Pain Physician 2008; 11:631-642 • ISSN 1533-3159

Systematic Review

Systematic Review of Thoracic Discography as a Diagnostic Test for Chronic Spinal Pain

Vijay Singh, MD[1], Laxmaiah Manchikanti, MD[2], Rinoo V. Shah, MD[3], Elmer E. Dunbar, MD[4], and Scott E. Glaser, MD[5]

From: [1]Pain Diagnostics Associates, Niagara, WI; [2]Pain Management Center of Paducah, Paducah, KY, [3]Guthrie Clinic Sayre, PA; [4]Pain Control Network PSC, Louisville, KY; and [5]Pain Specialists of Greater Chicago, Burr Ridge, IL.

Dr. Singh is Medical Director of Pain Diagnostics Associates, Niagara, WI
Dr. Manchikanti is Medical Director of the Pain Management Center of Paducah, Paducah, KY, and Associate Clinical Professor of Anesthesiology and Perioperative Medicine, University of Louisville, KY.
Dr. Shah is in the Department of Anesthesiology, Guthrie Clinic, Sayre, PA.
Dr. Dunbar is Medical Director of Pain Control Network, Louisville, KY.
Dr. Glaser is the President of Pain Specialists of Greater Chicago, Burr Ridge, IL

Address correspondence:
Vijay Singh, MD
Medical Director
Pain Diagnostic Associates
1601 Roosevelt Road
Niagara, WI 54151
E-mail: vj@wmpnet.net

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

Manuscript received: 08/08/2008
Accepted for publication: 09/12/2008

Free full manuscript:
www.painphysicianjournal.com

Background: Even though the prevalence of thoracic pain has been reported to be 15% of the general population and up to 22% of the population in interventional pain management settings, the role of thoracic discs as a cause of chronic thoracic and extrathoracic pain has not been well researched. The intervertebral discs, zygapophysial or facet joints, and other structures including the costovertebral and costotransverse joints have been identified as a source of thoracic pain.

Objective: To systematically assess the quality of clinical studies evaluating the diagnostic accuracy of provocation thoracic discography.

Study Design: A systematic review of provocation thoracic discography.

Methods: A systematic review of the literature was performed to assess the diagnostic accuracy of thoracic discography with respect to chronic, function limiting, thoracic or extrathoracic pain.

Studies meeting the Agency for Healthcare Research and Quality (AHRQ) methodologic quality criteria with scores of 50 or higher were included for the assessment of the level of evidence. Level of evidence was based on the United States Preventive Services Task Force (USPSTF) criteria for the assessment of accuracy of diagnostic studies. Based on the level of evidence, recommendations were made according to Guyatt et al's criteria.

Results: The clinical value of thoracic provocation discography is limited (Level II-3) with 2C/weak recommendation derived from low quality or very low quality evidence indicating that other alternatives may be equally reasonable.

Conclusion: Based on the available evidence for this systematic review, thoracic provocation discography is provided with a weak recommendation for the diagnosis of discogenic pain in the thoracic spine, if conservative management has failed. This is qualified by the need to appropriately evaluate and diagnose other causes of chronic thoracic pain including pain originating from thoracic facet joints.

Key words: Thoracic pain, chest wall pain, intervertebral disc, thoracic intervertebral disc, facet joint, thoracic disc herniation, discogenic pain, lumbar provocation discography, cervical provocation discography, thoracic provocation discography, false-positive response, diagnostic accuracy

Pain Physician 2008; 11:5:631-642

Provocation discography as performed today was first described in 1948 by Lindblom (1) when he used the term "diagnostic disc puncture." This procedure provisionally replaced oil-contrast myelography described by Dandy (2) in 1929 for the diagnosis of a herniated disc as a cause of radicular pain. During the "herniated disc" era, both axial and referred radicular pain were thought to be due to a herniated disc compressing neural elements (3). It is well known that Mixter and Barr (4) were the first to create widespread interest in the disc as a source of pain in American literature with their 1934 hallmark description of the herniated nucleus pulposus. However, soon after, Mixter and Ayers (5) in 1935 demonstrated that radicular pain could occur without disc herniation. Since then, numerous investigators (1,3,5-47) have described pain syndromes emanating from the intervertebral disc that are not associated with evidence of the mechanical compression of neural structures. Consequently, pain related to internal disc derangement without a specific disc herniation has assumed a major role as a cause of non-specific spinal pain.

