Anatomical Preconditions for Operative-Technical Errors in Right Trisectionectomy

Sağ Triseksiyonektomi Operatif-Teknik Hatalar İçin Anatomik Önkoşullar

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Abstract

Objective: Certain anatomical variations may represent preconditions for technical operation errors in right trisectionectomy. These variations include: the confluence of the common bile duct, the length of the left hepatic duct, the localization of the bile duct confluence for segments 2 and 3 of the umbilical portion of the left portal vein and the peculiarities of the afferent and efferent blood supply of these two segments. The aim of the present study is to identify and discuss such preconditions.

Materials and Methods: The anatomical variations of the common bile duct confluence were analyzed by intraoperative cholangiography in 112 patients undergoing liver resections and in 32 preparations after left hepatectomy. The variations of the afferent and efferent blood supply were morphologically examined in 43 liver resections.

Results: Seven types of anatomical variations of the common bile duct confluence were detected through intraoperative cholangiography, and three were extracted from the available literature. Three anatomical types (central, peripheral, and combined) of bile drainage from segment 4 were established. The mean distance between the bile duct confluence for segments 2 and 3 and the main hepatic duct confluence, i.e., the length of the left hepatic duct, was 3.68 cm. The anatomical peculiarities of the afferent and efferent arterial and venous supply of segments 2 and 3 were presented and discussed with respect to their roles in a safe right trisectionectomy.

Conclusion: Surgeons’ sound knowledge of anatomical variations of the biliary tract and hepatic blood vessels coupled with increased experience and technique refinements could contribute to better outcomes in right trisectionectomy.

Key Words: Bile duct anatomy, Bile duct confluence, Hepatic blood supply, Intraoperative cholangiography, Right trisectionectomy

Özet


Gereç ve Yöntem: Ana safra kanalı konfluensinin anatomik varyasyonları karaciğer rezeksiyonu uygulanan 112 hasta ve sol hepatektomi uygulanan 32 hastada intraoperatif kolanjiyografi ile analiz edildi. Afferent ve efferent kanlanmanın varyasyonları 43 karaciğer rezeksiyonunda morfolojik olarak incelendi.

Bulgular: Ana safra kanalı konfluensinin anatomik varyasyonlarının 7’si intraoperatif kolanjiyografi ile, 3’ü ise mevcut literatürde varolanlardan tespit edildi. Dördüncü segmentin safra drenajını sağlayan üç anatomik varyasyon (santral, periferik ve kombin) tespit edildi. Segment 2 ve 3 safra yollarının konfluensi ile ana hepatik kanal birleşimi arasındaki ortalama mesafe, yani sol hepatik kanalın uzunluğu; 3.68 cm olarak ölçüldü. Segment 2 ve 3’un afferent ve efferent arteriyel ve venöz kananların anatomik özellikleri sunulmuş ve güvenli bir sağ triseksiyonektomideki rolleri açısından tartışılmalıdır.

Sonuç: Safra yolları ve hepatik kan damarlarının anatomik varyasyonları konusunda cerrahları sağlam bir bilgi ve teknik iyileştirmeler ile artan deneyimi birleştigidde doğru triseksiyonektomi için daha iyı sonuçlar elde edilmesine katkıda bulunabilir.

Anahtar Kelimeler: Safra kanalı anatomisi, Safra kanalı birleşimi, Hepatik kan akımı, Intraoperatif kolanjiyografi, Sağ triseksiyonektomi

Introduction

‘Right hepatic trisectionectomy’ is referred to as ‘right hepatic trisegmentectomy’ in the USA and as ‘extended right hepatectomy’ or ‘right hepatic lobectomy’ in Europe [1, 2]. This resection was first reported in 1952 and standardized in 2003 [3, 4]. A safe technique was comprehensively described and modified to avoid injury to the left hepatic duct (DHS) [5, 6]. Right trisectionectomy includes the resection of segments 4-8 (Sg4-8) [7-9]. Two different approaches can be used for the segmentectomy of Sg4 in addition to the segmentectomy of Sg5-8. Resection of Sg4 is completed through selective ligation of its pedicle either prior to or during parenchymal transection.
We aim to reveal essential preconditions leading to technical operation errors in right trisectionectomy resulting from the anatomical variations of the common bile duct (DHC) confluence, DHS length, localization of the bile duct confluence for Sg2, 3 of the umbilical portion of the left portal vein (LPV) and the peculiarities of the afferent and efferent blood supply of Sg2, 3.

