Color Doppler flow mapping in patients with coarctation of the aorta: new observations and improved evaluation with color flow diameter and proximal acceleration as predictors of severity

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ABSTRACT We performed color Doppler flow mapping in 15 patients, 1 week to 17 years old (mean 42 months), with coarctation of the aorta that was confirmed subsequently by angiography and/or surgery. Twelve patients had native coarctation and three had mild recoarctation after surgical repair. Color Doppler flow maps were analyzed with a digital analysis package and a Sony computer system. The diameter in the region of coarctation from the color Doppler flow map (mean = 2.0 ± 0.8 mm [SD]) correlated well with the coarctation diameter measured at angiography (mean = 1.8 ± 0.8 mm; r = .83, SEE 0.43 mm) in the 10 patients with native coarctation undergoing angiography, but the coarctation diameter measured by two-dimensional echocardiography (3.9 ± 1.5 mm) was poorly predictive of the angiographic severity (r = .23). Additionally, spatial acceleration was seen in all patients proximal to the coarctation site, with an aliased and accelerating stream narrowing progressively as it proceeded toward the coarctation site, a pattern that is not seen in healthy subjects. Computer analysis of the color Doppler images provided pseudo three-dimensional and digital velocity maps for blue, red, and green (turbulent) flow velocities to allow an enhanced appreciation of the accelerating stream, easily separating this from normal descending aortic aliasing patterns. The narrowing of the acceleration area in the proximal descending aorta (distal/proximal acceleration zone ratio) was also predictive of the angiographic severity of coarctation (r = .83). The distribution of low-level turbulence seen proximally paralleled the distribution of the proximal accelerating stream. Highly turbulent flow distal to the coarctation was identified in all patients, continuing into diastole in the seven patients with increased diastolic flow velocities on continuous-wave Doppler images. Color Doppler flow mapping allows new observations of coarctation flow diameter, spatial aortic acceleration, and turbulence in the proximal descending aorta that enhance the noninvasive assessment of patients with coarctation of the aorta.


TWO-DIMENSIONAL echocardiography has been quite useful for the noninvasive assessment of patients with coarctation of the aorta1, 2 and when high-resolution images are obtained many patients can safely undergo surgery without the need for a confirmatory invasive study. In normal newborn infants, however, mild ischemic narrowing is a common finding and confusion may arise in attempts to diagnose coarctation from the two-dimensional echocardiogram, especially when the ductus is still patent. Also, in older patients in whom image resolution is poorer because of the distance between the suprasternal notch and the descending aorta, accurate diagnosis and assessment of severity of coarctation may be difficult with imaging alone. Doppler ultrasound allows accurate measurement of flow velocities and prediction of pressure gradients across stenotic lesions3-14 and therefore it has been applied in patients with coarctation, but with varying results since coarctations are often tortuous and long-segment obstructions.15-17 Pulsed Doppler ultrasound can provide a qualitative assessment of coarctation from the flow velocity pattern in the descending aorta in the presence or absence of patent ductus arteriosus,18 but continuous-wave Doppler ultrasound

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has been used most often to measure the pressure drop across coarctation of the aorta.19, 20 When continuous-wave Doppler is used, the importance of recognizing the effect of the velocity proximal to the coarctation site on gradient estimation has also been emphasized21 and is of particular importance in patients with associated aortic stenosis in whom the proximal velocity may be significantly increased. However, it is clear that the pressure gradient measured across the coarctation site by continuous-wave Doppler or cardiac catheterization is dependent on a number of factors, including the shape and length of the obstruction, cardiac output, and the presence and extent of collateral flow and flow through a patent ductus arteriosus,22 and therefore the Doppler-derived pressure gradient, although potentially accurate, may over- or underestimate the actual degree of obstruction at the coarctation site. While spectral Doppler imaging can provide good temporal information and identify flow velocity patterns associated with coarctation under different hemodynamic circumstances,21, 22 the inherent sampling limitations of the technique (information is obtained from individual sample volumes) makes accurate evaluation of spatial information difficult. Color Doppler flow mapping23–25 allows a spatial map and temporal determination of flow velocities in relationship to the structural detail provided by simultaneous two-dimensional echocardiographic imaging. We therefore undertook this study to test whether flow mapping would allow accurate delineation of the extent of narrowing of the flow stream at the site of coarctation. Additionally, we evaluated whether the spatial and temporal flow information could delineate the complex flow relationships that exist both proximal and distal to the coarctation site to provide an improved understanding of the physiology of flow in the presence of coarctation to assist noninvasive investigation of this lesion.