Discography has mainly been used as an imaging tool over the years and has been considered to be superior to radiographs, myelography, magnetic resonance imaging (MRI), and computed axial tomography (CT) scanning in imaging intervertebral disc morphology (3,7-10,14-21,24,33-36,39-46). Advances in CT and MRI scanning have added to the knowledge of disc pathology, structural abnormalities such as degenerative disc changes, herniations, associated end plate changes, and annular tears. There are no definitive tests for the diagnosis of discogenic pain (14-20,22-28,33-38,47-60). Further, structural abnormalities are present in patients asymptomatic of spinal pain, thus increasing the importance of discography as the most specific and sensitive test to assess if a disc is painful (35,38,43-46,50-52). Discography continues to be the criterion standard (19,33,34,36,48,49) to determine whether or not a particular disc is painful irrespective of the evidence or lack thereof for degenerative changes utilizing other imaging modalities. The appropriate performance and diagnostic value of lumbar discography, and, to a somewhat lesser extent, cervical discography, has been extensively documented, practiced, and refined over the past 6 decades since its first descriptions in the 1940s. However, thoracic discography continues to be in its nascent stages of clinical application and specifically in the arena of evidence-based medicine, with the first descriptions of thoracic discography appearing in 1975 (15), approximately 30 years after the description of lumbar discography (1).

Simmons and Segil (15), in 1975, described thoracic discography and nucleography in the evaluation of a man with mid-thoracic radicular pain with a diagnosis of a posterior annular tear that reproduced his thoracic symptoms. In 1994, Schellhas et al (16) published a retrospective review of 100 outpatient thoracic discographies performed on patients whose MRI findings revealed thoracic disc degeneration. In 1999, Wood et al (18) published a prospective study of MRI and thoracic discography in asymptomatic and symptomatic individuals. Over the past few decades, thoracic discography has been used as a safe procedure by skilled interventionalists, with its main purpose of precisely identifying and localizing the disc level or levels which are the source of chronic thoracic spinal pain.

The Task Force on Taxonomy of Classification of Chronic Pain in 1994 described criteria for the diagnosis of discogenic pain (50-52). The Task Force (50) defined thoracic discogenic pain as thoracic spinal pain, with or without referred pain. The key diagnostic criteria of thoracic discogenic pain is that the patient's pain must be shown conclusively to stem from an intervertebral disc by provocation discography of the putatively symptomatic disc with reproduction of the patient's accustomed pain, with provocation of at least 2 adjacent intervertebral discs, clearly not reproducing the patient's pain, and provided that the pain cannot be ascribed to some other source innervated by the same segments that innervate the putatively symptomatic disc. The Task Force (50) cautioned that thoracic discography alone is insufficient to conclusively establish a diagnosis of discogenic pain because of the propensity for false-positive responses, either because of apprehension on the part of the patient or because of the coexistence of a separate source of pain within the segment under investigation.

Degeneration of the thoracic disc, along with endplate irregularities and changes due to osteophyte formation, are common findings (37,38). However, the contribution of disc and facet joints as sources of thoracic spinal pain have received only scant attention (14-18,20,24,35,37,38,46,50,61-69). The proportion of patients suffering from chronic upper or mid back pain secondary to thoracic disorders is relatively small compared to chronic low back and neck pain. Linton et al (61) estimated that the prevalence of thoracic pain is 15% of the general population in contrast to 56%

reporting low back pain and 44% reporting neck pain. Involvement of thoracic discs and facet joints as sources of pain has been described (14-18,48-50,53,62-68).

