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Color Doppler anatomical assessment of the vessels in the rabbit liver

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Abstract

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The aim of the present study was to investigate the geometry, topography and trajectory of the rabbit liver's vessels by color Doppler US. Ten sexually mature healthy clinically New Zealand white rabbits, aged 8 months and weighed from 2.8 kg to 3.2 kg have been studied. The results were related to the color geometry of the vessels, which was used to define their topography. The visualization of the rabbit liver blood and biliary vessels was real and corresponded to the variations of the color Doppler spectrum from blue to red gamma. The hemodynamic data were simultaneous to the morphological results. Both they represented anatomical information for the studied vessels. The present investigation is with practical application in the morphological science. It is summarized that the Doppler US study of the rabbit liver is suitable to obtain detail information for the anatomical and physiological characteristics of the organ. In conclusion the results could be used as a morphological base for investigation in human and rabbits.

Keywords: Color Doppler ultrasound; rabbit; liver; vessels

Introduction

Color Doppler ultrasound (US) is a non-invasive imaging anatomical method for detecting the morphological characteristics of the vessels in the animals and humans (Lang, 2006; Grgurević et al., 2009; Grigorov, 2010).

Doppler US is still rarely applicable method for anatomical study of the hepatic vessels in domestic animals (Probst & Kunzel, 1993; Carlisle et al., 1995; WU & Carlisle, 1995).

Color Doppler US of the liver is a method for non-invasive morphological assessment of the hepatic vessels, gall bladder and biliary ducts. The distinct differentiation of veins from arterial vessels avoids interpreting the image on the gray-white scale (Bismuth, 1982; Bismuth et al., 1982; Tomov & Naumov, 1992; Belcher & Beidle, 1998; Kruskal et al., 2004; Poon, 2006; McNaughton & Abu-Yousef, 2011).

Szatmári et al. (2001) have found that the spectral profile of the portal vein is related to the variations of the intraabdominal pressure, provoked by breathing.

Color Doppler US study of the human liver in oblique and transversal aspect presents data for the blood pressure in portal vein in order to define the portal vascular system from hepatic veins and arteries. The color profile of the blood flow in hepatic arteries and portal vein determine hepatopetal flow direction. Due to the proximity of the hepatic veins close to the caudal vena cava, there are fluctuations of the blood flow in them, which are related to the contractions of the right atrium during systolic and diastolic phase. The blood flow in the hepatic veins is displayed in blue (Smith et al., 1985; Gallix et al., 1997; Belcher & Beidle, 1998; Görg et al., 2002; Görg et al., 2004; Pandharipande et al., 2005; Vogt, 2005; Owen & Meyers, 2006; Daskalov et al., 2008; Goyal et al., 2009).

Doppler US anatomical features of the hepatic vessels are applicable for morphological interpretation of the hepatic parenchyma and *porta hepatis*. Contrary to the other US methods Doppler US allows anatomical differentiation of the portal veins to the hepatic arteries (Koslin & Berland, 1987; Lafortune & Lepanto, 2002; Perišić et al., 2008).

Doppler US is used for imaging anatomical studies of the liver in dogs. The portal vein is visualized after immobilization of the animals in supine recumbence. The approach is transabdominal percutaneous right hypochondriac. The blood flow is retrograde to the liver. Caudal vena cava and hepatic veins are displayed in blue, and portal vein and abdominal aorta are displayed in red (Nyland & Fisher, 1990; Lamb & Mahoney, 1994; Spaulding, 1997; Bodner & Hudson, 1998; Mwanza et al., 1998; Nyland et al., 2002; Smithenson et al., 2004; Faverzani et al., 2006; Molazem et al., 2007).

The undulation of the blood flow in the portal vein in the man and carnivores decreases in *inspirium*, and in *expirium* it increases. The color profile of the blood flow determines its highest velocity in the center of the vessel. The velocity decreases peripherally as it is lowest close to the wall of the portal vein (Nyland & Fisher, 1990; Rumack et al., 1991; Abu-Yousef, 1992; Lamb & Mahoney, 1994; Nyland et al., 2002; Riharson et al., 2008).