Patients and methods

We performed color Doppler flow mapping examinations in 15 patients, from 1 week to 17 years old (mean 42 months), with coarctation of the aorta confirmed at angiography and/or surgery. The clinical details of the patients are shown in table 1. Twelve patients had native coarctation and three had mild recoarctation after surgical repair. Conventional echocardiographic examination and color Doppler flow mapping were performed in all patients with a Toshiba SSH65A with a 3.75 MHz transducer from the suprasternal notch or high right parasternal position. Flow mapping images were all obtained at a 4 kHz pulse repetition frequency and with moderately high gains just below a gain level that produced random noise in the color signal. Patients were studied supine and at rest without sedation. All echocardiographic and Doppler images were recorded on videotape for subsequent analysis. Continuous-wave Doppler interrogation was performed with a stand-alone continuous-wave transducer or the 3.5/2.25 MHz phased-array/continuous-wave Doppler transducer of an Irex IIIB ultrasound system (in 13 patients), with the Doppler spectra recorded on a strip-chart recorder. Since only four of the patients had transcatheter gradients measured at catheterization, we used the continuous-wave traces to examine prolongation of high-velocity flow into diastole and not for estimation of peak gradient.

Analysis of color Doppler flow map images. Frame-by-frame videotape review of color Doppler images was performed in all patients (figure 1). Measurement of the diameter at the site of coarctation from the flow map was performed from a systolic frame, as was measurement of diameter from the two-dimensional echocardiographic image; each was rounded to the nearest 0.25 mm by use of an on-screen digitizing analysis package and a Sony Medical Systems 70G computer system. Images were measured by a single observer who was blinded to patient status other than the fact that the patient was in the coarctation study.

Additional analysis of the color Doppler flow maps was performed by use of the RGB digitizing system of the Sony computer. With frame-by-frame video playback, a systolic frame displaying maximum color velocity aliasing proximal to the coarctation site was digitized into an 8-bit RGB matrix. A region of interest was chosen to include the proximal aliasing in red for flow away from the transducer in the aortic arch, flow extending to the coarctation site, and flow in the descending aorta distal to the coarctation (figure 2, A). Within the region of interest, the computer analysis provided a numerical velocity assignment for each pixel color component of red (toward), blue (away), and green (turbulent) flow, with velocity calibration obtained from the on-screen color bar. Two bits were available for blue flow, allowing a numerical velocity assignment of 0 to 3, and 3 bits were available for both red and green, allowing numerical velocity assignments of 0 to 7 (figure 2, B). Spatial velocity maps of the region of interest were then constructed for each color, allowing an assessment of regional flow velocities and change in velocity, or spatial acceleration and deceleration.

The spatial nature of the color flow Doppler velocity maps and the computer quantitation of velocity assigned allows appreciation of flow velocity and acceleration despite the presence of color aliasing associated with high-velocity flow. Aliasing of an accelerating stream flowing away from the transducer produces increasing numerical blue intensity assignments that switch immediately to decreasing intensities of red, beginning with a high-velocity red value. In figure 2, the blue value rises to a peak and then the first aliased red value originates at a color intensity level of 4; it then decreases to a second alias from red to blue, with blue levels rising from 1 to 3 and a subsequent alias back to red, documenting continued acceleration. The number sequence with increasing values of blue and decreasing values of red characterizes an alias and is not seen in normal patients. Additionally, the separate color velocity assignments can be reconstructed into a semiquantitative pseudo three-dimensional display of red, blue, and green (turbulent) flow velocities (figure 2, C) in which the relative distribution and magnitude of the individual color velocities can more easily be appreciated.

