Pain Physician 2009; 12:541-559 • ISSN 1533-3159

Systematic Review

Systematic Review of Lumbar Discography as a Diagnostic Test for Chronic Low Back Pain

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Disclaimer: There was no external funding in the preparation of this manuscript.
Conflict of interest: None.

Manuscript received: 12/22/2008
Accepted for publication: 02/25/2009

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Background: The intervertebral disc has been implicated as an etiology of chronic lumbar spine pain based on clinical, basic science, and epidemiological research. However, there is lack of consensus regarding the diagnosis and treatment of intervertebral disc disorders. Based on controlled evaluations, the lumbar intervertebral discs have been shown to be sources of chronic back pain without disc herniation in 26% to 39%. 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, controversy continues about provocation lumbar discography.

Study Design: A systematic review of the lumbar provocation discography literature.

Objectives: To systematically assess the diagnostic accuracy of lumbar discography.

Methods: A systematic review of the literature was performed to assess the diagnostic accuracy of lumbar discography with respect to chronic low back pain. Study inclusion/exclusion criteria were based on International Association for the Study of Pain (IASP) standards with pain provocation and determination of controlled discs. Selected studies were then subjected to a rating instrument for diagnostic accuracy studies. Specific data were then culled from these studies and tabulated. Quality of evidence was assessed using modified Agency for Healthcare Research and Quality (AHRQ) diagnostic accuracy evaluation. Studies meeting methodologic quality criteria scores of 50 or higher were included in the assessment of the level of evidence. Qualitative analysis was conducted using 5 levels of evidence, ranging from Level I to III, with 3 subcategories in Level II. The rating scheme was modified to evaluate the diagnostic accuracy.

Results: Based on a modified U.S. Preventive Services Task Force (USPSTF) level of evidence criteria, this systematic review indicates the strength of evidence as Level II-2 for the diagnostic accuracy of lumbar provocation discography utilizing IASP criteria.

Limitations: Limitations include a paucity of literature, poor methodologic quality, and very few studies performed utilizing IASP criteria.

Conclusion: Based on the current systematic review, lumbar provocation discography performed according to the IASP criteria with control disc (s) with minimum pain intensity of 7 of 10, or at least 70% reproduction of worst pain (i.e. worst spontaneous pain of 7 = 7 x 70% = 5) may be a useful tool for evaluating chronic lumbar discogenic pain. Discography is an important imaging and pain evaluation tool in identifying a subset of patients with chronic low back pain secondary to intervertebral disc disorders.

Key words: Chronic low back pain, lumbar intervertebral disc, lumbar discography, provocation discography, pain generator, false-positives, diagnostic accuracy, sensitivity, specificity

Pain Physician 2009; 12:541-559

Our understanding of the causes of low back pain has significantly evolved over the past century. The zygapophysial (facet) joints, sacroiliac joints, and the intervertebral discs have all been demonstrated to be common causes of chronic low back pain (1-13). The prevalence of discogenic low back pain, with or without internal disc derangement, is estimated to range between 26% and 39% of chronic low back pain sufferers without radicular symptoms (1-7).

The intervertebral disc has been implicated as a source of spinal pain based on decades of pre-clinical, clinical, and epidemiological research. Diagnostic tests, such as history, physical exam, and radiological imaging, have low sensitivity and specificity in determining whether or not the disc is a primary source of low back pain (14). When combined with pain provocation, discography is believed to have improved diagnostic capabilities compared to these single dimensional tools.

In a systematic review of tests (15-18) designed to identify the disc as a pain generator, Hancock et al (14) concluded that centralization was the only clinical feature associated with a discogenic pain etiology. Certain physical exam findings have been purported to aid in identifying the underlying cause(s) of low back pain, but these have been difficult to validate by scientific methods (19-22). Additionally, certain provocative maneuvers intended to identify pain generators result in stresses to other structures, thereby nullifying their usefulness.

Advances in computed tomography (CT) and magnetic resonance imaging (MRI) scanning have magnified our ability to discern discogenic structural abnormalities such as architectural changes, herniations, end plate changes, and annular tears. CT images obtained after discography are exquisitely sensitive in detecting internal disc disruption (IDD) (1,7,23-32). However, these changes are also present in as many as 64% to 89% of asymptomatic individuals (24,33-36). According to one review, among the various features observed on MRI, only the absence of degeneration reduced the likelihood that the disc was the source of back pain.

