JACC Vol. 19, No. 7
June 1992:1500–7

Regurgitant Flow in Cardiac Valve Prostheses: Diagnostic Value of Gradient Echo Nuclear Magnetic Resonance Imaging in Reference to Transesophageal Two-Dimensional Color Doppler Echocardiography

HANS J. DEUTSCH, MD, RAINALD BACHMANN,* UDO SECHTEM, MD,
JULIUS M. CURTIUS, MD, MARKUS JUNGEHÜLSING, MD,* HARALD SCHICHA, MD,*
HANS H. HILGER, MD

Cologne, Germany

Gradient echo nuclear magnetic resonance (NMR) imaging and transesophageal two-dimensional color Doppler echocardiography are flow-sensitive techniques that have been used in the diagnosis and grading of valvular regurgitation. To define the diagnostic value of gradient echo NMR imaging in the detection of regurgitant flow in cardiac valve prostheses and the differentiation of physiologic leakage flow from pathologic transvalvular or paravalvular leakage flow, 47 patients with 55 valve prostheses were examined. Color Doppler transesophageal echocardiography was used for comparison. Surgical confirmation of findings was obtained in 11 patients with 13 valve prostheses.

Gradient echo NMR imaging showed regurgitant flow in 37 of 43 valves with a jet seen on transesophageal echocardiography and it detected physiologic leakage flow in 4 additional valves. There was 96% agreement between the two methods in distinguishing between physiologic and pathologic leakage flow. The methods differed on jet origin of pathologic leakage flow in six prostheses. The degree of regurgitation was graded by both NMR imaging and transesophageal echocardiography, according to the area of the regurgitant jet visualized; gradings were identical for 75% of valve prostheses. Quantification of jet length and area showed a good correlation between the two methods (r = 0.85 and r = 0.91, respectively).

Gradient echo NMR imaging is a useful noninvasive technique for the detection, localization and estimation of regurgitant flow in cardiac valve prostheses. However, because transesophageal echocardiography is less time-consuming and less expensive, gradient echo NMR imaging is unlikely to displace transesophageal echocardiography and should be used only in the occasional patient who cannot be adequately imaged by echocardiography.

(J Am Coll Cardiol 1992;19:1500–7)

Under normal conditions, all cardiac valve prostheses demonstrate some degree of regurgitation (closing volume and leakage volume). This normal regurgitant flow rarely exceeds 15% of the forward flow in mechanical prostheses (1,2). However, the distinction between this physiologic regurgitation and pathologic leakage flow may present a diagnostic problem.

The value of transesophageal two-dimensional color Doppler echocardiography in the assessment of prosthetic heart valves has been well established (3–6). An estimation of the severity of a regurgitant lesion as well as the differentiation between transvalvular or paravalvular leakage flow is possible, especially in mitral valve prostheses. However, artifacts and flow masking caused by the synthetic material of artificial valve prostheses may interfere with the diagnostic capabilities of transesophageal ultrasound (7).

Previous in vitro and in vivo work (8,9) has shown that patients with an artificial cardiac valve can be safely examined in high field magnets (8,9). Interest in the diagnostic capabilities of gradient echo nuclear magnetic resonance (NMR) imaging for the detection and quantification of valvular regurgitation was stimulated by the observation that turbulent blood flow, associated with widely different flow velocities, results in areas of signal loss within the high intensity blood pool on NMR images (10–16). However the capability of gradient echo NMR imaging for diagnosing regurgitant flow in cardiac valve prostheses has not been evaluated.

Consequently, the purpose of the present study was to define the diagnostic value of gradient echo NMR imaging and compare the technique with color Doppler transesophageal echocardiography with regard to 1) the detection of regurgitant flow in cardiac valve prostheses, and 2) the differentiation between physiologic regurgitant flow and pathologic transvalvular or paravalvular leakage flow.

Methods

Study patients. The study group consisted of 47 patients (28 men, 19 women) with 55 valve prostheses. Patients with

From the Klinik III für Innere Medizin und *Klinik und Poliklinik für Nuklearmedizin, University of Cologne, Cologne, Germany.

Manuscript received August 26, 1991; revised manuscript received December 4, 1991, accepted January 3, 1992.

Address for reprints: Udo Sechtem, MD, Klinik III für Innere Medizin, Universität zu Köln, Joseph-Stelzmann-Str. 9, 5000 Cologne 41, Germany.

©1992 by the American College of Cardiology

0735-1097/92/$5.00

Table 1. Types of Cardiac Valve Prostheses Implanted in 42 Patients

Type	AVP	MVP	TVP	Total
St. Jude Medical	21	13	1	35
Medtronic Hall	2	5	—	7
Lillehei-Kaster	2	1	—	3
Duromedics	1	—	—	1
Starr-Edwards	1	—	—	1
Carbomedics	1	—	—	1
Carpentier-Edwards bioprosthesis	2	3	—	5
Hancock bioprosthesis	2	—	—	2
Total	32	22	1	55

AVP, MVP and TVP = aortic, mitral and tricuspid valve prosthesis, respectively.

an implanted pacemaker were excluded. Thirty consecutive patients underwent routine transesophageal echocardiographic examinations as part of another study of postoperative left ventricular function after aortic or mitral valve replacement. The other 17 patients were consecutive patients referred for further evaluation of clinical findings suggesting incompetence of an implanted artificial valve. Ethical committee approval was given by the relevant hospital committee and informed written consent was obtained from each patient.

The mean age of the patients was 52 years (range 27 to 76). Forty patients had single-valve replacement (25 aortic valve prostheses, 15 mitral valve prostheses), 6 had replacement of both aortic and mitral valves and 1 had replacement of aortic, mitral and tricuspid valves. Valve types are shown in Table 1. Eleven patients with 13 valve prostheses underwent reoperation with surgical confirmation of imaging findings.

The median time interval between gradient echo NMR imaging and transesophageal echocardiography was 8 days (range 1 to 138); 92% of patients were examined within 2 weeks. There was no change in the clinical status of any patient during the interval between examinations. One observer, experienced in interpreting NMR images, reviewed all NMR examinations without knowledge of the results of the other observer, who was experienced in the interpretation of transesophageal echocardiographic images and reviewed those examinations.

Gradient echo NMR imaging. Gradient echo NMR imaging was performed with a 1.5-tesla superconducting magnet (Gyroscan S 15, Philips). The gradient echo technique employed low flip angles of 30° and gradient-refocused echoes with an echo time (TE) of 12 ms and a repetition time (TR) of 28 ms. The image acquisition was electrocardiographically gated. The acquisition matrix was 128 × 256, with a field of view of 32 cm. For display, the acquisition matrix was interpolated to 256 × 256. Imaging of the heart was performed in transverse planes from the diaphragmatic boundary of the heart to the bifurcation of the pulmonary artery. Two slices were simultaneously scanned with a slice thickness of 8 mm and an interslice gap of 1.6 mm to avoid level interaction. Twelve to 14 tomographic sections were required to encompass the entire heart. Usually two repetitions were averaged.

In patients with a mitral valve prosthesis, additional oblique sagittal planes were obtained to avoid uncertainties due to partial volume effects at the inferior and superior borders of the valve ring. Patients with an aortic valve prosthesis had additional oblique coronal sections obtained through the valve for the same reason. Imaging time was about 60 min.

Transesophageal echocardiography. For transesophageal two-dimensional color Doppler echocardiography, Vingmed CFM 750 scanning equipment with a monoplane 5-MHz transducer at the tip of the probe was used. The oropharynx was liberally sprayed with aerosolized lidocaine 5 min before the procedure. No other medication was given. The examination was performed with the patient in the right lateral decubitus position. After lubricating the distal part of the echoscope with lidocaine jelly, the probe was introduced into the esophagus. Imaging planes included the basal short-axis view, the four-chamber view and the transgastric short-axis view (17). For each color Doppler examination, care was taken to use an optimal gain setting, which was defined as the maximal gain level possible without introduction of signals outside flow areas or onto tissue from an adjoining chamber. The nonuniformity of velocities in one pixel (turbulent flow) was displayed by the addition of green to each color, giving a multicolored mosaic pattern.

Image analysis. For gradient echo NMR imaging, time frames of each section of the heart were displayed on a computer monitor in an endless cine loop to evaluate changes in blood pool intensity during the cardiac cycle. Mitral regurgitation was judged to be present when a signal void emanated from the mitral valve prosthesis into the left atrium during ventricular systole. Aortic regurgitation was identified by the appearance of a signal void extending from the aortic valve prosthesis into the left ventricular chamber during ventricular diastole. The origin, shape, direction and extension of the signal void within the respective cardiac chamber were noted throughout the cardiac cycle. The transverse image that showed the largest signal loss was used for measurement of the [illegible] void area. When there was more than one reflux jet [illegible] the transverse plane, the reflux jet areas were added. A software program for computerized planimetry, already incorporated into the scanning equipment, was used.

Color Doppler flow sequences were documented on videotape (VHS recorder) for further analysis. The origin and spatial distribution of the reflux jet in the valve prosthesis were noted. The maximal jet length and jet area of turbulent regurgitant flow were calculated by outlining the regurgitant signals with a trackball cursor and measuring the area by computerized planimetry. Because one central and two side orifices are present in bileaflet prostheses and two orifices in tilting disc prostheses, up to three physiologic reflux jets can be detected by transesophageal echocardiography. When

Table 2. Evaluation of Regurgitant Flow by Nuclear Magnetic Resonance (NMR) and Transesophageal Color Doppler (TEE) Imaging in 55 Prostheses

	NMR		
	Normal	Pathologic	NDP
TEE			
Normal	33	1	—
Pathologic	—	20	—
NDP	—	1	—

NDP = no distinction possible.

Table 4. Pathologic Reflux Patterns in 20 Aortic and Mitral Valve Prostheses by Nuclear Magnetic Resonance (NMR) and Transesophageal Color Doppler (TEE) Imaging

	NMR		
	Paravalvular	Transvalvular	NDP
TEE			
Paravalvular	10	4	—
Transvalvular	—	4	—
NDP	—	2	—

NDP = no distinction possible.

more than one reflux jet was visible in the transverse plane, the reflux jet areas were added. Portions of the regurgitant jet showing nonaliased color representation were excluded.

Definitions. Regurgitant flow in cardiac valve prostheses identified by both gradient echo NMR imaging and color Doppler transesophageal echocardiography was classified by using the following definitions.

No regurgitation was defined as the absence of any turbulent reflux. *Transvalvular regurgitation* in which the jet originated from inside the valve ring was considered to be physiologic if the turbulent jet area was <2.5 cm^2 (mild regurgitation). Both findings were classified as normal.

A pathologic regurgitant jet was assumed to be present if the turbulent jet area was >2.5 cm^2. A jet area <5 cm^2 was defined as moderate regurgitation and an area >5 cm^2 as severe regurgitation (3,5).

A pathologic transvalvular regurgitant jet originated near the central part of the valve artifact (gradient echo NMR imaging) or inside the rim of the valve prosthesis (color Doppler transesophageal echocardiography) as defined by a forward flow pattern.

Paravalvular leakage was thought to be present if the jet originated laterally from the valve artifact (gradient echo NMR imaging) or laterally to the valve ring (color Doppler transesophageal echocardiography). This finding was always judged to be pathologic, but turbulent reflux areas <2.5 cm^2 were not considered to be hemodynamically important.

Table 3. Normal Regurgitant Flow Findings in 33 Cardiac Valve Prostheses by Nuclear Magnetic Resonance (NMR) and Transesophageal Color Doppler (TEE) Imaging

	NMR		
	No Reflux	Physiologic Reflux	NDP
TEE			
No reflux	6	4	—
Physiologic reflux	6	17	—
NDP	—	—	—

NDP = no distinction possible.

Results

All NMR and transesophageal echocardiographic examinations were performed without complications and were well tolerated.

Qualitative Analysis

NMR imaging versus echocardiography (Table 2). There were identical diagnoses of "normal" and "pathologic" with both techniques in 53 valve prostheses. In one patient with aortic valve replacement, NMR imaging showed pathologic moderate transvalvular regurgitation, even though the regurgitant jet seemed to be physiologic in transesophageal echocardiographic images. In another patient with combined aortic and mitral valve replacement, NMR imaging demonstrated pathologic moderate transvalvular aortic regurgitation that was not seen by transesophageal echocardiography because of acoustic shadowing and reverberations caused by the mitral prosthesis. Surgical confirmation was not available in these two patients.

Normal findings (Table 3). Thirty-three valve prostheses appeared normal by both techniques. In six prostheses, no reflux jet was visible. Seventeen prostheses showed a physiologic regurgitant flow (Fig. 1 and 2). In four aortic valve prostheses, NMR showed physiologic regurgitant flow that was not seen by transesophageal echocardiography. Conversely, transesophageal echocardiography documented physiologic reflux seen by NMR imaging in five aortic valve prostheses and one mitral valve prosthesis.

Pathologic findings (Table 4). These were observed by both techniques in 20 valve prostheses. Ten regurgitant jets were judged by both techniques as paravalvular (Fig. 3 and 4) and four as transvalvular. All discrepant findings were related to jet origin and occurred in aortic valve prostheses. In four aortic valve prostheses, NMR imaging depicted a pathologic transvalvular reflux that seemed to be paravalvular on transesophageal echocardiographic images (Fig. 5 and 6). In two patients, one with an aortic valve prosthesis and the other with combined aortic and mitral valve prostheses, no distinction between pathologic transvalvular and paravalvular leakage flow was possible by transesophageal echocardiography because of artifacts and flow masking caused by the valve prosthesis, whereas on NMR images pathologic

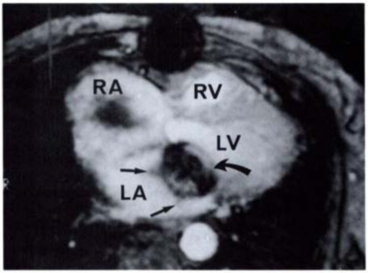


Figure 1. Transverse gradient echo NMR image of a St. Jude Medical mitral valve prosthesis with physiologic regurgitant flow. The blood pool is displayed with a higher signal intensity than that of myocardium. The metallic implant in the mitral position causes image artifacts (curved arrow), but these do not preclude assessment of regurgitation. Two small physiologic reflux jets are visible in this plane (small arrows). LA = left atrium; LV = left ventricle; RA = right atrium; RV = right ventricle.

transvalvular reflux was identified in both aortic valve prostheses.

In contrast to aortic valve prostheses, both techniques showed identical findings of pathologic reflux in mitral valve prostheses. Distinction between paravalvular and transvalvular reflux was possible in all mitral valve prostheses.

Correlation with surgical findings. Eleven patients with 13 valve prostheses (8 aortic and 5 mitral) underwent reoperation because of hemodynamically important lesions of the valve prosthesis itself as judged from the results of cardiac catheterization or because of relevant lesions of another native valve. Identical NMR and transesophageal echocardiographic findings were confirmed at surgery in 11 prosthe-

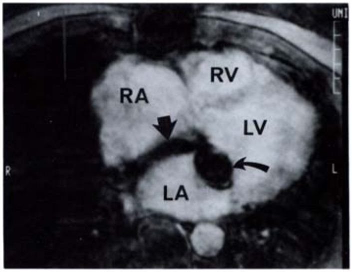


Figure 3. Transverse NMR image from a patient with a mitral valve prosthesis and pathologic paravalvular leakage. The eccentric leakage flow (wide arrow) originated laterally from the valve artifact (curved arrow). Abbreviations as in Figure 1.

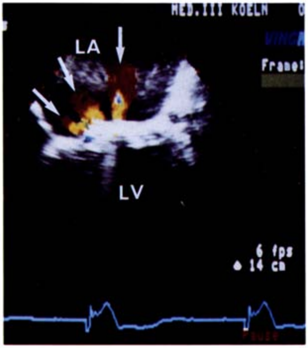


Figure 2. Transverse transesophageal color Doppler image from the same patient as in Figure 1. Because one central and two side orifices are present in a bileaflet prosthesis, three regurgitant jets can be demonstrated (arrows). Turbulent flow is noted only at the origin of the regurgitant jets. The colored jets consist predominantly of red pixels representing laminar flow toward the transducer. Abbreviations as in Figure 1.

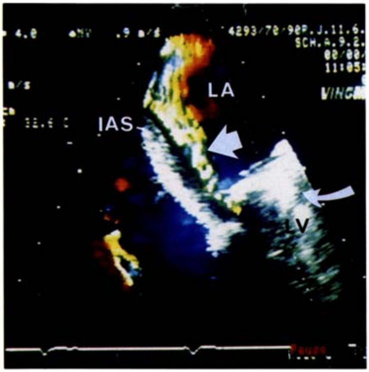


Figure 4. Transverse transesophageal color Doppler image from the same patient as in Figure 3. The severe turbulent reflux jet (wide arrow) in the left atrium (LA) arising from the left ventricle (LV) was identified as paravalvular leakage flow. Curved arrow indicates valve artifact. IAS = interatrial septum.

JACC Vol. 19, No. 7
June 1992:1500–7

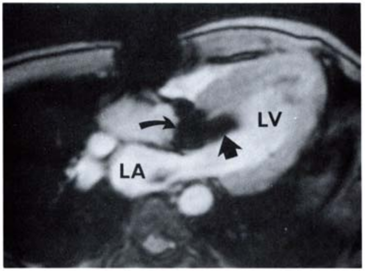
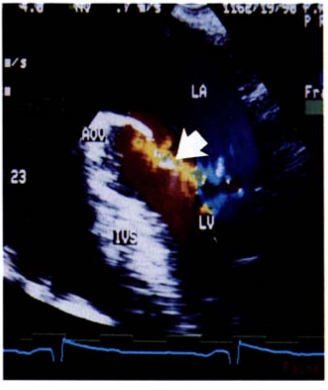


Figure 5. Transverse diastolic NMR image from a patient with an aortic valve prosthesis. The NMR diagnosis is pathologic transvalvular leakage flow because of a large signal void (large arrow) that appears to originate from the center of the valve artifact (curved arrow) and extend into the outflow tract of the left ventricle (LV). LA = left atrium.

ses (normal findings in 3 aortic valve prostheses and 1 mitral valve prosthesis, paravalvular leak in 1 aortic valve prosthesis and 3 mitral valve prostheses, transvalvular leak in 2 aortic valve prostheses and 1 mitral valve prosthesis). In two patients with an aortic valve prosthesis, a paravalvular leak

Figure 6. Transverse transesophageal color Doppler image from the same patient as in Figure 5. The regurgitant jet (arrow) in the left ventricular (LV) outflow tract seems to originate laterally to the valve ring. The color Doppler examination led to the diagnosis of pathologic paravalvular leakage flow. Surgical confirmation was not available. IVS = interventricular septum; LA = left atrium.



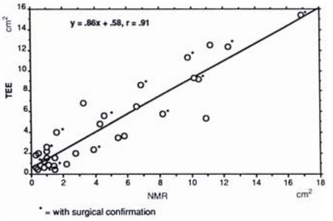


Figure 7. Correlation of leakage flow areas measured by gradient echo nuclear magnetic resonance imaging (NMR) and color Doppler transesophageal echocardiography (TEE).

was documented intraoperatively. In one patient the leak had been correctly diagnosed by transesophageal echocardiography; in the other patient the distinction between pathologic transvalvular and paravalvular reflux was not possible because of reverberations. On NMR images, pathologic reflux seemed to be transvalvular in both cases. Thus, preoperative NMR findings were correct in 11 (85%) of 13 prostheses and transesophageal echocardiographic findings were correct in 12 (92%) of 13 prostheses.

Quantitative Analysis

In 32 of 37 valve prostheses with a physiologic (n = 17) or pathologic (n = 20) reflux pattern detected by both NMR imaging and transesophageal echocardiography, quantification of leakage flow areas was possible by both methods (Fig. 7). By NMR imaging, a small physiologic regurgitant jet visualized in one aortic valve prosthesis and one mitral valve prosthesis could not be quantitated because of low contrast between the jet and blood pool on still frames. Complete measurement of the reflux jet area was not possible on transesophageal echocardiographic images in two aortic valve prostheses, because of acoustic shadowing and reverberations produced by the prosthesis, and in one mitral valve prosthesis, because the regurgitant jet extended beyond the small field of view. In the remaining 13 valve prostheses with physiologic reflux and 19 valve prostheses with pathologic reflux, the reflux jet area could be measured. There was a good correlation between both techniques (r = 0.91). Maximal regurgitant jet length also correlated well (r = 0.85) (Fig. 8).

By transesophageal echocardiography, 16 cases of regurgitation were classified as mild, 4 as moderate and 12 as severe (Table 5). In contrast, NMR imaging classified 15 cases of regurgitation as mild, 5 as moderate and 12 as severe. In 25 (75%) of 32 prostheses, classification of regurgitation was identical with both methods. In seven valve prostheses, the grading differed by a maximum of one grade, especially when regurgitation was judged as moderate. Nu-

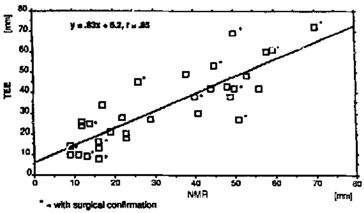


Figure 8. Correlation of the maximum regurgitant jet length by gradient echo nuclear magnetic resonance imaging (NMR) and color Doppler transesophageal echocardiography (TEE).

clear magnetic resonance imaging overestimated or underestimated transesophageal echocardiographic findings in four and three cases, respectively.

Discussion

Echocardiographic evaluation of prosthetic valve function. Color Doppler transesophageal echocardiography provides reliable diagnostic information about prosthetic valve function (18). A semiquantitative grading of regurgitant flow in valve prostheses by color Doppler transesophageal echocardiography based on jet length and jet area correlates reasonably well with angiographic gradings, especially in mitral valve prostheses (3). In aortic valve prostheses, color Doppler transesophageal echocardiography can underestimate reflux areas in comparison with transthoracic color Doppler echocardiographic findings (6) because of the interposition of the valve between the transducer and the regurgitant jet. The differentiation of transvalvular and paravalvular regurgitation in aortic valve prostheses is better with color Doppler transesophageal echocardiography than with color Doppler transthoracic echocardiography but is not possible in all patients (5). Because of the high image quality, color Doppler transesophageal echocardiography is widely used in clinical practice. However, transesophageal echocardiography is semi-invasive and an alternative technique with a similar diagnostic yield might be useful in some patients.

Table 5. Grading of Regurgitant Flow in 32 Prosthetic Valves by Nuclear Magnetic Resonance (NMR) and Transesophageal Color Doppler (TEE) Imaging

	NMR		
	Physiologic	Moderate	Severe
TEE			
Physiologic	14	2	—
Moderate	1	1	2
Severe	—	2	10

Comparison with NMR imaging. In the present study, the diagnostic value of gradient echo NMR imaging was defined in 55 valve prostheses and compared with that of color Doppler transesophageal echocardiography. Gradient echo NMR imaging had a similar sensitivity in detecting regurgitant jets and showed some regurgitant flow in 78% of the valve prostheses examined, whereas color Doppler transesophageal echocardiography documented reflux jets in 82% of the valve prostheses. There was an agreement of 96% between both methods in the distinction between normal valve prostheses (no reflux or physiologic reflux) and valve prostheses with pathologic leakage flow.

Jet shape and area. The shape of the regurgitant flow on NMR and transesophageal echocardiographic images was similar. Physiologic regurgitation was assumed when only a small area of signal void was found on NMR images and when turbulent flow was present only at the origin of short and narrow reflux jets on correlative transesophageal echocardiographic images. The presence of multiple small reflux jets was another indicator of physiologic regurgitant flow. Transesophageal echocardiographic and NMR findings of physiologic regurgitant flow were confirmed intraoperatively in four patients who underwent reoperation because of a relevant lesion of another native valve. The area of turbulent regurgitant flow on NMR and transesophageal echocardiographic images was <2.5 cm^2 (3,5). Severe pathologic regurgitation was demonstrated by a large area of high signal loss on NMR images and by a large area (>5 cm^2) with a multicolored mosaic pattern on transesophageal echocardiographic images. These findings were corroborated intraoperatively in seven patients with hemodynamically important lesions of the valve prostheses.

Localization of the jet origin. Pathologic transvalvular or paravalvular leakage flow in mitral valve prostheses was clearly differentiated by NMR imaging and transesophageal echocardiography and later confirmed by surgical findings. Identification of the origin of pathologic leakage flow in aortic valve prostheses remained a diagnostic problem with both techniques. Findings by NMR imaging of a transvalvular reflux in four aortic valve prostheses were judged to be paravalvular by transesophageal echocardiography. Two of these patients underwent reoperation and there was surgical confirmation of a paravalvular leak. In contrast, no distinction between transvalvular and paravalvular regurgitation was possible by transesophageal echocardiography in two prostheses. One reason for the difficulty in defining the origin of regurgitant flow in aortic valve prostheses by both methods is the anatomic configuration of the left ventricular outflow tract. The narrow left ventricular outflow tract leaves no space for the regurgitant jet to follow a straight course but may alter jet direction immediately behind the jet origin. Therefore, the position of the jet relative to the valve may be misleading. The metallic artifacts on NMR images further complicate identification of the exact jet origin, which is usually covered by the artifact. A coronal angulated NMR imaging plane parallel to the flow

JACC Vol. 19, No. 7
June 1992:1500–7

direction of the regurgitant jet was not helpful in defining the jet origin.

Difficulties with monoplane transesophageal echocardiography include partial shadowing of the jet by the aortic valve ring, reverberations, restricted imaging planes and a less favorable Doppler angle to flow within the left ventricular outflow tract (close to 90°). Biplane transesophageal echocardiography may be helpful to further improve localization of reflux jet origin (19,20). In two patients with both aortic and mitral valve prostheses, NMR imaging had the potential to demonstrate aortic reflux, whereas color Doppler transesophageal echocardiography was limited because of acoustic shadowing and reverberations caused by the aortic and mitral valve prostheses. However, transthoracic color Doppler echocardiography provided results similar to those with NMR imaging in these patients.

Quantification of regurgitation. Quantification of leakage flow areas showed a good correlation ($r = 0.91$) between both flow-sensitive methods, although entirely different physical principles of image formation were used. By NMR imaging, only very small physiologic regurgitant jet areas could not be quantitated because of the valve artifact and the low contrast between the jet and the blood pool on still frames. On transesophageal echocardiographic images, complete measurement of the regurgitant jet area was not possible when the reflux jet extended beyond the limited field of view or when there was acoustic shadowing. Nuclear magnetic resonance imaging has the advantage of an unlimited field of view, thus facilitating the display of the entire regurgitant jet. Image artifacts caused by the metallic implant do not preclude assessment of the presence and severity of regurgitation by NMR imaging. Our findings support reports (21) that the maximal area of regurgitant flow measured in transverse images by gradient echo NMR imaging and color Doppler transesophageal imaging is a clinically useful indicator of the severity of valvular regurgitation. However, precise determination of regurgitant volumes cannot be made by measuring jet areas on NMR or transesophageal echocardiographic images (22).

Limitations. One possible limitation of the study is the preponderance of patients with mild and severe regurgitation in comparison with patients with moderate regurgitation. This distribution of severity was likely caused by our patient selection (routine postoperative cases and patients with a clinical suspicion of valve dysfunction). Therefore, it cannot be excluded that the correlation of area measurements between the two techniques was falsely improved by comparing mainly extreme cases.

Clinical consequences. The present study indicates that gradient echo NMR imaging can be used to detect regurgitant flow and define the jet origin in mitral valve prostheses with a diagnostic accuracy similar to that of color Doppler transesophageal echocardiography, whereas localization of the jet origin is often uncertain in aortic valve prostheses. The severity of regurgitation can be graded in a way similar to that used with color Doppler transesophageal echocardiography. In contrast to transesophageal echocardiography, however, opening function and structural abnormalities of valve prostheses (such as vegetations, thrombus formation, fibrous ingrowth, leaflet thickening and prolapse or flail motion of tissue valves) cannot be evaluated by NMR imaging because valvular structures are covered by the metallic artifact.

Other limitations of NMR imaging include the inability to evaluate critically ill patients and the immobility of the equipment. Furthermore, NMR examinations are more time-consuming (60 vs. 20 min) and more expensive ($750 vs. $150 in US currency [the fee charged in Germany]). Therefore, the clinical role of NMR imaging in the evaluation of patients with incompetent valve prostheses will be limited to those who cannot adequately be examined by transthoracic and transesophageal echocardiography.

