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MORPHOLOGICAL CHARACTERISTICS AND FREQUENCY OF ACCESSORY RIGHT HEPATIC VEINS – EVALUATION WITH COMPUTED TOMOGRAPHY

Jure Mišič[1], Peter Popović[1,2], Marija Hribernik[3], Andrej Starc[4] and Raja Dahmane[5]

[1]Clinical Institute of Radiology, University Medical Centre Ljubljana, Ljubljana, Slovenia; [2]Faculty of Medicine, University of Ljubljana, Ljubljana, Slovenia; [3]Institute of Anatomy, Faculty of Medicine, University of Ljubljana, Ljubljana, Slovenia; [4]Faculty of Health Sciences, University of Ljubljana, Chair of Public Health, Ljubljana, Slovenia; [5]Faculty of Health Sciences, University of Ljubljana, Chair of Biomedicine in Health Care, Ljubljana, Slovenia

SUMMARY – In the liver, there are many vascular variants, which are important in liver surgery, the presence of accessory right hepatic veins (aRHVs) in particular. Their frequency, number and diameter vary considerably. Detailed imaging diagnostics with computed tomography (CT) should be undertaken before surgery. The aim of our study was to examine the characteristics of aRHVs and their demographic correlations. The study included data on 188 patients that underwent CT examination of the abdomen with contrast media, 103 men (54.8%) men and 85 (45.2%) women, mean age 63.1±14.3 (range, 21-94) years. The measurements of hepatic veins were carried out on CT images, which were obtained from the Clinical Institute of Radiology, University Medical Centre of Ljubljana. Forty-five of 142 patients had at least one aRHV: one aRHV in 37 (26.1%) cases, two aRHVs in seven (4.9%) cases, and three aRHVs in one (0.7%) case. The incidence of aRHV was between 24% and 39.3% (mean, 31.7%) and of more than one aRHV between 2.3% and 10.3% with 95% confidence interval (CI). Based on the test of proportions, the proportion of cases with inferior aRHV of at least 7 mm was between 7.2% and 18.1% with 95% CI. The mean distance between the aRHV and the main RHV confluences into the inferior vena cava was 3.73 cm (between 3.32 cm and 4.13 cm, 95% CI). The proportion of cases with confluence distance of at least 4 cm was between 21.6% and 49.5% in cases with at least one aRHV. In cases with more than one aRHV, the distance between the middle aRHV and the main RHV ranged from 1.90 cm to 4.32 cm (95% CI). The T-test of independent samples showed no effect of age on the incidence of accessory veins (p=0.18), and the test of differences of interests showed no impact of sex (p=0.75). Evaluation of the incidence and diameter of aRHVs is of great importance for safe surgical procedure. Their presence can change the surgeon's decision in 10%-20% of cases when employing appropriate imaging technique. CT examination, which is easily accessible and minimally invasive for patients, was successful in only 80% cases, when using standard protocol for CT scanning.

Key words: *Liver - surgery; Hepatic Veins; Tomography, X-Ray Computed; Slovenia; Diagnostic Imaging*

Introduction

The knowledge of liver anatomy based on the internal vascular and biliary branching patterns to the segmental level has led to rapid advances in liver surgery in recent decades[1,2]. Surgical planning of vascular anastomoses is of crucial importance for liver

Correspondence to: *Asst. Prof. Andrej Starc, PhD, BSc*, Faculty of Health Sciences, University of Ljubljana, Chair of Biomedicine in Health Care, Zdravstvena pot 5, 1000 Ljubljana, Slovenia
E-mail: andrej.starc@guest.arnes.si
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surgery, such as transplantation, tumor resection, and laparoscopic hepatobiliary surgery, and is proven to reduce mortality and complications after surgery[3,4].