Conversely, there is evidence that subtle but painful lesions may be present in discs that appear morphologically normal on MRI. Discography has been shown to reveal abnormalities in symptomatic patients with normal MRI scans (24,35).

The detection of morphologic abnormalities on discography is becoming less relevant to therapeutic decision-making. This phenomenon has parenthetically served to underscore the importance of the provocative aspect of discography as a diagnostic aid in decision-making. The provocation of pain with real time imaging as an indicator of the presence of discogenic pain is the raison d'être for performing discography. When performed appropriately, discography can enhance sensitivity and specificity compared to non-provocative imaging. This in turn can improve clinical outcomes and prognostication through better selection of candidates and therapies. Equally important, it can reduce the likelihood that discs which are not contributing to pain are inappropriately treated. Discography continues to be the only diagnostic tool capable of establishing whether or not a particular disc is painful, irrespective of the presence or absence of degenerative pathology observed on other imaging modalities (25,27,35,37-43).

Nonetheless, there continues to be controversy surrounding discography with respect to diagnostic accuracy (38,39,42,43), utilization (44-48), and its impact on surgical volume (49-55). Lumbar discography has been refined substantially since its inception 6 decades ago in an attempt to improve its sensitivity and specificity. Concerns regarding pain provocation in asymptomatic patients and normal discs have been raised, and were most recently addressed by Wolfer et al (25) in a meta-analysis of false-positive rates. Contrary to recently published studies, they concluded that discography is associated with a low false-positive rate.

The purpose of this systematic review is to systematically evaluate the diagnostic accuracy of lumbar discography.

Methods

Diagnostic Criteria

The International Association for the Study of Pain (IASP) criteria (40) for lumbar discogenic pain includes 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.

Literature Search

Relevant clinical trials meeting the inclusion cri-

teria for this review were identified in the following manner:

A computerized database search was performed of PubMed, EMBASE, and evidence-based medicine reviews (Cochrane database and Cochrane Central Register of Controlled Trials) from 1966 to December 2008 using the following terms: lumbar intervertebral disc, provocation discography, and intervertebral disc/injection. All systematic and narrative reviews were then manually sorted to identify articles missed during the electronic search. Only English language articles were considered for analysis.

Inclusion Criteria

This systematic review considered studies conducted on both asymptomatic volunteers and symptomatic patients, including those with a prior history of surgery. Discography, alone or in combination with other tests, must have been clearly described and performed according to IASP standards with intensity of pain of 6 or 7 of 10.

Excluded from analysis were animal studies, technical papers, expert opinion, review articles, and single case reports.

Review Methods

Clinical studies evaluating discogenic pain utilizing IASP criteria intensity of pain of 6 or 7 of 10 were included in methodological quality assessment and evidence synthesis.

Methodological Quality Assessment

The quality of each article was evaluated by the Agency for Healthcare Research and Quality (AHRQ) rating scale for diagnostic studies (56). Based on a weighted scoring system, the AHRQ allots up to 100 points for each study. The weighted scores of methodologic quality criteria were developed and subsequently revised by the guidelines committee of the American Society of Interventional Pain Physicians (ASIPP), and have been utilized in numerous systematic reviews (27,42,57-63). Only studies scoring 50 or more were included in this analysis.

Each study was scored independently by 2 reviewers. Articles in which conflicts arose were reviewed and mediated by a third author to arrive at a consensus.

Qualitative Analysis of Evidence

Qualitative analysis was conducted using 5 levels of evidence for lumbar provocation discography as illustrated in Table 1 (64). This evidence has been modified for diagnostic studies as randomized trials are not utilized for diagnostic accuracy studies (42,65-69).

Results

Literature Search

Figure 1 illustrates the search results.

Controlled Discography

Methodological Quality Assessment

The search yielded 69 publications for inclusion (1,2,7,24,28,30-32,35,70-129). Of these, 19 studies performed discography under controlled conditions (1,2,7,79,80-83,86,89-94,96,99-101). However, of these, 7 studies were performed without a control disc (81,82,86,89,92,94,100), 2 studies (79,90) analyzed other data, and 2 studies (1,2) utilized the same patients. Thus, the methodologic quality assessment criteria are provided in Table 2 for the 9 included studies.

Study Characteristics

Descriptive characteristics of these studies are illustrated in Table 3. However, for descriptive purposes, all 19 studies were included in this table.