Color Doppler Doppler US is a non-invasive method to study the macromorphological and physiological parameters of the abdominal aorta in Gottingen mini-pigs. The obtained results are used as anatomical model for Doppler US visualization of the abdominal vessels (Konrad et al., 2000).

The rabbit is a suitable animal model for studying the physiological condition of the human liver by Doppler US. The morphological data for hemodynamic processes in the terminal branches of hepatic arteries and portal vein are real. Color Doppler US defines the anatomical map of the hepatic vessels (Shmulewitz et al., 1993; Du et al., 2003; Lhuillier et al., 2006).

The anatomical features of the hepatic vessels are studied by Doppler US mainly in man and pets. The studies on the rabbit liver are scarce. The use of the rabbit as anatomical model for investigation of the color Doppler US profile of the human hepatic vessels is motif to conduct Doppler US study.

Materials and Methods

Ten sexually mature healthy clinically New Zealand white rabbits, aged 8 months and weighed from 2.8 kg to 3.2 kg have been studied. The animals were anesthetized with 15 mg/kg Zoletil® 50 (tiletamine hydrochloride 125 mg and zolazepam hydrochloride 125 mg in 5 ml of the solution) Virbac, France. The investigation was approved by Institutional Ethical Committee of animal care of the Faculty of Veterinary Medicine, Trakia University, Stara Zagora, Bulgaria.

The study was carried out by ultrasonic device VOLUSON 730 PRO V GE Healthcare (USA) and 7.5 MHz multi frequent linear transducer L742. The scan mode was color Doppler (CFM) and M/anatomic M, color M. The animals were positioned in supine recumbence.US approach was percutaneous, transabdominal, hypochondriac. Ultrasonic gel G0064 (FIAB SpA) was used for better contact between skin and transducer. Caudal vena cava, portal vein, hepatic veins, abdominal aorta and biliary vessels were scanned progressively on LCD monitor and wide-angle high-resolution matrix. Using red and blue gradation, we determined the direction of blood flow to the transducer (Stamatova-Yovcheva, 2016). The results were interpreted in accordance with NAV (2012).

Results

The color Doppler geometry of the abdominal aorta at the level of the liver demonstrated elongated turbulent profile of the blood flow. The anatomical lines of aorta were regular, and the blood flow was centripetal. The streamlines lost the parallelism to the wall and became unstable (turbulent). They were visualized as vortex structures near the vascular wall. The color profile of the blood flow varied from blue to red (Figure 1).

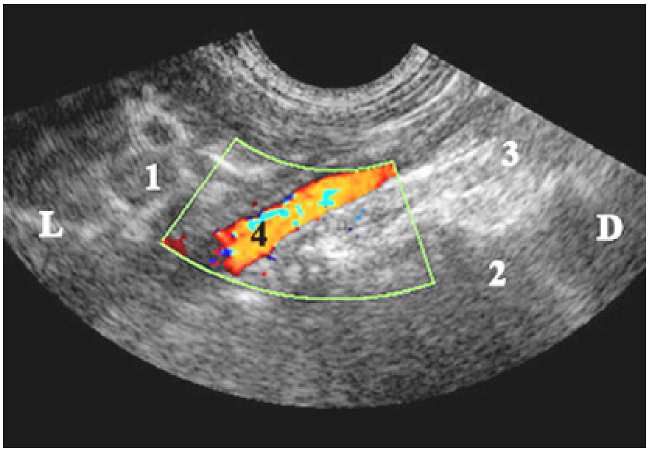

Fig. 1. Color Doppler US image of the abdominal aorta close to the liver (Color and pulse Doppler transducer – 7.5 MHz). L –left; D –right. (1) stomach; (2) liver; (3) small intestines; (4) abdominal aorta

The bile's color profile was in red as predominated the dark red color. In the body and fund of the gall bladder were found separate fluid components, with random direction. They defined an area with increased velocity. The color profile of the bile bordered the gall bladder's anatomical parts. The narrowest parts, outlining the bile trajectory were infundibulum and neck of the gall bladder and cystic duct (Figure 2).

