Doppler Ultrasonography Findings of Splenic Arterial Steal Syndrome After Liver Transplant

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Abstract

Objectives: **Splenic arterial steal syndrome is an important cause of morbidity and mortality after orthotopic liver transplant. Splenic arterial steal syndrome is characterized by arterial hypoperfusion of the graft; and if left untreated, causes ischemic biliary tract injury. Selective arterial embolization is important when treating splenic arterial steal syndrome. Doppler ultrasound has been used to follow-up liver transplant patients. This study sought to analyze alterations in portal vein velocity, peak systolic velocity, and resistivity index of the hepatic artery before diagnosis and after treatment of splenic arterial steal syndrome.**

Materials and Methods: **We analyzed the Duplex Doppler ultrasonography results of 20 liver transplant recipients who developed angiographically proven splenic arterial steal syndrome between January 2005 and March 2009. Peak systolic velocity and resistivity index of the hepatic artery were noted during transplant surgery, before selective arterial embolization, and after embolization procedures.**

Results: **A statistically significant decrease was found in peak systolic velocity and resistivity index of the hepatic artery between the intraoperative and pre-embolization values. In contrast to the statistically significant increase in peak systolic velocity of the hepatic artery, there were no significant changes in resistivity index after the selective arterial embolization. Portal vein velocity did not show a statistically significant change between intraoperative and preprocedure values. Portal vein velocity did show a tendency to decrease after coil embolization, but this was not significant.**

Conclusions: **Doppler ultrasound surveillance is a valuable tool in early detection of hepatic arterial complications. A decrease in peak systolic velocity and resistivity index compared to the corresponding intraoperative data should raise suspicion of splenic arterial steal syndrome. Also Doppler ultrasound can be effectively used to examine the hepatic arterial inflow after selective arterial embolization.**

Key words: *Liver transplant, Splenic arterial steal syndrome, Duplex Doppler ultrasound*

Introduction

Arterial steal syndrome is defined by *decreased perfusion of 1 arterial branch because of diversion of the blood flow into a different arterial branch originating from the same trunk.*[1] Splenic arterial steal syndrome (SASS) after orthotopic liver transplant is characterized by arterial hypoperfusion of the graft, caused by a shift in blood flow into the splenic artery.[2] Splenic arterial steal syndrome has been reported to occur with an incidence of 3% to 8% after orthotopic liver transplant.[1]

The hepatic artery remains the sole supplier of arterial blood to the intrahepatic biliary epithelium after liver transplant.[1, 3] Consequently, insufficiency of hepatic arterial supply to the biliary duct causes necrosis, which leads to hepatic parenchymal infarction.[4] While biliary necrosis is incompatible with graft survival and is an absolute indication for retransplant, uncomplicated biliary ischemia without necrosis may be reversible if hepatic arterial flow can

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be retained.[5] Splenic arterial steal syndrome leads to decreased arterial flow to the graft liver after orthotopic liver transplant. Early postoperative diagnosis and treatment of complications maximize both graft and patient survival.[6]

Color and Duplex Doppler ultrasound are the important techniques for preoperative, intraoperative, and postoperative evaluation of liver transplant recipients. They assess vascular supply of the graft by various indices including peak systolic velocity (PSV), pulsatility index, resistivity index (RI), and acceleration time of the hepatic artery, portal vein velocity, and resistivity index of the splenic artery.[7] This study sought to investigate how various Doppler indices change in SASS regarding their corresponding intraoperative values and to validate the effect of endovascular treatment on these indices.

Materials and Methods

Study population

Between January 2005 and March 2009, 210 orthotopic liver transplants were performed at Baskent University Hospital. During follow-up after transplant, 30 patients developed arterial steal syndrome, which was shown by angiography. Our exclusion criteria were as follows: steal syndrome to the collaterals other than the splenic artery (ie, to the left gastric or gastroduodenal artery), concomitant stenosis in the hepatic artery, patients with more than 1 arterial anastomoses, patients in whom we could not detect Doppler signal, and concomitant portal vein thrombosis. We excluded 3 patients with concomitant hepatic artery stenosis, 3 with steal syndrome to the gastroduodenal artery, 2 with more than one arterial anastomosis, and 2 because a Doppler pulse could not be found. There was no concomitant portal vein thrombosis. Our study included the results of Duplex Doppler ultrasonography in 20 patients with SASS. The study group was composed of 15 males and 5 females (mean age, 20 y; range, 7-55 y). All protocols of this retrospective study were approved by the institutional review board before the study began, and the protocols conformed with the ethical guidelines of the 1975 Helsinki Declaration.