Carragee et al (79,80,89-94) performed multiple studies related to discography in subjects with or without low back pain. Of these, 3 studies met inclusion criteria with provocation pain of 6 of 10, and a control disc (80,91,93), 2 studies examined the data from

Table 1. *Modified quality of evidence developed by USPSTF.*

I:	Evidence obtained from multiple properly conducted diagnostic accuracy studies.
II-1:	Evidence obtained from at least one properly conducted diagnostic accuracy study of adequate size.
II-2:	Evidence obtained from at least one properly designed small diagnostic accuracy study.
II-3:	Evidence obtained from diagnostic studies of uncertainty.
III:	Opinions of respected authorities, based on clinical experience descriptive studies and case reports or reports of expert committees.

Adapted and modified from the U.S. Preventive Services Task Force (USPSTF) (64).

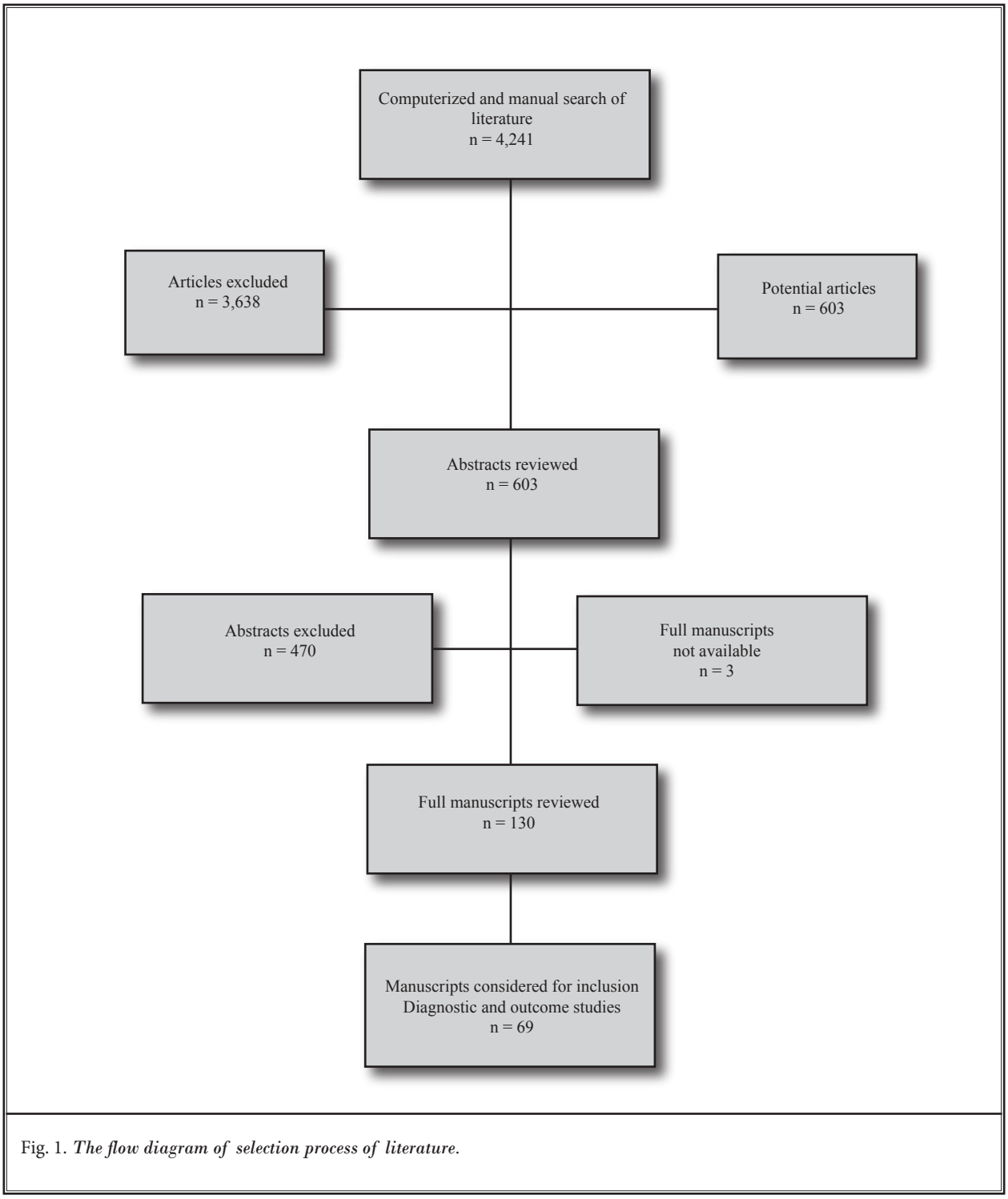

Fig. 1. *The flow diagram of selection process of literature.*

Table 2. *Methodologic quality evaluation and scoring of lumbar discography studies.*