Numerous anatomical variations of the hepatic veins (HV) have been found, especially the presence of accessory right hepatic veins (aRHVs) in the right hemiliver. Their incidence, number, diameter and other characteristics, which have been studied with different methods, vary considerably[5-8]. For appropriate surgical treatment, the knowledge and exact pictorial representation of the anatomical variations of the main and accessory hepatic veins are of great importance[3]. In a study on donor and recipient livers, Sahani *et al*. report that the diameter and other aRHV characteristics are important in liver transplantation, especially if the diameter of the aRHV exceeds 3 mm. In this case, a special surgical approach must be adopted, the aRHV should be separately transplanted, and adequate anastomoses should be ensured in order to avoid unnecessary complications such as hemorrhage and ischemic damage to the graft[4]. The presence of a substantial aRHV also influences the course of liver mobilization during liver resections. Damage to such a vein can cause life-threatening bleeding. In addition to the diameter of aRHV, distance between confluences of the aRHV and the main RHV to the inferior vena cava (IVC) is also important in planning and deciding on the appropriate surgical technique during liver transplantation. If the distance exceeds 4 cm, it is difficult to transplant both veins using just one vascular compressor on IVC. In this case, the distance should be determined before the procedure due to the increased complexity of the surgery. Moreover, two or more aRHVs increase the procedure complexity even more[3,4,9].

The presence of the inferior aRHV is very important during resections of the 7th and 8th liver segment. In the presence of a substantial inferior aRHV (at least 7 mm thick), the right-inferior portion of the liver (segments 5 and 6) can be preserved, despite removal of the main RHV[10].

Development of imaging methods has improved surgical treatment of the liver. The anatomy of arterial, portal, venous and biliary systems, including anatomical variations, liver parenchyma and pathological changes in the abdominal cavity can be assessed by CT[3,11,13]. CT angiography of the liver can be combined with multiphase examination of different abdominal organs.

Different methods have been used to evaluate aRHVs in different studies, namely, the method with liver castings[6,7], CT imaging method[3,8,11], magnetic resonance[4], sonography[5], or resection of cadaveric livers[12]. The incidence of aRHV has been reported to be between 6% and 52.5% of the population. Xing *et al*. report that the incidence of the inferior aRHV is higher in older population and that the diameter of the main RHV depends on the diameter of the aRHV[10].

The aim of our study was to determine the incidence and morphological characteristics of the aRHVs in our population by the CT imaging method. Another aim of our study was to determine the correlation between some demographic predictive factors and the incidence of aRHVs.

The terminology for liver subunits used in the present article is in accordance with the Brisbane 2000 terminology[14].

Materials and Methods

The prospective/retrospective study included data on 188 patients that underwent CT examination of the abdomen with contrast media, 103 (54.8%) men and 85 (45.2%) women, mean age 63.1±14.3 (range, 21-94) years. We excluded 34 cases due to insufficient opacification of the hepatic veins, 10 cases due to pathological changes in the liver, and 2 cases due to motion artefact caused by patient breathing during measurements. In the end, the measurements of hepatic veins were performed in 142 patients, 68 (47.9%) men and 74 (52.1%) women. The measurements of hepatic veins were carried out on CT images, which were obtained from the Clinical Institute of Radiology, University Medical Centre of Ljubljana.

Computed tomography imaging protocol with contrast media

Computed tomography examinations were performed using the standard routine protocol for multiphase imaging of the abdomen with 64-slice helical CT scanner (Somatom Definition, Siemens AG Medical Solutions, Germany). Multiphase imaging of the abdomen was performed by intravenous application of 80-150 mL of nonionic contrast agent (Iomeron, iodine concentration 400 mg/mL; Ultravist, iodine concentration 370 mg/mL; or Visipaque, iodine concen-

tration 320 mg/mL) in bolus through venous cannulas, size 18-20 gauge. The contrast agent was injected at a flow rate of 3.5-5 mL/s with an automatic injector system (Stellant D Injection System, Medrad, Whippany, USA). The bolus tracer on the descending aorta with the trigger value of 120 Hounsfield units (HU) provides accurate timing data on the first passage of contrast agent in the early arterial phase. For liver portal and venous system approximately 65-75 s after the contrast agent application, the portal-venous phase is performed. A single phase is performed in one breathhold, which is a prerequisite for the precise presentation of liver structures. The venous phase of imaging was performed with the exposition of 120 kV and 160-200 mAs. In extremely thin or fat patients, the exposition was extended beyond these borders (minimum 120 mAs, maximum 400 mAs). The collimation of 1.2 mm and pitch of 0.6 at 0.5 s of gantry rotation time was used. All images were reconstructed with 2-mm image thickness and 1-mm increment, which reflects in 50% data overlapping. For image interpretation, multiplanar reconstruction (MPR) images in different planes and in some cases even maximum intensity projection (MIP) and volume rendering technique (VRT) images were made after examination. We used three kinds of contrast agents for CT examinations, i.e. Visipaque with iodine concentration of 320 mg/mL in 111 (59%), Ultravist with iodine concentration of 370 mg/mL in 12 (6.4%) and Iomeron with iodine concentration of 400 mg/mL in 65 (34.6%) cases. The mean amount of injected contrast agent was 113±13 mL *per* patient. The amount of injected contrast media was applied in proportion to the body mass index and iodine concentration in contrast agent.

