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Guidelines for the performance of fusion procedures for degenerative disease of the lumbar spine. Part 6: magnetic resonance imaging and discography for patient selection for lumbar fusion

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Recommendations

Standards. There is insufficient evidence to recommend a treatment standard.

Guidelines. 1) It is recommended that MR imaging be used as a diagnostic test instead of discography for the initial evaluation of patients with chronic low-back pain. 2) It is recommended that MR imaging–documented disc spaces that appear to be normal not be considered for treatment as a source of low-back pain. 3) It is recommended that lumbar discography not be used as a stand-alone test on which treatment decisions are based for patients with low-back pain. 4) If discography is performed as a diagnostic tool to identify the source of a patient's low-back pain, it is recommended that both a concordant pain response and morphological abnormalities be present at the pathological level prior to initiating any treatment directed at that level.

Options. 1) It is recommended that discography be reserved for use in patients with equivocal MR imaging findings, especially at levels adjacent to clearly pathological levels. 2) It is recommended that patients in whom discography is positive but in whom MR imaging evidence of disc degeneration is absent not be considered candidates for operative intervention.

Rationale

The successful surgical treatment of patients with low-back pain depends on an accurate diagnosis of the source of pain. In the absence of gross deformity or neural compression, the diagnosis of "discogenic" low-back pain may be established using diagnostic imaging and functional studies. Discography has been used as a diagnostic tool for the evaluation of patients with low-back pain with normal spinal alignment and without evidence of neural compression. The purpose of this review is to examine the medical evidence in the literature regarding discography as a diagnostic test for the localization of the source of low-back pain in these patients.

Literature Search

The database of the National Library of Medicine was searched for articles published between 1966 and November 2003. Use of the search terms "discography or discogram" limited to "human" and "English language" resulted in 304 matches. The titles and abstracts of these 304 abstracts were reviewed and duplicates, technical notes, reviews, and other papers that did not describe the use of

Abbreviations used in this paper: CT = computerized tomography; HIZ = high-intensity zone; MR = magnetic resonance; NPV = negative predictive value; PLF = posterolateral fusion; PPV = positive PV.

discography for the diagnosis and management of patients with low-back pain were discarded. The reference lists of the remaining articles were inspected and several more relevant papers were identified. References consisting of clinical series of patients managed with discography were identified and are briefly described in Table 1. A number of other references served as background information and are included in the bibliography.

Scientific Foundation

Discography has been used for decades for the diagnosis of lumbar intervertebral disc abnormalities in patients with low-back pain.[17,32] Currently, discography is the only diagnostic test that has a physiological end point used in the assessment of such patients (that is, the reproduction of concordant low-back pain).[46,60] Proponents of discography argue that the technique is more sensitive for the diagnosis of anatomical disc abnormalities and injuries than plain radiography, myelography, or MR imaging.[5–7,8–10] Critics of discography claim that the test is not specific because morphological abnormalities do not always correlate with clinical complaints and because intradiscography pain provocation occurs in patients with lumbar pain caused by nonspinal entities.[11] Indeed, several studies have demonstrated that severe low-back pain may be elicited by discography in individuals with no prior complaints of low-back pain.[11,13,24] Controversy also exists as to whether discography adds any diagnostic information to the data provided by MR imaging, a sensitive and specific noninvasive test for lumbar disease.[3,6,9,16,20,21,25–27,33,34,36,41,43,45,47,49–51,57]

Several studies have examined the sensitivity, specificity, and predictive value of MR imaging compared with the morphological findings on discography. In a large series of patients Bernard[2] compared MR imaging and discography and reported that the PPV of an abnormal MR image for a morphologically abnormal discogram was 92%. The NPV of a normal MR image in the same series was 88%. Using T_2-weighted MR imaging and discography to treat 101 disc levels, Schneiderman and colleagues[51] reported that MR imaging was 99% accurate in predicting abnormal morphological findings on discography. One group reported complete agreement between abnormal MR imaging findings and stage-two or stage-three disc disruption identified on CT discography (Dallas Pain Questionnaire).[37,46] Separate small studies by Lonergan, et al.,[34] and Gibson, et al.,[20] noted an approximate 90% concordance rate between abnormalities identified on MR imaging and discography. Although discography may, on occasion, identify abnormalities in patients with normal MR imaging findings, the significance of these findings is unclear. Current evidence indicates that MR imaging is a very good imaging tool for the determination of abnormal disc morphology and that it avoids the expense and invasiveness of discography.[19,29,52] For these reasons, lumbar MR imaging is recommended as the neuroimaging study of choice for the evaluation of patients with low-back pain.