Materials and Methods

During the period from 2003 to 2011, a total of 149 intraoperative cholangiographies were performed in 112 patients with benign and malignant liver diseases to record the anatomical variations of the DHC confluence. The distance from the bile duct confluence for Sg2, 3 to the DHC (i.e., DHS length) was measured given its essential importance in the preservation of bile drainage to these segments. The surgical anatomy of the afferent and efferent blood supply was examined while conducting 43 liver resections, including 9 segmentectomies of Sg4; 13 bisegmentectomies of Sg2, 3; 17 central hepatic resections and 4 right trisectionectomies as well as during the section of 32 preparations after left hepatectomy. With these 32 preparations, parenchymal transection at the border between the left medial and lateral sections enabled the exact localization of the bile duct confluence for Sg2, 3 as compared to the LPV umbilical portion, an important landmark during right trisectionectomy.

During these 43 resections, after clamping the middle hepatic vein (VHM), methylene blue in a dose of 10 mL was injected into the left branch of the portal vein (PV) above the site of drainage for Sg4 in order to characterize the venous outflow from Sg2, 3. Sg2, 3 were stained completely blue. In cases of normal venous outflow, the appearance of the hepatic parenchyma was restored within 2-3 min. Any durable blue staining of Sg2 or Sg3 was categorical evidence that the venous drainage was accomplished entirely through the VHM. Transection at the border between the left medial and lateral sections after left hepatectomy was used to purposefully search for an independent drainage of Sg2 or Sg3 into the VHM.

Results

Anatomical peculiarities of the bile duct confluence

Ten different anatomical variations of the bile duct confluence that could represent a precondition for a technical operation error in right trisectionectomy were established. Of them, seven were detected through intraoperative cholangiography and three were extracted from the available literature. The most common confluence pattern occurred in 61.6% of the cases when the right hepatic duct (DHD) and the DHS

Figure 1. A) The RPD joining the DHS (Type 2); B) The RPD joining the DHC (Type 4); C) The RPD joining the DC (divided) (Type 5); D) Ectopic bile duct drainage for Sg6 into the DC (Type 6).
merged to form the DHC. The second most common configuration occurred in 14.2% of the cases when the right posterior duct (RPD) joined the left hepatic duct (Type 2) (Figure 1a). The DHS formed a trifurcation with the right anterior duct (RAD) and the RPD in 10.7% of the cases (Type 3). The relationship between the RPD and the RAD at the trifurcation varied, with the RPD being four times more likely to be superior to the RAD than the reverse. In 2% of sample cases, the RPD joined the DHC (Type 4) (Figure 1b). The RPD joined the cystic duct (DC) in 1.7% of cases (Type 5) (Figure 1c). Ectopic bile duct drainage for Sg6 into the DC was established in only one case (Type 6) (Figure 1d).

The absence of a confluence of Sg2, 3 bile duct drainage into the DHD or the DHC was encountered in 1.7% of the cases (Type 7) (Figure 2a).

Length of the DHS and localization of the bile duct confluence for Sg2, 3 of the umbilical portion of the LPV

We established three anatomical types of bile drainage from Sg4, i.e., central, peripheral, and combined. The central type occurred in 36.8% of cases, and bile from Sg4 drained near the DHC confluence. The peripheral type occurred in 59.7% of cases as the bile from Sg4 drained into the DHS near the bile duct confluence for Sg2, 3. The combined type occurred in 3.5% of cases. We established nine anatomical subtypes of bile drainage from Sg4 that did not represent any preconditions for technical operation errors in right trisectionectomy. The mean distance between the bile duct confluence for Sg2, 3 and the main hepatic duct confluence i.e., the DHS length, was 3.68 cm (range, 0.8 to 8.7, Figure 2b).

