers and connective fibers, and loosening of the expanded portions, against injection pressure and viscosity of the resin.

In spite of such dilation of the vessels, however, the thickness in the constricted portion of the central vein is no more than 6–26.7 μ .

Judging from above, it is safe to imagine that the outflow of the blood be almost or entirely intercepted when the spiral sphincters in this portion constrict, as some seniors had suggested.

Tomonari (1953) described, studying about the muscular protuberances on the wall of the hepatic venous system in several animals, that the protuberances like tendrils in the sublobular veins of dog were oftener found in periphery of the liver. But in our studies, there are no regional differences within the liver, but, if the vessels are alike in their size, the aspect of the vulves is similar. Möllendorff (1932) mentioned that the protuberances of the sublobular veins appeared as if tendrils wound around a pole. His description nearly agrees with our observations in some of the central veins, almost of the sublobular veins and the small branches of the hepatic veins. Arey (1941) explained that the muscular protuberances in dog showed imperfectly spiral shape in the fine vein, perfect spiral shape as the thickness increases, and then ring shape in the thicker veins. Makiura (1954) described, in the central veins, the muscle fibers arranged in a shape of spiral or ring. In our observations almost of them were

not spiral in the central veins. We, at first, entertained doubt, as to the vulves which have appeared spiral by nature that they might turn into ring shape, broken by injection pressure and viscosity of the resin. Examining the resin injected and non-injected sections, however, we could gain confidence that they were not artificial products. Mautner and Pick (1915), Weatherford (1935) and Arey (1941) stated that, an anaphylactic shock phenomenon in dog was characterized by intense stasis of the liver and the visceral organs, especially by constriction of spiral sphincters of all the hepatic venous system.

5. Conclusion

The authors observed the sphincteral vulves on the inside wall of the hepatic venous system in dog, injecting acrylic resin into the hepatic vein, by corrosion specimens and resin injected serial sections. Measuring was carried out of various sizes of the venous branches, the thickness of the sphincteral (constricted) parts, and of the inter-sphincteral (expanded) parts, the interval between the sphincters, and the frequency of the constrictions at a certain distance of the vein.

The followings are the results of this research :

- (1) As the sphincteral vulves were triangular protuberances constructed of the smooth muscle fibers or connective fibers encircling in spiral or ring shape, they were evidently impressed on the corrosions as constrictions.
- (2) Sphincteral vulves were remarkably found from the central veins up to the small branches of the hepatic veins about 1 mm in thickness, and they were more outstanding in the finer branches, namely the central veins and the fine sublobular veins.
- (3) In the central veins, almost sphincteral vulves were not spiral, but ring shape. Thickness of the constricted part is mean $17.5\ \mu$, while that of the expanded part mean $41.1\ \mu$. Five to nine constrictions were found in the course of the central vein having a length of about $500\ \mu$. Compared with the dilability of the vessels on the corrosions and on the non-injected sections, they showed a dilation of 42.8% in the constricted portion, 80.1% in the expanded portion, owing to the resin injection.
- (4) In the sublobular veins, the vulves, in general, showed a series of typical spiral shape, and that they often in the finer veins divided or united among themselves, it was observed.
- (5) Up to the venous branches of about 1 mm in thickness, the vulves

showed spiral shape, but in the larger branches they turned into fine wrinkles, and in the further larger such aspects disappeared.

(6) In the central veins, the interval between the constrictions was longer than its thickness, so the veins on the corrossions showed single file spindle or rosary shape. In the sublobular veins, the interval between the constrictions was getting shorter and shorter, so the expanded parts on the corrossions showed thick discs in file in shape. Besides, the more the thickness of the vein increased, the more the thickness of the disc decreased. (the rate to the thickness grew less).

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Explanation of figures

Figures 1 to 10 are cut out of the corrosion specimens. All but figure 8, under falling light, are taken under transilluminating light.

Fig. 1. General view of a central vein. $\times 130$. Central vein which arises from the upside pours into a sublobular vein—part of it broken by mistake—in the bottom. Five constrictions are seen on the central. The upmost interconstricted portion is spindle shape, and to the downside the others rosary. The most constricted is the upmost, besides the vein is crooked at this portion. (Almost of sinusoids pouring into the vein are removed.)

Fig. 2. Part of a central vein. $\times 280$. Shown three constrictions which indicate the existence of the ring shaped vules, so the cast appears a typical rosary. The upmost parts are the sinusoids which pour into this vein.

Fig. 3. Central vein. $\times 320$. Three constrictions, and three interconstrictions which are shown as a single spindle shape.

Fig. 4. Finer sublobular vein. $\times 106$. Long and short intervals between the ring shaped constrictions. Two constrictions on the downside show one and a half round spiral. A bush on the middle is the central vein, with sinusoids, which pour into the vein.

Fig. 5. Sublobular vein. $\times 57$. Shown a long series of typical spiral.

Fig. 6. Sublobular vein. $\times 55$. The same spiral shape as that of Fig. 5, but the height and the thickness of each constriction are irregular.

Fig. 7. Sublobular vein. $\times 120$. Here also spiral, but this assumes different aspects from those of Figs. 5 & 6.

Fig. 8. Sublobular vein. $\times 30$. An anastomosis of the constrictions is seen ($\rightleftharpoons$). On this vein, the interconstricted portions appear thick discs in file in shape.

Fig. 9. Cast of sublobular veins up to a fine branch of the hepatic vein. Changes of the form of the constrictions and the interconstrictions on the corrosions. $\times 16$.

Fig. 10. Hepatic venous branches of about 1 mm in thickness. Constrictions appear as wrinkles. $\times 34$.

Fig. 11. A central vein on the non-injected section stained with Azan, as control. The vules are not spiral but two rings. $\times 192$.

Fig. 12. Spiral vules in a sublobular vein on the same specimen of Fig. 11. $\times 150$.