The clinical significance of MR imaging– or discography-identified morphological abnormalities of an intervertebral disc has been questioned. Both modalities are sensitive to disc abnormalities. The frequency of disc abnormalities identified by discography is quite high in patients with low-back pain. Grubb, et al.,[22] reported that 78% of patients undergoing discography assessment for low-back pain had morphologically abnormal discs at one or more levels despite normal plain spine radiography and myelography. Similarly, Schwarzer and colleagues[53] described abnormal discographic findings in 39% of 92 patients evaluated for low-back pain. Park, et al.,[42] also noted abnormal discographic findings in patients whose radiological evaluation for low-back pain was otherwise unremarkable. Morphologically abnormal discograms, however, have also been observed in 17 to 37% of asymptomatic patients.[13,24,60]

In an attempt to improve the diagnostic utility of discography, Walsh and associates[60] required that discography result in the production of pain identical or very similar to the patient's usual pain complaints to be considered "positive." The authors also required that this pain response occur in association with demonstrable morphological abnormalities of the disc space in question. The severity of the patient's pain, as determined using a visual analog scale as well as observation of patient behavior, must also be severe (three of five, or six of 10 on the visual analog scale).[14,60] The authors' description of a "positive" discogram has been adopted by most investigators and authors as a "concordant" discogram.

Several comparisons between disc morphology and concordant pain provocation during discography have been performed. These studies have revealed a discrepancy between morphological disc abnormalities and pain perception during discography. Antti-Poika and colleagues[1] reported that 13% of patients they reviewed reported pain on injection of morphologically normal discs. Millette and Melanson[38] reported that only 37% of patients with abnormal disc morphology experienced concordant pain with injection. Five percent of patients reported pain despite the presence of normal morphology.[40] Sachs, et al.,[46] reported a 13% incidence of abnormal disc morphology identified by discography in which concordant pain provocation was absent in their large series. Saifudin, et al.,[48] found that only anular tears could be reliably associated with the provocation of pain during discography and that other degeneration patterns were not necessarily associated with a pain response during injection. These studies indicate that disc morphology, as assessed by discography, does not adequately predict the provocation of symptomatic low-back pain. Therefore, the presence of abnormal discography-documented morphology in the absence of a concordant pain response should not be used to justify intervention at that disc level.

Abnormal disc morphology identified on MR imaging, including loss of T_2 signal intensity, disc space collapse, modic changes, and HIZs, are commonly observed in patients evaluated for low-back pain.[9,43] As with discography, these disc space abnormalities are also seen frequently on imaging studies obtained in asymptomatic patients.[12] The correlation of MR imaging abnormalities and pain provocation during discography has been examined in several series. Linson and Crowe[33] performed a prospective comparison of T_2-weighted MR imaging and discography findings. They found a likelihood ratio of 30 for an abnormal MR image and concordant pain provocation during discography. In another study, Braithwaite and colleagues[6] reported that modic changes on MR images were a specific, but not necessarily sensitive, predictor of con-

TABLE 1

*Summary of studies involving MR imaging and discography for selection of lumbar surgery**

