MAGNETIC RESONANCE IMAGING AND DISCOGRAPHY IN THE DIAGNOSIS OF DISC DEGENERATION

A COMPARATIVE STUDY OF 50 DISCS

M. J. GIBSON, J. BUCKLEY, R. MAWHINNEY, R. C. MULHOLLAND, B. S. WORTHINGTON

From Harlow Wood Orthopaedic Hospital and University Hospital, Nottingham

The lumbar spines of 22 patients were examined for disc degeneration by magnetic resonance imaging (MRI) and by discography. The results from 50 intervertebral discs visualised by both techniques were independently assessed and graded on a five-point scale from normality to gross degeneration and then compared.

In 44 discs the results agreed. Of the six discs which gave differing results, four discrepancies were due to observer error and two to incorrect placement of the discographic needle. MRI was shown to be more accurate than discography in the diagnosis of disc degeneration. It has several major advantages, which should make it the investigation of choice.

In the investigation of patients with mechanical back pain or those under consideration for spinal fusion, discography has, until recently, been the best investigation to decide whether an intervertebral disc is normal or abnormal (Feinberg 1964; Gresham and Miller 1969; Simmons and Segil 1975). Magnetic resonance imaging (MRI) of the spine is a new technique which offers an alternative method of obtaining this information. Modic and Weinstein (1984) and Han, Benson and Yoon (1984) have reported that disc degeneration can be demonstrated by using the spin echo technique with long echo delay (T_1) and radio frequency pulse intervals (T_R). With this imaging sequence, normal intervertebral discs show a bright clear signal from the nucleus pulposus, and there is no signal from the annulus fibrosus. Disc degeneration is shown by a change in the signal from the nucleus pulposus to give an irregular outline and a reduction in signal intensity.

An earlier study of MRI from Nottingham (Crawshaw *et al.* 1985), on the diagnosis of lateral canal stenosis, included five patients in whom discography had been performed at a total of 14 intervertebral levels. A marked similarity was noted between the appearances of the discs imaged by both techniques, and this led to the present

formal comparison of MRI and discography in the diagnosis of disc degeneration.

MATERIAL AND METHODS

A total of 22 patients under investigation for mechanical back pain or with a view to a spinal fusion were studied. There were 11 women and 11 men, with a mean age of 38 years (range 20 to 61 years). MRI demonstrated at least the lower four lumbar intervertebral discs in all cases, and often more. Only the lower four levels were considered in this study. Discography was attempted at 53 levels, and successfully performed at 50 levels. At least two intervertebral discs were demonstrated in every patient.

The MRI scans were all performed on the same unit, a Picker International 0.15 tesla-resistive magnet machine. The imaging sequence used was T_R 2000 ms/ T_E 80ms, which is T_2 -weighted and highlights the signal from the nucleus pulposus. The images were taken in the sagittal and parasagittal planes across the nucleus pulposus, with a slice thickness for each section of 1 cm. The MRI scans were reported independently without knowledge of the results of other investigations. For the purposes of this comparison, degeneration was graded according to a five-point scale, ranging from 0 = normal to 4 = total loss of nuclear signal.

Discography was performed on sedated patients, under local anaesthesia. The posterolateral approach was used to insert 21-gauge, 125 mm spinal needles (McCulloch and Waddell 1978). If there was difficulty or doubt concerning the correct position of the needle, a multi-hole 26-gauge needle (Quinnell and Stockdale 1980), curved if appropriate, was railroaded through the larger needle into the correct position. The contrast

M. J. Gibson, FRCS, Spinal Research Fellow
R. C. Mulholland, FRCS, Director, Spinal Research Unit
Harlow Wood Orthopaedic Hospital, Near Mansfield, Nottinghamshire NG18 4TH, England.

J. Buckley, MRCP, FRCR, NMR Research Fellow
R. Mawhinney, FRCR, Lecturer, Department of Radiology
B. S. Worthington, FRCR, Professor of Radiology
University Hospital, Queen's Medical Centre, Clifton Boulevard, Nottingham NG7 2UH, England.

Requests for reprints should be sent to Mr M. J. Gibson.

© 1986 British Editorial Society of Bone and Joint Surgery
0301 620X/86 3086 \$2.00

Fig. 1

Fig. 2

Fig. 3

Figures 1, 2 and 3—Images of lumbar spine showing normal discs at L3-4 and L4-5 levels, and Grade 3 (moderate) degenerative change at the L5-S1 level. Figures 1 and 2—Anteroposterior and lateral discographic views; the L5-S1 disc shows on the original lateral film. Figure 3—Sagittal MRI scan.

Fig. 4

Fig. 5

Figures 4 and 5—Lumbar spine showing a normal disc at L3-4, and degenerative changes at L4-5 and L5-S1 levels. Figure 4—Lateral discogram showing moderate degeneration at the L4-5 level, with a leak of contrast material. The L5-S1 disc could not be demonstrated. Figure 5—MRI scan confirming the abnormality at L4-5 and showing a degenerate disc at L5-S1.

Figures 6, 7 and 8—The discograms show an apparently "normal" disc at L3-4, an artefact produced by incorrect placement of the needle. The MRI scan shows Grade 2 degeneration at L3-4 level, a degenerative disc at L4-5 and a normal disc at L5-S1.

Fig. 6

Fig. 7

Fig. 8

Fig. 9

Fig. 10

Fig. 11

The discograms show a large leak of contrast material from the L5-S1 disc, suggestive of disc herniation. The MRI scan shows a minor reduction in signal intensity with a curious hole in the image of the nucleus pulposus which was seen on all the sections made at this level. In this type of case the discogram shows the abnormality more dramatically than the MRI scan.

medium was either Niopam 200 or Niopam 300 (E. Merck Ltd.). The result of the MRI, if this had already been done, was not known to the discographer.

At discography the following were recorded:

1. The resistance to injection; that is, whether the disc showed a high or a low pressure.
2. The pattern shown by the nucleus pulposus.
3. Any symptoms produced by the injection.

The results of discography were then graded 0 to 4 on a scale similar to that used for the MRI results.

RESULTS

In 17 patients, that is in 44 of the 50 discs demonstrated by both techniques, the findings were in complete agreement (Table I). The internal architecture of the disc, shown in the sagittal plane on MRI and in the lateral discographic view, was strikingly similar (Figs 1 to 11).

In six discs the findings from the two investigations were different (Table I and II). In four of these discs the difference was probably related to observer error in interpretation. In three of these four the discograms were initially reported to be normal but on re-examination minor lateral fissuring was found. This is probably one of the earliest signs of degeneration and was reflected in the MRI scan by an irregularity in the normally smooth nuclear outline and a minor decrease in signal intensity. In the fourth case the discogram was reported to show early disc degeneration while the MRI scan was considered to be normal.

In the other two discs which gave conflicting results a failure of correct placement of the needle accounted for the discrepancy. In both cases the needle was probably

Table I. Numbers of discs diagnosed as normal (Grade 0) or in Grades 1 to 4 of degeneration by MRI and by discography

Investigation	Normal discs		Degenerative discs			
	Grade 0	Total	Grade 1 (minor)	Grade 2	Grade 3	Grade 4 (gross)
MRI	22	28	3	9	12	4
Discography	25	25	2	7	12	4

Table II. Details of the six cases with discrepancies between MRI and discography in the assessment of lumbar disc degeneration

Level	Discography	MRI	Reason for discrepancy
L4-5	Normal (lateral fissuring present)	Grade 2 (moderate degeneration)	Error of interpretation
L5-S1	Normal (lateral fissuring present)	Grade 1 (early degeneration)	Error of interpretation
L3-4	Normal (lateral fissuring present)	Grade 1 (early degeneration)	Error of interpretation
L2-3	Grade 1 (early degeneration)	Normal	Error of interpretation
L3-4	Normal but not valid	Grade 2 (moderate degeneration)	Incorrect needle placement
L3-4	Normal but not valid	Normal	Incorrect needle placement

inside the annulus but outside the nuclear cavity. In one case this gave a result which was interpreted as normal; the MRI scan showed moderate disc degeneration. In the other case both findings were first reported as normal but re-examination of the discogram revealed the failure of needle placement, which invalidated that result.

There was failure to demonstrate a disc by discography at three levels, so that the 50 reported results derived from 53 attempts. In two of these failures it proved impossible to enter the L5-S1 disc space, while in the third the patient was unable to tolerate another needle puncture after the L3-4 and L4-5 discs had been entered, and no attempt was made at the L5-S1 level.

In seven patients the MRI scans showed unsuspected disc degeneration at levels in the lumbar spine other than those which had been examined by discography and at which there was no reason to suspect degeneration, either on clinical grounds or from radiographic disc space narrowing, traction spurs or other abnormalities. A leak of contrast from the disc on discography was demonstrated at five levels, giving a dramatic appearance and a "low pressure" disc which had little resistance to injection. The MRI scans of these discs confirmed an abnormality but showed only minor to moderate degeneration. Similar MRI scans were obtained from two levels at which operative discectomies had been performed. A nuclear signal, albeit an abnormal one, was still present and was recorded as showing a moderate degree of disc degeneration.

Symptoms of back or leg pain or both were reproduced during discography in six patients. This was difficult to interpret because the patients had been sedated.

The results were analysed by non-parametric statistical testing using the sign test. The total number of discs considered was 53 (all the discs in which discography should have been performed). At nine intervertebral levels the results disagreed or one of the techniques failed. In eight of these the error could be attributed to discography, while in only one case was there an error in interpretation of the MRI scan. This difference in incidence of error was weakly significant in favour of MRI at a *P* value of 0.04.

DISCUSSION

Our results show excellent correlation between the two techniques at levels demonstrated by both, with only six differences in 50 discs, four of which were due to observer error. Significant differences between the results were seen only after technical failure of the discography. Some failure is to be expected as discography is a complex technique relying on the skill of the investigator and on subjective interpretation. The two main technical errors were failure of insertion in two discs, and incorrect positioning in another two. These may give a normal appearance in an abnormal disc (Quinnell and Stockdale 1980), which might have been avoided by the use of multi-holed needles at all levels.

Discography cannot reveal unsuspected disc disease at other levels in the lumbar spine; these were revealed by MRI in almost one-third of our patients. Discography at more levels would reveal more degeneration but this makes the investigation longer, more unpleasant for the patient and also increases its potential hazards. Our

policy has been to perform discography only at levels where abnormality was suspected, and at the levels above and below this if operation for spinal fusion was planned.

The recognition of degeneration at any level in the spine does not necessarily prove that symptoms arise from that level. Therefore the reproduction of symptoms by discography should be one of its main advantages in helping with localisation. Unfortunately this does not seem to be a particularly reliable sign and in a patient under sedation it can be difficult to interpret.

Another situation in which discography gave more graphic results than MRI was when a discographic leak of contrast was present. Such a leak of contrast medium is not diagnostic of disc herniation, it can occur in a grossly degenerate disc; but when it is seen in a disc which is otherwise relatively normal, this is highly suggestive of a disc prolapse (Erlacher 1952). MRI consistently showed an abnormal nuclear signal from this type of disc, but this was often non-specific, similar to that seen from a degenerative disc, and did not localise the herniation.

In contrast to discography, MRI of the lumbar spine was simple to perform and relatively easy to interpret. Interpretation was helped by the double change in image, degeneration being shown both by alteration in shape of the nucleus pulposus and by reduction in the signal intensity. MRI also has a major theoretical advantage. The imaging sequence used is *T2*-weighted and should be sensitive to changes in water content. Thus it is probable that the brilliant signal on the spin echo sequence produced by the normal nucleus pulposus is due to its high water content. The changes seen in degenerate discs probably reflect the loss of water which is known to occur (Püschel 1930; Hirsch *et al.* 1952; Naylor and Horton 1955; Gower and Pedrini 1969). Since a normal disc functions in a hydrostatic manner (Virgin 1951; Nachemson 1960), an investigation that provides information about the water content of the nucleus pulposus is of great interest and potential value.

The main disadvantage of MRI was the absence of a view equivalent to an anteroposterior radiograph. Coronal MRI sections would provide similar information, but because of the lumbar lordosis a different set of sections would be needed at each intervertebral level. This was not feasible in our study, but in other circumstances a coronal section could be obtained of single specified levels. Serial sagittal and parasagittal sections across the disc did give some information on the three-dimensional shape of the nucleus pulposus.

Conclusions. This study has shown that MRI produces an image of the nucleus pulposus which is comparable in shape to that produced by discography. In the diagnosis of disc degeneration MRI has also been shown to be at least as accurate as discography and probably more so.

It has several major advantages: it is non-invasive and thus safer and less unpleasant for the patient; there is

no exposure to ionising radiation; it is simple to perform and easy to interpret, so there is less risk of observer error; and it provides information on the state of all lumbar discs at a single investigation.

We believe that MRI will become the most useful single investigation to determine the stage of disc

degeneration. Discography may still have a role as a "pain reproduction test" in selected cases.

We would like to thank Dr John Williams and Dr Gordon Higson for their continued advice and encouragement, Mr S. Chipperfield, the Superintendent Radiographer in the MRI unit, and Mrs S. Bawamia for helping with the preparation of the manuscript.

REFERENCES

- Crawshaw C, Kean DM, Mulholland RC, *et al.* The use of nuclear magnetic resonance in the diagnosis of lateral canal entrapment. *J Bone Joint Surg [Br]* 1984;**66-B**:711-5.
- Erlacher PR. Nucleography. *J Bone Joint Surg [Br]* 1952;**34-B**:204-10.
- Eyring EJ. The biochemistry and physiology of the intervertebral disk. *Clin Orthop* 1969;**67**:16-28.
- Feinberg SB. The place of diskography in radiology as based on 2,320 cases. *AJR* 1964;**92**:1275-81.
- Gower WE, Pedrini V. Age-related variations in protein-polysaccharides from human nucleus pulposus, annulus fibrosus, and costal cartilage. *J Bone Joint Surg [Am]* 1969;**51-A**:1154-62.
- Gresham JL, Miller R. Evaluation of the lumbar spine by diskography and its use in selection of proper treatment of the herniated disk syndrome. *Clin Orthop* 1969;**67**:29-41.
- Han JS, Benson JE, Yoon YS. Magnetic resonance imaging in the spinal column and craniovertebral junction. *Radiol Clin North Am* 1984;**22**(4):805-27.
- Hirsch C, Paulson S, Sylvén B, Snellman O. Biophysical and physiological investigations on cartilage and other mesenchymal tissues. VI. Characteristics of human nuclei pulposi during ageing. *Acta Orthop Scand* 1952;**22**:175-83.
- McCulloch JA, Waddell G. Lateral lumbar discography. *Br J Radiol* 1978;**51**:498-502.
- Modic MT, Weinstein MA. Nuclear magnetic resonance of the spine. *Br Med Bull* 1984;**40**:183-6.
- Nachemson A. Lumbar intradiscal pressure: experimental studies on post-mortem material. *Acta Orthop Scand* 1960;Suppl 43:1-104.
- Naylor A, Horton WG. Hydrophilic properties of the nucleus pulposus of the intervertebral disc. *Rheumatism* 1955;**11**:32-5.
- Püschel J. Der Wassergehalt normaler und degenerierter Zwischenwirbelscheiben. *Beitr Pathol Anat* 1930;**84**:123-30.
- Quinnel RC, Stockdale HR. An investigation of artefacts in lumbar discography. *Br J Radiol* 1980;**53**:831-9.
- Simmons EH, Segil CM. An evaluation of discography in the localization of symptomatic levels in discogenic disease of the spine. *Clin Orthop* 1975;**108**:57-69.
- Virgin WJ. Experimental investigations into the physical properties of the intervertebral disc. *J Bone Joint Surg [Br]* 1951;**33-B**:607-11.