Hepatic vein measurements

Data were acquired from axial and reconstructed images of the venous phase of CT examination. In all cases, we measured the diameter of the main RHV. In cases with one or more aRHVs, we measured their diameters and distances from their confluence to the main RHV confluence into ICV (Fig. 1).

Besides vein measurements, we collected data on patient sex, age, height and body weight, and also the amount and concentration of the contrast media injected. Hepatic vein opacification level was determined by measurements of HU in hepatic veins. A higher level of vein opacification results in higher contrast between hepatic veins and liver parenchyma.

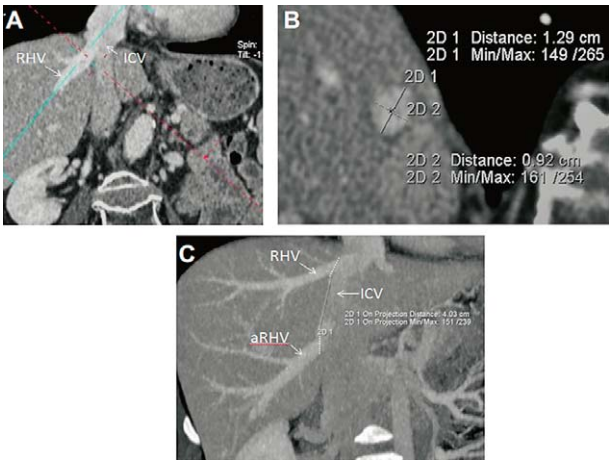

Fig. 1. Computed tomography measurements of hepatic veins: (A) appropriate plane setting; (B) measurement of maximal and minimal diameter of hepatic vein in cross-section position; (C) measurement of RHV and aRHV confluences (University Medical Centre Ljubljana).

Statistical analysis was performed using the SPSS statistical program. We assessed the incidence of aRHVs, the correlation between the aRHV incidence and patient age and sex, and verified the correlation between aRHV and the main RHV diameter. The basic statistical tests were performed using a significance level of 0.05. We also assessed the suitability of CT protocol for hepatic vein presentation, possibilities for its optimization, and the value of CT as an imaging method for surgical treatment planning.

Results

The measurements of hepatic veins were performed in 142 patients. We found at least one aRHV in 45 cases: one aRHV in 37 (26.1%) cases, two aRHVs in seven (4.9%) cases, and three aRHVs in one (0.7%) case. The incidence of aRHV was between 24% and 39.3% (mean, 31.7%) and of more than one aRHV between 2.3% and 10.3%, with the 95% confidence interval (95% CI) (Table 1).

The mean diameter of the main RHV was 1.09 cm (95% CI: 1.03-1.15 cm), and the mean diameter of the inferior aRHV was 6.8 mm (95% CI: 6.0-7.6 mm). In cases where more than one aRHV were present, the

Table 1. Proportion of subjects according to aRHV number

aRHV number	%
0	68.3
1	26.1
2	4.9
3	0.7

mean diameter of the middle aRHV was 6.5 mm (95% CI: 4.9-8.0 mm). In the only case where three aRHVs were present, the diameter of the main RHV was 3.5 mm. The diameter of the inferior aRHV was 5.6 mm and the diameters of the two middle aRHVs with confluence into IVC at the same level were 8.5 mm and 7.8 mm.

Based on the test of proportions, the proportion of cases with inferior aRHV of at least 7 mm was between 7.2% and 18.1%, with 95% probability. Among cases with at least one aRHV, this proportion was 40.0%.

The correlation between the aRHV and the main RHV diameters showed a negative correlation coefficient (-0.147), indicating a very weak negative correlation. The significance level was 0.33.

