Pulmonary Vessel Cross-sectional Area before and after Liver Transplantation:

Quantification with Computed Tomography

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Rationale and Objectives: Pulmonary vascular complications of liver disease have a substantial impact on morbidity and mortality in patients who undergo liver transplant. The effect of liver transplantation on the pulmonary vasculature in patients without pulmonary vascular disease, however, has not been described. This study was undertaken to characterize the regional effect of liver transplant on the cross-sectional area (CSA) of pulmonary vessels.

Materials and Methods: We performed a single-center, retrospective, cohort study of patients who had a liver transplant between 2002 and 2012 and who had chest computed tomography scans within 1 year before and after transplant. Using ImageJ software, we measured the CSA of small pulmonary vessels (0–5 mm^2) and the total lung CSA to calculate the percent CSA of pulmonary vessels <5 mm (%CSA<5) at the level of the aortic arch, carina, and right inferior pulmonary vein (RIPV). Pretransplant and posttransplant, %CSA<5 were compared, and associations of pretransplant %CSA<5 with clinical parameters were measured.

Results: There was a significant decrease in %CSA<5 at the level of the RIPV (0.19% [interquartile range {IQR}, 0.15–0.26] before vs. 0.15% [IQR, 0.12–0.21] after; $P = .0003$), with a median change of −16.2% (IQR, −39.3 to 3.9) posttransplant. Changes at the level of the aortic arch and carina were not significant. Pretransplant RIPV %CSA<5 was not significantly correlated with severity of liver disease or oxygenation but was inversely correlated with percent change in %CSA<5 ($r = −0.39$; $P = .0039$).

Conclusions: This is the first study to describe a significant regional change in the pulmonary vessels of patients without known pulmonary vascular disease who undergo liver transplant.

Key Words: Liver transplant; pulmonary vessel cross-sectional area.

Pulmonary vascular complications of liver disease, such as hepatopulmonary syndrome (HPS) and portopulmonary hypertension (POPH), have a substantial impact on morbidity and mortality in patients with cirrhosis and portal hypertension (1–2), but the relationship between the liver and the pulmonary vasculature remains poorly understood. HPS, characterized by intrapulmonary vascular dilation, and POPH, characterized by elevated pulmonary arterial pressure and pulmonary vascular resistance, also have implications for postoperative outcomes in liver transplantation (2–6). The current Model for End Stage Liver Disease (MELD) exception policy highlights the importance of these pulmonary vascular complications by favoring organ allocation to expedite liver transplantation in patients who meet certain criteria for HPS or POPH (4). Outcomes of these diseases with liver transplant, however, are variable. HPS typically improves with liver transplant (3–8), whereas outcomes of POPH are more unpredictable (4–5). Even less is known about the effect of liver transplantation on the pulmonary vasculature in patients with liver disease who do not meet criteria for HPS or POPH.

This study was undertaken to further characterize the effect of liver transplant on the cross-sectional area (CSA) of small pulmonary vessels in a cohort of patients with cirrhosis and portal hypertension. Because diseases such as HPS have a basilar predominance, we also sought to determine the regional effect of liver transplant on pulmonary vessel CSA at three anatomic levels. Additionally, we wanted to characterize the relationship between pretransplant CSA and clinical

