A Review of the Retroportal Artery in the Blood Supply of the Biliary Tree: Implications for Hepato-Pancreato-Biliary and Transplant Surgeons

TO THE EDITOR:

The Anatomy of the Retroportal Artery

The retroportal artery (RPA) as shown in Fig. 1A,B has been proposed as the major contributor to the blood supply of the extrahepatic biliary tree. However, this artery is not listed in *Terminologia Anatomica: International Anatomical Terminology*,[1] which is the official international terminology published in 1998 by the International Federation of Associations of Anatomists. The RPA was first described in 1979 by Northover and Terblanche[2] using a series of human resin casts of the arterial supply to the biliary tree. The RPA was found in all 21 cases studied (100%). They considered that the blood supply of the supraduodenal bile duct (BD) was dominated by major arterial branches from the RPA in 18 of 21 cases (85.7%). This part of the BD is surgically the most important segment compared with the other parts, which include the hilar and retropancreatic BDs. The RPA appearance was divided into the following 2 types: type I RPA (about 50.0%; Fig. 1A) arising from the superior mesenteric artery (SMA) or the coeliac trunk (CoT) and crossing the back of the portal vein (PV) to join the posterior superior pancreaticoduodenal artery (PSPDA), which has also been described as the retroduodenal artery (RDA). However, the RDA is a different artery from the PSPDA in the terminology of *Terminologia Anatomica: International Anatomical Terminology*, with both the PSPDA and RDA being branches of the gastroduodenal artery (GDA). The type II RPA (33.3%; Fig. 1B) arises from the SMA or CoT, crosses the back of the PV to reach the posterior surface of the supraduodenal BD, and then ascends to join the right hepatic artery (RHA).

According to these anatomical descriptions, the RPA is associated with connective tissue containing lymphatic and nerve tissue related to the pancreatic head as shown in Fig. 2A,B. The RPA has to be divided during pancreaticoduodenectomy (PD), although there are no articles that mention the artery in the context of this surgery. It may be so posterior or considered small in size that it is not noted or regarded as important by surgeons. However, small arteries are found along with nerve and lymphatic tissues during PD surgery. In addition, pancreatic ductal adenocarcinoma has a predilection to invade along the nerve plexus surrounding

Abbreviations: ABS, anastomotic biliary stricture; BC, biliary complication; BD, bile duct; CHA, common hepatic artery; CoT, coeliac trunk; CyD, cystic duct; GDA, gastroduodenal artery; HPB, hepato-pancreato-biliary; IPDA, inferior pancreatoduodenal artery; LHA, left hepatic artery; LN, lymph node; LT, liver transplantation; N, neural fiber; PD, pancreaticoduodenectomy; PLco, coeliac nerve plexus; PLph, pancreatic head nerve plexus; PLsm, superior mesenteric nerve plexus; PSPDA, posterior superior pancreaticoduodenal artery; PV, portal vein; RDA, retroduodenal artery; RHA, right hepatic artery; RHD, right hepatic duct; RPA, retroportal artery; SDA, supraduodenal artery; SMA, superior mesenteric artery; SMV, superior mesenteric vein.

