Contrast Enhanced Duplex Ultrasound Imaging of the Mesenteric Arteries

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Duplex ultrasound of the visceral arteries is a technically challenging procedure. We examined the clinical usefulness of perfluorin intravenous ultrasound contrast to improve the diagnostic accuracy of such studies. Seventeen patients were prospectively studied. A color duplex imaging study of the visceral vasculature was performed with and without the contrast agent. Vessels were imaged and peak systolic velocity and Doppler waveforms of the aorta, celiac artery, superior mesenteric artery, and the inferior mesenteric artery were examined. These results were independently compared to those of contrast angiography. From this analysis we concluded contrast-enhanced duplex imaging of the mesenteric arteries is safe but not routinely required when performed by an experienced sonographer. Ultrasound contrast may be helpful in difficult patients when the vessels are not initially successfully visualized.

INTRODUCTION

Duplex ultrasound evaluation of the visceral arteries is a technically challenging procedure hampered by the lack of reproducible uniform criteria among different institutions for the diagnosis of hemodynamically significant stenosis.1-3 Intravenous microbubble contrast agents enhance vascular reflective acoustic signals and have been found to improve ultrasound diagnostic accuracy in the examination of the heart, liver, and peripheral vasculature.4,5 We prospectively examined the potential clinical usefulness of an ultrasound contrast agent in the duplex examination of the mesenteric vasculature.

PATIENTS AND METHODS

During a 9-month period from March to November 2000, a study examining duplex imaging of the mesenteric arteries was performed at the Milton S. Hershey Medical Center of the Pennsylvania State University School of Medicine as part of a prospective multicenter open-label phase 2 clinical trial to assess the usefulness of contrast-enhanced imaging of renal artery stenosis sponsored by DuPont Pharmaceuticals Co. (Billerica, MA). The study was approved by the Institutional Review Board of the Penn State College of Medicine. Adult patients who had undergone abdominal contrast angiography for suspected renal or peripheral atherosclerotic disease within the prior 90 days were eligible for participation. Two patients (12%) had signs and symptoms of chronic mesenteric ischemia. After an 8-h fast, a complete abdominal color

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duplex ultrasound scan was performed by an experienced registered vascular technologist (M.N.), blinded to the results of the angiogram, using an ATL HDI 5000 (ATL Ultrasound, Bothell, WA) ultrasound scanner and a curved 2.5 MHz Doppler probe. The scanner’s parameters in terms of transmit power, gain, repetition frequency, and dynamic range were individually optimized for each patient. The aorta, celiac artery (CA), and its splenic and hepatic branches, superior mesenteric artery (SMA), and inferior mesenteric arteries (IMA) were imaged in two-dimensional (2-D) grayscale. The peak systolic (PSV) and end diastolic (EDV) velocities were measured and Doppler spectral waveform characteristics evaluated. Care was taken to maintain the angle of insonation between 40° and 60° and obtain Doppler velocity measurements from the center of the vessel. Doppler criteria for hemodynamically significant arterial stenosis were defined as a PSV of ≥275 cm/sec for the SMA, and ≥200 cm/sec for the CA and IMA.1,6

After the initial examination was completed, an identical contrast-enhanced study was performed by the same technologist with the same ultrasound scanner. A vial of perfluoropropane contrast agent (Definity™, DuPont Pharmaceuticals Co) was agitated for 45 sec at 4500 oscillations/min in a vial shaker. A volume of 1.3 mL was then injected into a 50-mL bag of 0.9% sterile saline solution. This was then infused intravenously at a constant rate of 2 mL/min via an 18-guage needle in a forearm vein throughout the duration of the duplex examination. All studies were recorded on tape. The duplex results were independently recorded (N.V.) and compared with the results obtained with contrast angiography, by which vessel patency and degree of stenosis were measured.

Clinical laboratory examinations, which included serum blood urea nitrogen (BUN) and creatinine, were performed at baseline before the duplex examination and at follow-up 48-72 hr later. Vital signs, consisting of respiratory rate (RR), heart rate (HR), and supine blood pressure, were measured within 15 min prior to the infusion of the contrast agent, during the infusion 30 min later, then at 1 and 3 hr. A follow-up visit was performed 2 to 3 days after the study and a history was compiled and clinical assessment made for possible adverse events.

All values are reported as mean ± standard error of the mean. Statistical analysis was performed using Sigma Stat 2.0 statistical software package (Jandel, San Rafael, CA). Paired Student t-testing was used for data comparisons. A p-value of <0.05 was considered statistically significant.

### Table I. Clinical risk factors

<table>
<thead>
<tr>
<th>Factor</th>
<th>Patients (%)</th>
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<tbody>
<tr>
<td>Hypertension</td>
<td>94</td>
</tr>
<tr>
<td>Tobacco use</td>
<td>88</td>
</tr>
<tr>
<td>Coronary artery disease</td>
<td>65</td>
</tr>
<tr>
<td>Peripheral vascular disease</td>
<td>65</td>
</tr>
<tr>
<td>Hyperlipidemia</td>
<td>56</td>
</tr>
<tr>
<td>Diabetes mellitus</td>
<td>12</td>
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</table>

### RESULTS

There were a total of 17 patients in the study. There were 11 males and 6 females with a mean age of 62 ± 3 years (range 47-79 years) and a body weight of 173 ± 8 pounds. They had the expected risk factors for systemic atherosclerotic disease (Table 1). The rate of contrast infusion was 2 mL/min in all except one patient who had an infusion rate of 4 mL/min. The mean total volume of infusion in each patient was 24 ± 2 mL of contrast solution.

For the CA, near equivalent results were obtained with duplex ultrasound alone and with contrast. Both methods correctly identified the two lesions of >70% stenosis but duplex alone could not visualize two vessels and falsely suggested a hemodynamically significant stenosis in a vessel with only a 40% stenosis by contrast angiography. With the addition of contrast, all vessels were successfully identified but two arteries with an angiographic 40% stenosis had a PSV of >300 cm/sec, falsely suggesting a hemodynamically significant stenoses. The accuracy of the methods for the CA was therefore 82% and 88%, respectively, with and without echocontrast.

Examination of the SMA showed an accuracy of 71% for duplex alone, correctly identifying 1 of 2 occlusions, 2 of 3 stenoses, and 9 of 12 normal vessels. With contrast, both occlusions and all the stenoses were correctly identified as well as two normal vessels (Fig. 1), for an accuracy rate of 94%. The diagnostic accuracy in the duplex examination of the IMA was significantly decreased compared to that of the SMA (p < 0.001). In the IMA, duplex alone did not correctly diagnose two of seven occlusions, two of four normal vessels, and five of six vessels with hemodynamically significant stenoses, for an accuracy rate of 35%. The addition of contrast was associated with an accuracy rate of 38%, correctly identifying three of the normal vessels, four occlusions, and one of the three stenoses examined (Fig. 2). Combining all 68 vessels, including the aorta, the accuracy rate for duplex alone was 72% and 85% for those studies performed with the