The mean distance between the aRHV and the main RHV confluences into IVC was 3.73 cm (range, 3.32-4.13 cm, 95% CI). The proportion of cases with confluence distance of at least 4 cm was between 21.6% and 49.5% in cases with at least one aRHV. In cases with more than one aRHV, the distance between the middle aRHV and the main RHV measured between 1.90 cm and 4.32 cm (95% CI).

For the correlation between the aRHV incidence and patient age, the t-test of two independent samples was performed. The sample data were divided into two groups, one including cases without aRHV and the other one with at least one aRHV. Arithmetic means of age were then compared between the two groups. The mean age of patients with at least one aRHV was a little lower. The significance level of the t-test was 0.18.

Differences in aRHV incidence between men and women were tested with the test of differences of two proportions. The significance level of the test was 0.75, which did not prove any statistical difference in the incidence between men and women.

Discussion

Surgical relevance

In our study, the incidence of aRHV was around 30%, which correlates with the findings of Trotovšek[7], who detected aRHVs in 38% of cases using the method of liver casting. The mean diameter of the inferior aRHV was 6.8 mm (6.0-7.6 mm) and of the middle aRHV 6.5 mm (4.9-8.0 mm). In the resection of the 7th and 8th liver segments, where the inferior aRHV has a diameter of at least 7 mm, the 5th and 6th liver segments can be preserved. In our study, we found the proportion of people with such an aRHV to range from 7.2% to 18.1%, however, among the patients with at least one aRHV the proportion was around 40%. CT is an accurate method for evaluation of a vein the diameter of which is at least 7 mm. The vein can thus be presented despite its potential inappropriate opacification[10].

Xing *et al*. discuss the correlation between the inferior aRHV and the main RHV diameters. They report that the larger the diameter of the main RHV, the smaller is the diameter of the inferior aRHVs[10]. Our study also showed a weak reverse correlation (correlation coefficient, -0.147).

The distance between the aRHV and the main RHV confluencing into IVC is an important measurement in planning liver resection. For distance measurement, the MIP reconstructions of 20-30 mm thickness were made. The spatial resolution of MIP reconstruction is little lower than those by MPR, but the distance is easier to determine because of bigger liver volume presentation. In our study, the mean distance between the inferior aRHV and the main RHV was 3.73 cm (range, 3.32-4.13), and the distance between the middle aRHV and the main RHV was 3.11 cm (range, 1.90-4.32). We found a substantial proportion of cases with the distance between the inferior aRHV and the main RHV of at least 4 cm (21.6%-49.5%). The information on the distance between the aRHVs and the main RHV is especially important in planning living donor transplantation and in tumor resections[4,9]. Based on hepatic vein information, the optimal surgical technique can be chosen to preserve the liver from bleeding and devitalization.

Another aim of our study was to determine the correlation between some demographic predictive

factors and the incidence of aRHVs. Our results did not support the data of Xing *et al*. on the influence of age on the incidence of aRHV[10]. The T-test of independent samples for age influence did not show any statistically significant differences in age between the group of patients with at least one aRHV and the group without it. The high significance level (0.18) showed that the possible differences in age between the two groups were random and the sample data could not be extrapolated to a larger population. The influence of sex on the aRHV incidence was ruled out with the test of differences in proportions (p=0.75). Based on these results, we cannot confirm any predictive factor for the incidence of aRHVs.

Computed tomography relevance

Multiphase CT imaging of the abdomen with contrast media is a common radiological method because it enables visualization of internal organs. It is characterized by good spatial resolution and the possibility to show internal structures in any 2D plane and also in 3D view. Because of the low natural contrast of some abdominal organs with a similar structure that absorbs a similar amount of x-rays, the distribution of injected contrast media in different time frames has an essential role in the evaluation of anatomical structures of organs, as well as pathological changes in the abdominal cavity. To ensure high-quality CT procedure, proper selection of many parameters is of great importance[3].