Two systematic reviews evaluating the role of provocation discography in the diagnosis of spinal pain (22,23) have presented limited evidence supporting the role of discography in identifying the subset of patients with thoracic discogenic pain. Further, multiple concerns have been raised in regard to the reported high false-positive rate, the lack of concordance, potential confounding factors, and safety of controlled diagnostic blocks (3,70-72). In a recent systematic review of lumbar provocation discography in asymptomatic subjects with a meta-analysis of false-positive rates, Wolfer et al (3), after extensive evaluation, concluded that the strength of evidence is Level II-2 based on the United States Preventive Services Task Force (USPSTF) criteria (73) and the criteria for assessment of accuracy of diagnostic studies (74).

In this systematic review, we sought to provide answers to the question: Is provocation discography valid in the diagnosis of thoracic discogenic pain?

Methods

Literature Search

The literature search included multiple databases including PubMed, EMBASE, and databases of multiple journals, Cochrane Reviews, systematic and narrative reviews, Clinical Trials Registry, and letters to the experts. A search was conducted from 1966 through July 2008. A review of the reference sections of selected articles was performed to identify all the relevant studies. However, only English language articles were reviewed.

The search was conducted utilizing the following terms: thoracic disc, thoracic discogenic pain, thoracic analgesic discography, and thoracic provocation discography.

Inclusion Criteria

Only the studies meeting the inclusion criteria of important participants (asymptomatic volunteers or symptomatic patients with thoracic pain of greater than 3 months duration) were included.

Exclusion Criteria

Studies including non-clinical studies, abstracts, technical papers, expert opinions, single case reports, and general review articles were excluded.

Review Methods

Study Selection

Studies were selected if they met the inclusion criteria.

Data Extraction

The relevant data on the methodology and outcome measures were collected.

Methodologic Quality Assessment

The Agency for Healthcare Research and Quality (AHRQ) criteria for diagnostic testing (74) as reported in Table 1 are used for methodologic quality assess-

Table 1. *Modified AHRQ methodologic assessment criteria for diagnostic interventions.*

CRITERION	Weighted Score
1. Study Population	30
• Subjects similar to populations in which the test would be used and with a similar spectrum of disease	
2. Adequate Description of Test	15
• Details of test and its administration sufficient to allow for replication of study	
3. Appropriate Reference Standard	20
• Appropriate reference standard (gold standard) used for comparison	10
• Reference standard reproducible	10
4. Blinded Comparison of Test	20
• Evaluation of test without knowledge of disease status, if possible	10
• Independent, blind interpretation of test and reference	10
5. Avoidance of Verification Bias	15
• Decision to perform reference standard not dependent on results of test under study	
TOTAL SCORE	100

Adapted and modified from West S et al. Systems to Rate the Strength of Scientific Evidence, Evidence Report, Technology Assessment No. 47. AHRQ Publication No. 02-E016 (74).

ment. The weighted scores of methodologic quality criteria were developed by consensus of the guidelines committee of the American Society of Interventional Pain Physicians (ASIPP) (70). Based on the weighted scoring system, a total of 100 total points may be awarded for each study. Only the studies scoring 50 or above were utilized in the analysis. Each study was scored independently by 2 reviewers. Any discrepancies and conflicts were reviewed by a third author to reach a consensus agreement. If disagreement still existed, all the reviewers discussed their differences until a consensus was reached.

Qualitative Analysis of Evidence

Qualitative analysis will be conducted using 4 levels of evidence for effectiveness of thoracic discography as illustrated in Table 2 (73). This evidence has been modified for diagnostic studies as randomized trials are not recommended for diagnostic accuracy studies (70,74-78).

Recommendations

Recommendations are provided as described in Table 3 based on Guyatt et al's grading criteria (79).

Table 2. *Modified levels of quality of evidence.*

I:	Evidence obtained from at least one properly randomized controlled trial or multiple well-conducted diagnostic studies
II-1:	Evidence obtained from well-designed controlled trials without randomization or at least one well-controlled diagnostic study of adequate size
II-2:	Evidence obtained from well-designed cohort or case-control analytic studies, preferably from more than one center or research group or evidence obtained from at least one properly designed small diagnostic accuracy study
II-3:	Evidence obtained from multiple time series with or without the intervention. Dramatic results in uncontrolled experiments (such as the results of the introduction of penicillin treatment in the 1940s) could also be regarded as this type of evidence
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) (73).

