The Peribiliary Portal System in the Rabbit Liver

Osamu OHTANI

Department of Anatomy (Prof. H. OUTI), Okayama University Medical School, Okayama, Japan

Received October 9, 1978

Summary. Arterial terminals and peribiliary plexuses in the rabbit liver were studied by the injection replica scanning electron microscope method.

The branches of the hepatic artery are classified into three categories: (1) branches forming the peribiliary plexus, (2) terminal and some collateral branches which directly pour into the sinusoids at the periphery of the hepatic lobules, (3) branches which form poor capillary networks in the Glisson's sheath and finally join the peripheral sinusoids.

The peribiliary plexus consists of two layers. The inner layer is a capillary network and the outer layer, a venous network. The efferent vessels arise from the venous network of the peribiliary plexus and have two different drainages: (1) into the adjacent hepatic sinusoids as the "lobular branches or routes" and (2) into the interlobular veins as the "prelobular branches or routes." The former branches correspond to the "radicular portal veins" of KIERNAN (1833), and the latter to the "internal roots" of FERREIN (1749). Both routes deserve designation of peribiliary portal system. The plexus surrounding small bile ducts comprises a single layer of fine capillaries. Their connections with the hepatic sinusoids and the interlobular veins are quite the same as in the two-layered plexus.

The pattern of the peribiliary drainage in the rabbit liver is similar to that in the rat liver (OHTANI and MURAKAMI, 1978).

A possible significance of the peribiliary portal system as the transport route of hormones produced from the bile duct wall is discussed.

Although the terminal distribution of the hepatic artery has been studied intensively, there have been some controversial problems.

Since the study by KIERNAN (1833) it is generally accepted that the hepatic artery branches supply the bile ducts. Concerning the drainage of the peribiliary plexus, however, there have been some different views. KIERNAN believed that the peribiliary plexus was drained into the interlobular vein by way of the "internal hepatic radicule" or "internal roots." This view was supported by AUNAP (1931), ELIAS and PETTY (1953) in the cat, and MITRA (1966) in the rat and man.

On the other hand, FERREIN (1749) suggested that blood from the peribiliary plexus is collected into a vein, i.e., the "radicular portal vein" which runs to supply the lobule. This view was supported by OLDS and STAFFORD (1930) in the cat and man. MURAKAMI et al. (1974) also showed that the peribiliary plexus of the monkey was drained exclusively to the hepatic sinusoids and proposed to call this vascular
route from the peribiliary plexus to the hepatic sinusoids the peribiliary portal system.

Using rat liver, Hase and Brim (1966) demonstrated that the peribiliary plexus was richly composed of capillaries and that it was connected with both the interlobular vein and the adjacent peripheral sinusoids by the "internal roots" of the interlobular vein and the "radicular portal veins," respectively.

The arterial terminals independent of the peribiliary plexus have also been a subject of controversy. Chrzonsczewsky (1866), Braus (1924) and Elias and Petty (1953) described an intralobular artery which supplied the center of the hepatic sinusoids, but these authors' findings have not been supported by later investigations.

Free hepatic arterio-portal anastomoses were observed by Wakim and Mann (1942), Kneisly, Block and Warner (1948) in the frog, Mitra (1966) in the rat and man, and Del Rio Lozano and Andrews (1966) in the cat, rabbit, guinea pig and rat.

A useful method for the study of microcirculation has been developed which consists of plastic casting and scanning electron microscopy combined with microdissection (Murakami, 1971). This injection replica scanning electron microscope method has enabled us to accurately demonstrate the three dimensional architecture of the vascular bed. Using this technique, we have recently shown the peribiliary plexus in the rat liver as having drainage both into the hepatic sinusoids and the interlobular veins, and have also demonstrated free hepatic arterio-portal anastomoses (Ohtani and Murakami, 1978).