From the digital computer analysis the onset and distribution of turbulence was assessed. The presence and onset of significant flow acceleration was arbitrarily identified from the first onset of aliasing (54 cm/sec) and a measurement was made of the length of the accelerating stream proximal to the coarctation site. Additionally, measurement was made of the width of the accelerating stream at its onset and immediately proximal to the coarctation site, including the second or other aliases. The ratio of acceleration width just before the coarctation (distal width), which was smaller than the denominator, the acceleration stream width at the point of first aliasing (proximal width), was calculated as the measurement of the extent of narrowing of the proximal accelerating stream (distal/proximal ratio).
TABLE 1
Patient data

<table>
<thead>
<tr>
<th>Patient No.</th>
<th>Age (yr)</th>
<th>Sex</th>
<th>CW velocity (m/sec)</th>
<th>Duration of increased diastolic velocity</th>
<th>PDA</th>
<th>Severity</th>
<th>Surgi-cal verification</th>
<th>Associated observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (R)</td>
<td>9 yr</td>
<td>M</td>
<td>3.2</td>
<td>—</td>
<td>N</td>
<td>Mild (C)</td>
<td>^</td>
<td>Aortic stenosis</td>
</tr>
<tr>
<td>2</td>
<td>3 mo</td>
<td>M</td>
<td>3.8</td>
<td>Pandiastolic</td>
<td>Y</td>
<td>Severe (C)</td>
<td>+</td>
<td>Musc. VSD</td>
</tr>
<tr>
<td>3</td>
<td>1 mo</td>
<td>F</td>
<td>4.0</td>
<td>Pandiastolic</td>
<td>Y</td>
<td>Severe (C)</td>
<td>+</td>
<td>Musc. VSD</td>
</tr>
<tr>
<td>4</td>
<td>5 mo</td>
<td>F</td>
<td>3.0</td>
<td>—</td>
<td>N</td>
<td>Severe (MRI)</td>
<td>+</td>
<td>Bicuspid aortic valve, mitral regurgitation</td>
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<tr>
<td>5</td>
<td>5 yr</td>
<td>M</td>
<td>3.0</td>
<td>—</td>
<td>N</td>
<td>Moderate (C)</td>
<td>(35 mm Hg)</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>4 mo</td>
<td>M</td>
<td>4.5</td>
<td>Pandiastolic</td>
<td>N</td>
<td>Severe (C)</td>
<td>+</td>
<td>Apical VSD, mild mitral stenosis, bicuspid aortic valve</td>
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<tr>
<td>7</td>
<td>1 wk</td>
<td>M</td>
<td>2.8</td>
<td>Mid-diastolic</td>
<td>Y</td>
<td>Moderate (C)</td>
<td>+</td>
<td>ASD, VSD, mitral regurgitation</td>
</tr>
<tr>
<td>8</td>
<td>16 mo</td>
<td>M</td>
<td>2.8</td>
<td>Mid-diastolic</td>
<td>N</td>
<td>Severe (C)</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>9 (R)</td>
<td>16 yr</td>
<td>F</td>
<td>2.6</td>
<td>—</td>
<td>N</td>
<td>Mild (C)</td>
<td>^</td>
<td>Tricuspid regurgitation, supravalvular aortic stenosis</td>
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<tr>
<td>10</td>
<td>1 wk</td>
<td>M</td>
<td>3.0</td>
<td>—</td>
<td>Y</td>
<td>Severe (C)</td>
<td>(10 mm Hg)</td>
<td>VSD, large collateral flow</td>
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<tr>
<td>11</td>
<td>2 yr</td>
<td>M</td>
<td>—</td>
<td>—</td>
<td>Y</td>
<td>Severe (C)</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>2 yr</td>
<td>M</td>
<td>4.0</td>
<td>Pandiastolic</td>
<td>N</td>
<td>Severe (C)</td>
<td>(40 mm Hg)</td>
<td></td>
</tr>
<tr>
<td>13 (R)</td>
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<td>M</td>
<td>—</td>
<td>—</td>
<td>N</td>
<td>Mild (C)</td>
<td>(20 mm Hg)</td>
<td>Aortic graft, hypertension</td>
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<tr>
<td>14</td>
<td>5 mo</td>
<td>M</td>
<td>4.0</td>
<td>Mid-diastolic</td>
<td>N</td>
<td>Moderate/severe (MRI)</td>
<td>+</td>
<td>Bicuspid aortic valve</td>
</tr>
<tr>
<td>15</td>
<td>5 mo</td>
<td>M</td>
<td>2.9</td>
<td>—</td>
<td>Y</td>
<td>Severe (C)</td>
<td>+</td>
<td>Musc. VSD</td>
</tr>
</tbody>
</table>

Individual patient data for 12 patients with native coarctation and three patients with recoarctation (R). Severity of coarctation was determined at catheterization (C) or magnetic resonance imaging (MRI) in addition to subsequent surgical verification in all native coarctations. Transcatheter gradients obtained at catheterization only in patients 5, 10, 12, and 13, are shown in parentheses.