Indications for liver transplants were hepatocellular carcinoma in 3 and cirrhosis in 17 patients. The underlying causes of the cirrhosis were Wilson disease in 6, postinfectious hepatitis in 4, cryptogenic cirrhosis in 2, primary sclerosing cholangitis in 2, progressive familial intrahepatic cholestasis in 1, Caroli disease in 1, and autoimmune hepatitis in 1 patient(s).

Doppler sonography technique

All patients were routinely examined by a single physician (N.U.) using 9.4 MHz and 5 MHz transducers (Antares, Siemens, Erlangen, Germany). Intraoperative examinations were performed after arterial anastomosis was maintained. Doppler indices were recorded as baseline values. If there appeared to be an abnormality in the Doppler examination, the anastomoses were re-established by the surgeon.

In the first week after surgery, Doppler surveillance was maintained on a 12-hour basis. Each examination included gray scale evaluation of the liver parenchyma and surroundings in a search for a possible complication. Free fluid in the abdomen was investigated thereafter. Then, color Doppler evaluation of the hepatic arteries, portal veins, and hepatic veins were done. After that, spectral analyses were performed, and Doppler indices were noted for each patient. These indices for hepatic arteries were PSV, and the RI. For the portal veins, we measured the maximal velocity (PVV). If an intervention was applied, the patient was re-examined with Doppler ultrasound just after the intervention.

Angiographic diagnosis and treatment

All patients suspected of having an arterial complication underwent diagnostic arteriography immediately within 12 hours. In all cases, celiac angiography and transcatheter arterial embolization of the splenic artery was performed by the same team of interventional radiologists.

A final diagnosis was made on celiac angiography with the following findings: A patent hepatic artery with delayed and reduced contrast filling rather than the other branches of the celiac axis; reduction in the contrast filling of the peripheral liver parenchyma; and demonstration of the main part of blood flow through the splenic, left gastric, or gastroduodenal arteries and splenomegaly. In SASS, parenchymal vessels show delayed arterial filling that occurs in the portal phase of the angiographic run. All patients were treated by selective arterial embolization with coil or vascular plug devices. Embolization material was placed in the proximal portion of the splenic

artery. After the embolization procedure, a control angiogram was performed to demonstrate the increase in hepatic arterial caliper and parenchymal perfusion.

Data acquisition and analyses

Doppler examinations of patients with SASS after orthotopic liver transplant were retrospectively analyzed. In this study, we included intraoperative Doppler indices just after vascular anastomosis as baseline values. Doppler indices closest to the intervention of the SASS were regarded as abnormal values (indicating the SASS). Values gained just after the interventions also were included.

Statistical analysis

Statistical analyses were performed with SPSS (SPSS: An IBM Company, version 11.0, IBM Corporation, Armonk, New York, USA). Patient demographics were analyzed using descriptive statistics. Differences in PSV, RI, and PVV were obtained intraoperatively, when a diagnosis of arterial steal syndrome (ASS) was made and after selective arterial embolization had been evaluated by Wilcoxon signed rank test. All tests were 2 sided; confidence intervals were defined as 95%.

Results

Twenty of 210 liver transplant recipients (9.5%) received a diagnosis of SASS angiographically. In our series, patients developed a progressive increase in liver function test results, associated with clinical deterioration within 1 to 170 days (median, 7 d) after liver transplant. In most patients, (n=15, 79.8%), the diagnosis of SASS was made within the first month after transplant.