In our study, the data on hepatic veins were obtained from images of the portal-venous phase of CT imaging of abdominal organs. The patients were referred to CT imaging for different reasons and not specifically for hepatic vein evaluation. The portal-venous phase was normally carried out 65-75 s after contrast agent application. In that period, the contrast agent in the liver is normally deployed in the portal and hepatic veins, which provides the contrast separation from liver parenchyma. Because of insufficient vein opacification, the measurement of hepatic veins could not be performed in 18.1% of cases. Below the 130 HU opacification level, the characteristics of hepatic veins could not be determined, especially in smaller hepatic veins, such as aRHVs. In the absence of pathological conditions, the insufficient opacification rate is mostly caused by insufficient amount of contrast media with slow injection flow or by an inappropriate time frame of data acquisition. The timing of acquisition for appropriate hepatic vein opacification is variable since the cardiac output and resultant blood flow (contrast media) may significantly differ from person to person[15]. For this reason, when evaluation of hepatic veins is desired, the higher amount of contrast agent with a high concentration of iodine in the agent and with higher injection flow (4.5-6 mL/s) is recommended.

Conclusion

Modern liver surgery is based on resecting the smallest possible functional unit of the liver while preserving as much healthy liver parenchyma as possible. Evaluation of the incidence and diameter of aRHVs is of great importance for a safe surgical procedure. Their presence can change the surgeon's decision in 10%-20% of cases, when good imaging technique is employed. CT examination, which is easily accessible and minimally invasive for patients, was successful in only 80% of cases, when using the standard protocol for CT scanning.

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Sažetak

MORFOLOŠKE ZNAČAJKE I UČESTALOST AKCESORNE DESNE JETRENE VENE – PROCJENA POMOĆU KOMPJUTORIZIRANE TOMOGRAFIJE

J. Mišič, P. Popović, M. Hribernik, A. Starc i *R. Dahmane*

U jetri postoji mnoštvo krvožilnih varijanata koje su važne u kirurgiji jetre, osobito prisutnost akcesornih desnih jetrenih vena (aDJV). Njihova učestalost, broj i promjer uvelike se razlikuju. Prije kirurškog zahvata treba provesti detaljnu slikovnu dijagnostiku kompjutoriziranom tomografijom (CT). Cilj ovoga istraživanja bio je ispitati značajke aDJV i njihove demografske korelacije. Istraživanje je obuhvatilo podatke 188 bolesnika podvrgnutih pretrazi pomoću CT abdomena s kontrastnim sredstvom, 103 (54,8%) muškarca i 85 (45,2%) žena, srednje dobi 63,1±14,3 (raspon dobi 21-94) godine. Mjerenje jetrenih vena provedeno je na snimkama CT dobivenim od Kliničkog zavoda za radiologiju Kliničkog bolničkog centra Ljubljana. Najmanje jednu aDJV imalo je 45 od 142 bolesnika: jedna aDJV utvrđena je u 37 (26,1%), dvije aDJV u 7 (4,9%) slučajeva i tri aDJV u jednom (0,7%) slučaju. Incidencija aDJV procijenjena je na 24%-39,3% (srednja vrijednost 31,7%), a za više od jedne aDJV na 2,3%-10,3%, uz 95%-tni interval pouzdanosti (95% CI). Prema testu proporcija je proporcija slučajeva donje aDJV od najmanje 7 mm procijenjena na 7,2%-18,1%, uz 95% CI. Srednja udaljenost između aDJV i sjecišta s glavnom DJV u donju šuplju venu bila je 3,73 (raspon 3,32-4,13) cm, uz 95% CI. Proporcija slučajeva sa sjecištem udaljenim najmanje 4 cm bila je 21,6%-49,5% u skupini slučajeva s najmanje jednom aDJV. U skupini slučajeva s više od jedne aDJV udaljenost između srednje aDJV i glavne DJV bila je 1,90-4,32 cm (95% CI). T-test nezavisnih uzoraka pokazao je da dob nema učinka na incidenciju aDJV (p=0,18), a testiranje razlika pokazalo je da ni spol nema takav učinak (p=0,75). Procjena incidencije i promjera aDJV veoma je važna za siguran kirurški zahvat. Njihova prisutnost može promijeniti kirurgovu odluku u otprilike 10%-20% slučajeva, uz primjenu dobre tehnike slikovnog prikaza. Pretraga pomoću CT kao lako dostupne i za bolesnika minimalno invazivne tehnike bila je uspješna u samo 80% slučajeva kad se primijenio standardni postupnik skeniranja pomoću CT.

Ključne riječi: *jetra – kirurgija; jetrene vene; tomografija, radiografska kompjutorizirana; Slovenija; dijagnostičko snimanje*