Table 3. *Grading recommendations of Guyatt et al (79).*

Grade of Recommendation/ Description	Benefit vs Risk and Burdens	Methodological Quality of Supporting Evidence	Implications
1A/strong recommendation, high-quality evidence	Benefits clearly outweigh risk and burdens, or vice versa	RCTs without important limitations or overwhelming evidence from observational studies	Strong recommendation, can apply to most patients in most circumstances without reservation
1B/strong recommendation, moderate quality evidence	Benefits clearly outweigh risk and burdens, or vice versa	RCTs with important limitations (inconsistent results, methodological flaws, indirect, or imprecise) or exceptionally strong evidence from observational studies	Strong recommendation, can apply to most patients in most circumstances without reservation
1C/strong recommendation, low-quality or very low-quality evidence	Benefits clearly outweigh risk and burdens, or vice versa	Observational studies or case series	Strong recommendation but may change when higher quality evidence becomes available
2A/weak recommendation, high-quality evidence	Benefits closely balanced with risks and burden	RCTs without important limitations or overwhelming evidence from observational studies	Weak recommendation, best action may differ depending on circumstances or patients' or societal values
2B/weak recommendation, moderate-quality evidence	Benefits closely balanced with risks and burden	RCTs with important limitations (inconsistent results, methodological flaws, indirect, or imprecise) or exceptionally strong evidence from observational studies	Weak recommendation, best action may differ depending on circumstances or patients' or societal values
2C/weak recommendation, low-quality or very low-quality evidence	Uncertainty in the estimates of benefits, risks, and burden; benefits, risk, and burden may be closely balanced	Observational studies or case series	Very weak recommendations; other alternatives may be equally reasonable

Adapted from Guyatt G et al. Grading strength of recommendations and quality of evidence in clinical guidelines. Report from an American College of Chest Physicians task force. *Chest* 2006; 129:174-181 (79).

Results

Literature Search

Figure 1 illustrates the search results. The search yielded 67 articles for review. Of these, only 4 were relevant to the study question, with 2 studies (16,18) and 2 systematic reviews (48,49).

Methodologic Quality Assessment

Methodologic quality assessment criteria for each study are with scores of 50 and 55 described in Table 4.