Median values of Doppler indices obtained during surgery, at the time the diagnosis of SASS were made and after selective arterial embolization procedures, are summarized in Table 1. Box plot distributions of PSV, RI, and PVV at 3 different observations are demonstrated in Figures 1 to 3. The dark line in each box marks the median, the width of the box corresponds to the interquartile range, and the "whiskers" mark the fifth and 95th percentiles. Observations lying beyond the fifth and 95th percentiles are indicated by round-shaped markers. Peak systolic velocity of the hepatic artery shows a statistically significant decrease in SASS ($P < .05$) compared with intraoperative values. After embolization procedure, hepatic arterial peak systolic velocities improved significantly ($P \leq .01$).

Resistivity index values of the hepatic arteries were lower when a diagnosis of SASS was made compared with baseline intraoperative values ($P < .05$). After selective arterial embolization, a change in RI values was not significant ($P > .05$).

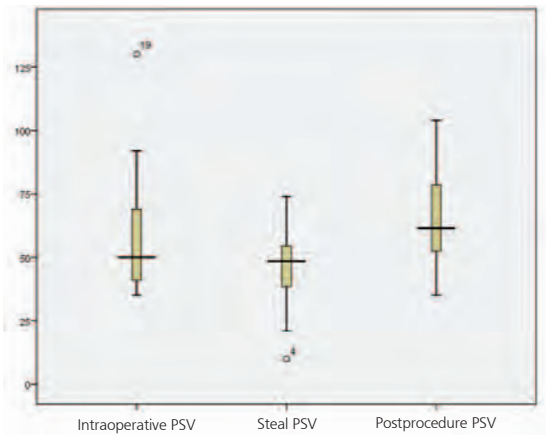
The median values of PVV at the time of SASS did not show a significant change when compared with intraoperative values ($P > .05$). There was a tendency of the PVV to decrease after treatment; however, this decrease was not significant ($P > .05$).

Table 1. The Median Values of Doppler Indices Obtained During Surgery, at the Time ASS was Suspected, and After the Selective Arterial Embolization Procedures

	Intraoperative	Preprocedure	Postprocedure
PSV (cm/sec)	53	47	65
RI	0.73	0.67	0.64
PVV (cm/sec)	99	88	72

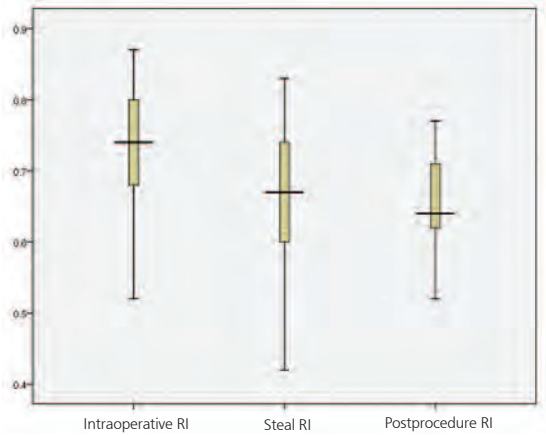
Abbreviations: ASS, arterial steal syndrome; PSV, peak systolic velocity; PVV, maximal velocity; RI, resistivity index

Figure 1. Boxplot Distribution of Hepatic Artery PSV



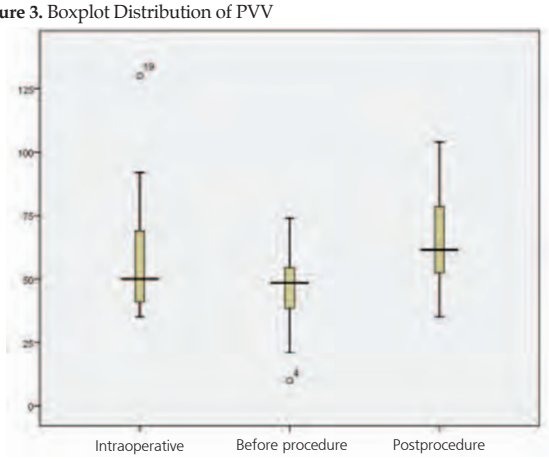
Abbreviations: PSV, peak systolic velocity

Figure 2. Boxplot Distribution of Hepatic Artery RI



Abbreviations: RI, resistivity index

Figure 3. Boxplot Distribution of PVV



Abbreviations: PVV, maximal velocity

Discussion

Arterial steal syndrome after orthotopic liver transplant has recently been recognized as one of the causes of graft hypoperfusion.[8, 9] Maintenance of arterial perfusion has a significant effect on the outcome of patients because a disturbance in the arterial inflow may cause patchy necrosis in the graft as well as biliary complications. This, in turn, may necessitate retransplant or may lead to death. However, early recognition and appropriate treatment of blood flow redirection have been shown to normalize patient outcomes.[10] Therefore, an imaging strategy to follow-up orthotopic liver transplant patients should focus on early detection of this entity. Conventional celiac angiography remains the criterion standard for diagnosis.

