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Systematic Review

An Update of the Systematic Appraisal of the Accuracy and Utility of Lumbar Discography in Chronic Low Back Pain

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Background: The intervertebral disc has been implicated as a major cause of chronic lumbar spinal pain based on clinical, basic science, and epidemiological research. There is, however, a lack of consensus regarding the diagnosis and treatment of intervertebral disc disorders. Based on controlled evaluations, lumbar intervertebral discs have been shown to be the source of chronic back pain without disc herniation in 26% to 39% of patients. Lumbar provocation discography, which includes disc stimulation and morphological evaluation, is often used to distinguish a painful disc from other potential sources of pain. Despite the extensive literature, intense debate continues about lumbar discography as a diagnostic tool.

Study Design: A systematic review of the diagnostic accuracy of lumbar provocation and analgesic discography literature.

Objective: To systematically assess and re-evaluate the diagnostic accuracy of lumbar discography.

Methods: The available literature on lumbar discography was reviewed. A methodological quality assessment of included studies was performed using the Quality Appraisal of Reliability Studies (QAREL) checklist. Only diagnostic accuracy studies meeting at least 50% of the designated inclusion criteria were included in the analysis. However, studies scoring less than 50% are presented descriptively and critically analyzed.

The level of evidence was classified as good, fair, and limited or poor based on the quality of evidence developed by the U.S. Preventive Services Task Force (USPSTF).

Data sources included relevant literature identified through searches of PubMed and EMBASE from 1966 to September 2012, and manual searches of the bibliographies of known primary and review articles.

Results: Over 160 studies were considered for inclusion. Of these, 33 studies compared discography with other diagnostic tests, 30 studies assessed the diagnostic accuracy of discography, 22 studies assessed surgical outcomes for discogenic pain, and 3 studies assessed the prevalence of lumbar discogenic pain. The quality of the overall evidence supporting provocation discography based on the above studies appears to be fair. The prevalence of internal disc disruption is estimated to be 39% to 42%, whereas the prevalence of discogenic pain without assessing internal disc disruption is 26%.

Conclusion: This systematic review illustrates that lumbar provocation discography performed according to the International Association for the Study of Pain (IASP) criteria may be a useful tool for evaluating chronic lumbar discogenic pain.

Key words: Lumbar intervertebral disc, lumbar discography, provocation discography, analgesic discography, diagnostic accuracy

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In light of the increasing socioeconomic burden imposed by chronic low back pain, the resources utilized in treating it, the intense media attention devoted to the subject, and the growing number of modalities available for diagnosis and management, our understanding of the causes of low back pain has evolved over the past century (1-30). Nevertheless, providing a definitive diagnosis for patients remains a major challenge in the absence of overt disc herniations, pathognomonic physical findings, or confirmative electrodiagnostic findings (1,30-40). Kuslich et al (41) identified intervertebral discs, facet joints, ligaments, fascia, muscles, and nerve root dura as potential pain-generating structures in the low back. The intervertebral discs, the zygapophysial (facet) joints, and sacroiliac joints have all been demonstrated, with controlled diagnostic techniques to be common causes of chronic low back pain (1,34-40). Based on these evaluations, the prevalence of discogenic low back pain, with or without internal disc derangement, is estimated to affect between 26% and 39% of chronic low back pain sufferers without radicular symptoms (32,34-37). Further, the intervertebral disc has been implicated as a source of spinal pain based on decades of pre-clinical, clinical, and epidemiological research, though the precise mechanisms continue to be debated as the literature evolves (34-37,42-67). Diagnosis based on history, physical exam, and radiological imaging has low sensitivity and specificity in determining whether or not the disc is a primary source of low back pain (1,32-36,40,46,68-101).

Hancock et al (40) performed a systematic review evaluating the ability of different diagnostic modalities to identify the disc as the source of low back pain. They considered 28 studies investigating the disc. They showed that, in the majority of studies, various features observed on magnetic resonance imaging (MRI) (i.e., high-intensity zone, endplate changes, and disc degeneration) provided information that increased the probability of the disc being the source of low back pain. However, centralization was the only clinical feature found to increase the likelihood of the disc being the primary source of pain. The absence of degeneration on MRI was the only test found to reduce likelihood of the disc being the source of pain (89). The authors also found that whereas the presence of a high-intensity zone significantly increased the probability of the disc(s) being a source of pain, a negative test does not meaningfully reduce the chances of the disc(s) being the pain generator.

In an evaluation of physical examination and lumbar provocation discography, Laslett et al (89) found that the sensitivity, specificity, and positive likelihood ratios of centralization observed during repeated movement testing were 40%, 94%, and 6.9%, respectively. Although centralization was highly specific for positive discography, the sensitivity was low. In another study by Laslett and colleaugues (90) that sought to correlate clinical features with lumbar provocation discography findings, the authors were unable to identify any screening test useful for ruling out discogenic pain. Young et al (91) attempted to correlate clinical examination characteristics with 3 sources of chronic low back pain. They reported that centralization of pain was diagnostic for symptomatic discs. Donelson et al (92) also prospectively evaluated the centralization phenomenon as a predictive tool for discographic pain provocation and annular competence. They found that the McKenzie Assessment Process reliably differentiated discogenic from non-discogenic pain as well as a competent annulus from an incompetent annulus, and concluded that discography was superior to MRI in distinguishing painful from non-painful discs. However, the ability of centralization to predict positive discography was unreliable.

When discography is combined with pain provocation and analgesia, its diagnostic capabilities are considered superior to the single dimensional tools (31-37,46,81,102-112). However, others insist rather vigorously the contention that discography fails to improve diagnostic capabilities (9,113-125). Furthermore, there is ongoing debate regarding the gold standard evaluation of discogenic pain (34,35,122,123), and the conservative, minimally invasive, and surgical management of discogenic pain (43,123-147).

Although controversy exists and the debate continues on various modalities of treatments, there is some evidence that discogenic pain may respond as well as disc herniation, spinal stenosis and failed back surgery syndrome to epidural injections (133-154). Evidence also suggests that surgery does not afford superior results to non-invasive techniques (155-170).

The pathophysiology of discogenic pain depends on the sensory nerves. Typically, these innervate the outermost third of the annulus. However, in degenerated discs, the innervation is deeper and more widespread; some fibers even penetrate the nucleus pulposus (48,171-179). Aging causes fissures and tears in the annulus. There are also multiple types of chemical changes that occur in the degener-

ated discs, with release of inflammatory substances (42-51,54,73,77,78,80,180).

The accuracy of a diagnostic test is pivotal when selecting patients for treatment (1,19-22,24,29,30,34,35,38-40,124,181-206). For a treatment with low costs and low risks such as facet joint radiofrequency denervation, a screening test with high sensitivity is desirable, as the failure to correctly diagnosis the index condition can lead to unnecessary expensive and invasive treatments (e.g., surgery). But for a treatment that carries considerable risks and costs such as spine fusion, a test with high specificity and positive predictive value is preferable, which reduces unnecessary risk exposure. The value of discography as a screening tool increases with the inexperience of the referring surgeon, as those with less selectivity will likely refer more patients with non-discogenic pain, or a greater degree of psychosocial pathology. The greatest challenges concerning discography continue to be the "gold standard" dilemma and the treatments applied based on the results of the test (1,9,19,34,35,122-125,127-129,159,186,187). Opponents of discography contend that escalating numbers of unnecessary fusions have been performed in the United States each year for indications of discogenic pain (123,124,207-214). Yet, when properly utilized, discography screening can decrease the number of unnecessary operations. However, the lack of positive outcomes cannot be blamed on discography, since none of the surgical interventions have been proven to be beneficial in discogenic pain. Proponents of discography argue that it is the only diagnostic modality that attempts to correlate pathology with symptoms. This point is reasonable given the fact that close to two-thirds of asymptomatic subjects have been found to have abnormal findings on MRI and computed tomography (CT) scans of their lumbar spines, with many of the findings of a non-specific nature (72,74,104,215-235). But opponents of discography argue that the significance of discographic pathology is low, the validity of provoked symptoms is unproven, and that fusion outcomes do not correlate with findings. These criticisms are further supported by the relative lack of specificity of discography, the inherent difficulty in validating provoked symptomatology, and multiple studies showing false-positive discograms in patients without low back symptoms (104,113-122,236).

In a systematic review of lumbar discography as a diagnostic test for chronic low back pain (34), based on modified U.S. Preventive Services Task Force (USPSTF) level of evidence criteria, Manchikanti et al reported the strength of evidence was Level II-2 for the diagnostic accuracy of lumbar provocation discography utilizing International Association for the Study of Pain (IASP) criteria (237). Based on this systematic review, the authors (34) recommended that lumbar provocation discography performed according to the IASP criteria may be a useful tool for evaluating chronic lumbar discogenic pain.

The purpose of this review is to systematically evaluate the diagnostic accuracy of lumbar discography utilizing provocation or analgesia, determine its applicability in clinical practice identifing deficiencies in the available evidence, and to describe implications for clinical practice and further research in this area. This systematic review is an update of a previously published systematic review (34).

1.0 Methods

The IASP criteria (237) for lumbar discogenic pain include reproduction of a patient's typical pain with disc stimulation, while injection of 2 adjacent intervertebral discs fails to provoke pain. In addition, the pain cannot be ascribed to some other source innervated by the same segments that innervate the putatively symptomatic disc.

The degree of relief following local anesthetic injected into one or more discs is, theoretically, a more robust method to determine the degree to which the discs are contributing to the patient's symptoms (102). Thus, combining local anesthetic in equal concentration with contrast media injected into one or more discs during provocation discography confirms a positive provocative response and estimates the degree of pain caused by the one or more discs injected. Mixing local anesthetic with contrast is less traumatic than functional anesthetic discography, which requires using a large bore needle to enable the insertion of a catheter (102,103,112,238,239). Although the addition of local anesthetic to all injected discs cannot always distinguish symptomatic from asymptomatic discs, the degree of post-procedure relief experienced may help assuage concerns of false-positive responses (35,107,108,111,206,238,240-242).

1.1 Criteria for Considering Studies for the Review

1.1.1 Types of Studies

Diagnostic accuracy studies of lumbar discs provocation and/or analgesic discography.

1.1.2 Types of Participants

Participants of interest were adults aged at least 18 years with chronic low back pain of at least 3 months duration.

Participants must have failed previous pharmacotherapy, exercise therapy, etc., prior to discography.

1.1.3 Types of Interventions

The interventions were lumbar provocation and/or analgesic discography.

1.1.4 Types of Outcome Measures

- The primary outcome parameter was either pain provocation and/or pain relief with analgesic discography.
- At least 2 of the review authors independently, in an unblinded standardized manner, assessed the outcome measures. Any disagreements between reviewers were resolved by a third author and consensus.

1.2 Literature Search

Searches were performed from the following sources without language restrictions:

1. PubMed from 1966
   www.ncbi.nlm.nih.gov/sites/entrez?db=pubmed
2. EMBASE from 1980
   www.embase.com
3. Cochrane Library
   www.thecochranelibrary.com/view/0/index.html
4. U.S. National Guideline Clearinghouse (NGC)
   www.guideline.gov
5. Previous systematic reviews and cross references
6. Clinical Trials
   clinicaltrials.gov

The search period was from January 1966 through September 2012.

1.3 Search Strategy

The search strategy emphasized chronic low back pain and diagnostic interventional techniques with special emphasis on provocation and/or analgesic discography.

The search terms used were lumbar discography, discography, disc stimulation, analgesic discography, and provocation discograhy.

At least 2 of the review authors independently, in an unblinded standardized manner, performed each search. All searches were combined to obtain a unified search strategy. Any disagreements between reviewers were resolved by a third author and consensus.

1.4 Data Collection and Analysis

This systematic review focused only on invasive diagnostic studies provocation and analgesic discography. The population of interest was patients suffering from chronic low back pain, with or without lower extremity pain, for at least 3 months. Only the diagnostic accuracy of lumbar discography with respect to chronic low back pain was evaluated. Reports without appropriate diagnosis, non-systematic reviews, book chapters, and case reports were excluded.

The quality of each individual article used in this assessment was assessed using the Quality Appraisal of Reliability Studies (QAREL) checklist (Table 1) (195). This checklist has been validated and utilized in multiple systematic reviews (190-196). Each study in the final sample of eligible manuscripts was assessed using the 12-item checklist designed to assess quality and applicability. The face validity of this check was established by consultation with methodology experts (195) and comparison with similar checklists used in other systematic reviews examining diagnostic reliability (194,202,203,243-248). This checklist was also developed in accordance with the Standards for the Reporting Studies of Diagnostic Accuracy Studies (STARD) (191) and the Quality Assessment of Diagnostic Accuracy Studies (QUADAS) (192) appraisal tool. Studies were not given an overall numeric quality score; instead each item was considered separately and graded as "yes," "no," "unclear," or "not applicable."

1.4.1 Selection of Studies

- In an unblinded, standardized manner, 2 review authors screened the abstracts of all identified studies against the inclusion criteria.
- All articles with possible relevance were then retrieved in full text for comprehensive assessment of internal validity, quality, and adherence to inclusion criteria.