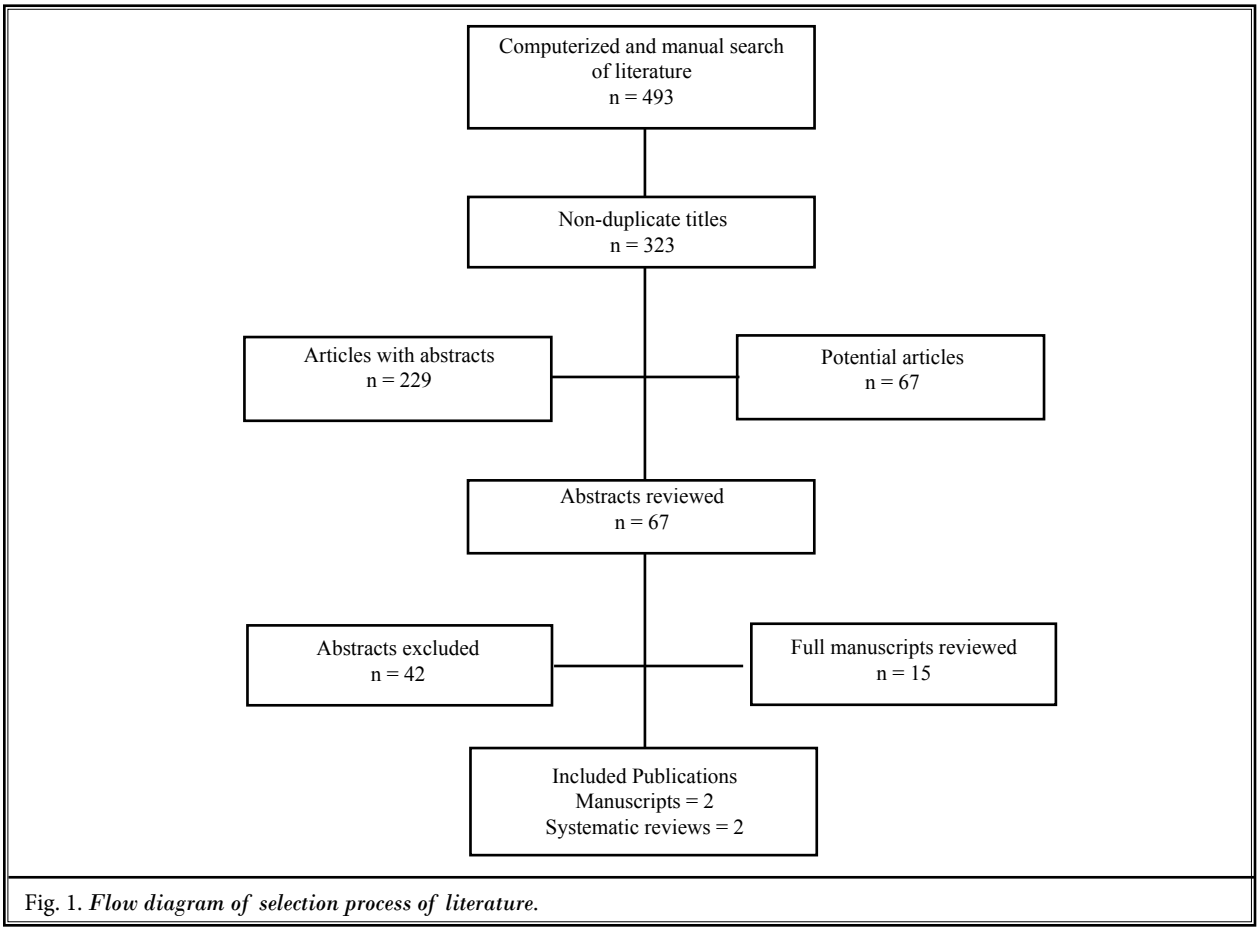

Fig. 1. *Flow diagram of selection process of literature.*

Table 4. Methodologic quality evaluation and scoring of thoracic discography studies.

		Weighted Score	Schellhas et al 1994 (16)	Wood et al 1999 (18)
1	Study Population	30	20	20
2	Adequate Description of Test	15	15	15
3	Appropriate Reference Standard	20		
	Appropriate reference standard (gold standard) used for comparison	10	5	10
	Reference standard reproducible	10	10	5
4	Blinded Comparison of Test	20		
	Evaluation of test without knowledge of disease status, if possible	10	--	--
	Independent, blind interpretation of test and reference	10	--	--
5	Avoidance of Verification Bias	15	--	5
Total		**100**	**50**	**55**

Study Characteristics

Schellhas et al (16) in 1994 published their experience with thoracic discograms performed on 100 outpatients by a retrospective analysis. After MRI, clinically suspect, morphologically abnormal thoracic discs and at least one nearby controlled level disc were injected with either non-ionic contrast or saline, filmed and individually described by the patient as concordant versus non-concordant relative to clinical pain, and rated in pain intensity on a scale of 0 to 10. The results illustrated discs with annular tears, intrinsic degeneration, and vertebral body endplate infarctions to be painful approximately 75% of the time. They demonstrated a clinical concordance of 50% with painless control levels. In this series, clinically concordant extraspinal pain such as chest wall, intrathoracic, and upper abdominal pain were frequently provoked with thoracic disc injections. They described that non-protruding disc derangements such as may be seen either in active or old juvenile discogenic disease (Scheuermann's disease). Internal disc derangements may be painful and clinically significant with more than 50% of the painful discs that they studied falling into this category. The authors concluded that thoracic discography can be performed safely by experienced individuals as a reliable tertiary diagnostic procedure to determine if degenerated discs on MRI studies are related to clinical complaints. The shortcomings of this evaluation include it being a retrospective evaluation. They described the technical aspects extensively, even though characteristics of patients' pain patterns were not provided at baseline. Further, a consistent reference standard was not applied. There was no blinded comparison of the test.