Authors & Year	Class	Description	Conclusions
Holt, 1968	III	Disco was performed on 30 patients w/o history of LBP. 37% reported onset of back (no leakage but irregularity of disc space noted) or back & leg (leakage of dye) pain w/ injection.	Disco unreliable for diagnosis of discogenic back pain due to high false positive rate.
Simmons & Segil, 1975	III	Painful disc injection was used as guide for op (either simple discectomy or discectomy & PLF) in large pre-MRI & CT series. Most patients did well.	Disco can help to localize pathological levels in patients w/ back pain & radiculopathy.
Brodsky & Binder, 1979	III	Discogram was used to select patients for op. Many w/ negative myelography had positive discograms.	Disco may be positive in the face of a normal myelogram.
Park, et al., 1979	III	14/400 patients w/ back pain who had abnormal discograms despite normal plain films & in some cases venography or radiculography.	Disco may disclose abnormalities in patients w/ back pain otherwise normal films.
Milette & Melanson, 1982	III	Retrospective review of large disco series: 5% normal morphology had pain response, 37% abnormal morphology had pain response.	Disco useful for the diagnosis of LBP; pain response is important.
Johnson & Macnab, 1985	III	24 patients w/ surgically documented pseudarthrosis at 33 levels were studied preop w/ disco. 20/29 successfully injected levels resulted in typical back pain. There were 3 false-positive & 9 false-negative discograms.	Disco appears to be useful in demonstrating pain related to PA.
Gibson, et al., 1986	II (MRI vs disco morphology)	50 discs studied w/ MRI & disco. Concordant morphometric findings were noted in 44, & in 6 discs errors were made by the observers.	MRI is as good or superior to disco for identification of disc degeneration: LR+ 8, LR− 0.05.
Grubb, et al., 1987	III	Disco was performed on 346 discs in 108 patients. 78% had pain reproduced at 1 or more levels; 37% had abnormalities on plain films or myelograms.	Disco more sensitive than plain films or myelogram for evaluation of LBP.
Sachs, et al., 1987	III	Developed new classification system for CT disco & applied it to group of 59 patients. 13% of patients had positive CT disco findings w/o pain provocation.	New classification of CT disco aids in diagnosis: LR+ 1.46; LR− 0.16.
Schneiderman, et al., 1987	II	101 disc levels studied by T_2 MRI & discography. MRI was 99% accurate in predicting morphological discographic results.	MRI 99% accurate in predicting morphological discogram results. LR+ 49; LR− 0.02.
Blumenthal, et al, 1988	III	34 patients w/ positive disco underwent ALIF. Of those who achieved fusion, 73% had a good clinical result.	Successful fusion of disco-positive discs w/ ALIF results in good results 73% of the time.
Colhoun, et al., 1988	III (no patients w/ normal disco treated; selection criteria unclear; definition of success unclear)	195 patients were studied w/ disco & 182 went on to solid fusion (of some type). Of those w/ abnormal & painful discs (137), 89% derived benefit from fusion. Of those with abnormal but nonpainful discs (25), 52% had good outcomes.	Treatment of discs w/ pain provocation & abnormal morphology results in successful outcome 89% of the time. Treatment of abnormal but not painful discs results in success 52% of the time.
Vanharanta, et al., 1988	III	816 discograms performed in patients with multiple low-back disorders. Many abnormalities seen.	Disco abnormalities are common in patients w/ low-back disorders.
Zucherman, et al., 1988	III	18 patients identified w/ normal MRI & abnormal disco.	Discos may be abnormal in face of normal MRI.
Vanharanta, et al., 1989	III	790 discs studied w/ discogram. Scored by DPQ. 87% of normal discs were painless. Slight degeneration was associated w/ pain in 33% of younger patients & 12% of oldest group. This pattern was reproduced in moderately & severely degenerated discs.	Proportion of painless but degenerated discs on disco increases w/ age.
Antti-Poike, et al., 1990	II (discographic morphology vs pain provocation)	Abnormal morphology on discograms associated w/ pain provocation 52.8%; normal morphology associated w/ pain provocation 13.2%. Use of postdisco CT did not add to diagnostic accuracy; morphology PPV 53% & NPV 87%.	Normal morphology has NPV of 87% for pain provocation & abnormal morphology has a PPV of 53% for pain provocation. LR+ 3; LR− 0.34.
Bernard, 1990	III (utility of disco); II (MRI vs disco)	250 patients studied w/ disco/CT. Disco added useful information 93% of the time (according to radiologist author). PPV of MRI compared w/ disco was 92%, NPV was 84%.	MRI correlated w/ disco/CT 89% of the time.
Linson & Crowe, 1990	II	Prospective comparison btwn T_2 MRI & disco was performed (94% correlation). PPV MRI vs painful disco was 98% & NPV was 88%.	Abnormal MRI has high likelihhood for painful disc on disco (LR+ 30) & normal MRI has an LR− 0.09.
Walsh, et al., 1990	III (no sensitivity able to be reported)	7 LBP patients & 10 volunteers underwent multilevel disco. Disco was abnormal 17% of the time in asymptomatic patients, but no patient had a positive pain response.	Radiological results of disco are unreliable. Pain response is reliable for the determination of painful disc disease.
Simmons, et al., 1991	II (MRI vs disco as gold standard); III (MRI or disco vs painful disc disease)	164 patients w/ LBP underwent disco & MRI. Compared to pain-provoking disco, MRI had an NPV of 94% & a PPV of 58%.	MRI is oversensitive for diagnosis of painful disc disease. Abnormal disco occurs despite negative MRI 6% of the time.