CW = continuous-wave; ASD = atrial septal defect; PDA = patent ductus arteriosus; VSD = ventricular septal defect; + = surgical verification; − = lack of verification.

*Previous surgery had been performed in these patients with recoarctation.

The measurement of coarctation diameter from the two-dimensional echocardiographic images was also made on a systolic frame of the two-dimensional echocardiographic image obtained in the same view as the color Doppler image (figure 1, B) with the use of the on-screen measurement system of the Sony computer.

**Angiography.** Satisfactory color Doppler flow maps were obtained in all 10 patients with native coarctation who were undergoing angiography. Angiograms were calibrated by diameters of catheters placed in the aorta near the region of the coarctation or by a grid for left ventricular angiograms. Most angiograms were obtained in left anterior oblique views with slight cranial angulation. Analysis of the angiograms was performed independent of the results of color Doppler examinations and measurement was made of the angiographic diameter at the coarctation site. This procedure was followed in the patients with mild recoarctation who were being recatheterized for other associated lesions still present after coarctation repair.

**Surgical assessment.** Surgical verification of coarctation diameter was by a qualitative judgment of the luminal diameter of the aorta in the freshly resected segment and was termed moderate or severe. This judgment alone was used for verification in the two patients who underwent magnetic resonance imaging only before surgery. Data from these patients were not included in the quantitative correlations.

**Statistical analysis.** Tests of statistical significance were performed by paired Wilcoxon analysis and correlation with use of the Pearson method of analysis.

**Results**

Satisfactory echocardiographic images and color Doppler flow maps were obtained in 14 of the 15 patients. For the 10 patients studied at angiography, there was no significant difference between the coarctation diameter measured at angiography and that measured by color Doppler flow mapping (1.8 ± 0.8 mm on the angiogram vs 2.0 ± 0.8 mm on color Doppler map, mean ± SD, p = NS) and there was a good correlation between the two techniques (r = .83, SEE = 0.43 mm; figure 3). However, there was a significant difference between the coarctation diameter at angiography and that measured by conventional two-
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FIGURE 1. A, Color Doppler flow map from patient 12, who had severe coarctation. Note that the color flow diameter is extremely small at the coarctation site, indicating almost complete aortic obstruction, confirmed subsequently at angiography and surgery. In the descending aorta, there is aliasing to red and a second alias to blue proximal to the coarctation site, indicating the presence of proximal acceleration. B, Tissue echocardiographic and flow images from patient 2. The tissue (left) echocardiographic estimate of the coarctation diameter was 3.5 mm; the color flow (right) estimate was 2 mm. Angiographic size was 2 mm in this patient.

dimensional echocardiography (1.8 ± 0.8 mm on the angiogram vs 3.9 ± 1.5 mm on the two-dimensional echocardiogram, p < .02) and a poor correlation (r = .23) between the two techniques.

Spatial acceleration and turbulent flow. Significant flow acceleration, with a long first alias and often a second or third alias throughout most of systole, was seen in the descending aorta proximal to the coarctation site in all patients. The onset of acceleration could be routinely and consistently identified by the onset of aliasing on color Doppler flow maps (see figure 1). The length of the proximal accelerating flow stream ranged from 6.1 to 24.6 mm, (mean 12.5 mm), but showed no correlation with the anatomic severity of coarctation. There was a reasonably good correlation between the coarctation diameter at angiography and the width of the accelerating stream immediately proximal to the coarctation site (r = .78), but no correlation with the width of the acceleration zone at its initial or proximal onset. However, the acceleration narrowing ratio, i.e., the degree of narrowing of the proximal accelerating stream, expressed as distal width/proximal width ratio (mean 0.38, range 0.2 to 0.67) correlated well (r = .83) with the anatomic severity of coarctation at angiography, with the smallest ratios corresponding with the smallest angiographic diameters (figure 4). Small, short, center-stream areas of aliasing are often seen in healthy subjects at peak systole in the descending aorta but are localized near the carotid artery as flow becomes parallel to the interrogation transducer in the suprasternal notch. Normal aliasing is also pure red, with no turbulence and no extensions, and it appears quite different from what we observed in patients with coarctation. In the healthy subjects, there was no nar-
FIGURE 2. A, Color Doppler flow map from patient 4, who had coarctation, showing the region of interest for digital computer color Doppler analysis. Note the narrowing of the accelerating stream and the continuing acceleration toward the coarctation site shown by the second aliasing of the jet to blue and the third alias to orange at the lower corner of the region of interest just proximal to the site of maximal coarctation (arrow). B, Velocity assignment maps for blue, red, and green (turbulent) flow velocities from region of interest in A. Note the initial aliasing from high values of blue to moderately high values of red, with decreasing red values indicating progressive acceleration as the flow velocity stream narrows. There is switching to low blue values at the second aliasing. The distribution of the green (turbulent) flow parallels the accelerating stream proximal to the obstruction and turbulence is seen again distal to the second alias. (See text for details.) C, Pseudo three-dimensional maps of blue, red, and green (turbulent) flow velocities within the region of interest shown in A. Note the high-velocity blue proximally, aliasing to a red, narrowing, accelerating stream, and a second aliasing to blue distally. The distribution of the green (turbulent) flow velocities parallels the distribution of the accelerating stream.
tracings, it was not possible to assess the precise duration of turbulent flow distal to the coarctation because of the relatively poor temporal resolution of color Doppler flow mapping. Diastolic flow through the coarctation was often seen but with lower proximal velocities and little proximal aliasing (figure 5).

Two infants studied by color Doppler flow mapping underwent surgical repair without cardiac catheterization. Color flow diameter (1.7 and 2.0 mm) and acceleration narrowing ratio (0.3 and 0.37) both suggested significant coarctation, which was confirmed by magnetic resonance imaging and graded as severe coarctation subsequently at surgery.

Three patients with clinical evidence of mild restenosis after previous surgical repair were also studied. In two patients, color Doppler flow maps of good quality were obtained, and coarctation diameters of 10.5 and 7.0 mm and acceleration narrowing ratios of 0.73 and 0.67 confirmed the clinical impression of mild obstruction; this was subsequently confirmed at angiography. In the remaining patient (No. 13, table 1), who had a tubular graft inserted at surgical repair, satisfactory echocardiographic/Doppler imaging of the graft or graft flow was not obtained. Acceleration proximal to the graft was seen on the color Doppler flow map, with a narrowing ratio of the visualized accelerating jet of 0.6. Cardiac catheterization confirmed only minimal obstruction at the proximal end of the graft anastomosis, with a 20 mm Hg gradient and mild obstruction apparent on the angiogram.

![Graph](image)

**FIGURE 3.** Comparison of the color flow diameter at the coarctation site (ordinate) with the smallest coarctation diameter measured at angiography (abscissa). $r = .83$, SEE 0.43, $y = 0.9x + 0.4$.

narrowing of the short, aliased zone, and computerized analysis of this region did not show continued acceleration (i.e., decreasing numbers of red).

In one patient with severe coarctation, satisfactory echocardiographic imaging of the coarctation site itself was not obtained on a preliminary echocardiographic examination. However, flow acceleration was still present and the narrowing ratio of the visualized accelerating stream was 0.38. Subsequent echocardiographic examination after sedation provided good image resolution of a severe discrete coarctation and color Doppler flow mapping identified a proximal accelerating stream with slightly more extensive narrowing (ratio 0.3) when the total accelerating stream was visualized.

With use of the computer-digitized color pixel analysis, green pixels of "turbulent" flow, not apparent on the visualized color image, were seen proximal to the site of coarctation, the onset of turbulence coinciding with the onset of flow acceleration and its distribution matching that of the accelerating stream proximal to the site of coarctation (figure 2, B and C).

The presence of grossly turbulent flow distal to the coarctation was easily visualized on color Doppler flow maps in all patients, even before computer analysis, as increased variance and a resulting mosaic color pattern on the images. Frame-by-frame analysis revealed prolongation of turbulent flow distal to the coarctation site into diastole in those patients with severe coarctation in whom increased diastolic flow velocities greater than 1 m/sec were also identified by spectral Doppler imaging (figure 5). However, unlike with spectral Doppler

![Graph](image)

**FIGURE 4.** Comparison of the narrowing ratio (distal acceleration width/proximal acceleration width) (ordinate) with the severity of coarctation at angiography (abscissa). $r = .83$, $y = 0.2x + 0.1$. 