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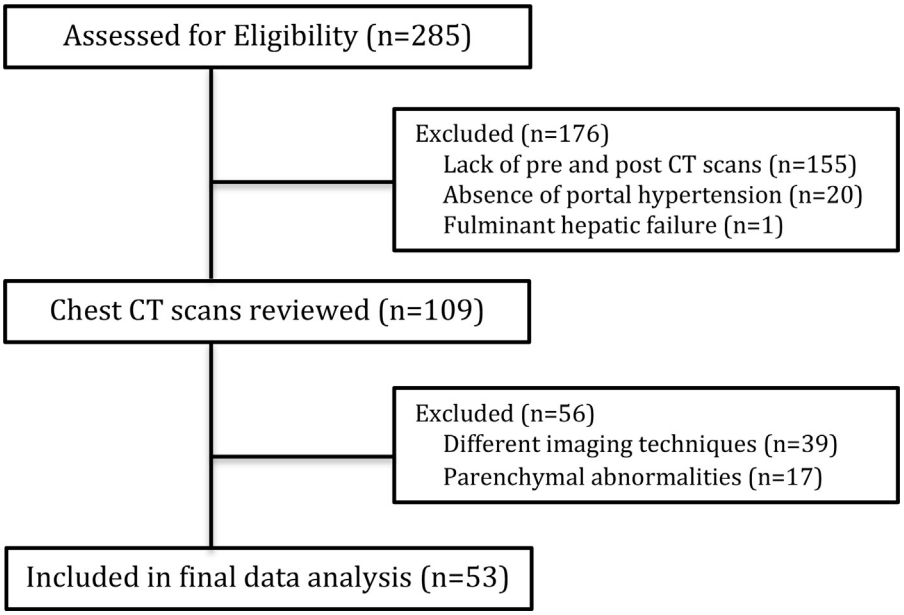

Figure 1. Flow diagram of patients included in final data analysis. CT, computed tomography.

parameters such as liver disease severity determined by the MELD score, etiology of liver disease, percent predicted diffusion capacity for carbon monoxide corrected for hemoglobin (%DLCO[Hb]), arterial partial pressure of oxygen (PaO2), and alveolar–arterial oxygen (A-a) gradient, as well as mortality. Finally, we wanted to determine if there was a difference in mortality between patients who had an increase versus a decrease in percent CSA of pulmonary vessels <5 mm^2 (% CSA<5) with transplant.

MATERIALS AND METHODS

Study Design and Subject Selection

We performed a retrospective cohort study of all patients who underwent a liver transplant at our institution from January 1, 2002 to December 31, 2012. Medical records were reviewed to identify subjects with clinical evidence of portal hypertension (at least two of the following by examination, imaging, or endoscopy: ascites, splenomegaly, or esophageal varices) that had a computed tomography (CT) scan of the chest during both the year before and the year after liver transplantation. When more than one CT scan was available within the 1-year period before or after transplant, the latest chronologic CT scan was used for data analysis and comparison. Patients with fulminant hepatic failure and patients who had a prior liver transplant were excluded.

We identified 109 patients with clinical evidence of portal hypertension that had chest CT scans both before and after liver transplantation. Thirty-nine patients were excluded owing to lack of similar chest imaging for comparison (ie, contrast vs noncontrast studies or 3- vs 5-mm slices), and 17 patients were excluded owing to the presence of parenchymal abnormalities or large effusions that precluded reliable CSA calculations. CT scans were compared for a total of 53 patients (Fig 1). Demographic and clinical information, including etiology of liver disease, comorbidities, and laboratory data, was collected from review of the medical record. Characteristics of the study patients are detailed in Table 1. As shown, the majority of patients were men and had a diagnosis of hepatocellular carcinoma (HCC). One patient included in the study had a clinical diagnosis of POPH and was on sildenafil treatment. No patients in the final cohort had a clinical diagnosis of HPS.

Imaging

CT scans were clinically acquired high-resolution images. Images were reconstructed using eFilm Lite software for selection of slices. Slices were 5 mm thick and evenly spaced every centimeter. ImageJ software was used, as previously described (9), to measure the CSA of small pulmonary vessels (0–5 mm^2) and the total lung CSA at three anatomic levels of each CT scan: the aortic arch (AA), carina, and the right inferior pulmonary vein (RIPV). We then calculated the percentage of small pulmonary vessel CSA compared to the total lung CSA (%CSA<5) at each level.

Statistical Analysis

Our primary outcome was the difference between pretransplant and posttransplant %CSA<5 at the levels of the AA, carina, and RIPV. Our null hypothesis was that there would be no significant difference. Pretransplantation and