The Value of Magnetic Resonance Imaging of the Left Ventricular Outflow Tract in Patients With Hypertrophic Obstructive Cardiomyopathy After Septal Artery Embolization

Jeanette Schulz-Menger, MD; Oliver Strohm, MD; Jürgen Waigand, MD; Frank Uhlich, MD; Rainer Dietz, MD; Matthias G. Friedrich, MD

Background—We tested the value of magnetic resonance imaging (MRI) in the follow-up of patients with hypertrophic obstructive cardiomyopathy after septal artery embolization. MRI provides a noninvasive visualization of transplanar turbulent flow in order to quantify left ventricular outflow tract obstruction.

Methods and Results—We followed 10 patients who were treated with septal artery embolization for 12 months. We used gradient echo sequences to document continuous improvement of the outflow tract area and T1- and T2-weighted spin echo sequences to visualize myocardial infarction. A continuous, but not linear, improvement of the outflow tract area occurred after septal artery embolization during the 12-month follow-up period. The improvement of the outflow tract area correlated well with the amelioration of symptoms ($r^2 = 0.86$).

Conclusions—We conclude that MRI reliably detects the degree of obstruction in patients with hypertrophic obstructive cardiomyopathy. This modality may be especially useful for follow-up after septal artery embolization. (Circulation. 2000;101:1764-1766.)

Key Words: hypertrophy ■ cardiomyopathy ■ magnetic resonance imaging ■ embolism ■ ventricular outflow obstruction

The hemodynamic relevance of hypertrophic obstructive cardiomyopathy (HOCM) is determined by the degree of left ventricular outflow tract (LVOT) obstruction. The pressure gradient serves as a follow-up parameter and is generally estimated by transthoracic echocardiography. Pressure gradients can be calculated by a modified Bernoulli formula, according to which maximal flow velocities across a stenosis reflect the severity of obstruction. Pressure gradients calculated by echocardiography may be overestimated compared with those measured invasively. However, a significant number of patients have an impaired acoustic window, thereby contributing to the disappointing reproducibility of echocardiographic pressure gradients. Cardiac catheterization allows for the comparison of simultaneous pressures proximal and distal to the obstruction. However, this technique is invasive and is also susceptible to variations of preload, afterload, and contractility, as well as to poststenotic pressure recovery. A reliable noninvasive technique to assess the hemodynamic relevance of LVOT obstruction in HOCM would be highly useful. Such a method should provide information on the degree of the anatomical obstruction rather than on blood flow velocities or pressure gradients. Dall Agata et al reported their initial experience with semi-invasive 3D echocardiography in describing LVOT obstruction in 13 patients with congenital LVOT obstruction.

The advent of septal artery infarction to decrease LVOT obstruction in HOCM patients mandates objective monitoring. Recent series have included up to 114 patients. Gradient echo sequences with magnetic resonance imaging (MRI) permit the visualization of transplanar turbulent flow. When adequate echo times are used, a signal void is generated by turbulent blood flow due to the dispersion of spin magnetization. We capitalized on the turbulent flow crossing the imaging plane to estimate the degree of LVOT obstruction in HOCM patients undergoing septal artery embolization.

Methods

We investigated 10 patients (7 men and 3 women) with HOCM who were undergoing septal artery embolization. Their mean age was 66±22 years. The intervention was performed when patients had a status of New York Heart Association (NYHA) class III or IV (mean 3.2±0.2) and when maximal medical treatment was no longer helpful. One patient sequentially underwent the embolization of 2 septal arteries. MRI was performed before embolization and 3, 7, 14, 28, 90, 180, and 360 days after the intervention. MRI was performed using a standard clinical system (Magnetom Expert/1.0T, Siemens AG). We assessed left ventricular morphology...
left ventricular ejection fraction was calculated in a biplanar fashion. The diameters of the left ventricle were measured, and the T1-weighted multislice spin echo sequence images (4 to 6 acquisitions; TE, 30 ms, TR, 480 to 725 ms) before and 20 minutes after the application of contrast media (0.1 mmol/kg gadolinium-DTPA, Magnevist; Schering AG) into the antecubital vein (Figure 1, A and B). After embolization, the resulting myocardial infarction was assessed by T1-weighted multislice spin echo sequence images (4 to 6 acquisitions; TE, 30 ms, TR, 480 to 725 ms) before and 20 minutes after the application of contrast media (0.1 mmol/kg gadolinium-DTPA, Magnevist; Schering AG) into the antecubital vein (Figure 1, A and B). We then visualized the turbulent flow in the long axis of the LVOT by a flow-sensitive gradient echo sequence (2D FISP). Finally, we placed a multiplanar series (slice thickness, 5 mm) perpendicular to the base of the turbulent jet (”vena contracta”) at the time of peak systolic flow. From the resulting image set, the image with the smallest area of turbulent flow (narrowest part of the obstruction) was selected for evaluation. The area of the proximal vena contracta (perpendicular to this slice) was then quantified by simple planimetry (Figure 1, A and B). After embolization, the resulting myocardial infarction was assessed by T1-weighted multislice spin echo sequence images (4 to 6 acquisitions; TE, 30 ms, TR, 480 to 725 ms) before and 20 minutes after the application of contrast media (0.1 mmol/kg gadolinium-DTPA, Magnevist; Schering AG) into the antecubital vein (Figure 1, A and B). The diameters of the left ventricle were measured, and the left ventricular ejection fraction was calculated in a biplanar fashion.