The blood flow's profile in hepatic veins and portal vein was parabolic. Its velocity was the highest along the portal vein's axis and the lowest velocity was peripherally. Portal vessels were observed in depth, as short segments, and had a nonlinear way. Their blood flow was encoded intrahepatically and was hepatopatal (blood flow towards the liver). The hepatic veins'blood flow demonstrated waves with a direction away from the transducer. The color coding of the blood flow was blue and defined its diastolic character. Its direction was hepatofugal (flow directed away from the liver). Hepatic veins were rectilinear and had intrahepatic anatomical localization. The anatomical border between both veins was defined by the colour spectrum of the blood flow, which varied from blue to red (Figure 3).

The blood flow in hepatic veins was directed away from the liver. There were single areas, colored in light red and orange, due to the retrograde blood flowing from the right ventricle to caudal vena cava and hepatic veins (Figure 4).

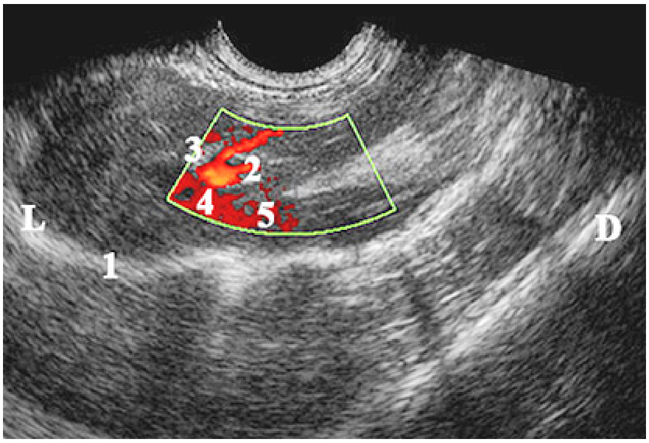

Fig. 2. Color Doppler US image of gall bladder (sagital section, color and pulse Doppler transducer – 7.5 MHz). L – left; D – right. (1) diaphragm and fibrous capsule; (2) gall bladder fund; (3) body of gall bladder; (4) infundibulum and neck of the gall bladder; (5) cystic duct

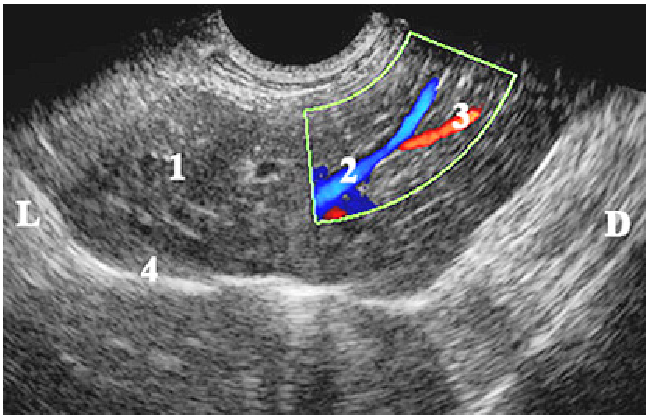

Fig. 3. Color Doppler US image of hepatic veins and portal vein (color and pulse Doppler transducer – 7.5 MHz). L – left; D – right. (1) left lobe of the liver; (2) hepatic veins; (3) portal vein; (4) fibrous capsule and diaphragm

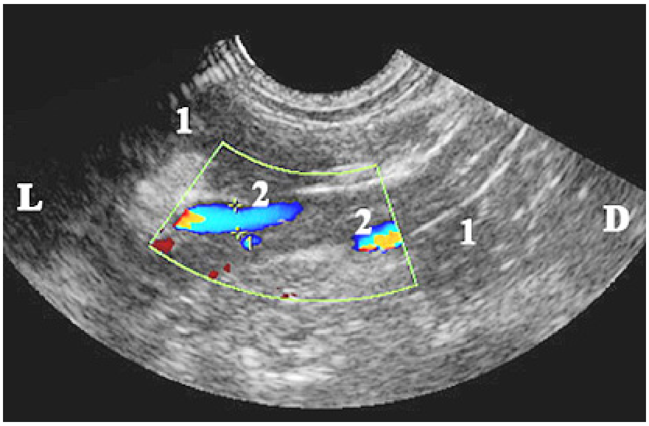

Fig. 4. Color Doppler anatomical image of hepatic veins (color and pulse Doppler transducer – 7.5 MHz). L – left; D – right. (1) liver parenchyma; (2) hepatic veins

Discussion

Our anatomical Doppler US results are based on the color map of the hepatic vessels in order to obtain alivemorphologic information for their topography and geometry.