Parenchymal transection showed that the bile duct confluence for Sg2, 3 was located to the left of the umbilical portion of the LPV in 46.4% of cases, posterior to it in 44.4% of cases and to the right of it in 9.2% of cases.

Anatomical peculiarities of efferent blood vessels for Sg2, 3

Sg3 remained durably stained with methylene blue in 11.6% of the cases. In some cases, removal of the clamp on the middle hepatic vein (MHV) normalized venous outflow and restored the normal appearance of Sg3 parenchyma, evidence that the blood from Sg3 was entirely drained by the MHV. In other cases, blood from Sg2, 3 was drained entirely by the left hepatic vein (LHV). An independent vein for Sg3 draining directly into the MHV was identified in 9.3% of the 32 preparations. In the remaining cases, the LHV originated from the confluence of a transverse vein draining Sg2 and a sagittal vein draining Sg3.

A long DHS and the localization of this confluence to the left of the umbilical portion of the LPV are considered optimal. In such cases, the danger of parenchymal damage to the DHS is minimized, and the bile duct for Sg4 can be severed at a safe distance from the bile duct confluence for Sg2, 3 (Figure 2c).

Anatomical peculiarities of the afferent blood vessels for Sg2, 3

The anomalies of the hepatic arterial system rival those of the biliary tract. The right, middle and left hepatic arteries (RHA, MHA and LHA) originated from the common hepatic artery (CHA) in 57.3% of cases. In right trisectionectomy, the LHA and the accessory arterial vessels for Sg2, 3 were obligatorily preserved.

The accessory LHA originated most commonly (in 22.6% of cases) from the left gastric artery (LGA) (Figure 3a). There was an accessory artery to the left hemiliver originating from the CHA before its bifurcation in 6.6% of cases studied. The hepatic arterial trunk originated entirely from the superior mesenteric artery (SMA) in 2.6% of the cases studied.

At the hepatic hilus, the PV divides into right and left branches on which both right and left hemilivers depend, respectively. This conventional PV anatomy was identified in

Figure 2. A) The absence of confluence of bile duct drainage for Sg2 and Sg3 into the DHD or the DHC; B) Cholangiography after right hepatectomy with anastomosis between the DHS and the intestine; C) Transection along the lig. falciforme hepatis. Bile duct confluence for Sg2, 3 is located to the left of the umbilical portion of the LPV. Central type bile drainage from Sg4. Presence of bile ducts for Sg4a and Sg4b.
86.6% of cases. We failed to reveal any anatomical variations of the left PV branch that could represent a precondition for technical operation errors in right trisectionectomy leading to the devascularization of Sg2, 3. The right portal vein (RPV) presented with more variation. In three cases, two from our study and one reported in the literature, there existed a danger of such devascularization [10]. There was a trifurcation of the main PV as the RPV immediately divided into two separate branches in 9.3% of cases (Figure 3b).

Discussion

Many variations of the biliary tree exist, as the ‘conventional’ anatomy occurs in only about 50% of the population [10]. We reported six rare anatomic bile tract variations [11]. In right trisectionectomy, both the localization of the bile duct confluence for Sg2, 3 and the DHS length are important.

Type 1 configuration was reported in less than 61% of patients studied [12]. The incidence of Type 2 configuration was similar to previously reported figures [13], occurring in 19% of cases. The incidence of Type 3 configuration varied between 5%, 10%-12% and 16% of cases [10, 13-16]. Type 4 configuration varied between 6%, 4.5% and 4% [10, 13, 15]. The frequency of Type 5 configuration was reported at 1% and 2% of subjects [10, 15]. A similar variation of Type 6 was reported, as the bile duct for Sg6 was entirely drained into the DHC [13]. Type 7 configuration incidence did not surpass 1% [10]. With respect to Type 8, the bile ducts for Sg2, 3 drained individually into the RAD in 2% of cases [10]. In Type 9, the bile duct for Sg5 drained into the DHC [13]. Finally, in Type 10, the DHD drained into the DC in less than 0.3% of cases [15]. The distance between the bile duct confluence for Sg2, 3 and that of the main hepatic duct was a mean value of 3.25 cm (range, 0.5 to 5.7 cm) [17]. This confluence was located to the left of the umbilical portion of the LPV in 41.7% of cases, posterior to the umbilical portion of the LPV in 42.7% of cases and to the right of the umbilical portion of the LPV in 15.6% of cases [17].