**Results**

Total measuring time generally required ~45 minutes. No complications occurred, and image quality was sufficient for evaluation in all patients. Septal artery embolization was successful, as defined by a rapid onset of regional septal hypokinesia resulting in an immediate decrease of the pressure gradient from 88±10 mm Hg to 31±11 mm Hg (P<0.001), which was measured during the catheter procedure. No significant correlation existed between the initial decrease in the pressure gradient and the clinical outcome after 12 months (r=0.03; P<0.9). During the intervention, 5 patients reported chest pain, and 2 developed nausea and vomiting. All patients recovered quickly and uneventfully. Creatine kinase levels increased to 624±214 mmol/L within the first 24 hours after the intervention. In 3 patients, the ECG revealed signs of septal infarction, as defined by ST segment elevation (>0.1 mV) in ≥2 adjacent chest leads (V2 to V4). Transient third-degree atrioventricular block occurred in 2 patients. The temporary pacemakers were removed 6 to 48 hours after the intervention. All patients left the hospital ~1 week after undergoing the treatment.

The clinical status of all patients improved: NYHA class improved from grade 3.3±0.1 to grade 1.3±0.3. The diameter of the septum at the site of the obstruction was reduced from 24±2 to 19.2±1.0 mm (23.9%) within 12 months. No significant change occurred in posterior wall thickness (from 15.1±2.1 to 13.7±1.8 mm) or the ejection fraction (from 70±5% to 71±4%).

Three independent cardiologists experienced in cardiac MRI, who were not aware of the each other’s results or the patients’ symptoms, performed LVOT planimetry in 11 typical cases (of the 80 performed MRIs) using images with varying quality. The resulting intraobserver variability was 10.7%. The interobserver variability was 12.8%. The LVOT area increased from 1.3±0.1 cm² to 3.5±0.6 cm², which represents a 128±12% (range, 100% to 156%) improvement. A close relationship existed between the increase in LVOT area and the decrease in septal wall thickness (r=0.93; P<0.018; r² =0.86). Remarkably, the increase in LVOT orifice area was not complete within the first weeks after embolization. Instead, most patients reached maximum improvement no earlier than 3 months after the intervention (Figure 2A). The LVOT increase paralleled the degree of clinical (NYHA class) improvement (Figure 2B). A close relationship (P<0.0001; r² =0.95) between LVOT orifice area and NYHA class was identified.

**Discussion**

Our study documents the usefulness of MRI in following HOCM patients treated with septal artery embolization. The LVOT orifice area determined by the planimetry of the transplanar flow with MRI proved to be a suitable parameter to characterize patients with HOCM, both initially and during follow-up. In contrast to parameters routinely used in echocardiography, MRI is relatively free of interobserver variability and variable imaging conditions. Other investigators have measured interobserver variability with MRI and found such variability to be negligible for both estimates of mass and diameter.11,12 In contrast to cardiac catheterization, MRI is noninvasive and free of radiation. MRI was successful in visualizing the extent of myocardial infarction after septal artery embolization and the relationship of the lesion to the outflow tract. Thus, MRI served as a tool to evaluate the morphological and functional changes due to interventional or medical therapy. The time course of the decrease in LVOT obstruction after septal embolization varied. The initial pressure gradient decrease was not a good predictor of long-term outcome after 12 months. The systolic
pressure gradient decrease was mainly related to the loss of systolic septal contraction. The total increase in LVOT area during follow-up did include the fibrotic involution of the infarcted septum. The decrease of the septal wall largely determined the increase in the LVOT area. Thus, the impact of septal artery ablation on morphology and function followed a biphasic pattern. Posterior wall thickness was not influenced by the intervention, and left ventricular function remained unaltered. The maximum patient benefit could only be evaluated 4 months after the intervention, and it was stable for the remainder of the observation.

Septal artery embolization is gaining popularity as a treatment for refractory HOCM. Our experience documents the utility of MRI in following these patients. We suggest that MRI provides major advantages and will become the diagnostic tool of choice.

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References

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