In the present study we re-examined the terminal distribution of the hepatic artery in the rabbit as a part of a comparative study of the hepatic vascular architectures of various species including man. Discussion will be made on the morphological differences of the terminal distribution of the hepatic artery between the rabbit and the rat, and also on the possible role of the peribiliary portal system.

### MATERIALS AND METHODS

Normal rabbits weighing 1.5–2.0 kg were anesthetized by intravenous administration of nembutal, perfused with Ringer's solution through a polyethylene tube inserted into the thoracic aorta, and injected through the tube with a dilute mixture of commercially available methacrylate medium (Mercox, Dainippon ink Co., Ltd.) (Ohtani and Murakami, 1978) until the inferior vena cava was filled with the injected medium. The injected liver was removed placed in a warm water bath (60-70°C), corroded for 24 hrs in warm 10-20% NaOH aqueous solution, washed in a neutral detergent aqueous solution and rinsed in water. The vascular samples thus prepared were frozen in water and trimmed with a handsaw and razor blades into suitable blocks. The blocks of vascular replicas were washed again, dried in air, and fixed on metal stubs. They were dissected under a binocular microscope with sharpened needles and forceps, coated with gold in a vacuum evaporator and observed under a scanning electron microscope using 5kV accelerating voltage (JSM-U3 and S-310). This procedure of dissection and scanning electron microscopy was repeated until the terminal branches of the hepatic artery were sufficiently exposed.
RESULTS

The entire vascular beds of the rabbit can be perfused with diluted Mercox by injection through the thoracic aorta. Since the casts prepared with this medium are appropriately brittle and readily dissected with sharpened needles and forceps, the intrahepatic arterial branches can be clearly exposed.

In the large and medium sized Glisson's sheath, some branches of the hepatic artery form a poor network of capillaries (the so-called periportal plexus) to supply the Glisson's sheath tissue, and without connection to the peribiliary plexus, enter into the hepatic sinusoids (Fig. 1, 2). Most of the hepatic artery branches, however, contribute to the formation of the peribiliary plexus (Fig. 3, 4).

Larger peribiliary plexuses are formed by two layers, an inner layer of fine capillary network which represents the submucosal plexus and an outer layer of venous network which represents the adventitial plexus, with capillary connections between these two layers (Elias and Petty, 1953; Hase and Brim, 1966) (Fig. 3, 6, 7). The hepatic artery sends out many branches to the peribiliary plexus. They enter deep into the plexus to contribute to the capillary network of the inner layer (Fig. 1, 3).

---

Fig. 1. Scanning electron micrograph of a microdissected vascular cast of the rabbit liver. Note that a hepatic artery branch (HAb) is ramified to supply the portal canal tissue. V interlobular vein, HS hepatic sinusoids, GS surface of a lobule faced to the Glisson's sheath. ×50
From this capillary network arises the outer venous network which collects to form larger, fairly independent vessels. These efferent vessels, in turn, form either the "internal roots" running into the interlobular vein, or the "radicular portal veins" pouring into the hepatic sinusoids (Fig. 7, 8). These two types of efferent vessels are observed almost in the same frequency.

In smaller Glisson's sheath, the peribiliary plexus generally consists of a single network of capillaries. As in larger peribiliary plexuses, its afferent vessels arise from the hepatic artery branches and its efferent vessels are connected to the interlobular veins as well as to the hepatic sinusoids (Fig. 4, 5).

The terminal branches of the hepatic artery run in the interlobular space with small interlobular vein branches and pour into the hepatic sinusoids near the end of the Glisson's sheath (Fig. 10).

On rare occasions, some collateral branches from the hepatic artery enter a narrow interlobular space without being accompanied by interlobular veins, and enter into the peripheral part of the hepatic sinusoids (Fig. 9).

We have failed to demonstrate free arterio-portal anastomoses in the rabbit liver.