The RHA, MHA and LHA originate from the CMH in approximately 55% of the population [18]. Central, peripheral, and combined types of bile drainage from Sg4 occurred in 35.5%, 54.6% and 9.9% of cases, respectively [17]. In another study, central type drainage occurred in 80% of cases and peripheral drainage occurred in 22% of cases [14]. In addition to these three anatomical variations of the afferent blood supply as preconditions for technical operation errors and devascularization of Sg2, 3, a fourth variation has also been identified [19, 20]. An accessory LHA from the LGA occurred in up to 25% of cases [10]. An accessory artery to the left hemiliver originating from the CHA before its bifurcation has been described [21]. The hepatic arterial trunk originated entirely from the SMA in 2%-5% of cases [22].

Portal vein variants accounted for approximately 20% of all significant variants [23]. The portal blood supply of Sg2,3 was furnished primarily through the LPV branch. The anatomy of the left portal venous system was remarkably consistent [23]. The RPV immediately divided into two branches in 10% and 15% of the cases [10]. The anterior RPV originated directly from the LPV in 2% of cases. A third variation was characterized by the absence of the LPV [10]. In such cases, the main portal trunk was undivided as it entered the liver. Within the liver, the right segmental branches separated and the trunk turned left, crossing the umbilical fissure intraparenchymally as the LPV and supplied branches to the left lobe segments. The blood from Sg3 was drained entirely by the MHV in 10% of the population [10]. We failed to encounter any independent blood outflow from Sg2 or Sg2, 3 as a unit into MHV [10, 18].

Similar anatomical bile duct variations were recently reported [24]. This knowledge is very important for a successful and safe right trisectionectomy [7, 20, 24-28].
There is serious danger of damage to the bile drainage of Sg2, 3 when the localization of this confluence is to the right of the umbilical portion of the LPV (Type 7) and the DHS is either short or absent (Type 8). Based on cadaver dissections and corrosion casts, similar morphology was identified in roughly 10% of cases where the DFS was absent as Sg2, 3 ducts joined near the hepatic hilus [19]. This resulted in two separate ducts across the surface of Sg2, 3 that must anastomose individually into a Roux loop [19]. Failed recognition of this variation interrupts the bile duct confluence for Sg2, 3 in right trisectionectomy and causes severe postoperative complications. The combination of a short DHS (<1 cm) with patterns of Type 2 or Type 3 configurations represents a significant risk for forming an intraoperative lesion of the bile drainage system for Sg2, 3 [29].

In some cases, DHC removal with subsequent anatomosis between the DFS and an isolated intestinal Roux loop is needed to avoid these complications. With large neoplasms, typically an anterior approach is employed for right trisectionectomy. Its combination with drainage of the RPD into the DHC (Type 4) or into the DC (Type 5) creates a risk of postoperative bile leaks [10, 15]. When combined with an anterior approach, unrecognized Type 6 configuration causes postoperative bilirrhagia due to a non-hermetized DHC, while unrecognized Type 10 leads to biliary peritonitis.

Precise dissection at the hepatic hilus avoids the complications caused by these anatomical bile duct variations but could also be dangerous. One should minimize handling and dissecting at the hilus in a right trisectionectomy, not only to prevent injury to anomalous ducts but also to preserve the underlying vascular plexus, which contributes to the blood supply of the DFS and the DHC. Delayed anastomotic and non-anastomotic strictures are common and often due to unrecognized ischemic bile duct injury. The hepatic duct confluence appears particularly vulnerable to such ischemic-type strictures [30].