Doppler US anatomical results for the portal vein and *vv. hepaticae* in the rabbit reflect the color Doppler change in blood flow over a conventional B-image. According to us, the hemodynamic and morphological information are simultaneous. In this aspect the anatomical localization of the hepatic vessels was determined as well the physiological features of the hepatic fluid in the rabbit.

The anatomical closeness of the hepatic veins towards the caudal vena cava determines the colour gamma of the blood flow in the hepatic veins, in accordance to the heart rhythm.

The Doppler anatomical image of the hepatic vessels does not correspond to the human portal triad, given by some authors (Lafortune & Lepanto, 2002 and Stamatova-Yovcheva, 2016). In the colour map of the blood flow in the rabbit liver the portal and hepatic vessels are visualized separately.

The anatomical localization of the hepatic vessels and blood flow's features of the rabbit liver add the data for the human (Bismuth, 1982; Bismuth et al., 1982; Daskalov et al., 2008; Grigorov, 2010).

The color profile of the rabbit liver's blood flow was changing depending on the direction of the US beam. We argue that the obtained information could be used as anatomical base for the evaluation of the blood flow velocity in the rabbit liver, as it has been defined by previous studies for human (Tomov & Naumov, 1992; Kruskal et al., 2004; Goyal et al., 2009;McNaughton & Abu-Yousef, 2011).

Our Doppler US data for the rabbit liver vessels present a detailed anatomical image either for the lobes either for the vessels. That corresponds to the results of Lang (2006), Grgurević et al. (2009), Grigorov (2010) for human and to Faverzani et al. (2006) for the dog.

Based on the information received from the color card of the portal vein and hepatic veins, as well their definition as venous vessels, similarly to the attitude of Stamatova-Yovcheva (2016), we propose the portal vein to be used as a marker for imaging anatomical visualization of the rabbit liver's lobes.

We find difference in the color code of the blood flow in the hepatic veins (hepatopetal) and in the portal vein (hepatofugal). This fact motivates us to determine them as venous vessels, compared to hepatic artery wherein the blood flow is undulated.

The application of Doppler US to obtain information for the morphological features of the venous hepatic vessels of the rabbit added the angiographic study of Raharison et al. (2008) for the lemurs.

We prove the possibilities of Doppler US to investigate either the geometry, topography and lines of the rabbit portal vein, hepatic veins and abdominal aorta, either the blood flow's definition in them (parabolic in the portal vein and hepatic veins and permanent in the abdominal aorta). Therefore, the given data for the rabbit liver's vessels could correspond to the published results of some authors for the carnivores and human (Koslin & Berland, 1987; Spaulding, 1997; Bodner & Hudson, 1998).

We confirm that the qualitative parameters of the Doppler spectrum of the rabbit liver's vessels can be used as morphological model when interpret many hemodynamic features of the liver. Our attitude corroborates the hypothesis of Shmulewitz et al. (1993), Du et al. (2003), and for the rabbit.

The detailed anatomical visualization of the rabbit liver's vessels (using the liver as acoustic window), allowed us to achieve anatomical and geometric definition of the organ's vessels, color profile of the blood and bile flow. Our statement that the color Doppler US is a suitable method for anatomical study of the hepatic vessels in the domestic rabbit corresponds to the given data of some authors (Vogt, 2005; Owen & Meyers, 2006) for the human.

From the imaging-anatomical representation of arterial and venous vessels through color Doppler visualization, we presume to offer the color Doppler US anatomical study of the portal vein and hepatic veins as a suitable method for obtaining spectral images of the rabbit vessels.

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