STUDY	1 Study Population (15)	2 Adequate Description of Test (10)	3 Appropriate Reference Standard (30)		4 Blinded Comparison of Test (30)		5 Avoidance of Verification Bias (15)	TOTAL (100)
			Appropriate reference standard (gold standard) used for comparison (15)	Reference standard reproducible (15)	Evaluation of test without knowledge of disease status, if possible (15)	Independent, blind interpretation of test and reference (15)		
Carragee et al 2006 (80)	15	10	15	-	5	-	15	60
Carragee et al 2002 (91)	15	10	15	-	5	-	15	60
Carragee et al 1999 (93)	15	10	15	-	5	-	15	60
Derby et al 1999 (99)	15	10	15	5	-	-	15	60
Derby et al 2005 (83)	15	10	15	5	-	-	15	60
Schwarzer et al 1995 (1)	15	10	15	5	-	-	15	60
Cohen et al 2002 (96)	15	10	15	5	-	–	15	60
Manchikanti et al 2001 (101)	15	10	15	5	-	–	15	60
Manchikanti et al 2001 (7)	15	10	15	5	-	–	15	60

Methodological criteria and scoring adapted from West S et al. Systems to Rate the Strength of Scientific Evidence, Evidence Report, Technology Assessment No. 47. AHRQ Publication No. 02-E016 (56).

previous studies (79,90), 3 studies (89,92,94) were performed without a control disc. The first study evaluated subjective concordance assessment in patients with no prior back pain history 2–4 months after iliac crest bone graft harvesting for non-thoraco lumbar procedures (93). Of the 3 published papers (89,92,94) in 2000, the first study (94) evaluated false-positive lumbar discography rates in 3 groups of subjects: those devoid of pain complaints, those with chronic cervical pain, and those with primary somatization disorder, according to the protocol described by Walsh et al (100). The second study (89) aimed to determine whether discography could cause long-term back symptoms in these same groups of subjects. The third study in 2000 (92) sought to determine the rate of positive discograms in operated discs among symptomatic and asymptomatic subjects who had previously undergone single-level discectomy. A study published by Carragee et al (91) in 2002 evaluated provocative discography in volunteer subjects with mild persistent low back pain who had previously undergone cervical spine surgery. In the manuscript published in 2006, Carragee et al (79) retrospectively reviewed previously published data to determine the false-positive rate in various cohorts using a low-pressure threshold as the criterion for a positive discogram. In another manuscript, the group compared surgical fusion outcomes of patients with a single-level positive discogram using strict criteria to a control group with single-level grade I or II spondylolisthesis who had negative or no pre-operative discography (80).

Derby et al also published multiple studies (81-83,99). Of these, 2 studies (83,99) met inclusion criteria. In 1999 Derby et al (99) published a retrospective

Table 3. *Descriptive characteristics of controlled studies of lumbar discography.*

Study	Participants	Authors' Conclusion	Review Conclusion
Carragee et al 2006 (80)	Discogenic pain = 32 Spondylolisthesis group = 30	Positive discography not highly predictive of success of fusion.	Fusion is not a proven treatment for discogenic pain.
Carragee et al 2002 (91)	Mild CLBP = 25 CLBP = 52	36% positive challenged specificity	Similar to 26%–39% in controlled trials (2,7).
Carragee et al 1999 (93)	8 asymptomatic subjects who had undergone posterior iliac crest bone graft harvesting, and who, by pain drawing and psychometric testing, appeared 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 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 (25).
Derby et al 1999 (99)	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.
Derby et al 2005 (83)	279 discs from 86 patients (55 men, 31 women) who were referred for discography of suspected chronic diskogenic 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.
Schwarzer et al 1995 (1)	92 consecutive patients with chronic low back pain and no history of previous lumbar surgery were studied. Each patient underwent a standard physical examination. Computed tomography discography was performed at a minimum of 2 levels.	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.	This study provided prevalence of internal disc disruption.
Cohen et al 2002 (96)	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 (101)	50 randomly assigned patients, with 25 patients in Group I without somatization disorder and 25 patients in Group II with diagnosis of somatization disorder. 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 somatization disorder, depression, and generalized anxiety disorder.	There was no difference when somatization was evaluated utilizing appropriate described criteria.
Manchikanti et al 2001 (7)	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.
Carragee et al 2006 (79)	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. somatization disorder patients and symptomatic chronic low back pain patients).

Table 3 (cont.). *Descriptive characteristics of controlled studies of lumbar discography.*

Study	Participants	Authors' Conclusion	Review Conclusion
Carragee et al 2000 (89)	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 2000 (92)	Asymptomatic postsurgery = 20 Intractable pain-laminectomy = 27	High false-positive rate after limited lumbar discectomy.	Poor operational criteria.
Carragee et al 2000 (94)	26 individuals without low back pain, with 10 pain free, 10 chronic neck pain, 6 primary somatization disorder.	Significant positive responses in patients with chronic neck pain (40%), somatization disorder (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.
Derby et al 2005 (82)	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 (81)	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 provocation discography is performed utilizing appropriate criteria.
Shin et al 2006 (86)	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 (100)	7 patients with low back pain and 10 volunteers without history of low back pain underwent discography at 3 levels.	5 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 also 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.
Schwarzer et al 1994 (2)	92 consecutive patients with chronic low back pain were studied using both discography and blocks of the zygapophyseal joints.	In patients with chronic low back pain, the combination of discogenic pain and zygapophyseal joint pain is uncommon.	This study provided confirmation that combined discogenic and facet joint pain is rare.
Carragee et al 2004 (90)	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 LBP history.	Painful disc injections are poor independent predictors of subsequent LBP episodes in subjects initially without active lower back complaints. Anular 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.

NA = not applicable; LBP = low back pain; CLBP = chronic low back pain

study evaluating the effect pressure controlled discography had on surgical and non-surgical outcomes. They found that patients with chemically-sensitive discs obtained better long-term outcomes with interbody/combined fusion than with intertransverse fusion. This suggests that categorization of positive discographic diagnoses can facilitate therapeutic decision-making. In 2005, the authors re-examined the rate of false-positive discograms in asymptomatic volunteers, albeit with controlled injection pressures and manometric standardization (81). In another study (82), the authors sought to differentiate discograms in asymptomatic subjects from the control discs in low back pain patients. Derby et al (83) also evaluated the relationship between annular disruption on CT scan and pressure-controlled discography. They evaluated 279 discs in 86 patients who were referred for suspected discogenic low back pain. They showed that the extent of annular disruption was significantly correlated with the reproduction of concordant pain. They concluded that annular disruption reaching the outer annulus fibrosus is a key factor in pain generation.

Walsh et al (100) performed lumbar discography in normal subjects prior to the establishment of IASP guidelines in an attempt to re-evaluate Holt's findings using more stringent criteria (127).

In 1995, Schwarzer et al (1) performed discography in 92 patients with chronic low back pain utilizing IASP criteria in an effort to identify historical or physical exam features associated with discogenic pain. In addition to concordant pain reproduction at a disc containing a grade 3 or 4 radial fissure, a negative control disc had to be present for a disc to be deemed a pain generator. Overall, 36 patients, or 39%, satisfied the criteria for a positive discogram. The 95% confidence limits for this proportion were 29% to 49%. The authors concluded that a diagnosis of painful IDD can only be made with discography.

The study by Manchikanti et al (7) evaluated the relative contributions of potential pain generators in 120 patients with chronic non-radicular low back pain. All patients initially underwent controlled comparative diagnostic facet joint nerve blocks with lidocaine and bupivacaine. In patients with negative medial branch blocks, sacroiliac joint injections were performed in those patients with tenderness overlying the joint and positive provocative maneuvers. In subjects in whom the facet and SI joints were ruled out as causative factors, provocation discography was performed in accordance with IASP criteria. Overall, the prevalence of discogenic pain was estimated to be 26% (95% CI, 18%, 34%).

In an attempt to qualify the effect the needle insertion site had on discography results, Cohen et al (96) performed 366 discograms in 127 patients with non-radicular low back pain who had failed facet joint interventions. Overall, 65% of subjects experienced ≥ 6/10 concordant pain at one or more levels, along with an abnormal morphological appearance and a negative control disc. The authors concluded that performing discography from the same side as the patient's pain complaints had no effect on pain provocation. .

The final study meeting inclusion criteria was by Manchikanti et al (101), who performed provocation discography in 50 patients equally divided by the presence or absence of somatization disorder. All patients had failed trials with epidural steroid injections and facet blocks. Fifty-one percent of the entire cohort had at least one positive discogram, with no differences noted between outcomes when patients were stratified by somatization disorder, depression, or anxiety. The authors concluded psychopathology had minimal impact on discography results when the procedure is performed according to IASP criteria.

Prevalence

Prevalence of pain due to IDD is estimated to range between 26% and 39% of unscreened patients suffering from chronic non-radicular low back pain (1,7) (Table 4).

Table 4. *Data of prevalence of lumbar discogenic pain utilizing IASP criteria.*

Study	Methodological Quality Scoring	Participants	Prevalence
Schwarzer et al 1995 (1)	60	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.
Manchikanti et al 2001 (7)	60	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.

Validity

According to International Spine Intervention Society (ISIS) guidelines (41), the requirements for a positive discogram are ≥ 7/10 concordant pain elicited at ≤ 50 psi above opening pressure, a grade III anular tear, and a painless control disc. In an ideal scenario, the gold standard would be tissue confirmation of the presence or absence of disease; however, surgical inspection of a degenerated disc cannot determine whether or not that disc is painful.

The accuracy of discography as an imaging test is comparable to that of MRI, and possibly superior for detecting radial annular fissures (130). 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 published data were re-analyzed based on IASP criteria (25).

False-Positive Rates

A series of published studies investigated the potential for false-positive results by performing discography on asymptomatic volunteers (81,89,91-94,100). The Holt study (127) was performed on prisoners, with outdated techniques, noxious, irritating contrast dye (128), and 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 (91,92,94) according to low pressure criteria. They (79) 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, 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 pressure, which is higher than the standard set by ISIS/IASP of ≤ 15 psi a.o. (80). 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 (79) re-analysis. Each subgroup merits individual scrutiny (Table 5). 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), with markedly abnormal psychometric scores, and active worker's compensation litigation. Using high pressure provocation (pressure ≤ 100 psi a.o.), Carragee et al (79) reported a false-positive rate of 40%; however, because of the small numbers, the 95% confidence level ranged between 10% and 70%. If one substitutes the ISIS/IASP (40,41) 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%) (25). Furthermore, Carragee et al (79) included 4 patients with somatization disorder in this analysis who might arguably be removed from consideration. However, a prospective study by Manchikanti et al (101) found no difference in the rate of positive discograms between patients with and without somatization disorder (Table 5).

Lastly, Carragee et al (91) included 25 patients with a history of persistent, low intensity back pain. Thirty-six percent (n = 9) of these subjects were deemed false-positive in the original protocol analysis, which declined only slightly to 28% (n = 7) in the re-analysis. Yet, the contention that these patients represent false-positive responses is contestable. An alternative explanation is that these individuals were in a more quiescent phase of their illness, or simply were more stoic. This argument is bolstered by the original 36% false-positive rate, which is similar to the 39% prevalence rate of discogenic pain reported by Schwarzer (1). In summary, Carragee et al's (79) 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 (100) sought to replicate Holt's work (127), but attempted

to remediate some of the shortcomings by including in their criteria pain intensity ratings, concordance, and observed pain behaviors. Although discograms were morphologically abnormal in 5 of the 10 subjects, none elicited concordant pain. More recently, Derby et al (82) 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 takes into consideration pain intensity and the amount of pressure needed to provoke symptoms, the false-positive rate is less than 10%. Wolfer et al (25) conducted a meta-analysis on all complete data sets obtained from lumbar discography studies done in 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 (Table 5). This systematic literature review demonstrates that lumbar discography performed in accordance with accepted guidelines is associated with a low false-positive rate.

Table 5. *Summary of false-positive rates (%) per patient and per disc for experimental studies in subjects asymptomatic of low back pain.*†*

STUDY	Walsh et al (100)/Carragee et al (94)		Derby et al (99)		ISIS/IASP						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 (100): Asymptomatic volunteers (95% CI)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)
Carragee et al (93): 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 (94): 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 (94): 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 (89): 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 (81): Asymptomatic volunteers (95% CI)	0 (–)	0 (–)	0 (–)	0 (–)	0 (–)	0 (–)	0 (–)	0 (–)	0 (–)	0 (–)	0 (–)	0 (–)	0 (–)	0 (–)
Carragee et al (91): 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 (92): 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 (127) and Massie and Steven (126) are not included as 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 (25).

Outcomes Assessment

Carragee et al (80) used fusion results as the criterion standard in demonstrating 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 (130-136). 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 (49,131). The surgical outcomes for the treatment of IDD are widely acknowledged to be inferior than for radiculopathy, with the reported success rates ranging from less than 50% to greater than 80% (132-134). The few randomized studies comparing fusion outcomes to conservative treatment demonstrated mixed results (132,135,136). In addition, although there are multiple published studies evaluating disc replacement outcomes (130), 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 (DDD) (49), 622 articles on the presurgical use of discography were reviewed. Issues that were evaluated included the reliability of discography, 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. Their 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 DDD; 2) because of low quality and heterogenous 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 DDD; 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 (70,72) to assess the test-retest and inter-reader 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 reader at different times (i.e., test-retest) or by different readers (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 pre-surgical discography to predict outcomes. This was done by comparing 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 (125) 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 non-concordant pain (positive; n = 60). Gill and Blumenthal (76) categorized 3 groups of patients based on the morphology of the suspected disc: small annular tear that did not extend to the periphery (type I, n = 14); 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 (97) 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 discographic screening. In the Willems et al. study (125), 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. In the Colhoun et al (97) 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 (76) 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 (99), 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 (99), no study used manometry as a determining factor in discographic interpretation. Esses et al (137) and Madan et al (107) failed to duplicate the results of Colhoun et al (97). In 2 reviews by Cohen et al (130,131), 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 for the use of fusion to treat degenerative disc disease and methodological flaws in the component studies, make data interpretation exceptionally difficult (49,131). Thus, fusion outcomes should not be used as criterion standard in evaluating the accuracy of lumbar provocation discography.

MRI Correlation

Lei et al (122) correlated a new MRI classification of disc degeneration, found to have good intra- and inter-observer agreement, with discography. The sensitivity and specificity of MRI in predicting a painful disc was 94% and 77%, which favorable compared to endplate signal changes and high intensity zones, which were found to haves sensitivities of 32% and 27%, respectively. The authors concluded that an MRI is an excellent tool for assessing disc morphology, but should be used in conjunction with discography for planning surgical treatment.

O'Neill et al (138) evaluated the accuracy of MRI in diagnosing discogenic pain in 143 patients, taking into consideration the interdependence of MRI parameters. Parameters evaluated included high intensity zone, bone marrow intensity, nuclear signal, disc height, and disc contour. Nuclear signal alone was as accurate as any individual or combination of MRI parameters. Moderate loss of nuclear signal and disc bulging had the best sensitivity (79.8%) and specificity (79.3%). Accounting for either moderate loss of disc height or the presence of a high intensity zone reduced sensitivity but improved specificity. Notably, the incorporation of a high intensity zone reduced sensitivity (73.6%) and improved specificity (92.6%). The authors concluded that MRI parameters correlate both with each other and discography findings, and that nuclear signal is the most important MRI characteristic to consider.

Scuderi et al (123) prospectively conducted a 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 cannot be predicted by noninvasive means, including biomarker assays.

Derincek et al (124) performed discography on a series of patients with back pain and MRI evidence of DDD. Those patients experiencing pain during injection into a morphologically normal disc were studied. These individuals underwent repeat discograms on the morphologically normal disc, but the morphologically abnormal (adjacent disc) was anesthetized. None of their patients experienced pain during the repeat discogram. The authors recommended anesthetizing the morphologically abnormal disc before testing potentially normal (control) discs.

Level of Evidence

Based on the 9 studies (1,7,80,83,91,93,96,99,101) meeting methodologic quality assessment criteria, the level of evidence using U.S. Preventive Services Task Force (USPSTF) criteria is II-2 for provocation discography as a diagnostic test in evaluating and managing chronic low back pain without disc herniation, facet joint, or sacroiliac joint pain.

Discussion

This systematic review indicates an evidence level of II-2 for lumbar provocation discography in identifying patients with chronic low back pain. The prevalence of discogenic pain is estimated to be 29% to 36% (1,7) utilizing IASP criteria (40). Despite the plethora of often contradictory literature available, only 9 studies (1,7,80,83,91,93,96,99,101) met inclusion criteria. The results of this assessment are similar to previous systematic reviews (25,38,39,42). However, they are in contrast to many other evaluations, specifically those by Carragee et al (78-80,89-95), and guidelines based on these studies (139,140), leading to unintended consequences (141-145). The rationale for these consequences is based on several studies describing pain provocation in patients with no history of back pain (79) and a relatively modest positive predictive value of around 50% for surgical fusion in patients

with single-level, discography-confirmed DDD (80). Yet, 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 greatest challenge concerning discography continues to be the gold standard dilemma. Two prior systematic reviews exhaustively discussed this issue (38,39), which is not unique to discography. Knottnerus et al (146) outlined the methodological challenges that must be addressed when interpreting diagnostic accuracy studies. These include the gold standard problem, spectrum and selection bias, "soft" measures (subjective phenomena), observer variability and bias, complex relations, clinical impact, sample size deficiencies, and the rapid evolution of knowledge and technical advances (146). In this and prior reviews, these concerns have been explored; unfortunately, most discography studies cannot overcome the methodological limitations.

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 as to whether or not the disease exists. Some authors implicitly assume that discography is a pre-surgical 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 suspect treatment(s). The treatment of discogenic pain continues to be a challenging endeavor, with no treatment having been found that provides significant relief to a majority of presumed patients on a consistent basis.

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 both evaluating the quality of a diagnostic test and identifying an ideal cutoff value (147-149). 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 ROC curves for discography (38). Only one paper has subsequently done this (83). Derby et al (83) used an ROC curve to develop strict operational criteria for defining a symptomatic disc, then correlated this information with abnormal disc morphology. If paired together, the false-positive rate could be significantly reduced during discography.

In a meta-analysis by Wolfer et al (25), the calculated false-positive rate among 11 studies was 6% based on IASP criteria. Among truly asymptomatic patients, the false-positive rate was 3% per patient and 2.1% per disc. In patients with somatoform disorder, the false-positive rate rose to 50% per patient and 22.2% per disc. In post-discectomy patients, the rate was 15% per patient and 9.1% disc. The authors concluded that the false-positive rate was acceptably low and indicated the level of evidence for discography was Level II-2.

A recent literature search demonstrated that investigators are attempting to optimize MRI criteria to better identify painful discs. Lei et al (122) and O'Neill et al (138), however, concluded that MRI should continue to supplement discography rather than replace it. Willems et al (125) used an external transpedicular fixation system to select patients for spinal fusion; yet, this technique is not routinely used in the United States and poses a heightened complication risk 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 (124) 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.

Recently, Glasziou et al (150) 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 IASP/ISIS criteria for categorizing disc provocation are not devoid of methodological weaknesses. These flaws include the arbitrary designation of a

pressure threshold for labeling a disc as "positive," the absence of any objective confirmatory parameters such as heart rate response (151) or facial expressions (100), and the inherent subjectivity regarding the designation of "concordant" vs. "non-concordant" pain, which is likely contingent on a plethora of non-anatomical variables. But perhaps the most glaring shortcoming is the capricious choice of a numerical rating scale cutoff score completely detached from baseline levels. Pain is a prototypically subjective experience, yet the IASP guidelines completely ignore this axiom. This can lead to irreconcilable inconsistencies. According to IASP criteria, a functional patient with 10/10 pain can be classified as positive if disc stimulation provokes only 70% of the baseline discomfort, whereas an incapacitated patient who stoically rates his preprocedure as 4/10 would be categorized as "negative" even if discography produces a 50% increase in pain score. The severing of any connection between baseline pain and the quantification of provoked pain is in direct contradistinction to the reference standards used to diagnose other sources of back pain such as facet and sacroiliac joint pain, whereby all previous investigators have evaluated the analgesic response to diagnostic injections in the context of pre-injection pain (152-154). But, in spite of its weaknesses, the IASP criteria with minimum pain intensity of 7 out of 10, or at least 70% reproduction of worst pain (i.e. worst spontaneous pain of 7 = 7 x 70% = 5, rather than 7), provides a solid foundation from which discography parameters can and must be standardized.

Finally, even though lumbar provocation discography with a double needle technique is considered safe (155), discitis is a serious problem. Further, needle puncture injury was shown to affect intervertebral disc mechanics and biology in an organ culture model (156). In addition, incidence of intravascular uptake during fluoroscopically guided lumbar disc injections also has been demonstrated (157).

Conclusion

This systematic review illustrates that lumbar provocation discography performed according to the IASP criteria may be a useful tool for evaluating chronic lumbar discogenic pain. The results show that based on modified USPSTF evidence criteria, the indicated evidence is Level II-2 for the diagnostic accuracy of lumbar provocation discography utilizing IASP standards.

Acknowledgments

The authors wish to thank Rinoo Shah, MD, for advice and previous manuscripts, the editorial board of Pain Physician, for review and criticism in improving the manuscript; Vidyasagar Pampati, MSc, statistician; Sekar Edem for assistance in search of literature; and Tonie M. Hatton and Diane E. Neihoff, transcriptionists (Pain Management Center of Paducah); for their assistance in preparation of this manuscript.

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