Wood et al (18) performed a prospective evaluation. They sought to determine the responses to thoracic discography by asymptomatic and symptomatic individuals. They evaluated 10 adult lifelong asymptomatic volunteers, ages 23 to 45 years, who underwent MRI of the thoracic spine, by a 4-level discography. Provocation responses were graded on a scale of 0 (no sensation) to 10 (extreme pain or pressure), and filmed discs were graded using a modified Dallas scheme. Concomitantly, 10 non-litigious adults, ages 31 to 55 years, experiencing chronic thoracic pain were similarly studied. The results showed the mean pain responses in the asymptomatic volunteers to be 2.4/10. Three discs in the asymptomatic group were intensely painful with scores of 7/10, 8/10, and 10/10, with all 3 exhibiting prominent endplate irregularities and annular tears typical of thoracolumbar Scheuermann's disease. On discography, 27 of 40 discs were abnormal, with endplate irregularities, annular tears, and/or herniations. They also reported that the 10 discs read as normal on MRI showed annular pathology on discography. Further, in the group with chronic thoracic pain, the average pain response was 6.3/10 ($P < 0.05$). Of the 48 discs studied, 50% or 24 were concordantly painful, with a response of 8.5/10 ($P < 0.05$). Seventeen discs had non-concordant pain or pressure, with an average pain score of 4.8/10 ($P < 0.05$) and 5 had no response. On MRI, 21 of the 48 discs appeared normal, whereas on discography, only 10 were judged as normal. They concluded that on discography, thoracic discs with prominent Schmorl's nodes may be intensely painful, even in lifelong asymptomatic individuals, but the pain is unfamiliar or non-concordant. Further, they also concluded that thoracic discography may demonstrate disc pathology not seen on MRI.

They also provided evidence for the relative lack of reliability of MRI at identifying painful deranged discs (18). They reported a high incidence of relatively painless disc pathology, including annular tears and frank herniations, with discography in both the symptomatic and asymptomatic patients that was missed on MRI. Nonetheless, they noted a general trend toward more painful responses was being observed with greater degrees of pathology, especially with endplate pathology such as Scheuermann's disease. They also reported variability in the perceived pain or pressure, even though it typically was on the same side as the disc pathology, whether it was a tear or herniation.

This first ever controlled prospective study in asymptomatic and symptomatic individuals had some deficiencies (18). There were only 10 lifelong asymptomatic volunteers. While they concluded that thoracic discography in the truly asymptomatic individual is not painful, regardless of the degree of pathology observed, they reported 3 of the 40 discs (7.5%) as intensely painful with pain of 7, 8, and 10 on a scale of 0 to 10. However, the 3 of them exhibited prominent endplate changes typical of thoracolumbar Scheuermann's pathology; further, 2 of these painful responses were in one volunteer. Consequently, 20% of the asymptomatic volunteers reported pain when they had severe Scheuermann's pathology. Once the 3 painful discs or 2 painful patients were removed, the average pain response was less than 2/10. Only one volunteer reported aching muscle-like pain for 48 hours, which resolved quickly at that point with no sequelae. The authors have not provided detailed re-

sults with regards to negative contiguous discs, one above and one below, thus, the criteria was limited to only elicitation of concordant pain. Twenty-seven of 49 or 55% of the discs studied in the symptomatic group were concordant.

Validity

Wood et al (18) evaluated validity of the concordant pain and the role of false-positive responses. They reported the mean pain response in the asymptomatic volunteers as 2.4/10 even though 3 discs exhibiting prominent endplate irregularities and annular tears typical of thoracolumbar Scheuermann's disease were intensely painful. Further, of the 48 discs studied, only 21 appeared normal on MRI and only 10 were judged as normal after provocation discography. The discs which exhibited concordant pain (24 of 48 or 50%) exhibited a pain response of 8.5/10, statistically higher pain levels than the 17 discs that exhibited non-concordant pain pressure with an average pain of 4.8/10, and 5 discs with no pain response at all.