Continued

TABLE 1 *Continued*

Authors & Year	Class	Description	Conclusions
Gill & Blumenthal, 1992	II	53 patients underwent L5–S1 fusion for concordant pain on disco. Those w/ concordant pain & abnormal MRI did well 75% of the time; those w/ concordant pain & normal MRI did well 50% of the time. The authors found that MRI predicted morphological changes on disco 100% of time.	MRI predicts morphological changes on disco well. Patients w/ normal MRI & concordant pain on disco do relatively poorly following fusion. PPV of abnormal MRI in this setting is 74% (as opposed to 66% overall for concordant pain response).
Horton & Daftari, 1992	III	63 discs in 25 patients studied w/ MRI and disco. MRI signal patterns correlated w/ disco findings.	Certain MRI findings are highly associated w/ concordant pain provocation & a normal image was highly associated w/ no concordant pain. There are intermediate signal characteristics that do not reliably predict pain provocation.
Maezawa & Muro, 1992	III	Large series of disco (1477). Imperfect relationship of pain to radiographic findings in patients w/ LBP was found.	Disc morphology & pain response not necessarily related.
Murtagh & Arrington, 1992	III	Authors studied discs adjacent to degenerative levels to determine whether to include adjacent level in fusion. They found morphological discographic abnormalities in 54% of adjacent discs.	Morphological abnormalities are present in ~ half of discs adjacent to other degenerative discs.
Buirski & Silberstein, 1993	III	MRI abnormal discs were characterized in symptomatic & asymptomatic patients. No intergroup differences were seen in terms of frequency or severity of MRI changes. All MRI abnormal discs subjected to discography were found to be painful.	MRI is unreliable for the identification of painful discs.
Knox & Chapman, 1993	III	22 patients w/ disco-positive pain had ALIF performed based on disco. All 2-level fusions did poorly. Among single-level fusions, 35% were good, 18% were fair, & 47% were poor.	ALIF based on discography associated w/ poor results.
Brightbill, et al., 1994	III	7 patients were found to have abnormal disco despite normal MRI.	Normal MRI does not exclude abnormal disco.
Loneragan, et al., 1994	III	Small series of patients were subjected to disco & MRI. Overall concordance for the 2 modalities was 90%.	Concordance btwn MRI & CT disco (morphology) is ~90%.
Moneta, et al., 1994	III	Correlation was noted btwn discographic pattern & pain provocation. Outer anular tears were associated w/ pain; however, generalized but degeneration was not.	Anular disruption as seen on disco is associated w/ a pain response.
Wetzel, et al., 1994	III	48 patients treated w/ fusion based on symptomatic disco. 46% of patients had an excellent or good (satisfactory) outcome. Of the 23 w/ a solid arthrodesis, 22 had satisfactory clinical outcomes.	Symptomatic discography predicts surgical results in 46% of patients. This result may be related to fusion success.
Rhyne, et al., 1995	III	25 patients w/ LBP and concordant provocative disco were followed nonop for various reasons for a minimum of 3 yrs: 68% improved, 8% stayed the same, 24% worsened. Most patients who worsened had significant psychiatric disease.	Most patients w/ disco concordant back pain improve w/o treatment.
Schwarzer, et al., 1995	III	92 patients w/ LBP studied w/ disco. Provocation disco was positive in 39%.	Provocative disco is positive in a large number of patients w/ back pain.
Block, et al., 1996	II	Patients w/ LBP were studied with disco & MMPI. Those who reported pain had significantly higher hypochondriasis & hysteria scores on the MMPI.	Psychological factors contributed heavily to disco results.
Ricketson, et al., 1996	III	80 discs in 29 patients studied w/ MRI & disco. No patient w/ HIZ had a morphologically normal disc. No definite relationship was found btwn HIZ & pain response (only 7 patients w/ HIZ; discrepancy btwn tables & reported results).	Presence of HIZ does not necessarily predict painful disc: LR+ 1.3; LR− 0.96.
Schellhas, et al., 1996	II	100 patients w/ HIZ discs & 67 patients w/ non-HIZ discs subjected to discography. 87/100 HIZ discs and 2/67 non-HIZ discs painful: PPV HIZ 87%, NPV non-HIZ 97%.	Presence of HIZ highly correlated w/ pain on disco (LR+ 5.76; LR− 0.002).
Heggeness, et al., 1997	III	Retrospective review of 83 postdiscectomy patients who underwent discography was performed.	Previously op discs were more frequently painful than nonop discs (72 vs 38%). Dye extravasation was associated w/ pain 75% of the time.
Braithwaite, et al., 1998	II (MRI vs disco)	Disco performed at 152 levels including 23 w/ modic changes. PPV for modic changes predicting concordant pain was 91.3% & the NPV was 46.5%.	Modic changes on MRI are relatively specific, but not sensitive for the concordance of pain on discography. LR+ 7.6, LR− 0.8.

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TABLE 1 *Continued*

Authors & Year	Class	Description	Conclusions
Ito. et al.. 1998	II (MRI vs disco)	Retrospective comparison of MRI HIZ vs painful disc on disco were performed.	HIZ was sensitive for predicting a painful disc (87%) but not specific (65%; PPV 43%). "Massive degeneration" or "severe disc space collapse" was specific for painful disco. The PPV for nonconcordant pain or no pain for a normal MRI appearance was 97.3%.
Saifuddin. et al.. 1998	II	Morphology of disco compared w/ pain response; response usually associated w/ isolated posterior anular tear.	Isolated posterior anular tears significantly associated w/ concordant pain.
Saifuddin. et al.. 1998	II	HIZ presence was compared w/ disco results: sensitivity 26.7%. specificity 95.2%. PPV 88.9%. & NPV 47%.	HIZ is highly specific & associated w/ a high likelihood for pain provocation; LR+ 6.8; LR− 0.7.
Smith. et al.. 1998	II (HIZ vs painful disco)	Retrospective analysis of patients w/ MRI & discogram w/in same year. A κ value of 0.57 was found btwn neuroradiologists evaluating scans for HIZ. Sensitivity of HIZ for anular disruption was only 25%. but specificity was 99%. Sensitivity for pain response was 23% & specificity 90%.	HIZ is a specific but not very sensitive indicator of painful disc disruption.
Carragee. et al.. 1999	II	24 discs in 8 selected patients w/ nonspinal LBP were injected: concordant pain elicited in 8 discs & 4 patients had severe pain in 1 disc & no pain in others (met criteria for op).	Lumbar disco cannot reliably differentiate the source of LBP due to a high–false positive rate (50%): LR+ 0.72. LR− 0.72.
Derby. et al.. 1999	III	Retrospective comparison of patients w/ positive disco who underwent different fusion procedures.	Patients w/ "chemically sensitive" discs do better w/ an interbody fusion compared w/ PLF.
Milette. et al.. 1999	II	Retrospective comparison of MRI findings & disco findings was performed.	Loss of disc space height. abnormal central signal intensity. protrusions & disc bulges predicted Stage 2 or 3 disruptions on disco; most of these were painful.
Rankine. et al.. 1999	III	Observational study of 83 patients w/ back &/or leg pain. 45% had an HIZ noted on MRI.	HIZ is a common finding in patients w/ LBP.
Carragee. et al.. 2000	II	26 patients w/o back pain followed for 1 yr after discography. No patient w/o a somatization disorder suffered back pain as a result of disco.	Disco does not cause chronic LBP in patients w/o somatization disorders. Pain correlates w/ somatization ($p < 0.03$).
Carragee. et al.. 2000	II	2 selected groups of patients status postdiscectomy w/ or w/o back pain. Disco was positive in 40% of asymptomatic group & 63% of symptomatic group.	Lumbar disco has a high–false positive rate in patients w/o back pain (40%): LR+ 1.05. LR− 0.93.
Carragee. et al.. 2000	II	Selected populations of LBP & non-LBP studied w/ MRI & disco. LBP patients had significantly higher rate of HIZ. but 24% of asymptomatic patients also had HIZ.	HIZ is too nonspecific for clinical use in LBP; it may predict discogram pain: LR+ 14.6. LR− 0.60.
Carragee. et al.. 2000	III	False-positive rate of disco in noncompensated patient was low (10%). but much higher in compensated patients & those w/ somatization disorders.	Positive discogram rates correlated closely w/ disability claims. somatization. & anular disruption.
Lam. et al.. 2000	II	92 HIZs were identified in 73 patients undergoing workup for fusion for LBP. Blinded comparison btwn MRI presence of HIZ & pain response. PPV for HIZ for pain response was 87%.	HIZ good predictor of painful disco.
Sandhu. et al.. 2000	III	Compared modic changes & results of discography in 53 patients w/ LBP. Not all levels underwent disco. Authors found no relationship btwn modic changes & pain provocation on disco.	Modic changes on MRI do not predict pain provocation w/ disco.
Slipman. et al.. 2001	III	40 carefully selected discograms evaluated to determine relation of side of anular tear & side of symptoms in patients w/ concordant back pain. No relationship found.	Side of anular tear not related to side of back or leg pain.
Weishaupt. et al.. 2001	II (MRI vs disco)	Prospective study of 50 patients w/ LBP who underwent MRI & disco. Normal MRI had NPV for pain provocation of 98%. Only moderate-to-severe endplate changes had a high PPV (100%).	MRI good tool for predicting pain provocation w/ disco.