References

1. Fisher J, Reece IJ, Wheatley DJ. In vitro evaluation of six mechanical and six bioprosthetic valves. Thorac Cardiovasc Surg 1986;34:157–62.
2. Rashtian MY, Stevenson DM, Allen DT, et al. Flow characteristics of four commonly used mechanical heart valves. Am J Cardiol 1986;58:743–52.
3. Nellessen U, Schnittger I, Appleton CP, et al. Transesophageal two-dimensional echocardiography and color Doppler flow velocity mapping in the evaluation of cardiac valve prostheses. Circulation 1988;78:848–55.
4. Khandheria BK, Seward JB, Oh JK, et al. Value and limitations of transesophageal echocardiography in assessment of mitral valve prostheses. Circulation 1991;83:1956–68.
5. Mohr-Kahaly S, Kupferwasser I, Erbel R, Todt M, Oelert H, Meyer J. Transesophageal evaluation of aortic valve prostheses. In: Erbel R, Khandheria BK, Brennecke R, Meyer J, Seward JB, Tajik AJ, eds. Transesophageal Echocardiography. Berlin, Heidelberg: Springer-Verlag, 1989:183–90.
6. Mohr-Kahaly S, Kupferwasser I, Erbel R, Oelert H, Meyer J. Regurgitant flow in apparently normal valve prostheses: improved detection and semiquantitative analysis by transesophageal two-dimensional color-coded Doppler echocardiography. J Am Soc Echocardiogr 1990;3:187–95.
7. Sprecher DL, Adamick R, Adams D, Kisslo J. In vitro color flow, pulsed and continuous wave Doppler ultrasound masking of flow by prosthetic valves. J Am Coll Cardiol 1987;9:1306–10.
8. Soulen RL, Budinger TF, Higgins CB. Magnetic resonance imaging of prosthetic heart valves. Radiology 1985;154:705–7.
9. Randall PA, Kohman LJ, Scalzetti EM, Szeverenyi NM, Panicek DM. Magnetic resonance imaging of prosthetic cardiac valves in vitro and in vivo. Am J Cardiol 1988;62:973–6.
10. Schiebler M, Axel L, Reichek N, et al. Correlation of cine MR imaging with two-dimensional pulsed Doppler echocardiography in valvular insufficiency. J Comput Assist Tomogr 1987;11:627–32.
11. Sechtem U, Pflugfelder P, Cassidy MM, et al. Mitral and aortic regurgitation: quantification of regurgitant volumes with cine MR imaging. Radiology 1988;167:425–30.
12. Utz JA, Herfkens RJ, Heinsimer JA, Shimakawa A, Glover G, Pelc N. Valvular regurgitation: dynamic MR imaging. Radiology 1988;168:91–4.
13. Nishimura T, Yamada N, Itoh A, Miyatake K. Cine MR imaging in mitral regurgitation: comparison with color Doppler flow imaging. AJR 1989;153:721–4.
14. Pflugfelder PW, Sechtem U, White RD, Cassidy MM, Schiller NB, Higgins CB. Noninvasive evaluation of mitral regurgitation by analysis of left atrial signal loss in cine magnetic resonance. Am Heart J 1989;117:1113–9.
15. Pflugfelder PW, Landzberg JS, Cassidy MM, et al. Comparison of cine

MR imaging with Doppler echocardiography for the evaluation of aortic regurgitation. AJR 1989:152:729–35.

16. Evans AJ, Hedlund LW, Herfkens RJ. A cardiac phantom and pulsatile flow pump for magnetic resonance imaging studies. Invest Radiol 1988; 23:579–83.
17. Seward JB, Khandheria BK, Oh JK, et al. Transesophageal echocardiography: technique, anatomic correlations, implementation, and clinical applications. Mayo Clin Proc 1988;63:649–80.
18. Daniel LB, Grigg LE, Weisel RD, Rakowski H. Comparison of transthoracic and transesophageal assessment of prosthetic valve dysfunction. Echocardiography 1990;7:83–95.
19. Seward JB, Khandheria BK, Edwards WD, Oh JK, Freeman WK, Tajik AJ. Biplanar transesophageal echocardiography: anatomic correlations, image orientation, and clinical applications. Mayo Clin Proc 1990;65: 1193–213.
20. Curtius JM, Leischik R, Arnold G, Sander C, Deutsch HJ. Biplane transesophageal echocardiography: anatomical orientation and suggestions for standard planes. Am J Noninvas Cardiol 1991;5:65–71.
21. Kapur KK, Fan P, Nanda NC, Yoganathan AP, Goyal RG. Doppler color flow mapping in the evaluation of prosthetic mitral and aortic valve function. J Am Coll Cardiol 1989;13:1561–71.
22. Suzuki J, Caputo GR, Kondo C, Higgins CB. Cine MR imaging of valvular heart disease: display and imaging parameters affect the size of the signal void caused by valvular regurgitation. AJR 1990:155:723–7.