Doppler ultrasound examination of orthotopic liver transplant patients has been accepted as an effective tool to monitor vascular complications and is regarded as a standard of care.[6, 7] For this reason, our Doppler surveillance program in our clinic includes an intraoperative examination to show maintenance of vascular anastomosis. We perform Doppler sonography on a 12-hour basis during the first 7 days after the operation.

Twenty of 210 (9.5%) liver transplant recipients in our series received a diagnosis of ASS angiographically. Previous studies have reported an incidence of 3% to 8%. This difference may be due to the variability in recognizing this relatively new entity because patients with SASS may be asymptomatic in the early course after surgery, but they may present with ischemic biliary damage later.[11]

The onset of the SASS is variable and may occur in the first few hours after liver transplant or can occur as late as several weeks after transplant.[12] It is conceivable that early cases of ASS occur in patients with previous hyperdynamic states and splenomegaly, hence they have reduced splenic arterial resistance and increased splenic arterial flow before surgery.[13] Another reason for early SASS is injury preservation. Later cases are supposed to be related more to the progressive increase in splenic arterial flow owing to the earlier increased splenic arterial flow (not clinically significant at the time of the transplant and aggravated by rejection of the graft or viral hepatitis).

It is not surprising to find a decreased peak systolic velocity in the hepatic arteries owing to diversion of the arterial flow to other branches of the celiac truncus. We showed that peak systolic velocity decreases with the onset of SASS and improves after selective embolization of the corresponding artery. Loss of hepatic artery flow signal is a nonspecific finding of SASS.[7] Similarly, we excluded 2 cases because we could not detect a Doppler signal.

We observed that hepatic artery RIs before coil embolization were in a wide range. Although we showed a significant decrease in hepatic artery RI from baseline intraoperative values to preprocedure values, this variability makes these results difficult to interpret. Even though RI measurements are thought to be related to vascular resistance, it is a reflection of vascular resistance, vascular compliance, and heart rate.[14] These may have different effects in different individuals.

In conjunction with the previous study of Bárcena and associates, RI values in our study decreased after coil embolization, but this was not significant.[10] They also showed an improvement in peak and mean flow rates of the left and right hepatic arteries after coil embolization, which parallels the increase in PSV in our study.

In our series, portal vein velocity did not change when SASS developed compared with baseline values. However, after selective arterial embolization, PVVs showed a tendency to decrease, which was not significant. Our results agree with the findings of a previous report that showed a significant decrease in mean portal vein velocity after embolization.[15]

Hepatic artery buffer response indicates that an increase in portal flow causes intraparenchymal

resistance, which in turn causes a decrease in arterial inflow.[16] Decreases in PVV and improvements in PSV of the hepatic artery after coil embolization support the idea that portal hyperperfusion may play a role in SASS.

Selective arterial embolization is effective in treating SASS and has been shown to be safe, especially when coil deployment is placed in the proximal or midportion of the splenic artery.[11] In previous reports, patients treated with selective embolization were followed up with their clinical findings and routine Doppler studies.[13] This study shows Doppler ultrasound findings after selective splenic artery embolization. Peak systolic velocity values improved significantly after intervention; however, RI values did not show a significant change after embolization. Accordingly, we suggest using hepatic artery PSV as an indicator of successful treatment of ASS but not the RI.

In conclusion, Doppler ultrasound surveillance is a valuable tool in surveillance of hepatic arterial complications. A decrease in the PSV and RI compared with corresponding intraoperative data should raise the suspicion of SASS. Also, Doppler ultrasound can be used effectively to examine the hepatic arterial inflow after selective arterial embolization.

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