* ALIF = anterior lumbar interbody fusion; disco = discography; DPQ = Dallas Pain Questionnaire; LBP = low-back pain; LR = likelihood ratio; MMPI = Minnesota Multiphasic Personality Inventory; PA = pseudarthrosis.

cordant pain provocation during discography. Weishaupt, et al.,[61] found that moderate-to-severe endplate changes predicted a concordant pain response 100% of the time. In contrast, Sandhu, et al.,[49] did not identify a significant relationship between modic changes on MR imaging and concordant pain responses during discography. Ito and colleagues[26] found that the absence of an HIZ had a strong likelihood (negative ratio 0.08) of predicting the absence of a pain response. Conversely, Saifuddin, et al.,[47] reported that the presence of an HIZ on MR imaging was specific (96%) and predictive (likelihood ratio 6.8) of a concordant pain response during discography. Schelhas, et al.,[50] reported similar findings in that the presence (positive likelihood 5.8) or absence (negative likelihood 0.002) of an HIZ on MR imaging was predictive of the presence or absence, respectively, of concordant pain during discography.

Lam and colleagues[31] performed a prospective blinded evaluation of HIZs identified on MR imaging compared with discography. They found an 87% PPV of the HIZ for the provocation of pain with discography and reported sensitivity and specificity values of 81 and 79%, respectively. Ricketson and colleagues[45] identified a significant association between the presence of an HIZ and concordant back pain during discography; however, only seven HIZs were noted. Several other studies confirmed the high NPV (94–100%) of a normal MR image for the production of a concordant pain response during discography.[25,26,47,50,55,61] Although there are conflicting reports, the majority of evidence reported in the literature indicates that certain MR imaging findings, particularly the presence of an HIZ, are closely correlated with the provocation of discographic concordant pain in patients with low-back pain. It is also apparent that a concordant pain response is extremely uncommon in the presence of normal MR imaging findings.

The knowledge of the relative ability of one imaging study (such as MR imaging) to predict the results of another diagnostic test (such as provocative discography) is useful for the selection of diagnostic tests; however, the true litmus test is the ability of the diagnostic test to predict the outcome of treatment based on the results of the test. In the low-back pain population, fusion is often performed to treat patients with recalcitrant low-back pain. The next relevant question concerns the ability of discography or MR imaging to predict the outcome after lumbar fusion. If discography (or MR imaging) were to have an accuracy of 100% in terms of diagnosing the source of a patient's low-back pain and if successful fusion of the pathological interspace diagnosed using discography (or MR image) were 100% effective for the treatment of low-back pain, then every patient with a positive discogram (or MR image) and a successful fusion would be expected to experience relief of low-back pain. Conversely, a patient with a negative discogram (or MR image) would not experience pain relief despite a successful fusion.

To address this issue, Gill and Blumenthal[21] reported on the outcomes of 53 patients who underwent L5–S1 fusion, based primarily on concordant pain provocation during discography. They found that patients with concordant pain and abnormal MR imaging findings did well approximately 75% of the time. This success rate was compared with results obtained by the same authors in a group of patients similarly treated based on concordant pain on discography but in whom MR imaging was normal. Only half of these latter patients experienced a favorable result. There was a trend for an abnormal MR imaging study to predict functional outcome following surgery ($p < 0.10$). Colhoun and colleagues[15] reported an 89% favorable result following fusion in patients with abnormal disc morphology and a concordant pain response compared with a 52% favorable rate in patients with abnormal disc morphology alone. Both of these studies provide Class III medical evidence suggesting that both anatomical abnormality and a concordant pain response together are required for a discogram to have a PPV for fusion outcome after lumbar surgery.

Other authors have provided more sobering reports of outcomes following lumbar fusion when discography alone has been used as a diagnostic tool. Wetzel, et al.,[62] and Knox and Chapman[30] each described surgical series in which patient selection was dependent primarily on discography. The results of both of these series are disappointing, with successful outcome rates of 35 to 46%. These results are particularly troubling given the findings by Rhyne, et al.,[44] that the majority (68%) of patients with discographic concordant pain in their experience improved without surgical treatment during a 3-year follow-up period. The fusion rates and techniques may have influenced the overall results. In the series by Wetzel, et al.,[62] for example, in the majority of cases believed to represent a successful fusion outcomes were satisfactory. Some authors argue that the techniques used to achieve fusion are important. For example, Derby and colleagues[18] have suggested that the elimination of motion at the pathological disc space through the use of interbody implants is important for adequate relief of discogenic pain. This hypothesis is partly based on the observation that discography can elicit pain at disc spaces within a solidly fused segment following PLF.[28] Consequently, although acceptable results following surgical treatment of discography-diagnosed low-back pain have been reported, the best medical evidence suggests that treatment of a disc in a patient with low-back pain, a positive discogram, and a normal MR imaging study is not likely to influence favorably the natural history of the pain. Discography is not, therefore, recommended for the evaluation of patients with normal MR imaging examinations of the lumbar spine.

Discography has been used as an adjunct for the study of discs associated with equivocal MR imaging findings, particularly those adjacent to clearly pathological interspaces considered for fusion. Discs that are morphologically abnormal but painless at discography may be excluded from the fusion construct.[40] Discography may also have a role in the diagnosis of painful pseudarthrosis, although the literature on this is scant.[28] Provocation of pain at disc levels that are morphologically normal on MR imaging is a contraindication for surgical (or other invasive) intervention. Discography-provoked pain at multiple disc levels in a patient with equivocal morphological findings on discography or MR imaging should raise a significant red flag for the presence of factors reported to be associated with poor surgical outcomes following lumbar fusion surgery.[4,11]

Summary

Discography is an exquisitely sensitive but not specific

diagnostic test for the diagnosis of discogenic low-back pain. The restriction of the definition of a positive discographic study to one that elicits concordant pain from a morphologically abnormal disc improves the definition's accuracy. Fusion surgery based on discography alone, however, is not reliably associated with clinical success. Therefore, discography is not recommended as a standalone test for treatment decisions in patients with low-back pain. Magnetic resonance imaging is a sensitive and noninvasive test for the presence of degenerative disc disease. Discography should not be attempted in patients with normal lumbar MR images. Discography appears to have a role in the evaluation of patients with low-back pain, but it is best limited to the evaluation of abnormal interspaces identified on MR imaging, the investigation of adjacent-level disc disease, and as a means to rule out cases of nonorganic pain from surgical consideration.

Directions for Future Research

A large cohort series comparing the results of discography and MR imaging for predicting the success of surgical intervention via a standardized protocol would be a valuable addition to the literature. These data would provide at least Class II evidence for the value of either imaging technique for predicting the response of a patient to a given treatment strategy.

References

1. Antti-Poika I, Soini J, Tallroth K, et al: Clinical relevance of discography combined with CT scanning. A study of 100 patients. **J Bone Joint Surg Br 72:**480–485, 1990
2. Bernard TN Jr: Lumbar discography followed by computed tomography. Refining the diagnosis of low-back pain. **Spine 15:** 690–707, 1990
3. Birney TJ, White JJ Jr, Berens D, et al: Comparison of MRI and discography in the diagnosis of lumbar degenerative disc disease. **J Spinal Disord 5:**417–423, 1992
4. Block AR, Vanharanta H, Ohnmeiss DD, et al: Discographic pain report. Influence of psychological factors. **Spine 21:** 334–338, 1996
5. Blumenthal SL, Baker J, Dossett A, et al: The role of anterior lumbar fusion for internal disc disruption. **Spine 13:**566–569, 1988
6. Braithwaite I, White J, Saifuddin A, et al: Vertebral end-plate (Modic) changes on lumbar spine MRI: correlation with pain reproduction at lumbar discography. **Eur Spine J 7:**363–368, 1998
7. Brightbill TC, Pile N, Eichelberger RP, et al: Normal magnetic resonance imaging and abnormal discography in lumbar disc disruption. **Spine 19:**1075–1077, 1994
8. Brodsky AE, Binder WF: Lumbar discography. Its value in diagnosis and treatment of lumbar disc lesions. **Spine 4:**110–120, 1979
9. Buirski G, Silberstein M: The symptomatic lumbar disc in patients with low-back pain. Magnetic resonance imaging appearances in both a symptomatic and control population. **Spine 18:**1808–1811, 1993
10. Carragee EJ, Chen Y, Tanner CM, et al: Can discography cause long-term back symptoms in previously asymptomatic subjects? **Spine 25:**1803–1808, 2000
11. Carragee EJ, Chen Y, Tanner CM, et al: Provocative discography in patients after limited lumbar discectomy: a controlled, randomized study of pain response in symptomatic and asymptomatic subjects. **Spine 25:**3065–3071, 2000
12. Carragee EJ, Paragioudakis SJ, Khurana S: 2000 Volvo Award winner in clinical studies: Lumbar high-intensity zone and discography in subjects without low back problems. **Spine 25:** 2987–2992, 2000
13. Carragee EJ, Tanner CM, Khurana S, et al: The rates of false-positive lumbar discography in select patients without low back symptoms. **Spine 25:**1373–1381, 2000
14. Carragee EJ, Tanner CM, Yang B, et al: False-positive findings on lumbar discography. Reliability of subjective concordance assessment during provocative disc injection. **Spine 24:** 2542–2547, 1999
15. Colhoun E, McCall IW, Williams L, et al: Provocation discography as a guide to planning operations on the spine. **J Bone Joint Surg Br 70:**267–271, 1988
16. Collins CD, Stack JP, O'Connell DJ, et al: The role of discography in lumbar disc disease: a comparative study of magnetic resonance imaging and discography. **Clin Radiol 42:**252–257, 1990
17. Collis JS Jr, Gardner W: Lumbar discography. An analysis of one thousand cases. **J Neurosurg 19:**452–461, 1962
18. Derby R, Howard MW, Grant JM, et al: The ability of pressure-controlled discography to predict surgical and nonsurgical outcomes. **Spine 24:**364–372, 1999
19. Fraser RD, Osti OL, Vernon-Roberts B: Discitis after discography. **J Bone Joint Surg Br 69:**26–35, 1987
20. Gibson MJ, Buckley J, Mawhinney R, et al: Magnetic resonance imaging and discography in the diagnosis of disc degeneration. A comparative study of 50 discs. **J Bone Joint Surg Br 68:**369–373, 1986
21. Gill K, Blumenthal SL: Functional results after anterior lumbar fusion at L5–S1 in patients with normal and abnormal MRI scans. **Spine 17:**940–942, 1992
22. Grubb SA, Lipscomb HJ, Guilford WB: The relative value of lumbar roentgenograms, metrizamide myelography, and discography in the assessment of patients with chronic low-back syndrome. **Spine 12:**282–286, 1987
23. Heggeness MH, Watters WC III, Gray PM Jr: Discography of lumbar discs after surgical treatment for disc herniation. **Spine 22:**1606–1609, 1997
24. Holt EP Jr: The question of lumbar discography. **J Bone Joint Surg Am 50:**720–726, 1968
25. Horton WC, Daftari TK: Which disc as visualized by magnetic resonance imaging is actually a source of pain? A correlation between magnetic resonance imaging and discography. **Spine 17 (6 Suppl):**S164–S171, 1992
26. Ito M, Incorvaia KM, Yu SF, et al: Predictive signs of discogenic lumbar pain on magnetic resonance imaging with discography correlation. **Spine 23:**1252–1260, 1998
27. Jackson RP, Becker GJ, Jacobs RR, et al: The neuroradiographic diagnosis of lumbar herniated nucleus pulposus: I. A comparison of computed tomography (CT), myelography, CT-myelography, discography, and CT-discography. **Spine 14:** 1356–1361, 1989 (Erratum in **Spine 15:**59, 1990)
28. Johnson RG, Macnab I: Localization of symptomatic lumbar pseudarthroses by use of discography. **Clin Orthop Relat Res 197:**164–170, 1985
29. Junila J, Niinimaki T, Tervonen O: Epidural abscess after lumbar discography. A case report. **Spine 22:**2191–2193, 1997
30. Knox BD, Chapman TM: Anterior lumbar interbody fusion for discogram concordant pain. **J Spinal Disord 6:**242–244, 1993
31. Lam KS, Carlin D, Mulholland RC: Lumbar disc high-intensity zone: the value and significance of provocative discography in the determination of the discogenic pain source. **Eur Spine J 9:**36–41, 2000
32. Lindblom K: Technique and results of diagnostic disc puncture and injection (discography) in the lumbar region. **Acta Orthop Scand 20:**315–326, 1951
33. Linson MA, Crowe CH: Comparison of magnetic resonance imaging and lumbar discography in the diagnosis of disc degeneration. **Clin Orthop Relat Res 250:**160–163, 1990

34. Loneragan R, Khangure MS, McCormick C, et al: Comparison of magnetic resonance imaging and computed tomographic discography in the assessment of lumbar disc degeneration. **Australas Radiol 38:**6–9, 1994
35. Maezawa S, Muro T: Pain provocation at lumbar discography as analyzed by computed tomography/discography. **Spine 17:** 1309–1315, 1992
36. McCutcheon ME, Thompson WC III: CT scanning of lumbar discography. A useful diagnostic adjunct. **Spine 11:**257–259, 1986
37. Milette PC, Fontaine S, Lepanto L, et al: Differentiating lumbar disc protrusions, disc bulges, and discs with normal contour but abnormal signal intensity. Magnetic resonance imaging with discographic correlations. **Spine 24:**44–53, 1999
38. Milette PC, Melanson D: A reappraisal of lumbar discography. **J Can Assoc Radiol 33:**176–182, 1982
39. Moneta GB, Videman T, Kaivanto K, et al: Reported pain during lumbar discography as a function of anular ruptures and disc degeneration. A re-analysis of 833 discograms. **Spine 19:** 1968–1974, 1994
40. Murtagh FR, Arrington JA: Computer tomographically guided discography as a determinant of normal disc level before fusion. **Spine 17:**826–830, 1992
41. Osti OL, Fraser RD: MRI and discography of annular tears and intervertebral disc degeneration. A prospective clinical comparison. **J Bone Joint Surg Br 74:**431–435, 1992 (erratum in **J Bone Joint Surg Br 74:**793, 1992)
42. Park WM, McCall IW, O'Brien JP, et al: Fissuring of the posterior annulus fibrosus in the lumbar spine. **Br J Radiol 52:** 382–387, 1979
43. Rankine JJ, Gill KP, Hutchinson CE, et al: The clinical significance of the high-intensity zone on lumbar spine magnetic resonance imaging. **Spine 24:**1913–1920, 1999
44. Rhyne A, Smith S, Wood K, et al: Outcome of unoperated discogram positive low back pain. **Spine 20:**1997–2001, 1995
45. Ricketson R, Simmons JW, Hauser BO: The prolapsed intervertebral disc. The high-intensity zone with discography correlation. **Spine 21:**2758–2762, 1996
46. Sachs BL, Vanharanta H, Spivey MA, et al: Dallas discogram description. A new classification of CT/discography in low-back disorders. **Spine 12:**287–294, 1987
47. Saifuddin A, Braithwaite I, White J, et al: The value of lumbar spine magnetic resonance imaging in the demonstration of anular tears. **Spine 23:**453–457, 1998
48. Saifuddin A, Emanuel R, White J, et al: An analysis of radiating pain at lumbar discography. **Eur Spine J 7:**358–362, 1998
49. Sandhu HS, Sanchez-Caso LP, Parvataneni HK, et al: Association between findings of provocative discography and vertebral endplate signal changes as seen on MRI. **J Spinal Disord 13:**438–443, 2000
50. Schellhas KP, Pollei SR, Gundry CR, et al: Lumbar disc high-intensity zone. Correlation of magnetic resonance imaging and discography. **Spine 21:**79–86, 1996
51. Schneiderman G, Flannigan B, Kingston S, et al: Magnetic resonance imaging in the diagnosis of disc degeneration: correlation with discography. **Spine 12:**276–281, 1987
52. Schreck RI, Manion WL, Kambin P, et al: Nucleus pulposus pulmonary embolism. A case report. **Spine 20:**2463–2466, 1995
53. Schwarzer AC, Aprill CN, Derby R, et al: The prevalence and clinical features of internal disc disruption in patients with chronic low back pain. **Spine 20:**1878–1883, 1995
54. Simmons EH, Segil CM: An evaluation of discography in the localization of symptomatic levels in discogenic disease of the spine. **Clin Orthop Relat Res 108:**57–69, 1975
55. Simmons JW, Emery SF, McMillin JN, et al: Awake discography. A comparison study with magnetic resonance imaging. **Spine 16 (6 Suppl):**S216–S221, 1991
56. Slipman CW, Patel RK, Zhang L, et al: Side of symptomatic annular tear and site of low back pain: is there a correlation? **Spine 26:**E165–E169, 2001
57. Smith BM, Hurwitz EL, Solsberg D, et al: Interobserver reliability of detecting lumbar intervertebral disc high-intensity zone on magnetic resonance imaging and association of high-intensity zone with pain and anular disruption. **Spine 23:**2074–2080, 1998
58. Vanharanta H, Guyer RD, Ohnmeiss DD, et al: Disc deterioration in low-back syndromes. A prospective, multi-center CT/discography study. **Spine 13:**1349–1351, 1988
59. Vanharanta H, Sachs BL, Ohnmeiss DD, et al: Pain provocation and disc deterioration by age. A CT/discography study in a low-back pain population. **Spine 14:**420–423, 1989
60. Walsh TR, Weinstein JN, Spratt KF, et al: Lumbar discography in normal subjects. A controlled, prospective study. **J Bone Joint Surg Am 72:**1081–1088, 1990
61. Weishaupt D, Zanetti M, Hodler J, et al: Painful lumbar disk derangement: relevance of endplate abnormalities at MR imaging. **Radiology 218:**420–427, 2001
62. Wetzel FT, LaRocca SH, Lowery GL, et al: The treatment of lumbar spinal pain syndromes diagnosed by discography. Lumbar arthrodesis. **Spine 19:**792–800, 1994
63. Zucherman J, Derby R, Hsu K, et al: Normal magnetic resonance imaging with abnormal discography. **Spine 13:**1355–1359, 1988

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