1.4.2 Inclusion and Exclusion Criteria

The following are the inclusion and exclusion criteria:

1. Are the patients described in sufficient detail to allow one to decide whether they are comparable to those who are treated in interventional pain management clinical practices?
   A. Setting office, hospital, outpatient, inpatient
   B. Physician interventional pain physician, gen-

Table 1. *Quality Appraisal of Diagnostic Reliability (QAREL) checklist.*

Item	Yes	No	Unclear	N/A
1. Was the test evaluated in a spectrum of subjects representative of patients who would normally receive the test in clinical practice?				
2. Was the test performed by examiners representative of those who would normally perform the test in practice?				
3. Were raters blinded to the reference standard for the target disorder being evaluated?				
4. Were raters blinded to the findings of other raters during the study?				
5. Were raters blinded to their own prior outcomes of the test under evaluation?				
6. Were raters blinded to clinical information that may have influenced the test outcome?				
7. Were raters blinded to additional cues, not intended to form part of the diagnostic test procedure?				
8. Was the order in which raters examined subjects varied?				
9. Were appropriate statistical measures of agreement used?				
10. Was the application and interpretation of the test appropriate?				
11. Was the time interval between measurements suitable in relation to the stability of the variable being measured?				
12. If there were dropouts from the study, was this less than 20% of the sample.				
TOTAL				

Lucas N, et al. Reliability of physical examination for diagnosis of myofascial trigger points. *Clin J Pain* 2009; 25:80-89 (194).

Table 2. *Clinical relevance questions.*

	P (+)	N (-)	U (unclear)
A) Are the patients described in sufficient detail to allow one to decide whether they are comparable to those who are treated in interventional pain management clinical practices			
B) Are the interventions and treatment settings described in sufficient detail to apply its use in clinical practice?			
C) Were clinically relevant outcomes measured and reported?			
D) Is the size of the effect clinically meaningful?			
E) Do the likely treatment benefits outweigh the potential harms?			

Scoring adapted and modified from Staal JB, et al. Injection therapy for subacute and chronic low back pain. *Cochrane Database Syst Rev* 2008; 3:CD001824 (249).

eral physician, anesthesiologist, physiatrist, neurologist, rheumatologist, orthopedic surgeon, neurosurgeon, etc.
   C. Patient characteristics duration of pain
   D. Previous non-interventional techniques or surgical intervention in the past
2. Is the intervention described in sufficient detail to enable one to apply its use to patients in interventional pain management settings?
   A. Nature of intervention
   B. Frequency of intervention
   C. Duration of intervention
3. Were clinically relevant outcomes measured?
   A. Proportion of pain relief
   B. Disorder/specific disability
   C. Functional improvement
   D. Allocation of eligible and non-eligible patients to return to work
   E. Ability to work

1.4.3 Clinical Relevance

The clinical relevance of the included studies was evaluated according to 5 questions recommended by the Cochrane Back Review Group (Table 2) (249). Each question was scored positive (+) if the clinical relevance item was met, negative (–) if the item was not met, and unclear (?) if data were not available to answer the question.

1.4.4 Methodological Quality or Validity Assessment

Each study was evaluated by at least 2 authors against the stated criteria, and any disagreements

were resolved with a third reviewer. Authors with a perceived conflict of interest for any manuscript were recused from reviewing that manuscript.

Only diagnostic accuracy studies meeting at least 50% of applicable inclusion criteria were included for analysis. Studies scoring less than 50% are reported descriptively with critical analysis.

1.4.5 Data Extraction & Management

Two review authors independently, in an unblinded standardized manner, extracted the data from the included studies. Disagreements were resolved by discussion between the 2 reviewers; if no consensus could be reached, a planned third author was called in to break the impasse. Data were analyzed separately based on whether the intervention was provocative or analgesic.

1.5 Analysis of Evidence

The evidence was analyzed using USPSTF criteria as illustrated in Table 3. These criteria have been utilized in many other reviews (9,19,163,185,250).

The analysis was conducted using 3 levels of evidence: good, fair, and limited or poor.

At least 2 of the review authors independently, in an unblinded standardized manner, analyzed the evidence. Any disagreements between reviewers were resolved by a third author and consensus. If there were any conflicts of interest (e.g., with authorship), those reviewers were recused from assessment and analysis.

1.6 Outcome of the Studies

Outcome evaluations included the prevalence of lumbar discogenic pain and false-positive results.

2.0 Results

Figure 1 shows a flow diagram of study selection. There were 163 studies considered for inclusion (31,32,36,37,82-92,102-108,110-122,124-129,131-170,205,216,238-242,251-326).

2.1 Comparative Evaluation of Discography

The correlation of discography was performed with radiologic studies. Table 4 describes 33 studies comparing lumbar discography with CT scanning or MRI in patients with degenerative disc disease. Of these, 13 showed good correlation, 7 showed fair correlation, and 13 showed limited or poor correlation. Overall, 20 of 33 studies showed good or fair correlation.

2.2 Diagnostic Accuracy Studies

Table 5 describes 30 studies evaluating the accuracy of discography. Of these, 25 studies evaluated provocation discography, 2 studies evaluated functional anesthetic discography, and 4 studies evaluated anesthetic discography. Among the 25 studies evaluating provocation discography, DePalma et al (67) reported subgroup analysis in 5 additional manuscripts. Of the 25 manuscripts assessed, 16 confirmed the validity of diagnostic discography. In contrast, 9 of the 25 manuscripts reported multiple confounding issues with provocation discography that could undermine its validity.

Recently, the use of anesthetic discography has generated significant interest as a means to reduce the high false-positive rate associated with provocation discography in certain patient subgroups. The rationale for this contention is extrapolated based on the reference standard used for other diagnostic spinal injections, such as facet and sacroiliac joint blocks (327). Currently, the ability of anesthetic discography, used as either an adjunct or replacement for provocation discography, to enhance the accuracy of diagnosis is mixed. One study by Alamin et al (112) conducted in 52 patients who underwent both procedures, found a 46% discordance rate between provocation and analgesic discography, with the large majority of discrepancies involving patients who were either found to be negative with analgesic discography after a positive provocation discogram (24%) or found to have only single-level disease on analgesic discography instead of 2-level involvement (16%). However, in a recent multi-center study involving 251 patients using 4 different discography protocols and criteria, Derby et al (326) found no significant differences in prevalence rates between techniques involving pain provocation alone, pain provocation in combination with analgesic discography, or analgesic discography as a stand-alone test.

2.3 Correlation with Surgical Outcomes

Table 6 describes 22 studies of lumbar fusion and disc displacement surgery in patients with discogenic pain who were diagnosed using preoperative discography.

Of these, only 4 studies reported good results, with the remaining studies reporting limited effectiveness of provocation discography as a diagnostic tool.

Table 3. *Method for grading the overall strength of the evidence for an intervention.*

Grade	Definition
Good	Evidence includes consistent results from well-designed, well-conducted studies in representative populations that directly assess effects on health outcomes (at least 2 consistent, higher-quality RCTs or studies of diagnostic test accuracy).
Fair	Evidence is sufficient to determine effects on health outcomes, but the strength of the evidence is limited by the number, quality, size, or consistency of included studies; generalizability to routine practice; or indirect nature of the evidence on health outcomes (at least one higher-quality trial or study of diagnostic test accuracy of sufficient sample size; 2 or more higher-quality trials or studies of diagnostic test accuracy with some inconsistency; at least 2 consistent, lower-quality trials or studies of diagnostic test accuracy, or multiple consistent observational studies with no significant methodological flaws).
Limited or Poor	Evidence is insufficient to assess effects on health outcomes because of limited number or power of studies, large and unexplained inconsistency between higher-quality trials, important flaws in trial design or conduct, gaps in the chain of evidence, or lack of information on important health outcomes.

Adapted and modified from methods developed by U.S. Preventive Services Task Force (9,250).

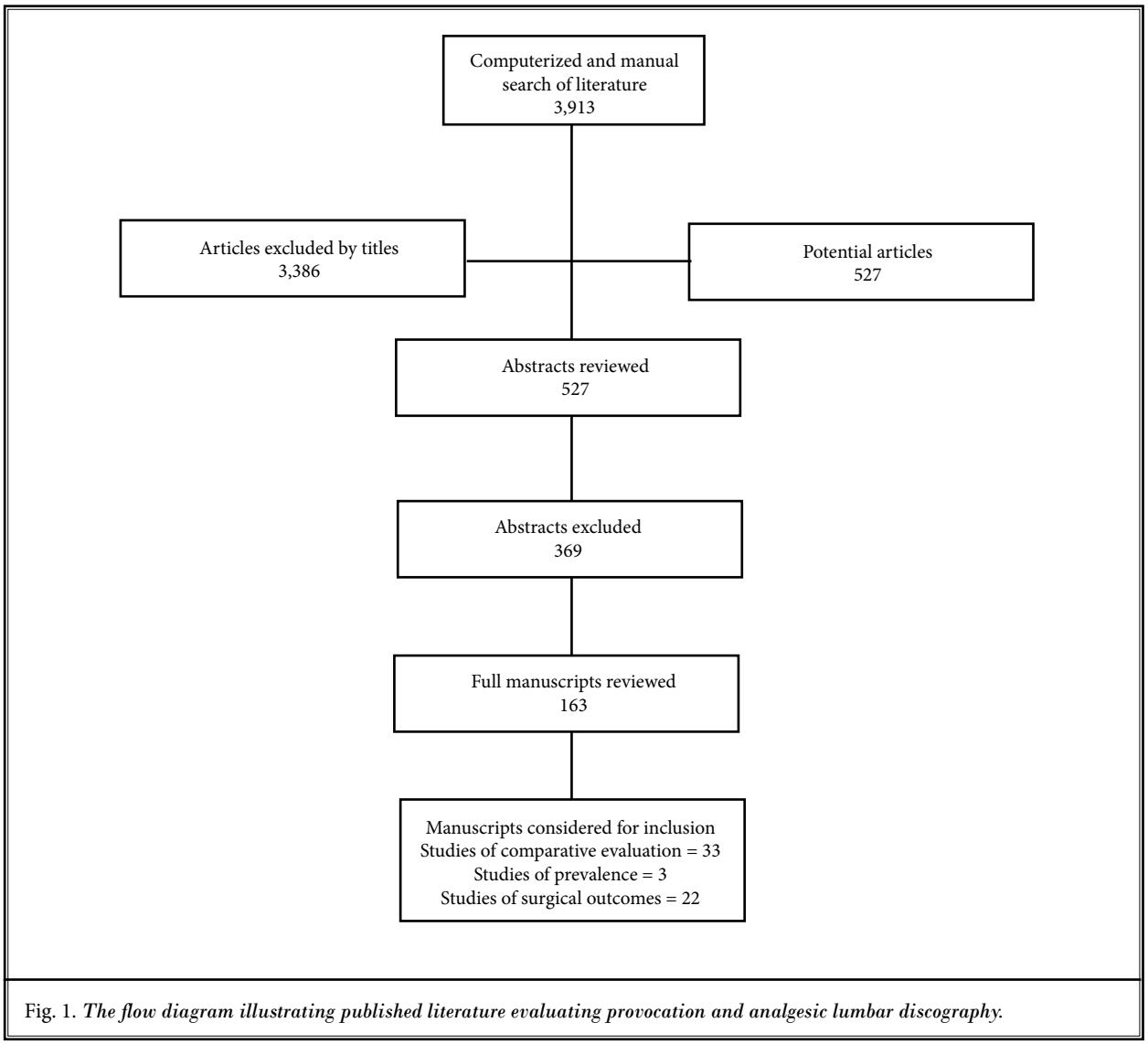

Fig. 1. *The flow diagram illustrating published literature evaluating provocation and analgesic lumbar discography.*

Table 4. *Studies comparing lumbar discography with CT scanning or MRI in patients with degenerative disc disease.*

Author, Year	Subjects	Nature of Study	Results	Correlation	Comments
Peng et al, 2006 (55)	52 patients with LBP without disc herniation underwent MRI and discography successively.	This study attempted to interpret the correlation between the presence of HIZ on MRI and awake discography, as well as its characteristic pathology.	The study found that in all of 142 discograms in 52 patients, 17 presented HIZ. All 17 discs with HIZ showed painful reproduction and abnormal morphology with annular tears extending either well into or through the outer third of the annulus fibrosis.	Good	HIZ of the lumbar disc on MRI in the patients with LBP could be considered a reliable marker of painful outer annular disruption.
Borthakur et al, 2011 (56)	Chronic LBP patients, 17 with 68 levels and control subjects, 11 with 44 levels underwent MRI. The LBP patients also received multilevel provocative discography before their MRI.	This study was designed to determine whether T1ρ MRI and discography opening pressure was quantitative by a marker of disc degeneration in LBP patients and in asymptomatic volunteers.	T1ρ was significantly lower in the painful discs from control and non-painful discs. Mean opening pressure for the painful discs was significantly lower than that for non-painful discs. Receiver-operating characteristic area under the curve was 0.91 for T1ρ MRI and 0.84 for opening pressure for predicting painful discs.	Good	In this study of LBP patients undergoing MRI and provocation discography, authors used an alternative technique that is sensitive to Pfirrmann degenerative grade content in cartilage in the T1ρ time constant obtained by spin-lock MRI. There was significant and strong correlation between T1ρ values and in vivo opening pressure measurements obtained by provocation discography in LBP patients.
O'Neill et al, 2008 (71)	143 patients in a spinal pain specialty center	The study was designed to determine the accuracy of MRI for diagnosis of discogenic pain, taking into consideration the interdependence of MRI parameters. Five MRI characteristics were defined: HIZ, nuclear signal, disc height, disc contour, and bone marrow intensity change. Discography was classified as either positive or negative.	Moderate loss of nuclear signal and a disc bulge have the best combination of sensitivity (79.8%) and specificity (79.3%). Adding moderate loss of disc height improves specificity (82%) slightly, and decreases sensitivity (73.6%) slightly, while incorporating HIZ Grade II further improves specificity (92.6%) and decreases sensitivity (54.7%). HIZ Grade I and bone marrow intensity change have minimal influence, even when there is moderate loss of nuclear signal.	Fair	The practical implication for physicians using discography is that the most important single MRI parameter to consider is nuclear signal. If nuclear signal is normal, the disc is very likely to be negative on discography, while if there is severe loss of nuclear signal, it is very likely to be positive. Discography was the most useful in discs with moderate loss of nuclear signal, particularly if there are no other MRI abnormalities present.
Chen et al, 2011 (75)	93 patients with MRI of lumbar spine and subsequent provocation discography.	The study aimed to correlate MRI findings and discography with pain response at provocation discography in patients with LBP.	Concordant pain significantly correlated with type IV to V discs on discography, Grade IV to V disc degeneration on MR image, the presence of HIZ, and endplate abnormalities. Disc degeneration grades on MRI showed an association with discographic grades.	Good	This study shows good correlation between MRI and discography with provocative concordant pain. Type IV to V discs on discography, Grade IV to V discs on MR images, the presence of HIZ, and endplate abnormalities might indicate discogenic pain in patients with chronic LBP.
Kim et al, 2009 (77)	23 patients who showed automated pressure control discography. Positive discs were selected for analysis.	The study attempted to analyze the clinical parameters critical for diagnosis of discogenic pain and to correlate imaging findings with intradiscal pressure and pain responses in patients with pressure controlled discography positive discs. CT discogram findings and the degree of nuclear degeneration seen on MRI were analyzed.	MRI abnormalities were statistically correlated with grading of CT discography results; with most pain response observed in CT discogram Grades III and IV. Pain provocative pressure was not statistically correlated with MRI grading. However, it was higher in Grade III than Grade IV.	Limited	There was limited correlation with MRI grading.