Schellhas et al (16) evaluated concordant pain and also at least one nearby controlled level disc. They demonstrated clinical concordance in approximately 50% of the discs, with controlled levels being painless.

Prevalence

Prevalence of thoracic discogenic pain has not been determined.

False-positive Rates

Utilizing the data by Wood et al (18), it appears that the false-positive rate with thoracic discograms is 0 if a pain response of 7 or above is considered as positive with concordant pain with negative contiguous discs. However, if endplate irregularities and annular tears are taken into consideration as shown in the asymptomatic patients, even though the mean response in volunteers was 2.4/10, 3 discs in 2 patients were intensely painful with scores ranging from 7 to 10 of 10. Consequently, in patients with severe pathology, pain may be produced in 20% of the patients. Considering the clinical realities which dictate provocation thoracic discography to be performed only in symptomatic patients, utilizing the International Association for the Study of Pain (IASP) criteria (50), and that these positive patients may have been dormant and fall within the range of the prevalence of discogenic pain, it is considered that the false-positive rate with thoracic provocation discography is low.

Schellhas et al (16) evaluated concordant pain with a controlled disc at least at one level. They demonstrated a clinical concordance of 50% with painless control levels. They also concluded that they were able to determine whether observed disc pathology related to clinical pain complaints in every patient. In isolated cases in which patient uncertainty existed after thorough questioning about pain-pressure concordance at individual disc levels, the authors interpreted the response at that level as to be either indeterminate or non-concordant. They showed that in these cases, at least one other disc was clearly concordant; hence, the total examination was considered to be conclusive. In this study, they evaluated a total of 306 discs. Customarily they studied consecutive discs including more than one normal-appearing control level disc if necessary (27). Further, morphologically deranged thoracic discs produced more painful responses compared with normal-appearing control levels, even though these responses were not necessarily concordant relative to the pain being investigated (28,30,31). Based on the results of this study, it appears that false-positive rates are low when discography is performed appropriately using concordance of pain and negative control discs.

Fluke (80) criticized the report on its definition of reliable, high degree of accuracy, and Schellhas et al's conclusion that they were able to determine whether observed disc pathology related to clinical pain in every patient. Fluke contended that Schellhas et al failed to provide the data necessary to determine whether their techniques were accurate or not, because true-positive, true-negative, and false-negative rates were not reported.

In reply, Schellhas (81) referred to the formal prospective investigations of false-positive rates in the lumbar spine (30,82). Schellhas also pointed out that discography results do not provide an "excuse to operate."

Level of Evidence

Based on the one study meeting the inclusion criteria, the level of evidence is Level II-3.

Recommendation

Based on Guyatt et al's criteria (79) the recommendation is 2C/weak recommendation, low quality or very low quality evidence, with methodologic quality of supporting evidence derived from observational studies or case series with a recommendation that other alternatives may be equally effective.

Discussion

This systematic review provides an evidence level of II-3 for provocation discography in identifying patients with chronic thoracic discogenic pain. There are no prevalence or false-positive data available. Considering that thoracic facet joint pain is present in 34% to 48% of the patients with chronic non-specific function-limiting mid back and upper back pain with false-positive rates of 42% to 58% with a single block (65-67), it appears that thoracic discogenic pain may be present in at least an equal proportion of patients to facet joint pain. Chronic lumbar discogenic pain has been reported in 26% to 39% of the patients with or without internal disc disruption (7,8). The prevalence of chronic discogenic neck pain has been reported as 16% and possibly 41% of the patients (9,10).

There are multiple methodological challenges in assessing the accuracy of thoracic provocation discography, apart from the paucity of literature. The major drawbacks of this evaluation on thoracic discography is that only 2 studies are available from the same group of authors, with the last study being published in 1999, and no attempts by others to replicate or confirm these results. