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Vascular injuries within the hepatoduodenal ligament

Recognition by laparoscopic color Doppler ultrasound

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Abstract.
Background: Lesions of vascular structures are rare but serious complications of laparoscopic cholecystectomy. The purpose of this blind randomized animal study was to investigate the possibility of detecting different vascular lesions within the hepatoduodenal ligament using laparoscopic color Doppler ultrasound (LCDU).
Methods: Twenty-four lesions of the hepatic artery and portal vein were created laparoscopically in six farmer pigs using titanium clips. The following injuries were studied: (a) partial occlusion of the hepatic artery (eight cases), (b) complete occlusion of the hepatic artery (eight cases), (c) partial occlusion of the portal vein (eight cases). There were also eight cases without lesions of the vascular vessels. The order in which the injuries were created was randomly assigned. The study was performed in a blind fashion. Recognition of the injuries was attempted with LCDU.
Results: All injuries were recognized correctly by LCDU. There were no false positive results. The clips were reliably located. Using color Doppler imaging, partial occlusions of the hepatic artery and portal vein were visualized by changes of the blood flow from laminar to turbulent behind the clip. Complete occlusion of the hepatic artery was recognized as a complete cessation of the colored blood flow.
Conclusion: LCDU is a very efficient tool for visualizing vascular structures and evaluating the bloodstream. Partial or complete vascular occlusion by clips that may occur as a result of difficult dissection during laparoscopic cholecystectomy can be visualized reliably using this technique.

Key words: Color Doppler ultrasound — Laparoscopic cholecystectomy — Laparoscopic intraoperative ultrasonography — Vascular injuries

Vascular injury is a rare but potentially serious complication of laparoscopic cholecystectomy [15, 22]. Bleedings are usually caused by vascular lacerations, but occlusions of the blood vessels are also seen. [22]. Partial or complete ligation of blood vessels within the hepatoduodenal ligament by clips may occur, especially following a difficult dissection in Calot's triangle [13, 16].

The sequellae of vascular lesions are still controversial. Generally, they depend on the extent and location of the injury [13, 14]. For example, complete ligation of the hepatic artery may be tolerated if there is a sufficient supply of oxygen and nutrients from the portal vein and collateral arteries running through the liver's peritoneal attachments [14]. In some cases, however, injury to the hepatic artery is not tolerated and ultimately leads to severe ischemic infarction of the liver [14]. In addition, it is well known that partial occlusions of the portal vein—for example, by extraluminar tumor compression or iatrogenic injuries—may lead to thrombosis [14, 20]. But if the occluding cause is eliminated immediately, further damage can be prevented; therefore it is very important to recognize the injuries intraoperatively.

Laparoscopic ultrasound is an excellent method for intraoperative visualization of biliary and vascular structures [1, 3, 8, 9, 11, 12, 17, 18, 21, 23, 24]. During the same examination, color Doppler application allows the pattern of blood flow to be characterized.

It has already been shown that laparoscopic intraoperative ultrasonography is an effective tool for the recognition of biliary injuries [2]. Therefore, we set out to investigate the possibility of detecting partial and complete occlusions of blood vessels within the hepatoduodenal ligament using laparoscopic color Doppler ultrasound (LCDU) under normal operative conditions where the surgeon is unaware of the presence or type of injury.

Materials and methods

In six farmer pigs (age, 4–5 months; weight, 22–35 kg), 24 lesions of the hepatic artery and portal vein were studied in a blind fashion. Under

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general anesthesia, a pneumoperitoneum was created and cannulas were placed.

A preliminary ultrasound was performed to visualize the portal vein and the hepatic artery. The pattern of blood flow was judged by color Doppler imaging. Then the sonographer left the operating room. The hepatoduodenal ligament was dissected laparoscopically by two other surgeons, and lesions of the blood vessels were created by using titanium clips (Ligaclip Extra; Ethicon). The injuries created under randomized conditions were as follows:

partial occlusion of the hepatic artery (one hemoclip applied partially across the hepatic artery)	8
complete occlusion (one hemoclip applied across the hepatic artery)	8
partial occlusion of the portal vein (one hemoclip placed on the ventral wall of the portal vein)	8

We also studied eight cases without any injury.

In all pigs, multiple injuries were created to limit the number of animals required for the study.

The operating field was flooded with saline solution, and the sonographer was called in to perform the examination. The ultrasound probe was placed into the abdominal cavity through a 10-mm cannula in a left paramedial position.

All examinations were performed with a 9.5-mm ultrasound transducer (type 8555; B&K Medical A/S, Naerum, Denmark). The ultrasound probe has a mobile tip with a 60° convex array, which can be moved 90° up and down via a lever on the probe handle. The scanner is equipped with a B&K Medical ultrasound unit 3535. An ultrasound frequency of 7.5 MHz and color Doppler application was used in all cases.

Results

Complete imaging of the hepatic artery and the portal vein within the hepatoduodenal ligament was accomplished in all six animals before surgery.

In all cases in the -group without lesions, the integrity of vascular structures was demonstrated reliably by laminar flow pattern (Figs. 1 and 2). There were no false positive results.

All partial occlusions of the hepatic artery and portal vein were recognized correctly. B-mode ultrasound showed the titanium clip as an hyperechoic reflex with a “comet tail” artifact or shadowing posterior to the clip (Fig. 3). The visualization was enhanced considerably by the use of color Doppler imaging. Change of the blood flow from laminar to turbulent behind the clip is clearly displayed by a significant alteration of the intraluminar color (Figs. 4 and 5).

Similarly, all total occlusions of the hepatic artery were detected with color Doppler imaging as a complete cessation of the colored-coded blood flow in front of the occluding clip (Fig. 3).

Discussion

Iatrogenic injuries of the blood vessels within the hepatoduodenal ligament are a possible complication of hepatobiliary, pancreatic, and gastric surgery [14].

There are a number of reports that describe the frequency and effects of vascular lesions during cholecystectomy [6, 10, 16, 17]. In open cholecystectomy, vascular injuries have been reported in ≤7% of cases [10]. In laparoscopic cholecystectomy, severe vascular lesions occur in 0.08–0.25% of cases; these injuries are usually caused by insertion of the Veress needle or trocars into the abdominal cavity [6, 7].

Less information is available regarding occluding injuries of the blood vessels during laparoscopic cholecystectomy [13]. Bleeding vascular lacerations are usually recognized immediately, but thermal damage and partial or complete occlusions often go undetected. The sequellae of vascular lesions depend on their extent and location and may ultimately include ischemic injury to the liver. It is likely that these lesions are underreported because they may be asymptomatic or manifest with uncharacteristic symptoms that do not indicate the real cause. Thus, vascular lesions may be responsible for some cases of the so-called postcholecystectomy syndrome.

There are several factors that contribute to iatrogenic blood vessel occlusions, including injudicious use of clips to control bleeding, chronic inflammation with dense scarring, operative bleeding that obscures the field, and fat in the portal area [6, 22]. Anatomic variations of the biliary and vascular structures within the hepatoduodenal ligament are common, and they pose a well-recognized danger in biliary surgery [13, 14, 17, 22]. Tenting makes the structures especially susceptible to injury. The inclusion of tissue other than the cystic duct may also result in partial closure of the affected structures.

Different iatrogenic bile duct injuries, such as type E lesions according to the Strasberg classification, are frequently associated with injury to the hepatic artery. In these cases, the hepatic artery is divided because it is misinterpreted as the cystic artery, just as the common bile duct is often misinterpreted as the cystic duct [22].

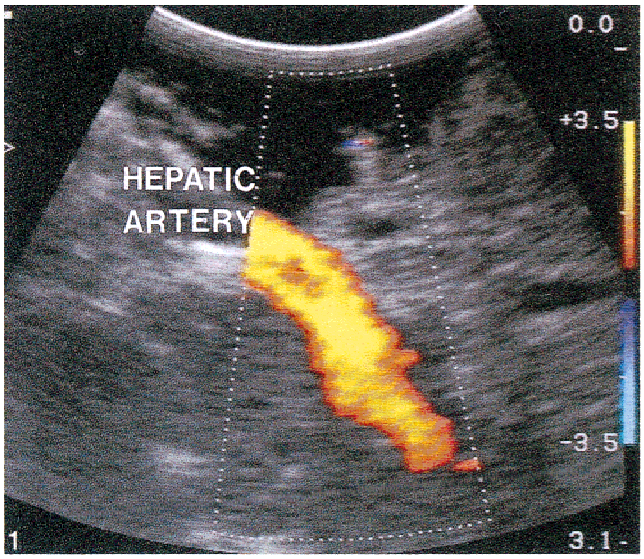
Most surgeons have more experience with complete ligation of the hepatic artery. The liver may survive ligation of the artery owing to the portal flow and the supply of arterial blood from collateral vessels. In humans, the portal vein provides about two-thirds of the blood and half of the oxygen to the liver [14, 19].

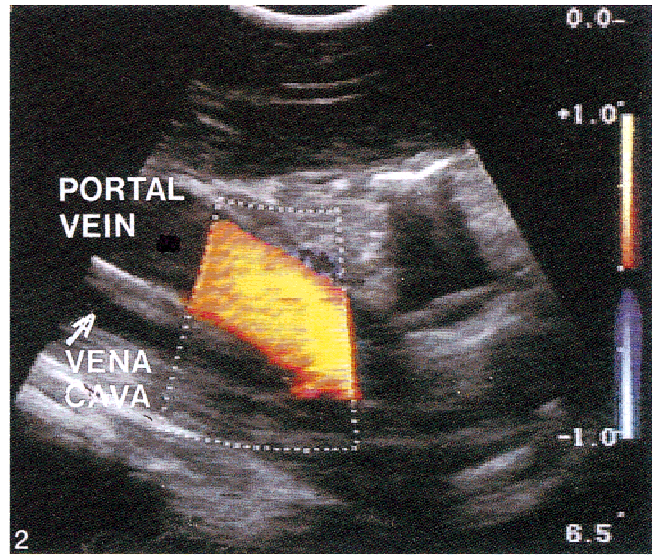
There is nothing in the literature on the subject of sequellae of partial ligation of the hepatic artery. However, reduced perfusion of the liver or a secondary occlusion by a thrombembolic occlusion is possible [14]. Irregularity of the wall or partial occlusions of the portal vein may lead to a decreased and turbulent blood flow, resulting in portal vein thrombosis [13].

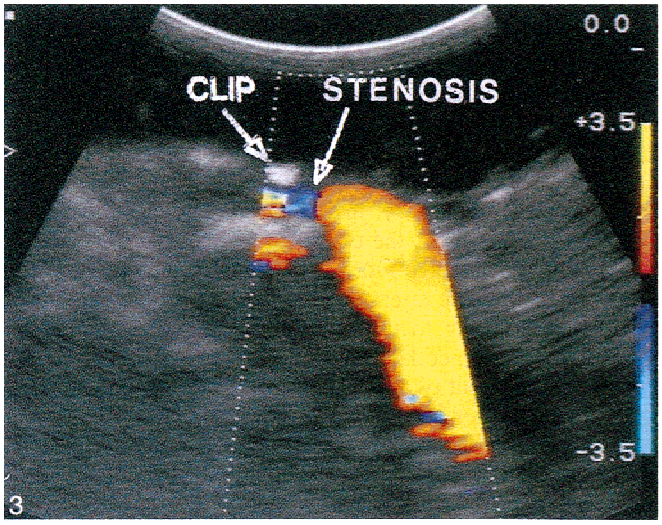
Laparoscopic ultrasound is well established as an efficient intraoperative diagnostic tool for excellent visualization of all structures—biliary and vascular—within the hepatoduodenal ligament, even where there are anatomical variations [1, 5, 11, 12, 17, 18, 23]. In a prospective randomized study of intraoperative evaluation of the biliary tree during laparoscopic cholecystectomy, ultrasound was shown to be comparable to cholangiography [3]. Animal studies performed in a blind fashion have demonstrated that relevant injuries of the biliary tree can be identified by laparoscopic ultrasonography [2, 4].

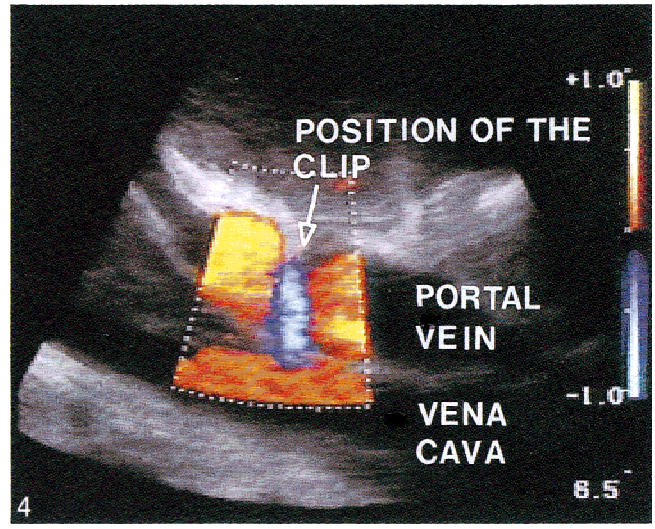
The use of color Doppler imaging allows not only an immediate discrimination of vascular and biliary structures even for the inexperienced examiner but also a direct evaluation of the pattern of blood flow.

The present study indicates that the presence and dimension of occluding vascular injuries can be detected reliably by LCDU, thus allowing the surgeon to take immediate therapeutic steps. The method is noninvasive and takes < 1 min. Furthermore, we believe that because it provides good visualization of all relevant structures and has repeated applicability, laparoscopic ultrasonography should be re-









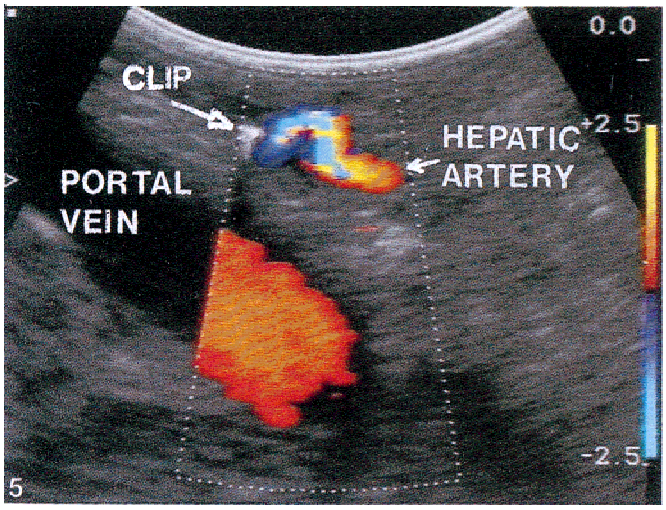


Fig. 1. Normal hepatic artery with laminar blood flow.
Fig. 2. Normal portal vein also showing a laminar flow pattern.
Fig. 3. Total occlusion of the hepatic artery. A complete cessation of the colored blood flow can be seen. The change of color demownstrates the reverse of the blood flow in front of the clip.
Fig. 4. Partial occlusion of the hepatic artery is characterized by a decrease and change of the blood flow (change of color) from laminar to turbulent posterior to the clip.
Fig. 5. Partial occlusion of the portal vein. The change in blood flow from laminar to turbulent is visualized as an alteration in color from red to blue posterior to the clip.

garded as a modality that can even prevent biliary and vascular injuries.

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