Table 4. (cont.) *Studies comparing lumbar discography with CT scanning or MRI in patients with degenerative disc disease.*

Author, Year	Subjects	Nature of Study	Results	Correlation	Comments
Thompson et al, 2009 (78)	The clinical records and MR images of 736 patients undergoing discography at 2,457 levels were reviewed.	The purpose of the study was to assess the value of vertebral body endplate signal intensity (Modic changes) on MRI mages in predicting the painful disc, with provocation discography as the reference standard. Each disc was assigned a Modic subtype from 0 to 3 indicating normal to sclerosis.	Type 1 changes with non-fatty high signal intensity (n=155) at a high positive predictive value (0.81; 95% CI: 0.74 to 0.87) with provocation discography. For a provocation discogram Type 2 changes with fatty signal intensity (n=126) at a lower positive predicted value (0.64; 95% CI: 0.55 to 0.72) for a positive discogram. Type 3 changes with sclerosis (n=21) positive predictive value (0.57; 95% CI: 0.34 to 0.78) that was not significant for a positive discogram.	Limited	Good for Type 1 Modic changes, limited for Type 2 Modic changes, and poor for Type 3 changes.
Milette et al, 1999 (80)	132 lumbar discs in 45 patients with chronic LBP were investigated by both MRI and discography.	The study was designed to assess some of the fundamental differences between lumbar disc protrusions, disc bulges, and discs with normal contour but abnormal signal intensity on T2-weighted MRI.	Loss of intervertebral height or abnormal signal intensity on MRI was significantly associated with disc disruptions extending into or beyond the outer annulus on discograms. 100% of disc protrusions and 80% of disc bulges were associated with Stage II or III annular disruptions and, in most instances, similar or exact reproduction of pain during disc injection.	Fair	In patients with chronic LBP, loss of disc height or abnormal signal intensity is highly predictive of symptomatic tears extending into or beyond the outer annulus. Disc bulges and disc protrusions do not represent discs with significantly different internal architecture, based on the findings of discography, and are no more suggestive of symptomatic tears than discs showing normal contour but decreased height or abnormal signal intensity.
Carragee et al, 2000 (119)	A total of 109 discs in 42 patients were evaluated in the symptomatic group compared with 143 discs in 54 patients in the asymptomatic group, all with chronic LBP.	The study was designed to compare the prevalence and significance of a HIZ in a group of patients asymptomatic for LBP, but who had known disc fractures for lumbar disc degeneration. This asymptomatic group was compared with a symptomatic group of patients with respect to the presence of annular HIZ and the pain response with discography.	The prevalence of HIZ in the patient population was 49% in the symptomatic group and 24% in the asymptomatic group. In the symptomatic group, 72.7% of the discs with HIZ were positive on discography, whereas 38.2% of the discs without a HIZ were positive. In the asymptomatic group, 69.2% of the discs with a HIZ were positive on discography, whereas 10% of the discs without a HIZ were positive.	Fair	In patients with or without chronic LBP, the presence of HIZ does not reliably indicate the presence of symptomatic IDD. However, HIZ was present in 73% of the discs in symptomatic patients and in the asymptomatic group only 10% of the patients had HIZ, even though 69% had positive discography, 10% with significant difference which was not analyzed. Further, discs with the HIZ were also significantly higher in the symptomatic group.
Horton & Daftari, 1992 (251)	25 patients with nonradicular LBP, involving 63 discograms	Comparative study between MRI and discography for discogenic LBP.	19 patients had positive discograms. Of the different MRI patterns, only 'dark/torn,' 'dark/bulged,' or 'speckled/flat' were more likely to be associated with positive rather than negative discograms.	Fair	MRI findings classified by pain pattern, not presence or absence of pathology.
Zucherman et al, 1988 (256)	18 patients with LBP with or without radicular symptoms	Clinical case series. In most cases discography was followed by CT scanning.	All patients had normal MRI and abnormal discograms.	None	Normal MRI and abnormal discograms were basis for inclusion.
Vanharanta et al, 1987 (257)	91 chronic LBP patients were compared to the pain provocation during the injection of contrast into the disc with 225 discs entered.	The study attempted to interpret the correlation between the presence of the HIZ on MRI and awake discography, as well as its characteristic pathology. 52 patients with low chronic LBP without disc herniation underwent MRI and discography. 11 specimens of lumbar intervertebral discs which contain HIZ in the posterior annulus from 11 patients with discogenic LBP were harvested for histologic examination.	The study found that in all of the 142 discograms in 52 patients, 17 presented HIZ. All 17 discs with HIZ showed painful reproduction and abnormal morphology with annular tears extending either well into or through the outer third of the annulus fibrosis.	Fair	This study suggests that the HIZ of the lumbar disc on MRI in the patient with LBP could be considered as a reliable marker of painful outer annular disruption.

Table 4. (cont.) *Studies comparing lumbar discography with CT scanning or MRI in patients with degenerative disc disease.*

Author, Year	Subjects	Nature of Study	Results	Correlation	Comments
Lim et al, 2005 (261)	47 patients underwent MRI and subsequent CT discography involving 97 discs.	Authors compared the results of provocation CT discography with MRI.	Concordant pain was significantly common in Grade IV or V disc degeneration (88% in concordant pain versus 48% in discordant pain and no pain), HIZ (56% versus 30%), combination of above 2 findings (53% versus 25%), fissured and ruptured disc at discogram (94% versus 57%), and contrast beyond inner annulus at CT discogram (97% versus 57%).	Good	In this study, patients with chronic LBP, with or without radiating pain, were evaluated with exclusion of disc extrusion, sequestration, spinal stenosis, spondylolysis, and previous surgery, etc. Overall, positive provocation discography correlated well with contrast beyond inner annulus at CT discogram (97%), fissured and ruptured disc at discogram (94%), Grade IV disc degeneration (88%), and with HIZ (56%), and combination of disc degeneration and HIZ (53%).
Collins et al, 1990 (264)	29 patients, 73 discograms	Compared MRI and discography in patients with axial LBP.	57 discs were abnormal on discography, with 13 producing concordant pain in 12 patients. Discography findings correlated with MRI in 90% of cases. 4 discs showed degeneration on discography w normal MRI, and 4 had abnormal MRI with normal discography.	Good	The 12 patients with positive discograms underwent spinal fusion, with 9 reporting clinical improvement at 9-month follow-up.
Greenspan et al, 1992 (266)	Prospective evaluation of 32 patients involving 78 discs with a clinical diagnosis of lumbar disc herniation studied by CT discography.	This prospective evaluation was conducted in patients with clinical diagnosis of lumbar disc herniation to compare the findings of CT discography and MRI with the pathology found on surgical exploration. 10 of the patients with 13 discs having both discography and MRI underwent exploratory surgery and the staging at surgery served as the standard against which the evaluative studies were judged.	Surgical staging was compatible with discography and MRI results in 5 discs, while in another 5 discs, it was compatible only with the discography results. In the remaining 3 discs, both discography and MRI misidentified the stages. The discography, more accurately defined the stage of disease than did the MRI, whereas the MRI was more precise than discography in only one disc.	Limited	Authors concluded that MRI was the ideal screening test for lumbar radiculopathy and LBP, and reserved discography for problematic cases.
Osti & Fraser, 1992 (273)	33 patients, 114 discs	Compared MRI and discography in patients with LBP.	All 54 discs identified as abnormal on MRI showed abnormal discogram patterns. 6 of the 60 discs identified as normal on MRI were abnormal on discography. Of the 39 discs that provoked concordant pain on discography, 27 were abnormal on MRI. 33 of the 39 asymptomatic discs by discography had normal MRI signals, with 24 having normal discographic patterns.	Good	Six of 46 discs classified as degenerate on MRI were asymptomatic at discography. Concluded discography is more accurate than MRI for detecting annular pathology. Patient population not well defined.
Schellas et al, 1996 (277)	63 patients, 100 discs with HIZ on T2 MRI in patients with LBP and/or radicular pain.	Retrospective analysis analyzing the significance of HIZ zones in predicting positive discography.	All 100 discs with HIZ were discographically abnormal, with 87 showing concordant pain. In 17 asymptomatic control patients, MRI scans revealed only one HIZ disc.	Good	37 patients had prior back surgery. Also included patients with radiculopathy.
Simmons et al, 1991 (278)	164 patients, 371 discs	Compared CT-discography and MRI in patients with chronic LBP with or without radiculopathy.	MRI normal and discogram abnormal in 34 discs. Discogram normal and MRI abnormal in 60 discs. 37% of discs abnormal on MRI were asymptomatic on discography. Did not include outcomes in 76 patients who underwent surgery.	Fair	55% correlation based on patients, 80% based on discs.
Scuderi et al, 2008 (285)	48 patients with symptomatic lumbar DDD were evaluated.	The purpose of the study was to correlate concordant pain on discography with MRI grade and biochemical markers of inflammation in a clinical setting.	None of the demographic variables were significantly related to concordant pain on discogram. VAS scores were not significantly correlated with opening pressures at any level.	Poor	Only weak correlations between demographic, discogram, and radiographic variables. Response to discogram cannot be predicted by non-invasive means.

Table 4. (cont.) *Studies comparing lumbar discography with CT scanning or MRI in patients with degenerative disc disease.*

Author, Year	Subjects	Nature of Study	Results	Correlation	Comments
Sandhu et al, 2000 (291)	53 patients with LBP, 133 discograms	Retrospective analysis comparing discography with vertebral endplate signal changes on MRI.	41% of discs with positive endplate changes were positive discograms vs. 27% without. Among positive discograms, only 23% exhibited T2-weighted MRI endplate changes.	None	No significant correlation between discography and endplate signal changes.
Brightbill et al, 1994 (292)	7 patients with LBP	Clinical case series involving patients with discrepancy between discography and MRI who underwent surgery and were found to have IDD.	All 7 subjects had normal MR imaging and positive discography.	NA	Did not consider surgical outcomes.
Yu et al, 1989 (293)	8 cadavers, 36 discs	Compared MRI and discography against cryomicrotomy anatomic sectioning for detecting annular tears.	Discography identified 15 radial fissures, 10 of which were seen on MRI. Two of the 15 annular fissures were missed on cryomicrotomy.	Fair	Included a newborn and 2-year-old. Considered only radial tears of annulus. Could not correlate findings with symptoms.
Kakitsubata et al, 2003 (294)	24 discs from 5 cadavers	Compared MRI and MR discography with anatomic correlation for detecting annular tears.	Sensitivity of MR-discography was 100%, 57%, and 21% for radial, transverse and concentric, tears in annulus, respectively, vs. 67%, 71%, and 21% for conventional MRI.	None	Could not correlate findings with symptoms.
Schneiderman et al, 1987 (295)	36 patients with LBP, with or without leg pain, 101 discograms	Compared MRI and discography.	MRI accurate in assessing disc morphology in 100 of 101 levels. Of 52 discs with normal MRI, only one had positive discogram. Of 49 discs with decreased MR signal, only 2 discograms normal.	Poor	Used only T2-weighted MRI. CT-discography used on 39 levels.
Linson & Crowe, 1990 (296)	50 patients, 97 discs	Compared MRI and discography in patients with chronic LBP.	91% correlation for disc degeneration between MRI and discography.	Good	5 of the 6 discs with negative correlation were read as normal by MRI and abnormal by discography. No mention of control discs during discography.
Gibson et al, 1986 (297)	22 patients, 50 discs	Compared MRI and discography in patients with mechanical LBP.	Discography results based on radiographic findings only as patients were sedated. In the 6 discs that didn't correlate, MRI was superior to discography.	Good	Agreement between studies in 44 of 50 discs.
Yoshida et al, 2002 (298)	23 patients, 56 discs	Examined correlation between MR images and pain response on discography.	Sensitivity, specificity, positive predictive value, and negative predictive value of T2-MRI were 94%, 71%, 59%, and 97%, respectively.	Good	Did not specifically compare discography and MRI. T2- weighted MRI superior to gadolinium-enhanced images.
Birney et al, 1992 (299)	90 patients, 264 discs	Examined correlation between MRI and discography for DDD and HNP. Compared surgical findings with discography in 57 patients.	Agreement between MRI and discography in 86% of discs. MRI more accurate for HNP; discography slightly superior to MRI for DDD (MRI missed one disc, discography 100% sensitive).	Good	Considered patients with LBP and radicular pain. Surgical findings correlated with diagnostic studies at 63 of 76 levels.
Loneragan et al, 1994 (300)	18 patients with chronic LBP thought to be discogenic (43 discs).	Compared MRI and CT discography in the diagnosis of DDD and HNP.	MRI missed 3 of 10 discs with early degenerative changes, and one of 3 herniations.	Good	In no cases did MRI offer more information than CT-discography.
Aprill & Bogduk, 1992 (301)	41 patients (105 discs) with chronic LBP with or w/o radicular symptoms.	Compared HIZ on T2-weighted MRI with CT discography.	In all patients who exhibited an HIZ on MRI, CT-discography revealed either a grade 3 or 4 annular disruption. A grade 3 or 4 disruption was also present in 34 patients w/o an HIZ.	Good	Concordant pain provocation with discography was present in 38 of 40 HIZ discs, and 22 of 78 discs w/o an HIZ. CT discography performed in only 41 out of 500 patients in whom MRI was examined.

Table 4. (cont.) *Studies comparing lumbar discography with CT scanning or MRI in patients with degenerative disc disease.*

Author, Year	Subjects	Nature of Study	Results	Correlation	Comments
Yu et al, 2012 (318)	45 patients with negative discography randomly received intradiscal injection of dexamethasone or saline as placebo in the control group	Compared patients with probable discogenic LBP and had obvious disc pathological changes on MRI, but showed negative discography.	Discography and CT scans of the 45 patients revealed that there were Grade V in 38 discs and Grade IV in 7 discs by means of modified Dallas classification. After about 6 month follow-up, the results showed that VAS scores and ODI scores were greatly improved during the first 3 month follow-up in the experimental group, compared with the pre-discography and between groups.	Limited	Authors evaluated diagnosis of discogenic LBP in patients with probable symptoms. Even though discography was negative, patients had discogenic pain.
Quero et al, 2011 (321)	62 patients with axial LBP that was likely to be disc related underwent lumbar discography with 178 discs being tested.	To correlate MRI findings with pain response for provocation discography in patients with discogenic LBP, with an emphasis on the combination analysis of HIZ and disc contour abnormalities. The MR images were evaluated for disc degeneration, disc contour abnormalities, HIZ, and endplate abnormalities. The MR image findings were analyzed in the base of concordant pain determined by discography.	Disc protrusion with HIZ sensitivity 45.5% specificity, 97.8% positive predictive value, 87% correlated significantly with concordant pain provocation. A normal or bulging disc with HIZ was not associated with reproduction of pain. Disc degeneration sensitivity (95.4%), specificity (38.8%), positive predictive value (33.9%), disc protrusion sensitivity (68%), specificity (80.6%), positive predictive value (53.6%), and HIZ sensitivity (56.8%), specificity (83.6%), positive predictive value (53.2%) were not helpful in the identification of a disc with concordant pain.	Limited	Disc protrusion with HIZ on MRI predicted positive discography in patients with discogenic LBP; however, a normal or bulging disc with HIZ was not associated with reproduction of pain.
Salem et al, 2011 (324)	48 patients with symptomatic lumbar DDD were evaluated.	The study was designed to critically evaluate discography in patients with lumbar intervertebral disc disease. Each patient underwent discography MRI and a biochemical analysis of disc lavage fluid.	There were only weak correlations between demographic, discogram, and radiographic variables. Response to discogram cannot be predicted by noninvasive tests. The disc lavage method was unable to identify the presence of specific inflammatory peptides with multiplex immunoassay.	Poor	Weak correlation among multiple variables.
Streitparth et al, 2011 (325)	41 patients scheduled for intradiscal electrothermal treatment, total disc replacement or spondylodesis were examined with evaluations examined with inclusion of 48 disc segments.	To evaluate the feasibility of MR-guided discography using any open 1 Telsa MRI system. After primary disc puncture under guidance of interactive PDw TSE imaging, 1-2 mL of gadolinium contrast saline mixture was injected into the disc. The occurrence of memory pain during injection was recorded.	The placement of the puncture needle in the targeted disc was accurate under real-time MR guidance. Injections were technically successful in all cases. Image quality of contrast-enhanced MR discograms was excellent when using an optimized gadolinium contrast saline mixture of one in 600. Memory pain was detected in 16 out of 48 affected segments.	N/A	Multi-plane or dynamic imaging facilitates the puncture of discs and provides high-quality MR discograms.

NOTE. Discography refers to discograms performed without CT scanning.

DDD = Degenerative Disc Disease; IDD = Internal Disc Disruption; HIZ = High-Intensity Zone on MRI; HNP = Herniated Nucleus Pulposus; LBP = Low Back Pain; MRI = Magnetic Resonance Imaging; MR = Magnetic Resonance; CT = Computed Tomography; VAS = Visual Analog Scale; ODI = Oswestry Disability Index; PDw = Proton-Density-Weighted; TSE = Turbo Spine-Echo

Revised and updated from Cohen et al. A comprehensive review of outcome studies, diagnostic accuracy, and principles. *Reg Anesth Pain* Med 2005; 30:163-183 (132).

Table 5. *Characteristics of diagnostic accuracy studies.*

Study	Participants / Results	Authors' Conclusion	Review Conclusion
PD			
Manchikanti et al, 2001 (32)	120 patients with a chief complaint of low back pain were evaluated with precision diagnostic injections, which included medial branch blocks, provocative discography, and sacroiliac joint injections.	The facet joint is the most common pain generator in chronic low back pain, with identification of the facet joint in 40% of patients, followed by the disc in 26% of patients, and the sacroiliac joint in only 2% of the patients.	Prevalence of discogenic pain was present in 26% of the sample.
Schwarzer et al, 1994, 1995 (36,37)	92 consecutive patients with chronic low back pain and no history of previous lumbar surgery were studied. Each patient underwent a standard physical examination. CT discography was performed at a minimum of 2 levels. Authors also used both discography and blocks of the zygapophyseal joints.	A diagnosis of internal disc disruption can be made in a significant proportion of patients with chronic low back pain, but no conventional clinical test can discriminate patients with internal disc disruption from patients with other conditions. In patients with chronic low back pain, the combination of discogenic pain and zygapophysial joint pain is uncommon.	This study provided prevalence of internal disc disruption. This study provided confirmation that combined discogenic and facet joint pain is rare.
Sheng et al, 2010 (65)	A total of 34 patients with low back and radiating leg pain, but without lumbar disc herniation on CT or MRI were examined by electrophysiological studies and discography to identify whether or not there were annular tears and nerve root injury.	To investigate whether annular tear is a cause of low back and radiating leg pain and explore the clinical characteristics and treatment for patients with this condition.	Even though MRI and electrophysiological studies play an important role in diagnosing annular tears, lumbar discography appears to be the decisive method for the diagnosis and potential interventions.
Depalma et al, 2012 (67)	157 patients with chronic low back pain underwent definitive diagnostic injections. Of these, 71 patients underwent PD in this subgroup analysis assessing relationships between age, gender, and body mass index and the source of chronic low back pain. Age, gender, and BMI were each significantly associated with the source of chronic low back pain. Increases in age were associated with significant decreases in the odds of internal disc disruption.	The authors concluded that lumbar internal disc disruption is more prevalent in young males.	The results of this subgroup analysis are in conformity with other studies.
DePalma et al, 2011 (82)	A total of 156 patients underwent diagnostic procedures including PD, dual diagnostic facet joint blocks, and sacroiliac joint injections. All patients suffered with chronic low back pain and failed conservative management. The PD was performed. Positive discography was defined as concordant or partial concordant low back pain above 6 or 10 at low pressure (below 50 psi) over opening pressure due to Grade III or higher annular tears. 71 patients underwent PD with a prevalence of 41.8%.	The authors concluded that the prevalence of internal disc disruption was present in 42% of the patients. Patients with internal disc disruption were significantly younger than those with facet joint pain or sacroiliac joint pain. Increased age was associated with a definitive probability of internal disc disruption and increased probability of facet joint pain and sacroiliac joint pain.	Well-performed evaluation in a group of patients with chronic low back pain yielding a prevalence of internal disc disruption of 42%.
DePalma et al, 2011 (83)	Authors evaluated 27 motor vehicle collision-induced chronic low back pain patients with lumbar PD and other diagnostic blocks in a retrospective evaluation. 15 of these patients tested positive with PD and meeting the diagnostic criteria for internal disc disruption yielding a 56% prevalence of discogenic pain.	The authors claim that this is the first to demonstrate that diagnostic spinal injections can identify particular spinal structures, namely the intervertebral discs, facet joints, and sacroiliac joints, as a specific source of chronic low back pain due to inciting motor vehicle collisions.	As the authors claim, this is the first study; however, it includes a very small number of patients yielding a very high positive rate for internal disc disruption.
DePalma et al, 2012 (84)	The authors evaluated the history of surgical discectomy related to the source of chronic low back pain. A total of 11 patients were included with surgical discectomy and of these, 82% were considered to have internal disc disruption compared to 41% internal disc disruption among patients with no previous surgical interventions.	Authors concluded that this is the first published investigation of the tissue source of chronic low back pain after surgical discectomy with 82% prevalence of internal disc disruption.	This is not the first study published in reference to internal disc disruption or discogenic pain after surgical discectomy. The study included a very small number of patients. Further, the issue has been discussed extensively.
DePalma et al, 2011 (85)	The authors evaluated the etiology of chronic low back pain in patients having undergone lumbar fusion in 28 fusion cases identified from 170 low back pain patients undergoing diagnostic procedures with chronic pain. PD was performed. The results showed internal disc disruption in 7 patients with a prevalence of 25%.	The authors concluded that in patients recalcitrant to non-interventional care, after lumbar fusion, internal disc disruption is not as common as sacroiliac joint pain.	The study was performed retrospectively as a subgroup analysis in a small number of patients.

Table 5 (cont). *Characteristics of diagnostic accuracy studies.*

Study	Participants / Results	Authors' Conclusion	Review Conclusion
Laplante et al, 2012 (88)	The authors evaluated the relationship between pain referral patterns and the source of the chronic low back pain. This is the subgroup analysis of (82). 68 patients underwent PD with a prevalence of 43% of internal disc disruption.	The authors concluded that the presence or absence of thigh pain possesses a significant correlation on the source of chronic low back pain for varying ages. Younger age was predictive of internal disc disruption regardless of the presence or absence of thigh pain.	The results are similar to the original manuscript (82).
Derby et al, 2005 (107)	4 lay persons and 9 physicians underwent lumbar discography, with manometry. Lumbar discs in asymptomatic volunteers can be made painful, but as a rule, the pain is mild and requires high pressures of injection.	If attention is paid to pressure of injection and intensity of response, operational criteria can be defined that provide lumbar discography with a potential false-positive rate of 0 or less than 10%.	This study provides a potential false-positive rate of less than 10% when lumbar PD is performed utilizing appropriate criteria.
Derby et al, 2005 (108)	16 healthy volunteers without current back pain and 90 patients with chronic low back pain. Pain tolerance was significantly lower in patients relative to symptomatic subjects. Negative patient discs and asymptomatic subject discs showed similar characteristics.	Pressure-controlled manometric discography using strict criteria may distinguish symptomatic discs among morphologically abnormal discs with grade III annular tears in patients with suspected chronic discogenic low back pain.	The study results indicated validity of discography.
Derby et al, 2005 (110)	279 discs from 86 patients (55 men, 31 women) who were referred for discography of suspected chronic discogenic low back pain.Annular disruption reaching the outer annulus fibrosus is a key factor in pain generation.	Disk morphology, including annular disruptions extending beyond the outer annulus, may permit increased discography specificity.	The study indicates validity of discography.
Derby et al, 1999 (111)	Long-term outcome was ascertained in 96 patients who had lumbar discography and subsequently underwent interbody fusion alone, combined fusion, intertransverse fusion, or no surgery. Patients with highly (chemically) sensitive discs appear to achieve significantly better long-term outcomes with interbody/combined fusion than with intertransverse fusion. Patients without disc surgery have the least favorable outcome.	Precise prospective categorization of positive discographic diagnoses may predict outcomes from treatment, surgical or otherwise, thereby greatly facilitating therapeutic decision-making.	This was the only study which used manometry as a determining factor in discography interpretation in evaluation of surgical outcomes.
Carragee et al, 2000 (113)	26 asymptomatic patients with (15) or without (11) psychological abnormalities	Significant back pain in patients with emotional problems.	Asymptomatic patients do not receive discography.
Carragee et al, 2004 (114)	50 subjects without low back pain were recruited for clinical and psychometric testing, MRI scanning, and experimental lumbar discography to determine the rate of painful lumbar disc injections in select subjects without low back pain history.	Painful disc injections are poor independent predictors of subsequent LBP episodes in subjects initially without active lower back complaints. Annular disruption is a weak predictor of future LBP problems. Psychological distress and pre-existing chronic pain processes are stronger predictors of LBP outcomes.	Patients without low back pain do not receive discography; thus, the conclusions are inappropriate.
Carragee et al, 2002 (115)	Mild chronic low back pain = 25 Chronic low back pain = 52	36% positive challenged specificity	Similar to 26%–39% in controlled trials (32,35,37).
Carragee et al, 2000 (116)	Asymptomatic postsurgery = 20 Intractable pain-laminectomy = 27	High false-positive rate after limited lumbar discectomy.	Poor operational criteria.
Carragee et al, 1999 (117)	8 asymptomatic subjects who had undergone posterior iliac crest bone graft harvesting, and who, by pain drawing and psychometric testing, appeared to be reliable discography candidates.	Authors questioned the ability of a patient to separate spinal from non-spinal sources of pain on discography and concluded that a response of concordant pain on discography may be less meaningful than often assumed.	Asymptomatic patients do not receive discography. Consequently, the usual gluteal area pain may not be reproduced. Reanalysis of the data showed a false-positive rate of 12.5% per patient or 7.1% per disc in contrast to the false-positive rate reported by Carragee et al of 50% per patient and 28.6% per disc (35).
Carragee et al, 2000 (118)	26 individuals without low back pain, with 10 pain free, 10 chronic neck pain, 6 primary SD.	Significant positive responses in patients with chronic neck pain (40%), SD (83%).	Inappropriate conclusions. With strict operational criteria and standards, false-positive rate can be reduced to 0% in chronic neck pain patients. SD patients with small sample size, broad CI, incomplete data set in 2/6 patients.

Table 5 (cont). *Characteristics of diagnostic accuracy studies.*

Study	Participants / Results	Authors' Conclusion	Review Conclusion
Carragee et al, 2006 (121)	Asymptomatic of significant low back pain illness = 69 Clinical low back pain group = 52	25% positive discograms in patients without significant low back pain illness.	Very broad CI levels with poor inclusion criteria (e.g. SD patients and symptomatic chronic low back pain patients).
Carragee et al, 2006 (122)	Discogenic pain = 32 Spondylolisthesis group = 30	Positive discography not highly predictive of success of fusion.	Fusion is not a proven treatment for discogenic pain.
Cohen et al, 2002 (239)	The charts of 127 patients who underwent discography were evaluated to determine the relationship between the location of pain, needle insertion site, and discography results.	False-positive discography results are unlikely to result from performing the procedure on the same side as a patient's reported pain.	This study provided the evidence that the results were similar when discograms were performed on the same side as the patient's reported pain.
Manchikanti et al, 2001 (259)	50 randomly assigned patients, with 25 patients in Group I without SD and 25 patients in Group II with diagnosis of SD. In addition, depression, generalized anxiety disorder, and combinations thereof were also evaluated.	Provocative discography provides similar results in patients with or without somatization, with or without depression, with somatization but with or without depression, or with other combinations of the psychological triad of SD, depression, and generalized anxiety disorder.	There was no difference when somatization was evaluated utilizing appropriate described criteria.
Shin et al, 2006 (260)	21 patients with clinically suspected discogenic low back pain who underwent pressure-controlled discography.	Pressure-controlled discography was useful to diagnose discogenic pain and an excellent guide in decision-making for spinal operations.	Pressure-controlled discography was useful to diagnose discogenic pain.
Walsh et al, 1990 (265)	7 patients with low back pain and 10 volunteers without history of low back pain underwent discography at 3 levels. patients had positive discograms on the basis of the study criteria, leading to the conclusion that with current techniques and in conjunction with standardized methods for assessment of pain, lumbar discography is a highly reliable and specific diagnostic test.	Authors concluded that discography is not the best diagnostic test for all patients who have low back pain.	This study provided a false-positive rate of 0% in asymptomatic subjects. The results indicate validity of discography.
FAD			
Alamin et al, 2011 (112)	The study was designed in 52 patients to compare the results of standard pressure-controlled PD to those of the FAD in a series of patients presenting with chronic low back pain and considering surgical treatment. The results on PD were 12% negative, 30% 2 level positive, and 58% one level positive with a positive rate of 88%. In contrast, on FAD, negative results were observed in 24% instead of 12% on PD. Overall, the 2 tests had divergent findings in 23 of the 50, or 46% of patients. In 13 of 50, the test was completely negative, whereas the provocative discogram had been positive; in 8 of 50, the test was positive at a single level only, whereas 2 or more discs were positive on provocation discogram; in 2 patients, a new positive was noted in the setting of a negative provocation discogram.	Authors concluded that the findings of the test differed from those of standard pressure controlled discography in 46% of the cases reported.	It appears that there may be more false-positives with provocation discogram and some false-negatives. FAD was performed in provocative lumbar discography negative patients only if it was felt by the surgeon that the MRI scan was highly clinically suspicious for asymptomatic level based on the presence of extensive Type I Modic change. There was no specific protocol for this determination. Only 3 patients in the series had a FAD performed in the setting of a negative PD. The disadvantages include a larger needle and catheterization. The procedure was tedious and time-consuming.
Derby et al, 2012 (326)	In this study authors compared subjective reported pain relief following provocative testing using the following protocols at three separate facilities: 23 patients undergoing routine provocative discography using contrast alone (PD); 47 patients undergoing provocative discography performed using an equal combination of local anesthetic and contrast (CPD); 120 patients injected with local anesthetic following routine PD (ADPD); 33 patients undergoing SAAD; and 28 patients injected with local anesthetic through a catheter (FAD) placed during provocative discogaphy testing.	The authors concluded if the criterion standard to confirm painful annular tears is concordant with pain provocation and 80% or greater pain relief following local anesthetic injected into lumbar discs, the SAAD, ADPD, and FAD protocols show statistically similar 20% to 30% prevalence.	There was no significant difference in prevalenc rate between techniques involving pain provocation alone, pain provocation with analgesic discograhy or FAD.

Table 5 (cont). *Characteristics of diagnostic accuracy studies.*

Study	Participants / Results	Authors' Conclusion	Review Conclusion
Anesthetic Discography			
Derby et al, 2010 (102)	In this evaluation, 70 patients were studied with 23 patients in the non-analgesic group and 47 patients in the analgesic group with chronic low back pain. The objective was to confirm that injecting local anesthetic in intervertebral discs would provide convincing pain relief and that the degree of pain relief would help confirm or refute the findings of provocative discography.	The addition of local anesthetic to contrast significantly reduced pain scores by 2 x 10 or greater during forward flexion and equal or greater to 50%. Authors concluded that using equal mixtures of injected local anesthetic and contrast during provocative discography in a cohort of patients did not provide significant overall subjective pain relief compared to using contrast alone in a comparative separate cohort.	The addition of local anesthetic to pressure controlled PD technique did not affect the number of positive results.
Bartynski & Rothfus, 2012 (106)	The purpose of the study was to evaluate potential correlation between disc-margin shape and annular internal derangement on post-discogram CT in significantly painful discs encountered at provocation lumbar discography. Significantly painful discs were encountered at 126 levels in 86 patients studied by provocation lumbar discography where no prior surgery had been performed and response to intradiscal lidocaine after provocation resulted in neither substantial nor total relief or no improvement after lidocaine administration. In discs with focal protrusion, 79% or 50 of 63 demonstrated Grade III radial annular defect with 21% or 13 of 63 patients demonstrating severe degenerative change only. In discs with generalized-bulge-only, 76% or 48 of 63 demonstrated degenerative change only with 15 of 23, or 24%, demonstrating a radial annular defect.	Pain elimination with intradiscal lidocaine correlated with discographic contrast leakage. Disc-margin shape correlates with features of internal derangement in significantly painful discs encountered at provocation lumbar discography. Discs with focal protrusion typically demonstrated radial annular defect while generalized bulging discs typically demonstrated degenerative changes. Disc margin shape may provide an important imaging clue to the cause of chronic discogenic low back pain.	The results of this study showed pain elimination with intradiscal lidocaine correlated with discographic contrast leakage. Lidocaine injection did not influence any other findings.
Oikawa et al, 2012 (216)	In a prospective study of 212 patients with groin pain but without low back pain or radicular pain, discogenic pain was assessed. The authors selected 5 patients with groin pain alone for investigation with PD. All patients underwent interbody fusion surgery with significant improvement in pain after one year of surgery.	The authors diagnosed discogenic groin pain by pain provocation on discography with pain relief by anesthetic discoblock, and lumbar surgery and treated them with lumbar surgery. The authors postulate that it is important to consider the existence of discogenic groin pain if patients do not show low back pain.	Very small number of patients with positive results leading to future evaluations, with limited evidence.
Derby et al, 2012 (326)	In this study authors compared subjective reported pain relief following provocative testing using the following protocols at three separate facilities: 23 patients undergoing routine provocative discography using contrast alone (PD); 47 patients undergoing provocative discography performed using an equal combination of local anesthetic and contrast (CPD); 120 patients injected with local anesthetic following routine PD (ADPD); 33 patients undergoing standalone analgesic discography (SAAD); and 28 patients injected with local anesthetic through a catheter (FAD) placed during provocative discogaphy testing.	The authors concluded if the criterion standard to confirm painful annular tears is concordant with pain provocation and 80% or greater pain relief following local anesthetic injected into lumbar discs, the SAAD, ADPD, and FAD protocols show statistically similar 20% to 30% prevalence.	There was no significant difference in prevalence rate between techniques involving pain provocation alone, pain provocation with analgesic discograhy or FAD.

CT = Computed Tomography; MRI = Magnetic Resonance Imaging; BMI = Body Mass Index; SD = Somatization Disorder; CI = Confidence Interval; FAD = Functional Anesthetic Discography; SAAD Standalone Analgesic Discography; LBP = low back pain; PD = Provocation Discography

Table 6. *Summary of outcome data for lumbar disc replacement or fusion surgery based on preoperative discography screening.*

Study, Year	Number of Disc Replacement or Fusion Patients	Type of Surgery	Outcomes	Comments
Derby et al, 1999 (111)	96 patients who underwent discography for LBP	Interbody fusion, or combined fusion, or intertransverse fusion, or no surgery	In patients with chemically sensitized discs (≥6/10 concordant pain @ < 15 psi above opening pressure, n = 36), success rates were 89% for interbody/ combined fusion, 20% for posterior intertransverse fusion, and 12% for no surgical treatment. Mean follow-up for surgical patients: 28 months. No difference between outcomes for interbody/ combined fusion and posterior intertransverse fusion for surgical sample as a whole.	There were no significant differences in long-term surgical outcomes across the entire sample. Significant outcome differences exist across the subgroup of patients with chemically sensitive discs. Positive results in chemically sensitive discs.
Carragee et al, 2006 (122)	Total patients = 62 Discogenic pain = 32 Spondylolisthesis = 30	360° single level fusion with pedicle screw and bone graft	In the control-spondylolisthesis group, 23 of 32 patients (72%) met highly effective success criteria, compared with 8 of 30 in the presumed discogenic pain cohort (27%). The proportion of patients who met the "minimally acceptable outcome" was 29 of 32 (91%) in the spondylolisthesis group and 13 of 30 (43%) in the presumed discogenic pain group. Authors calculated the best case positive predictive value of discography to be 50% to 60%. They concluded that positive discography was not highly predictive in identifying bona fide isolated intradiscal lesions, primarily causing chronic serious low back illness.	Even though authors have rated this as a negative study, positive predictive value of discography was calculated to be 50% to 60%; however, the major issue appears to be comparing discogenic pain with spondylolisthesis, which has been shown to be responsive to fusion surgery compared to discogenic pain, thus the results provide only limited evidence or underdetermined.
Madan et al, 2002 (124)	41 patients who underwent spinal arthrodesis without pre-op discography and 32 patients who underwent surgery based on positive discography.	Posterolateral interbody and posterior spinal arthrodesis	81% of patients who had surgery based on MRI and clinical findings had satisfactory outcome vs. 76% of patients who underwent arthrodesis based on positive discogram. Mean follow-up was 2.4 years in discography group and 2.8 years in MRI/clinical group.	There was no significant difference whether the patients underwent discography or not. The results are negative.
Ohtori et al, 2009 (127)	42 Discography versus discoblock for diagnosis	Anterior discectomy and interbody fusion	Authors concluded that pain relief after injection of a small amount of bupivacaine into the painful disc was a useful tool for the diagnosis of discogenic LBP compared with discography.	Patients undergoing disc block showed narrowly better results compared to those with provocation discography. The study had a small number of patients showing analgesic discography may be more useful. The results are undetermined.
Willems et al, 2007 (129)	82	Lumbar fusion	Authors concluded that in patients with an uncertain indication for lumbar fusion, the preoperative states of adjacent levels as assessed by provocative discography did not appear to be related to the clinical outcome after fusion.	The results are negative.
Moore et al, 2002 (158)	58	Anterior and posterior arthrodesis and posterior instrumentation	Fusion levels were delineated by MRI and provocative discography in correlation with history and physical examination. The solid arthrosis rate was 95%. 88% of the patients were able to return to work. 19% of the patients required long-term narcotics, whereas, 48% of the patient population were on narcotics before surgery. 86% of the patients had a better rating at final follow-up. 10% of the patients were the same and 3% were worse. Authors concluded that selected patients with discography-proven severe LBP secondary to DDD, who failed extensive nonoperative treatment, were treated successfully with anterior-posterior instrument arthrodesis. The good arthrodesis rate, return to work rate, and the patient satisfaction may justify the consideration of this aggressive treatment option in this specific patient population.	This study with 58 patients is a reasonably large study without a control group showing positive results. Fair evidence in favor of using discography for selection of fusion in discogenic pain.

Table 6 (cont.). *Summary of outcome data for lumbar disc replacement or fusion surgery based on preoperative discography screening.*

Study, Year	Number of Disc Replacement or Fusion Patients	Type of Surgery	Outcomes	Comments
Ohtori et al, 2011 (159)	41	Anterior interbody fusion and posterolateral fusion with pedicle screws	In a randomized trial of 41 patients divided into 3 groups: minimal treatment control, 20 patients; anterior interbody fusion, 15 patients; posterolateral fusion with pedicle screws, 6 patients. Results showed significant improvement in the 2 surgical groups compared with the minimal treatment control group 2 years after treatment. The authors concluded that surgical therapy is suitable for its treatment with anterior interbody fusion giving good results.	This is an extremely small study with unclear results of superiority of a fusion or pedicle screws over non-surgical management.
Gill & Blumenthall, 1992 (168)	53 patients with diagnosis of internal disc disruption at L5-S1.	A modified Crock anterior lumbar interbody fusion with allograft or autogenous iliac crest	A successful functional result after anterior lumbar fusion at L5-S1 was described as the ability to return to gainful occupation or normal activities, and no use of narcotic medications, with 76% to 100% relief of their back pain. Using these criteria 66% of the patients had a successful outcome of treatment. When evaluated by discographic findings only 50% of those patients with Type I discography, indicating a small annular tear that did not extend to the periphery and normal MRI scans, showed improvement on functional testing and pain report. 75% of those patients with Type II and III discography with annular tear and contrast extension to the periphery in Type II and beyond to the epidural space in Type III with MRI scans confirming degeneration of the nucleus signal and nuclear degeneration, showed significant improvement.	This is a positive study with good results based on provocation discography.
Parker et al, 1996 (169)	23 patients with mechanical LBP and positive discography.	Posterolateral intertransverse fusion	39% of patients reported good outcomes, 13% fair outcomes, and 48% had poor results. Abnormal discogram was basis for surgery. Mean follow-up 47 months.	Indeterminate results with only 39% with a good or excellent result.
Tsou et al, 2004 (205)	113	Posterolateral transforaminal selective endoscopic discectomy and thermal annuloplasty	The results showed overall over 43% of the patients showed either good or excellent results, with 30% fair results, and 27% poor results.	Seemingly good results; however, the relevance to discography is not clear. The results are unclear. Limited success rate with a large proportion of missing data in a retrospective evaluation offering no information on provocation discography.
Colhoun et al, 1988 (263)	162 patients with axial LBP	Anterior or posterior fusions, occasionally with a laminectomy	Of 137 patients in whom discogram revealed DDD and provoked concordant pain, 89% had favorable outcome. Only 52% of those patients in whom discography showed DDD but provoked no pain had a favorable outcome. Mean follow-up 3.6 years.	Positive correlation with positive discography with superior results in 89%, whereas it was 52% in those with negative discography.
Wetzel et al, 1994 (282)	48 patients with axial LBP who underwent lumbar arthrodesis following provocative discography.	Arthrodesis	At first follow-up (mean 5.3 wks), 66% had satisfactory outcome. At final follow-up (mean 35 months), 46% had satisfactory outcome. CT-discography used in all but one patient. Not all patients had a control disc (26 patients had single-level discography).	Only 46% were judged to have a satisfactory clinical outcome. There was no comparative group. The results are undetermined.
Knox & Chapman, 1993 (303)	22 patients who underwent anterior spinal fusion for discogram-concordant LBP	Anterior lumbar interbody fusion	Poor results in all 5 patients with 2-level fusions. In single level fusions, 35% of patients had good results, 18% fair, and 47% poor outcomes. Strong correlation between subjective (clinical improvement) and objective (fusion success) results.	Only 35% with good results. The results are negative.
Vamvanij et al, 1998 (304)	56 patients with discogenic LBP confirmed by CT discography who underwent one of 4 fusion techniques.	Four-fusion techniques	Overall rate of patient satisfaction: 46%. Success rate for patients who had anterior lumbar fusion with cage and facet fusion: 63%. Success rates for the other 3 groups ranged from 36% to 46%.	Very low success rate overall. The results are undetermined.

Table 6 (cont.). *Summary of outcome data for lumbar disc replacement or fusion surgery based on preoperative discography screening.*

Study, Year	Number of Disc Replacement or Fusion Patients	Type of Surgery	Outcomes	Comments
Blumenthal et al, 2003 (305)	57	Total disc replacement	63% of patients improved at 2-year follow-up (based on > 20 point improvement on VAS score).	Limited improvement
Shim et al, 2003 (306)	46	Partial disc replacement	Mean VAS score: 8.5 pre-op, 3.1 at 1-year follow-up. 11% had excellent and 67% good results.	Good results
van Ooij et al, 2003 (307)	27	Total disc replacement	Good outcome obtained in 12 of 26 patients, with variable follow-up period (range one month-10 years).	Fair results
McAfee et al, 2003 (309)	41	Total disc replacement	Mean VAS score: 73.5 pre-operatively, and 30.4 at 1–3 year follow-up.	Fair results
Zeegers et al, 1999 (311)	50	Total disc replacement	32 of 46 patients followed for 2 years had a positive clinical result. Did not provide separate data for patients having discography.	Good results
Hochshuler et al, 2002 (313)	56	Total disc replacement	52.7% improvement in mean VAS scores at 6-week follow-up. In the 22 patients followed for ≥ one year, improvements in VAS and Oswestry scores were maintained.	Limited
Enker et al, 1993 (317)	6	Total disc replacement	4 of 6 patients had satisfactory results (1 excellent, 2 good, one fair).	Limited
Berg et al, 2012 (319)	138	Not specified	Authors concluded that a high frequency of decision-making was altered in this group of surgeons when using discography as an additional examination in patients where uncertainty remains in how to treat after clinical examination, questioning, and MRI. However, it is unknown whether patient outcome improved, worsened, or was not affected by interpretation and use of the discography data in the study.	The results are unknown in reference to the significance of provocation discography in this group of patients.

NOTE(S). Table does not include studies lacking information about patient selection criteria.
Type I discogram designated as internal disc disruption (IDD) without extravasation of contrast associated with concordant pain reproduction.
Types II and III denote the presence of annular disruption with spread of contrast to the periphery and epidural space, respectively.
LBP = Low Back Pain; MRI = Magnetic Resonance Imaging; DDD = Degenerative Disc Disease; CT = Computed Tomography; VAS = Visual Analog Scale

2.4 Methodological Quality Assessment

A methodological quality assessment for prevalence studies was carried out utilizing QAREL criteria as shown in Table 7. Studies achieving 50% or higher scores were included. Scores of 67% or higher were considered to be high quality, ≥ 50% were considered to be moderate quality, and studies scoring less than 50% were considered to be of poor quality and excluded.

After the exclusion of duplicate publications, only 3 studies met inclusion criteria for diagnostic accuracy studies of prevalence. All 3 of them (32,36,82) met the methodological quality assessment criteria and all 3 were determined to be of high quality.

2.5 Clinical Relevance

Table 8 shows the clinical relevance of diagnostic accuracy and prevalence studies.

2.6 Prevalence Studies

Table 9 describes the 3 studies assessing the prevalence of discogenic low back pain. Two of the studies focused on internal disc disruption (36,82) and reported prevalence as 39% (36) and 42% (82), respectively. The third study evaluated only discogenic pain and reported a prevalence of 26% (32).

2.7 Meta-Analysis

No meta-analysis was feasible due to differences in patient populations, methodology, and outcome criteria. Wolfer et al (35) evaluated false-positive rates in a systematic review and meta-analysis of lumbar provocation discography in asymptomatic subjects using IASP criteria. The authors (35) identified 11 studies meeting inclusion criteria for analysis. Combining all extractable data, a false-positive rate of 9.3% per

Table 7. *Methodological quality appraisal of diagnostic accuracy studies of prevalence.*

	Manchikanti et al, 2001 (32)	Schwarzer et al, 1995 (36)	DePalma et al, 2011 (82)
1. Was the test evaluated in a spectrum of subjects representative of patients who would normally receive the test in clinical practice?	+	+	+
2. Was the test performed by examiners representative of those who would normally perform the test in practice?	+	+	+
3. Were raters blinded to the reference standard for the target disorder being evaluated?	+	+	+
4. Were raters blinded to the findings of other raters during the study?	+	+	+
5. Were raters blinded to their own prior outcomes of the test under evaluation?	+	+	+
6. Were raters blinded to clinical information that may have influenced the test outcome?	+	+	+
7. Were raters blinded to additional cues, not intended to form part of the diagnostic test procedure?	+	+	+
8. Was the order in which raters examined subjects varied?	+	+	+
9. Were appropriate statistical measures of agreement used?	+	+	+
10. Was the application and interpretation of the test appropriate?	+	+	+
11. Was the time interval between measurements suitable in relation to the stability of the variable being measured?	NA	NA	NA
12. If there were dropouts from the study, was this less than 20% of the sample.	+	+	+
TOTAL	11/11	11/11	11/11

Y=yes; N=no; U=unclear; N/A=not applicable

Lucas N, et al. Reliability of physical examination for diagnosis of myofascial trigger points. *Clin J Pain* 2009; 25:80-89 (194).

Table 8. *Clinical relevance of diagnostic accuracy and prevalence studies.*

Manuscript Author(s)	A) Patient description	B) Description of interventions and treatment settings	C) Clinically relevant outcomes	D) Clinical importance	E) Benefits versus potential harms	Total Criteria Met
Manchikanti et al, 2001 (32)	+	+	+	+	+	5/5
Schwarzer et al, 1995 (36)	+	+	+	+	+	5/5
DePalma et al, 2011 (82)	+	+	+	+	+	5/5

+ = positive; - = negative
Scoring adapted from Staal JB, et al. Injection therapy for subacute and chronic low back pain. *Cochrane Database Syst Rev* 2008; 3:CD001824 (249).

Table 9. *Prevalence of lumbar discogenic pain utilizing IASP criteria.*

Study	Methodological Quality Scoring	Participants	Prevalence
Manchikanti et al 2001 (32)	11/11	From a group of 120 patients with low back pain, 72 patients negative for facet joint pain underwent discography.	The prevalence of discogenic pain was established in 26% of total patient sample and 43% of patients negative for facet joint pain.
Schwarzer et al 1995 (36)	11/11	92 consecutive patients with chronic low back pain and no history of previous lumbar surgery referred for discography.	The diagnostic criteria for internal disc disruption were fully satisfied in 39% of the patients, most commonly at L5/S1 and L4/5.
DePalma et al, 2011 (82)	11/11	Of the 156 patients, 71 underwent provocation discography. They also underwent other diagnostic blocks including facet joint nerve blocks and sacroiliac joint injections.	The prevalence of internal disc disruption in this study was 42%.

patient and 6.0% per disc was found. Data pooled from asymptomatic subjects without low back pain or confounding factors revealed a false-positive rate of 3.0% per patient and 2.1% per disc. In data pooled from chronic pain patients without low back pain, the false-positive rate was found to be 5.6% per patient and 3.85% per disc. Chronic pain does not appear to be a confounding factor in a patient's ability to distinguish between positive (pathologic) and negative (non-pathologic) discs. Among additional asymptomatic patient subgroups analyzed, the false-positive rate per patient and per disc was as follows: iliac crest pain after bone grafting 12.5% and 7.1%; chronic neck pain 0%; somatization disorder 50% and 22.2%, and, post-discectomy 15% and 9.1%, respectively. In patients with chronic backache, no false-positive rate could be calculated. The authors concluded that use of more stringent, low-pressure positive criteria (≤ 15 psi a.o.) was associated with a low false-positive rate. Based on a meta-analysis of the data, using the International Spine Intervention Society (ISIS) standard, discography had a specificity of 0.94 (95% CI; 0.88 – 0.98) and a false-positive rate of 0.06 (35). These results are illustrated in Tables 10 and 11. Since the publication of this manuscript, there have not been any new studies that could affect these estimates.

2.8 Diagnostic Accuracy

As illustrated by Wolfer et al (35), significant debate and controversy surrounds the accuracy of discography. Wolfer et al (35) demonstrated that using strict criteria, discography could provide valuable, accurate information regarding the intervertebral discs as potential pain generators. Notwithstanding the work by Carragee et al (117) who shed doubt on the utility of discography in patients with chronic pain or poorly controlled psychopathology, the

Table 10. *Summary of false-positive rates (%) per patient and per disc for experimental studies in subjects asymptomatic of low back pain.* *†

Study	Walsh et al (265)/ Carragee et al (118)		Derby et al (111)		ISIS/IASP (323)						Low pressure < 22 psi a.o (Carragee)		Low pressure ≤ 15 psi a.o. (Derby)	
					a		b		c					
	%FP /pt	%FP /disc	%FP /pt	%FP /disc	%FP /pt	%FP /disc	%FP /pt	%FP /disc	%FP /pt	%FP /disc	%FP /pt	%FP /disc	%FP /pt	%FP /disc
Walsh et al (265): Asymptomatic volunteers (95% CI)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)
Carragee et al (117): Iliac crest (95% CI)	50 (5–95%)	28.6 (2–56%)	37.5 (0–81%)	21.4 (0–46%)	12.5 (0–42%)	7.1 (0–23%)	12.5 (0–42%)	7.1 (0–23%)	12.5 (0–42%)	7.1 (0–23%)	25 (0–64%)	14.3 (0–35%)	12.5 (0–42%)	7.1 (0–23%)
Carragee et al (118): pain–free(cs-good) (95% CI)	10 (0–33%)	10 (0–33%)	10 (0–33%)	10 (0–33%)	10 (0–33%)	10 (0–33%)	10 (0–33%)	10 (0–33%)	10 (0–33%)	10 (0–33%)	0 (–)	0 (–)	0 (–)	0 (–)
Carragee et al (118): chronic pain (cs–failed) (95% CI)	40 (3–77%)	58.3 (26–91%)	30 (0–65%)	33.3 (2–65%)	20 (0–50%)	16.7 (0–41%)	10 (0–33%)	8.3 (0–27%)	0 (–)	0 (–)	30 (0–65%)	25 (0–54%)	10 (0–33%)	8.3 (0–27%)
Carragee et al (113): Somatization disorder (95% CI)	75 (0–100%)	44.4 (4–85%)	50 (0–100%)	22.2 (0–56%)	50 (0–100%)	22.2 (0–56%)	50 (0–100%)	22.2 (0–56%)	50 (0–100%)	22.2 (0–56%)	50 (0–100%)	22.2 (0–56%)	25 (0–100%)	11.1 (0–37%)
Derby et al (107): Asymptomatic volunteers (95% CI)	0 (–)	0 (–)	0 (–)	0 (–)	0 (–)	0 (–)	0 (–)	0 (–)	0 (–)	0 (–)	0 (–)	0 (–)	0 (–)	0 (–)
Carragee et al (115): mild backache (95% CI)	36 (16–56%)	37.5 (20–55%)	36 (16–56%)	31.3 (14–48%)	20 (3–37%)	15.6 (2–29%)	20 (3–37%)	15.6 (2–29%)	16 (1–31%)	12.5 (0.4–25%)	28 (9–47%)	21.9 (7–37%)	28 (9–47%)	21.9 (7–37%)
Carragee et al (116): Post–discectomy (95 % CI)	35 (12–58%)	24.2 (9–40%)	35 (12–58%)	24.2 (9–40%)	25 (4–46%)	15.2 (2–28%)	25 (4–46%)	15.2 (2–28%)	15 (0–32%)	9.1 (0–19%)	25 (4-46%)	18.2 (4–32%)	25 (4-46%)	15.2 (2–28%)

*ISIS = International Spine Intervention Society; IASP = International Association for the Study of Pain; a = no control disc; b = control disc ≤ 6/10; c = painless control disc; FP = false-positive; pt = patient; cs-good = cervical spine surgery, good outcome; cs-failed = cervical spine surgery, poorest outcome; CI = confidence interval

† Studies by Holt (288) and Massie and Steven (287) are not included since pain and pressure were not reported in the published study.

Adapted from Wolfer L, et al. Systematic review of lumbar provocation discography in asymptomatic subjects with a meta-analysis of false-positive rates. Pain Physician 2008; 11:513-538 (35).

Table 11. *Summary of false-positive rates (%) per patient and per disc for combined analyses of experimental studies in subjects asymptomatic of low back pain.* *†‡◆

Combined Analysis Group	Walsh et al (265)/ Carragee et al (118)		Derby et al (111)		ISIS/IASP (323)						Low pressure < 22 psi a.o (Carragee)		Low pressure ≤ 15 psi a.o. (Derby)	
					a		b		c					
	%FP/ pt	%FP/ disc	%FP/ pt	%FP/ disc	%FP/ pt	%FP/ disc	%FP/ pt	%FP/ disc	%FP/ pt	%FP/ disc	%FP/ pt	%FP/ disc	%FP/ pt	%FP/ disc
Asymptomatic subjects† (95% CI)	3 (0~9%)	2.1 (0~6%)	3 (0~9%)	2.1 (0~6%)	3 (0~9%)	2.1 (0~6%)	3 (0~9%)	2.1 (0~6%)	3 (0~9%)	2.1 (0~6%)	0 (-)	0 (-)	0 (-)	0 (-)
Chronic pain (IC + cs-failed) ‡ (95% CI)	44.4 (19~70%)	42.3 (22~63%)	33.3 (9~58%)	26.9 (9~45%)	16.7 (0~36%)	11.5 (0~25%)	11.1 (0~27%)	7.7 (0~19%)	5.6 (0~17%)	3.85 (0~12%)	27.8 (5~51%)	19.2 (3~36%)	11.1 (0~27%)	7.7 (0~19%)
All subjects ◆ (95% CI)	25.3 (15~35%)	20.7 (13~28%)	21.3 (12~31%)	15.5 (9~22%)	14.7 (7~23%)	9.5 (4~15%)	13.3 (6~21%)	8.6 (3~14%)	9.3 (3~16%)	6.0 (2~10%)	16.0 (8~25%)	11.2 (5~17%)	10.7 (4~18%)	6.9 (2~12%)

*ISIS = International Spine Intervention Society; IASP = International Association for the Study of Pain; a = no control disc; b = control disc < 6/10; c = painless control disc; FP = false positive; pt = patient; cs-good = cervical spine surgery, good outcome; cs-failed = cervical spine surgery, poorest outcome; IC = Iliac Crest; CI = Confidence Intervals

†Asymptomatic subjects: Walsh et al (265), Derby et al (107) ,and Carragee et al (116) (pain free/cervical spine good outcome) studies.

‡Chronic pain subjects: Carragee et al (113) studies (iliac crest pain and chronic pain/cervical spine failed outcome)

◆ All subjects: excludes mild persistent backache patients and two somatization disorder patients, case numbers 25 and 26 with incomplete discogram data set.

present assessment shows at least fair evidence for diagnostic accuracy based on a total of 30 studies as listed in Table 5 with 8 studies showing negativity, whereas the remaining 22 studies show good to fair or positive evidence for accuracy.

2.9 Results of Comparative Evaluation

Studies comparing lumbar discography with CT scanning or MRI in patients with degenerative disc disease are described in Table 4. There is good correlation in 13 of the 33 studies, indicating limited to fair accuracy for lumbar discography when compared to other non-invasive diagnostic techniques.

2.10 Assessment with Outcomes

Outcomes data for lumbar disc replacement or fusion surgery based on preoperative discography screening are described in Table 6. Given that very few fusion studies report significantly better outcomes following discography, there is limited evidence supporting the use of discography prior to surgical procedures.

There is fair evidence supporting the management of discogenic pain with epidural injections (139-141).

There is limited evidence supporting the management of discogenic pain with intradiscal electrothermal therapy (IDET) and biacuplasty (166).

2.11 Analysis of Evidence

The evidence was available only for the prevalence of discogenic pain with provocation discography utilizing IASP criteria evaluated in 3 high-quality studies (32,35,82). There was limited evidence supporting functional anesthetic discography or provocation discography with local anesthetic injection.

The prevalence of internal disc disruption was estimated to be 39% in a younger cohort of patients following injury (36), and 42% in a heterogenous population comprised of all age groups and all types of low back pain (82). In a study that sought to determine the prevalence of discogenic pain without assessing internal disc disruption, the reported prevalence rate was 26% (32).

Thus, the evidence for provocation discography is fair based on 3 well-performed accuracy studies. Due to ongoing debate on the accuracy of this test and the lack of outcome parameters in patients undergoing surgical interventions, the evidence is subject to other interpretation.

The correlation between discography and various diagnostic tests was moderate to strong in 13 out of 33

evaluations, yielding limited to fair accuracy for lumbar discography compared to other non-invasive modalities of assessment.

Outcomes assessing the value of surgery in managing discogenic pain are shown in Table 6. Based on the paucity of studies illustrating significantly better outcomes with fusion following discography, there is limited evidence supporting the use of discography prior to surgical procedures.

There is fair evidence supporting the management of discogenic pain with epidural injections (139-141).

There is limited evidence supporting IDET and biaculoplasty (166).

3.0 Complications

Potential complications from discography include discitis, injury to nerve roots, disc herniation, intravascular uptake, bleeding, epidural abscess, allergic contrast reaction, subarachnoid puncture, chemical meningitis, and other side effects (321-323,328-355). A contrast allergy is a relative contraindication that can be circumvented by pre-medication with antihistamines and corticosteroids, substituting gadolinium for non-ionic contrast, or injecting saline without contrast.

Perhaps the most feared complication, the incidence of discitis is actually quite low, approximately one in 1,000. The treatment of discitis is compounded by the avascular nature of the disc, which makes the body's ability to fight infection, and the use of antibiotics less effective. Infection may be secondary to contamination of the needle tip with skin flora, or less commonly from inoculation secondary accidental puncture of the bowel, or hematogenous spread. The incidence of discitis can be reduced with meticulous aseptic technique and prophylactic antibiotics (334,335).

The use of a double-needle technique with stylets has been shown in one study to decrease the risk of discitis, though the contribution of each of these factors to reduce the infection rate is not known (334). The stylet prevents tissue from collecting within the needle and entering the disc. In the double-needle technique, a smaller needle is inserted through a larger gauge needle to puncture the disc, thereby avoiding contact with surface tissue.

Patients with discitis after discography usually present with symptoms of severe back pain 2 to 4 weeks after the procedure, though in some cases presentation may be delayed for several months. The pain is exacerbated by any motion and relieved by rest. Patients may report fever and chills, but true fevers or leukocytosis are less common (336). If discitis is suspected, MRI and erythrocyte sedimentation rate (ESR) should be ordered immediately to confirm the diagnosis. In the first 3 weeks after infection, bone scan, MRI, and ESR are commonplace (336), but MRI is considered the diagnostic test of choice for early detection of discitis (337-339).

Intravascular uptake of contrast material during lumbar discography has been reported (332) by Goodman et al (332), who studied a total of 280 discs from L1/2 to L5/S1 in 160 patients and found that 40 discs (14.3%) demonstrated fluorscopically confirmed intravascular uptake. Intravascular uptake during discography can only be detected by real-time fluoroscopy. No statistically significant correlation was noted between the degree of disc degeneration and the incidence of intravascular uptake.

The benefits of discography must also be weighed against the possibility that disc penetration can accelerate, or even cause, disc degeneration. Animal studies have shown that percutaneous needle puncture is a valid and reliable model for inducing disc degeneration, with the size of the needle and depth of penetration correlating with the degree of histological changes (356). Recently, Carragee et al (236) performed a prospective study in 50 individuals without low back pain who underwent baseline MRI and 3-level discography with 22 or 25-gauge needles, and were followed between 7 and 10 years, at which time they underwent repeat MRI. The authors found a higher incidence of progression of disc degeneration (54 vs. 21) and herniation (55 vs. 22) with the latter more likely to occur on the side of disc penetration. Although older studies failed to find evidence of disc injury following discography, these studies suffered from methodological flaws, less sensitive detection methods, and lack of long-term follow-up (357,358).

4.0 Discussion

This systematic review of lumbar discography shows fair evidence supporting the diagnostic accuracy of prevalence studies after controlling for test variability, lack of standardization, limitations in technique, and the paucity of studies evaluating outcomes. There is fair evidence for a significant correlation between discography and radiologic investigations, but poor evidence for a correlation with physical examination. This systematic review also shows limited evidence for the use of lumbar discography as a screening tool prior to fusion surgeries. Limited evidence was found for the efficacy of IDET and biaculoplasty, but fair evidence exists for

the effectiveness of epidural injections with or without steroids, for discogenic pain. The work of Carragee et al (113-122), and several guidelines based on these studies (359-362), have led to to the suggestion that discography may result in misdiagnosis, unnecessary surgery, and accelerated disc degeneration (9,19-21,363,364). The rationale for this conclusion is based on several studies describing the lack of accuracy of provocation discography, and a relatively modest positive predictive value of around 50% for surgical fusion in patients with single-level, discography-confirmed degenerative disc disease (122). In fact, these premises are inherently flawed. First, one of the hallmarks of modern day discography is that one must provoke "concordant" pain during disc stimulation, which is not possible in patients with no active back pain complaints. Second, calculating a predictive value using a marginally effective treatment intrinsically skews the interpretation.

The previous systematic review (34) showed an evidence level of II-2 for lumbar provocation discography. The prevalence of discogenic pain was estimated to be around 26% (32), whereas internal disc disruption was shown to affect approximately 39% of individuals with suspected discogenic pain (36). Despite of the numerous studies, commentaries, and guidelines on discography, only 3 studies met the inclusion criteria for prevalence (32,36,82). There is one additional study (82) since the previous assessment (34). In a retrospective study by DePalma et al (82) performed in 156 patients, the authors reported an overall prevalence of discogenic pain in 42% of the patients. They also published multiple subgroup analyses (67,83-85,88), showing prevalence rates of 56% after motor vehicle injuries, 82% after surgical discectomy, 25% after lumbar fusion. However, all the subgroup analyses suffered from multiple flaws, including small sample sizes. It is also possible that the high prevalence rate after discectomy may be partially due to a significant false-positive rate in this cohort (116). Overall, the results of this assessment are similar to some (19,34,35), but not other systematic reviews (9).

The greatest challenge concerning discography continues to be the "gold standard" dilemma. Two prior systematic reviews (365,366) exhaustively discussed this issue, which is not unique to discography. Knottnerus et al (367) outlined the methodological challenges that must be addressed when interpreting diagnostic accuracy studies. These include the "gold standard" problem; spectrum and selection bias; "soft" outcome measures (subjective phenomena); observer variability and bias; complex relations; clinical impact; sample size deficiencies; and the rapid evolution of knowledge, technical advances, and evolving concepts of evidence-based medicine, and comparative effectiveness research (9,19,24,367-373). These concerns have been explored in this and prior reviews. Unfortunately, most discography studies cannot overcome the methodological limitations.

The issue of the necessity of placebo-controlled studies, and even what constitutes a placebo, continue to be major issues in coverage policies and analyses of the evidence (9,19,24,374). However, the injection of non-analgesic solutions (e.g., saline), once considered to be placebo treatments, into painful structures have been reported to result in significant pain relief, not only for the spinal pain, but also for other chronic pain conditions as well (375,376). In fact, the injection of sodium chloride solution into intervertebral discs, zygapophysial joints, paraspinal muscles, epidural space, and over nerve roots has been shown to provide benefit for multiple spinal conditions (377-387). There are also numerous psychophysiological and possibly even structural influences involved in eliciting placebo and nocebo effects (381). Further, local anesthetic injections have been shown to provide prolonged neural blockade resulting in long-term pain relief (388-398). In essence, the interpretation of provocation discography encompasses a multitude of issues that cannot easily be overcome based on the present state of knowledge.

Glasziou et al (369) reported an innovation in evaluating a "new reference standard." They raised concerns about assessing the diagnostic accuracy of a test in isolation when deciding if an existing reference standard should be replaced. The authors suggested focusing on the clinical consequences of a decision, rather than on imperfect estimates of accuracy.

The face validity of discography is based on the premise that pressurizing a disc reproduces the physiological conditions that stress a disc until the nociceptive threshold is reached. Construct validity can be established by demonstrating a significant correlation between discography results and surgical outcomes. For a response to be considered positive, concordant pain must be reproduced, but in order to meet validity standards, at least one adjacent disc must be painless upon injection.

The sensitivity and specificity of discographic pathology are 81% and 64%, using radiological imaging as the criterion standard. A recent meta-analysis of provocation discography in asymptomatic subjects found a false-positive rate of 6% when previously pub-

lished data were re-analyzed based on IASP criteria (35,237).

A series of published studies investigated the potential for false-positive results by performing discography on asymptomatic volunteers (107,113,115-118,265). The Holt study (288) was performed on prisoners, with outdated techniques and using noxious, irritating contrast dye (289). It did not consider pain response as a criterion for a positive discogram.

In an attempt to determine the effect establishing pressure thresholds has on the rate of false-positives, Carragee et al re-analyzed previously published data (115,116,118) according to low pressure criteria (121). They (121) reported a false-positive rate of 25% (17/69 patients), which was not statistically significantly different from the 27% positive rate (14/52) in their comparison cohort of patients with presumed chronic discogenic pain. This exploratory post-hoc analysis was performed on 5 prior experimental groups (no pain (n = 10), no low back pain (n = 10); chronic pain (n = 10); somatization disorder (n = 4); post-discectomy (n = 20); and mild persistent backache (n = 25). Low pressure positive was defined as ≤ 22 psi above opening (ao) pressure, which is higher than the standard set by ISIS/IASP of ≤ 15 psi a.o. (122). The individual groups were found to have the following false-positive responses: pain free 0/10, chronic pain 3/10, somatization disorder 2/4, post-discectomy 5/20, and "benign" backache, 7/25 patients.

There are significant shortcomings in Carragee et al's (121) re-analysis. Each subgroup merits individual scrutiny. The pain-free group had a 0% false-positive rate. The chronic pain group included 10 chronic pain patients who were disabled volunteers with failed cervical fusions, on regular medications (including opioids), and with markedly abnormal psychometric scores, and active worker's compensation litigation. Using high pressure provocation (pressure ≤ 100 psi a.o.), Carragee et al (121) reported a false-positive rate of 40%; however, because of the small number of subjects, the 95% confidence level ranged between 10% and 70%. If one substitutes the ISIS/IASP (237,323) standard of ≤ 15 psi a.o., the false-positive rate decreases to 10% per patient (1/10) (95% CI, 0% – 33%) and 8.3% per disc (1/12) (95% CI, 0% – 27%) (35). Furthermore, the study included 4 patients with somatization disorder in this analysis who might arguably be removed from consideration. A prospective study by Manchikanti et al (259) found no difference in the rate of positive discograms between patients with and without somatization disorder.

Lastly, Carragee et al (115) included 25 patients with a history of persistent, low intensity back pain, 36% (n = 9) of whom were categorized as having a false-positive response in the original protocol analysis, which decreased only slightly to 28% (n = 7) in the re-analysis. Yet, the contention that these patients represent false-positive responses is debatable. An alternative explanation is that they were in a more quiescent phase of their illness, or simply were more stoic. This argument is supported by the original 36% false-positive rate, which is similar to the 39% prevalence rate of discogenic pain reported by Schwarzer (36). In summary, Carragee et al's (121) post-hoc analysis of select populations with low pressure positive discograms is subject to different interpretations. When more stringent criteria are applied, the false-positive rate in individuals without confounding factors is very low.

Not all studies have found high false-positive rates in asymptomatic volunteers. Walsh et al (265) sought to replicate Holt's work (288), but attempted to remediate some of the shortcomings by including concordance and observed pain behaviors in their criteria pain intensity ratings. Although discograms were morphologically abnormal in 5 of the 10 subjects, none elicited concordant pain. More recently, Derby et al (108) performed 3 or more discograms in 13 volunteers with no low back pain history. Although 44% of injected discs elicited pain, most required high pressures to reach the nociceptive threshold and, even then, were only mildly painful. The authors concluded that if one considers pain intensity and the amount of pressure needed to provoke symptoms, the false-positive rate is less than 10%. Wolfer et al (35) conducted a meta-analysis of all complete data sets obtained from lumbar discography studies involving subjects asymptomatic for low back pain. Using ISIS/IASP standards, the pooled analysis of 75 patients and 116 discs revealed a false-positive rate of 9.3% (95% CI; 3% – 16%) per patient and 6.0% (95% CI; 2% – 10%) per disc. This systematic literature review demonstrates that lumbar discography performed in accordance with accepted guidelines is associated with a low false-positive rate.

Treatments, particularly controversial ones, should not serve as the gold standard for a diagnostic test. Diagnostic tests detect the presence or absence of a disease process/entity. The effectiveness of a suspect treatment should not be misconstrued as evidence that confirms or negates the existence of a disease. Some authors implicitly assume that discography is a presurgical screening tool. This presupposes that the validity

of discography depends on the outcome of a controversial treatment, i.e., spinal fusion. If this concept is generalized, one could theoretically challenge the validity of any diagnostic test used to identify a disease with ineffective treatment(s), such as pancreatic cancer. The treatment of discogenic pain continues to be a challenging problem, with no treatment providing significant relief to a majority of patients on a consistent basis.

Carragee et al (122) used fusion results as the criterion standard to demonstrate the lack of validity of lumbar provocation discography; however, there is sparse evidence that either fusion or disc replacement is an effective treatment for discogenic low back pain (5,3,35,347-349,374,398-403). In spite of the widespread use of lumbar discography as a presurgical screening tool, few studies have evaluated its effect on surgical outcomes. The relative lack of controlled studies is further compounded by widespread variability in outcomes and the controversy surrounding spinal arthrodesis and disc prosthesis procedures for discogenic low back pain. The surgical outcomes for the treatment of internal disc disruption are widely acknowledged to be inferior to that for radiculopathy, with the reported success rates ranging from less than 50% to greater than 80% (214,398). The few randomized studies comparing fusion outcomes to conservative treatment have demonstrated mixed results at best (124,214,398-407). In addition, although there are multiple published studies evaluating disc replacement outcomes (132), none directly compared outcomes between patients whose selection was contingent on discography results and those who underwent disc replacement based solely on clinical and radiological findings. The presence of concomitant pain sources in most patients with discogenic pain, along with inconsistent clinical outcomes even with a technically successful surgery, are factors that must be considered when evaluating the predictive value of discography for surgical outcomes.

In a health technology assessment of spinal fusion and discography for chronic low back pain secondary to uncomplicated lumbar degenerative disc disease (182), 622 articles on the presurgical use of discography were reviewed. Issues that were evaluated included the reliability of discography, the prediction of pain reduction and/or improvement in functional status/quality of life after lumbar fusion surgery with presurgical discography, and the influence of presurgical discography on treatment outcomes. Conclusions were as follows: 1) the evidence is insufficient to permit conclusions about the reliability of discography for patients with chronic low back pain and uncomplicated lumbar degenerative disc disease; 2) because of low quality and heterogeneous results from 3 studies (n = 330 patients), the evidence is insufficient to permit conclusions about the use of discography to predict fusion outcomes in patients with chronic low back pain and uncomplicated lumbar degenerative disc disease; 3) the evidence is insufficient to permit conclusions about the influence of discography on fusion outcomes in patients with chronic low back pain and uncomplicated lumbar degenerative disc disease. The authors used 2 studies (80,408) to assess the test-retest and inter-rater reliability of discography. Both studies investigated at least one specific type of reliability: whether a given discogram is judged to have the same morphology grade by the same evaluator at different times (i.e., test-retest) or by different evaluators (i.e., inter-rater). Neither study repeated discograms on the same disc, nor investigated the reliability of patients' reports of pain provocation or concordance.

The same authors evaluated the ability of presurgical discography to predict outcomes. This was achieved through a comparison of surgical outcomes between patients who had positive pre-operative discography before surgery and those with negative discography. Three studies were included. However, all studies defined a positive discogram differently and assessed surgical outcomes differently. Willems et al (129) performed discography on disc(s) adjacent to segments selected for fusion based on pain relief after external fixation. They categorized 2 groups of surgical patients based on pain provocation in the adjacent-discs: those in whom disc stimulation provoked typical pain (negative, n = 22); and those in whom disc injection elicited no or nonconcordant pain (positive; n = 60). Gill and Blumenthal (168) categorized 3 groups of patients based on the morphology of the suspected disc: a small annular tear that did not extend to the periphery (type I, n = 14); an annular tear and contrast extension to the periphery, but not beyond (type II, n = 19); and an annular tear that extended beyond the periphery (type III, n = 20). Finally, Colhoun et al (263) categorized 4 groups of patients based on pain provocation and morphology: typical pain provocation and abnormal morphology (n = 137); no pain provocation and abnormal morphology (n = 25); neither pain provocation nor abnormal morphology (n = 6); and total disc resorption at one or more levels that precluded categorization (n = 27). The results of this analysis revealed that 2 of the 3 studies argued favorably for dis-

cographic screening. In the Willems et al study (129), no differences were found in fusion success rates between patients who had a positive discogram(s) adjacent to the fused levels and those who did not. However, these patients all had "equivocal" indications for lumbar fusion, with two-thirds having undergone previous surgery. In the Colhoun et al (263) study, 89% of those with provoked pain experienced a positive fusion outcome, which favorably compared to the 52% success rate in those whose discograms revealed morphological abnormalities but no pain provocation. Gill and Blumenthal (168) reported a 75% success rate in patients with a type II or III discography vs. a 50% success rate in patients with a type I discography. One study excluded from the analysis was that of Derby et al (111), whose retrospective review found an 89% success rate following interbody/combined fusion in those patients with chemically sensitized discs vs. success rates of 20% and 12% after an intertransverse fusion and non-operative treatment, respectively.

With the exception of Derby et al (111), no study used manometry as a determining factor in discographic interpretation. Madan et al (124) failed to duplicate the results of Colhoun et al (263). In 2 reviews by Cohen et al (132,327), the authors found no pooled differences in fusion outcomes between studies that used discography and those that did not. However, the lack of strong evidence supporting the use of fusion in treating degenerative disc disease and methodological flaws in the component studies, make data interpretation exceptionally difficult (124,327). The present evaluation also shows only limited evidence supporting the use of provocation discography as a diagnostic modality in selecting patients for fusion. Thus, fusion outcomes should not be used as a criterion standard in evaluating the accuracy of lumbar provocation discography.

In fact, one might alternatively classify discography results in terms of a numerical continuum rather than as a binary (i.e., positive or negative) result. In other words, if discography results were reported in terms of pressure pain thresholds (PPTs), the sensitivity and specificity would change at different cutoffs. The sensitivity (Y-axis) could then be plotted against 1-specificity (X-axis) by using the results obtained at different PPT cutoffs. This would establish a receiver operator characteristic (ROC) curve, which is an effective method for evaluating the quality of a diagnostic test and identifying an ideal cutoff value (354,409,410). If the ROC curve passes upwards to the left, the diagnostic test is nearly perfect in distinguishing disease from no disease. The previous systematic review recommended the use of ROC curves for discography (365). Only one subsequent paper has done so (110). Derby et al (110) used an ROC curve to develop strict operational criteria for defining a symptomatic disc, and then correlated this information with abnormal disc morphology. If paired together, the false-positive rate could be significantly reduced during discography.

A recent literature search demonstrated that investigators are attempting to optimize MRI criteria to better identify painful discs. Lei et al (284) and O'Neill et al (71), however, concluded that MRI should continue to supplement discography rather than replace it. Willems et al (129) used an external transpedicular fixation system to select patients for spinal fusion; yet, this technique is not routinely used in the United States and is associated with a high risk of complications when compared to discography. Other investigators are seeking surrogate tools, biomarkers, and sympathetic responses to support and improve the diagnostic accuracy of discography. Finally, Derincek et al (286) continues to validate the concept that an anatomically normal disc rarely ever causes pain — a concept that has been consistently confirmed over the past 20 years.

Scuderi et al (285) conducted a prospective biochemical analysis of disc leakage fluid obtained during discography. They found only weak correlations between demographic variables, Pfirrman grading (MRI), and discography. The authors concluded that pain provocation during discography could not be predicted by noninvasive means, including biomarker assays. Derincek et al (286) performed discography on a series of patients with back pain and MRI-supported evidence of degenerative disc disease. Those patients experiencing pain during injection into a morphologically normal disc were studied. These individuals then underwent repeat discograms on the morphologically normal disc, but only after the morphologically abnormal (adjacent) disc was first anesthetized. None of their patients experienced pain during the repeat discogram, suggesting a process analogous to central sensitization/expansion of receptive fields. The authors recommended anesthetizing the morphologically abnormal disc before testing potentially normal (control) discs.

In conclusion, there is fair evidence supporting the accuracy of provocation discography after controlling for various factors including methodological flaws, lack of standardization, and the absence of well-designed outcome studies.

5.0 Conclusion

This systematic review illustrates that lumbar provocation discography performed according to IASP criteria may be a useful tool for evaluating chronic lumbar discogenic pain. The results suggest that, based on modified USPSTF evidence criteria, the indicated strength of the evidence is fair for the diagnostic accuracy of lumbar provocation discography utilizing IASP standards after consideration of confounding factors.

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Conflict of Interest:

Dr. Benyamin is a clinical investigator with Epimed and receives research support from Cephalon/Teva, Bio-Delivery Sciences International, Inc., Mundipharma Research GmbH & Co., AstraZeneca, Purdue Pharma, LP, and Theravance.

Dr. Derby has stock options with Laurimed and Metronic.

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Dr. Caraway is a consultant for Medtronic, Inc., Spinal Modulation, Inc., and Vertos, Inc.

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