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Additionally, the other major observation evaluated in our study deals with the relative diameters of an alias zone at two points in the image, a ratio measurement that should be little affected by lateral resolution. The assessment of turbulent flow, displayed in the variance mode as shades of turquoise and orange interposed with red, blue, and white in a mosaic pattern, is helpful in identifying the coarctation site, with the onset of visually apparent turbulence occurring immediately distal to the site of coarctation. However, with use of computer-enhanced analysis, turbulent flow was also apparent proximal to the coarctation and paralleled the onset of flow acceleration. The phenomenon of spatial acceleration occurring proximal to the coarctation site is of particular interest. Since spatial information cannot easily be obtained by conventional single-gate or continuous-wave spectral Doppler techniques, color Doppler flow mapping is required to appreciate this spatial flow acceleration. By our definition of the first onset of clearly and reproducibly identifiable angle-independent acceleration as the onset of aliasing, it is not surprising that there was no correlation between the length of the proximal accelerating stream and the anatomic severity of coarctation. Aliasing in the descending aorta is not uncommon at peak systole in normal subjects with velocities exceeding the Nyquist limit and its onset will, therefore, be dependent on the cardiac output, vessel diameter, and velocity profile, in addition to the transducer frequency, pulse repetition frequency, and the intercept angle. In healthy subjects, this acceleration is not associated with turbulence. Thus, with increasing cardiac output, the onset of acceleration is likely to occur more proximally since the aorta is once again parallel to the
imaging direction at the posterior end of the aortic arch. Likewise, many patients with suspected coarctation may have mild aortic valve disease with increased ascending aortic velocities. However, from the computer-digitized velocity assignment profiles, in patients with coarctation there is progressive continuing acceleration toward the site of narrowing, a phenomenon we have not seen in healthy subjects who demonstrate only short, variable, single-color aliasing in the proximal part of the descending aorta. Additionally, unlike the patients with coarctation, in whom the aliased accelerating stream progressively narrows, the aliasing in healthy subjects does not narrow, and indeed may even increase in width.

The degree of progressive narrowing of the accelerating stream, as measured by the ratio of distal and proximal width, accurately predicted the anatomic severity of the coarctation in our study. This was not merely a reflection of the distal acceleration width being measured immediately proximal to the coarctation site, since the narrowing ratio correlated better with the severity of coarctation than did the distal acceleration width alone. Distal acceleration aliasing width was slightly, but variably, smaller than the total flow diameter at the narrowest portion and the latter measurement also correlated extremely well with severity. Nonetheless, narrowing of the accelerating stream proximal to the coarctation appeared to be predictive of the anatomic severity of coarctation rather than just a function of the pressure drop across the coarctation, since it predicted the severity of coarctation in one patient with severe coarctation but with extensive collateral flow and a reduced pressure gradient, and in six patients with coarctation who still had patent ductus arteriosus. However, since the numbers of these patients were small and individual patients were not studied under varying hemodynamic conditions, further evaluation of this observation will be required.

Since the presence of a narrowing, accelerating stream in the descending aorta appears to be predictive of a more distal obstruction, it is suggestive of coarctation even in a patient such as the one we encountered in whom the coarctation site was not adequately imaged.

Accurate estimation of the severity of coarctation by color Doppler flow mapping, particularly measurement of the diameter of coarctation, is only possible with high-quality ultrasound images. Although color Doppler flow mapping will enhance the assessment of patients in whom conventional imaging techniques prove difficult, the quality of the derived information will be dependent on the patient's suitability for ultrasound examination. In addition, appreciation of the proximal acceleration, and more importantly its narrowing, is often difficult in real time, and subsequent frame-by-frame video analysis is essential in our experience. Furthermore, it appears that computer-enhanced digital analysis is valuable in the assessment of spatial acceleration, multiple aliasing, and the distribution of associated turbulent flow.

In conclusion, our study shows that the spatial appreciation of flow velocities in relation to structural detail provided by color Doppler flow mapping offers considerable advantage over conventional echocardiography and spectral Doppler examination for the evaluation of patients with suspected coarctation. As a result, this technique will enhance the noninvasive assessment of patients with coarctation of the aorta, and in conjunction with digital video computer analysis, will allow new observations of turbulence relationships and flow acceleration in these patients so that insight can be gained into circulatory events in the descending aorta in children and infants with coarctation.

References

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