Not all hepatic vascular anomalies are surgically significant in right trisectionectomy. Each artery for Sg2, 3, either accessory or replaced, must be preserved for its specific area of blood supply. Typically, each artery is a terminal artery without intrahepatic anastomosis. The LHA originates from the LGA, passes through the lig. hepatogastricum and enters the hepatic hilus in the left hemiliver. This accessory LHA may provide the entire supply to Sg2, 3 in almost 50% of cases. For this reason, its disruption during right trisectionectomy necessitates its reconstruction. Otherwise, arterial blood supply to Sg2, 3 would be destroyed, leading to lethal hepatic failure. In one of our cases, clamping the accessory LHA that originated from the CHA before its bifurcation induced ischemic lesions of the lateral portion of Sg3 and required reconstruction after damage. This illustrates the high incidence of dual blood supply to Sg2, 3 [31]. The arterial blood supply of the entire liver could be destroyed if the hepatic arterial trunk originates solely from the SMA and both a right trisectionectomy and duodenopancreatic resection are simultaneously performed [32]. The damaged hepatic arterial trunk should be reconstructed.

The LPV is much longer than the RPV. Its initial portion lies in the hilus. It runs transversely and is 3-5 cm long. The second portion of the LPV curves anteriorly and to the left as an arch toward the base of the umbilical fissure, where it is joined anteriorly by the round ligament. The limited length of the transverse portion of the LPV may create surgical troubles in cases of trifurcation or the anterior RPV originating directly from the LPV. The LPV may be affected following right hemiliver devascularization in right trisectionectomy and must be reconstructed. In its absence, right trisectionectomy is contraindicated. This intervention completely disrupts the portal blood supply to Sg2, 3. If it is performed, however, despite this anatomical variation, blood flow should be restored by means of a graft placement linking the extrahepatic and intrahepatic portions of the PV servicing Sg2, 3 [22].

The intersegmental area between Sg4 and Sg2, 3 forms a watershed between the drainage areas of the MHV and the LHV. This region is drained by a tributary of the LHV that runs across the lig. falciforme hepatis in more than 60% of the cases and equally between tributaries of the LHV and the MHV in up 30% of the cases. In less than 10% of cases, the entire Sg3 is drained by its vein, which joins the MHV as opposed to uniting with the vein of Sg2. In right trisectionectomy, the resection line passes through this watershed zone and the tributaries of the LHV and the MHV, invariably draining this zone [7, 8]. Both the RHV and the MHV can be ligated without compromising the outflow of Sg2, 3. However, care is required when encountering venous drainage of Sg3 into the MHV. Following parenchymal transection, outflow of the MHV may require reconstruction and connection to the inferior vena cava [10]. In right trisectionectomy, Sg2, 3 should not be liberated, as small individual veins drain Sg3 directly into the suprahepatic inferior vena cava near the main left hepatic trunk.

Although comprehensive investigation such as preoperative and intraoperative ultrasonography, cholangiography, CT and MRI are currently used to map the hepatic vascular and biliary morphology, they are not yet routinely performed during right trisectionectomy. Moreover, not all anomalies can be readily identified by these diagnostic methods and some may only be evident when specifically sought. Liver surgeons should be particularly familiar with hepatic anatomy for critical recognition of the presence and implications of these anatomical variations. Recently, increasing experience coupled with refined techniques and sound knowledge of
normal and pathological anatomy facilitates improvement in surgical outcomes of patients undergoing right trisectionectomy [7, 8, 33-35].

Conflict of interest statement: The authors declare that they have no conflict of interest to the publication of this article.

References
17. Renz JR, Reichert PR, Emond JC. Biliary anatomy as applied to pediatric living donor and split-liver transplantation. Liver Transpl 2000; 6: 801-4. [CrossRef]
22. Kostov DV, Kobakov GL. Rare anatomical variants of bile ducts. Eur J Radiol 2003; 4: 61-4. [CrossRef]