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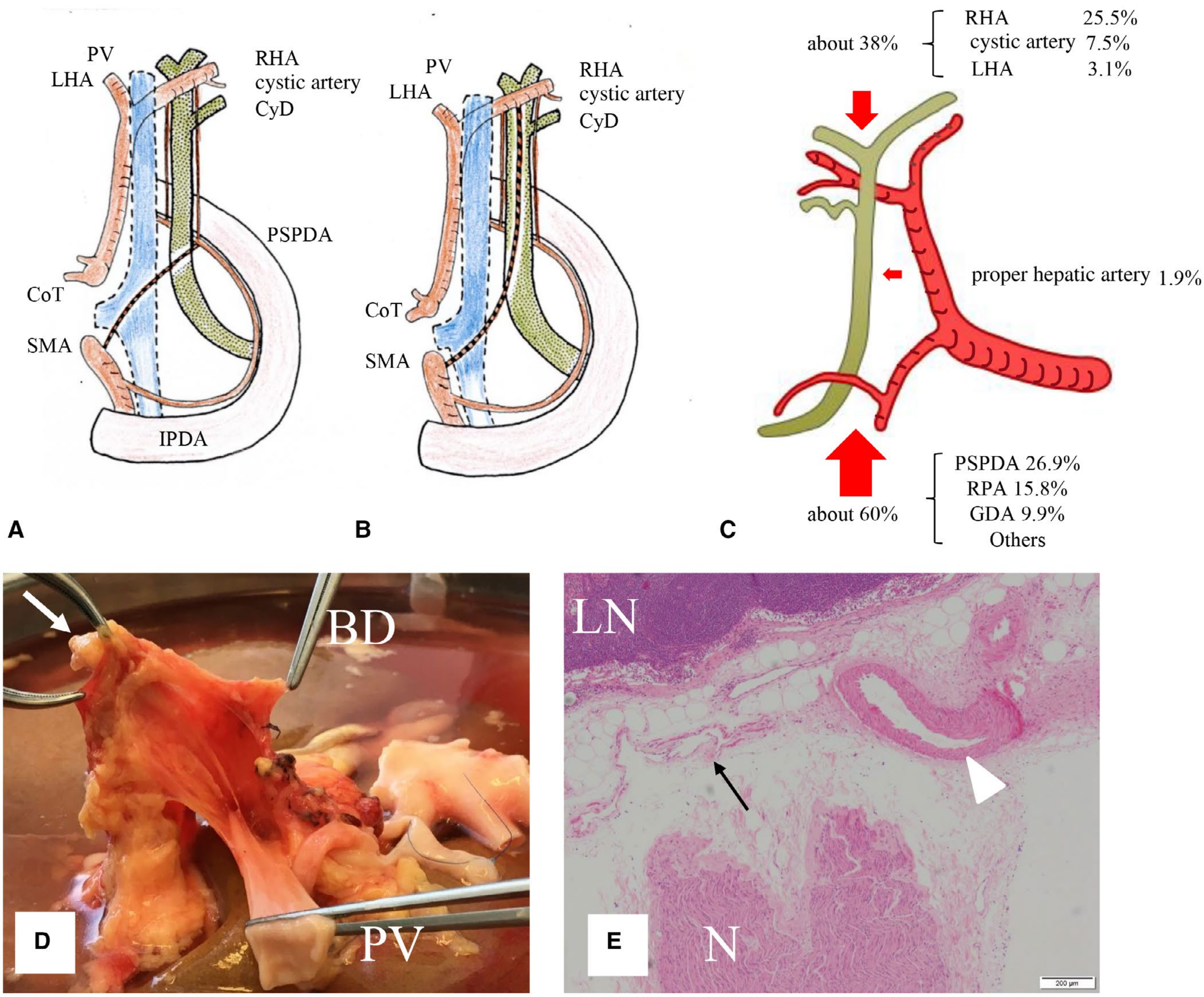

FIG. 1. Schematic of the retroportal artery and the relative proportions of the supply from 3 directions. Schematics of the (A) type I RPA arising from the SMA or the CoT and crossing the back of the PV and joining the PSPDA and the (B) type II RPA arising from the SMA or CoT, crossing the back of the PV to reach the posterior surface of the supraduodenal BD, and then ascending to join the RHA are drawn from the dorsal point of view. (C) These paracholedochal arteries are from above the RHA (25.5%), the cystic artery (7.5%), and the LHA (3.1%); from below the PSPDA (26.9%), the RPA (15.8%), the GDA (9.9%), and others; and from left the proper hepatic artery (1.9%), on average. (D) There is a bundle of white fibers (white arrow) behind the extrahepatic BD or sometimes behind the PV. (E) This tissue contains a small artery (arrowhead) running along with neural fibers accompanied by lymphatic ducts (black arrow) and lymph nodes.

and associated with the arterial supply, and as a consequence, the Japanese classification of pancreatic carcinoma[3] has a detailed description of these nerve plexus as shown in Fig. 2D. Understanding the anatomical location and course of the RPA is important and should be included with descriptions of the pancreatic head nerve plexus (PLph) regardless of whether it originates from the CoT or SMA as shown in Fig. 2A,B. It has been reported that about 80% of neural fibers of the superior part of PLph distribute via the biliary tree toward the liver and duodenum.[4] Based on this, we speculate that neural fibers associated with the RPA have a role in modulating the blood supply to the BD. Because the PLph receives the phrase nerve fibers from the coeliac and superior mesenteric nerve plexus (PLco and PLsm), it contains both splanchnic sympathetic