---

Fig. 2. Closer view of the boxed area in Figure 1. The terminals of the hepatic artery branch (HAb) are connected with the hepatic sinusoids (HS). Arrows indicate the typical connection sites between the terminal branches of the hepatic artery and the hepatic sinusoids. V interlobular venule. ×200
Fig. 3. Medium sized peribiliary plexus (PbP) and its connecting vessels. Note an afferent vessel (a) of the peribiliary plexus arising from the hepatic artery branch (HAb). V interlobular vein, HS hepatic sinusoids, LB lobular branch. ×100
Fig. 4. Scanning electron micrograph of a vascular cast of the rabbit liver obtained from a peripheral area. An interlobular vein (V) runs, together with a hepatic artery branch (HAb) and a peribiliary plexus (PbP) in the Glisson's sheath. The end-twigs of the interlobular vein ramify to from the hepatic sinusoids (HS) which converge onto the central vein (CV). x80
DISCUSSION

The present study has clearly demonstrated that most of the branches of the hepatic artery from the peribiliary plexus and that the vessels arising from the outer venous network of the plexus are connected to the interlobular veins as well as to the hepatic sinusoids.

ANDREWS et al. (1949) described a distinct plexus around the bile duct, which is connected to the interlobular veins by small direct vessels, i.e., “internal roots” of portal veins, and that in places, this plexus collects into larger vessels destined for the sinusoids. Although our findings coincide with those by ANDREWS and his co-workers, they suggest that the flow of blood is from the interlobular vein to the peribiliary plexus. DEL RIO LOZANO and ANDREW (1966) postulate that, when the internal root joins an inlet venule shortly before the latter supplies the lobules, blood flows from the bile duct to the inlet venule, and when the “internal root” joins an inlet venule near the interlobular vein, blood flows through the “internal root” towards the biliary tract (DEL RIO LOZANO and ANDREWS, 1966).

We could not, however, find any evidence for these views, but we believe that in the rabbit and also in the rat (see below) both the so-called “radicular portal veins”
and "internal roots" represent the peribiliary portal system described by Murakami et al. (1974) in the monkey.

Our previous study on the rat liver has shown the peribiliary plexuses as having both connections with the interlobular veins and with the hepatic sinusoids. In the rat liver the "radicular portal veins" are the main drainage of the peribiliary plexus, whereas in the rabbit liver "internal roots" occur as frequently as the "radicular portal vein."

In the present study the hepatic artery branches forming a poor network in the Glisson's sheath are connected to the hepatic sinusoids as Andrews et al. (1949) reported in the cat, rabbit, guinea pig and rat. In the rat liver, however, such hepatic artery branches supplying the Glisson's sheath tissue terminate at the interlobular venules (Ohtani and Murakami, 1978).

We have failed to demonstrate a free arterio-portal anastomosis in the rabbit, and believe that its occurrence, if any, in the rabbit is much rarer than in the rat.

Although the arterial twigs connect with the hepatic sinusoids at the periphery of the lobules as in Figure 9, the intralobular hepatic arteries such as described by Elias and Petty (1953) in the cat and human have not been encountered in the rabbit.

Figure 11 summarizes the liver microcirculation of the rabbit in a schematic drawing. Murakami et al. (1974) proposed to call the vascular route from the peri-
Fig. 7. A large sized peribiliary plexus (PbP) and its connecting vessels. An afferent vessel (a) of the peribiliary plexus enters deep into the plexus to form the capillary network of the inner layer from which arises the outer venous network and they collect to form a fairly independent vessel which was observed connecting to the interlobular vein (V) as the prelobular branch (pLB). Arrows indicate the direction of blood flow. HS hepatic sinusoids, PpP periportal plexus. ×80
biliary plexus to the hepatic sinusoids the *peribiliary portal system*. The vascular routes from the peribiliary plexus to the hepatic sinusoids by way of the "radicular portal veins" and the "internal roots" seen in the rabbit meet the criteria of a portal system.

The bile duct epithelium of mammals is known to possess basal-granulated cells. Recently substance P producing cells have been shown in the epithelium of the bile ducts in rabbits (Heitz et al., 1977). This substance has been reported to control blood flow in the liver lobules as well as intestinal movement and secretion (Erspamer and Melchiorri, 1977). It seems reasonable to postulate that substance P released from the bile duct wall might be taken up into the peribiliary capillary plexus and conveyed by the peribiliary portal vessels to the hepatic lobules as proposed by Fujita (1977).

The nomenclature of the peribiliary efferent vessels does not strictly represent the terminations of each vessels. We propose here to call the efferent vessels into the hepatic sinusoids "lobular branches," and those into the interlobular veins "prelobular branches." The former vessels correspond to the "radicular portal veins" of Kiernan (1833), and the latter to the "internal roots" of Ferrein (1749).
Fig. 9. A collateral branch (Clb) of the hepatic artery branch (HAb) without being accompanied by the interlobular veins enters into the narrow interlobular space and it is connected with the hepatic sinusoids (HS) as indicated by arrows. PbP peribiliary plexus, V interlobular venule. × 100
Fig. 10. A terminal of the hepatic artery branch (HAb) in the small Glisson's sheath is connected with the hepatic sinusoids (HS) as indicated by an arrow. V interlobular vein, PbP peribiliary plexus, LB lobular branch, HS hepatic sinusoids, CV central vein. ×80
Fig. 11. Schematic drawing showing the microcirculation of the rabbit liver. *V* interlobular vein, *HAb* hepatic artery branch, *HS* hepatic sinusoids, *Clb* collateral branch of the hepatic artery, *CV* central vein, *PbP* peribiliary plexus, *PpP* periportal plexus, *PLB* prelobular branch, *LB* lobular branch. Arrows indicate the direction of blood flow, double arrows junctions between the terminals of the hepatic artery branch and the hepatic sinusoids. *BD* bile duct.
ウサギ肝臓の胆管周囲門脈系

大 谷 修

ウサギ肝臓の動脈の終末と胆管周囲血管叢を鋳型走査電顕法で調べた。
肝動脈の終末枝は異なる分布様式をもつ3型に分類できる。すなわち(1)胆管周囲血管叢を形成する枝、(2)肝小葉の末梢で類洞に直接注ぐ枝、(3)グリソノ霧中に密な毛細血管網を形成し小葉末梢の類洞に合流するものである。胆管周囲血管叢は2層からなる。
内層は毛細血管網で、外層は静脈性血管網である。輸出血管は外層の静脈性血管網から起こり、(1)類洞に直接注ぐ“類洞枝”と(2)小葉間静脈に注ぐ“類洞前枝”の2種があるが、いずれも胆管周圍門脈系の名に価する性質をそなえている。小さい胆管周囲血管叢は1層からなるが、その輸出血管は2層からなる場合と同じであった。ウサギの胆管周囲血管叢の輸出血管の様式はラットの場合(OHTANI and MURAKAMI, 1978)と類似していた。本血管叢の機能的意義はいまだ知られていない。胆管周囲門脈系が胆管壁からのホルモンの輸送路である可能性に言及した。

REFERENCES

Aunap, E.: Ueber den Verlauf der Arteria hepatica in der Leber. Z. mikrosk.-anat. Forsch. 25:
238–251 (1931).
(1866).
Erspamer, V. and P. Melchiorri: Polypeptides of the amphibian skin active on the gut and
their mammalian analogues (Abstracts). In: (ed. by) V. Speranza, N. Basso and E. Lexoche:
Int. Symp. Gastrointestinal hormones and pathology of the digestive system. New trends
Hase, T. and J. Brim: Observation on the microcirculatory architecture of the rat liver. Anat.
Heitz, Ph., J. M. Polak, M. Kasper, C. M. Timson and A. G. E. Pearse: Immuneelectron
cytocchemical localization of motilin and Substance P in rabbit bile duct enterochromaffin
Knisely, M. H., E. H. Bloch and L. Warner: Selective phagocytosis. I. Microscopic observa-
...