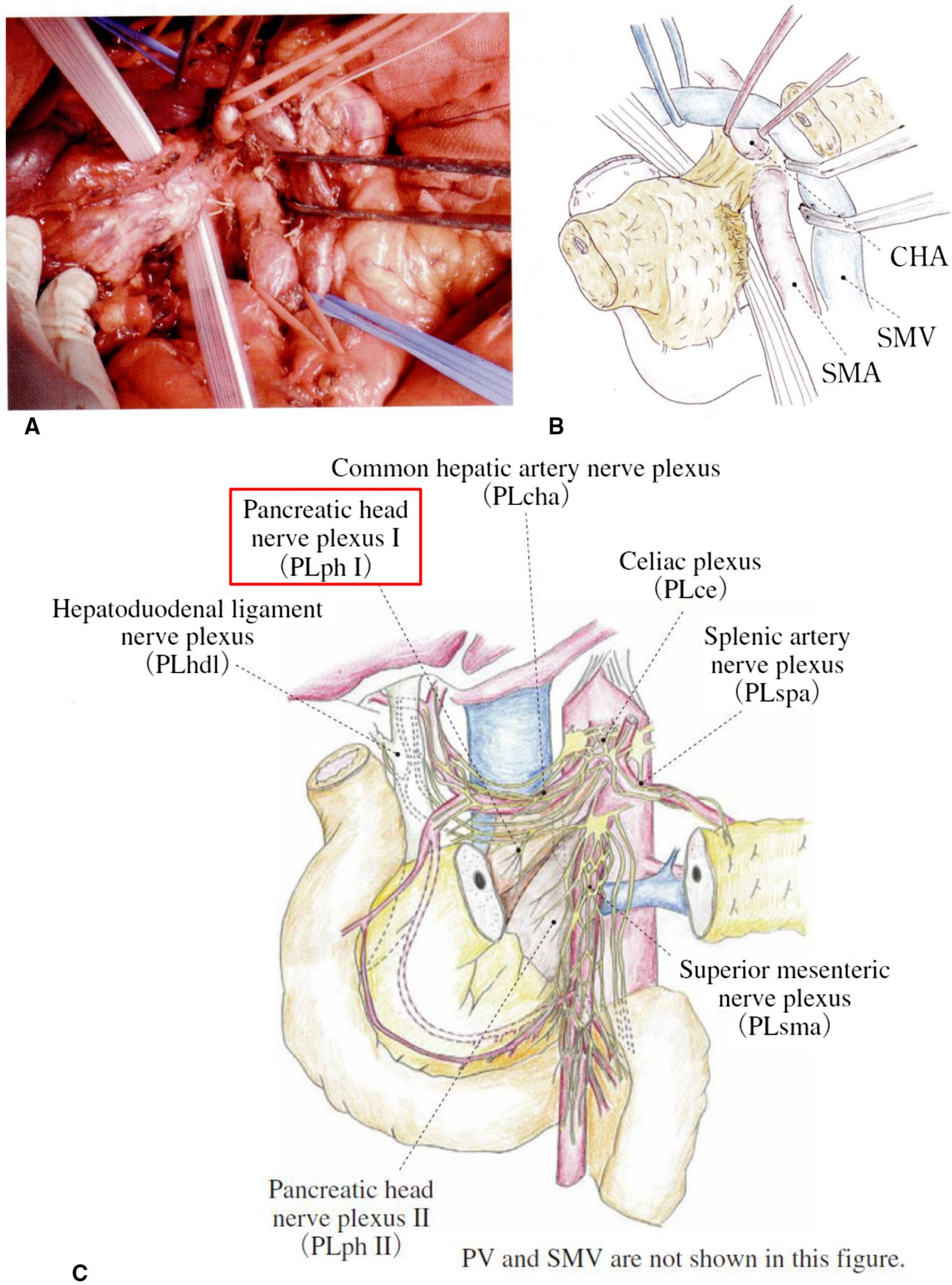

FIG. 2. Schematic of the pancreatic head nerve plexus from the *Classification of Pancreatic Carcinoma 4th English Edition*.[3] (A) The intraoperative image shows the superior part of the PLph and the distance between the roots of the CoT and SMA, which are close to the each other, and (B) a corresponding schematic of the previous image is drawn. (C) The superior part of the PLph is termed the *pancreatic head nerve plexus I* in Japan, given neural fibers from the PLco and PLsm, and distributed mainly to the biliary tree. Reprinted with permission from the *Classification of Pancreatic Carcinoma 4th English Edition*.[3] Copyright 2017, Kanehara & Co., Ltd.

and vagal parasympathetic nerves,[1] and if the sympathetic nerves are activated, the arteries must be spastic. Furthermore, denervation will cause early sphincter of Oddi dysfunction as well as late problems after surgery, the period in which biliary complications occur. For example, BD stricture after right hepatectomy for living related donor may not occur immediately after surgery. This is because the stricture may be caused by a division in the right hepatic duct (RHD) too close to the confluence of the RHD and left hepatic duct and by excessive dissection of the connective tissue surrounding the BD. This connective tissue may contain type II RPA and nerve tissue modulating the blood supply to the remnant biliary tree. In addition, ampullary or sphincter of Oddi dysfunction is likely to be related to denervation and is recognized in up to 7.0% of recipients after liver transplantation (LT).[5] Based on speculation regarding the neural contribution to the BD along the course of the RPA, it could be that injury to the PLph (and PLco and PLsm)[6] or RPA during mobilization of the common hepatic artery (CHA) for arterial reconstruction or exposure of the recipient PV at LT leads to nerve injury and ampullary dysfunction.

There is further evidence supporting the existence of the RPA from articles describing the importance of lymphadenectomy in the retroportal area during surgery for biliary malignancy.[7,8] Of clinical importance is the presence of a terminal lymph node draining the extrahepatic biliary tree located behind the PV, named the principal retroportal node by Ito et al.[8] The lymphatic drainage was described as passing from the pancreatic head neural plexus to reach celiac and superior mesenteric nodes as lymphatic drainage follows the course of the arterial supply. Therefore, with its nerve supply and lymphatic drainage, the RPA has clinical significance in oncological surgery of the BD.

The Role of RPA in the Blood Supply of the Biliary Tree

Northover and Terblanche described the relative proportion of each arterial supply as paracholedochal arteries, which have been named the “3 o’clock” and “9 o’clock” arteries after their locational relationship with the BD, and arise from above via the RHA (25.5%), cystic artery (7.5%), and left hepatic artery (LHA; 3.1%); from below by the PSPDA (26.9%), RPA (15.8%), GDA (9.9%) and others; and from the left by the proper hepatic artery (1.9%) as shown in Fig. 1C.[2]

In addition, Chen et al.[9] analyzed the proportion of blood supply based on the average diameter of the arteries and their numbers of branches and calculated the total cross-sectional area of each arterial distribution. In this study, they identified the RPA in 45 of 50 cases (90.0%), with an average diameter of 0.92 ± 0.52 (0.46–2.30) mm. They concluded that the total cross-sectional area of the RPA to the whole extrahepatic BD was 3.84 mm^2 (3.4%), which represents the fourth contributor to the arterial blood supply of the BD after the cystic artery, PSPDA, and RHA.

Implications for Hepato-Pancreato-Biliary and Transplant Surgeons

We believe that most surgeons have seen that there is always a bundle of fibrous tissue running behind the extrahepatic BD or sometimes behind the PV as shown in Fig. 1D. This bundle contains a small artery running along with neural fibers accompanied by lymphatics as shown in Fig. 1E. According to the anatomical findings described previously, the PSPDA, RHA, cystic artery, RPA, and middle hepatic artery provide the bulk of the blood supply to the BD. To preserve the arterial supply of the proximal and distal BD, transplant surgeons should be aware of the RPA and its variants as well as BD innervation. The focus has always been on the donor BD, but this article identifies preservation of optimal arterial inflow and nerve supply to the recipient BD as also being important. The techniques used in adult living donor LT preserving the arterial and biliary integrity appears to be optimal from this respect.

Three other issues need to be considered by hepato-pancreato-biliary (HPB) and transplant surgeons. First, to preserve the arterial supply and nerve tissue to the BD, the dissection has to keep a distance from the BD. It is important to avoid approaching more distal arteries from the GDA during preparation of the whole liver graft on the back table and in situ. With reduced grafts or surgery for hilar malignancy, excessive dissection near the hilar hepatic duct including the hilar plate should be minimized if unavoidable. Second, the optimal site for division of the supraduodenal BD may be variable based on the pattern of arterial supply, and each case should be considered separately. Because the authors are not always sure whether the contribution from the cystic artery is preserved, it may be better to divide the BD at the level of crossing with the RHA during PD or the donor BD during LT provided the recipient BD can reach this point. Otherwise, the donor BD should be cut as short as possible. Third, the optimal site for the ligation of the cystic artery and the cystic duct (CyD) should be as close as possible to the gallbladder for donor cholecystectomy and for all hepatectomies to avoid damage to the 9 o'clock artery of both the donor and recipient BD or the patient BD in HPB. At the time of ligation of the CyD, surgeons should take care not to involve the right marginal artery of the BD because it crosses the anterior aspect of the CyD at this level.[10]

Attention to detail in understanding and preserving the blood supply and innervation to the BD will reduce biliary complications (BCs) after LT. The use of the recipient's BD with its vasculature preserved for duct-to-duct anastomosis in living donor LT has become the accepted method of reconstruction with preservation of the RPA and proximal arterial supply, which makes anatomical sense.

The recent introduction of fluorescence cholangiography using indocyanine green allows surgeons to identify the course of the BD even when surrounded by connective tissues, which should be preserved as much as possible, but to date does not allow an assessment of the blood supply because the mucosal capillaries and epicholedochal plexuses surrounding the BD are too small. Technological innovation, precise knowledge of the anatomy, and use of surgical techniques that preserve RPA flow with surrounding nerve tissue optimize the arterial supply to the donor and recipient BDs and may help to reduce the incidence of BCs further, thus avoiding the Achilles' heel of all forms of LT.

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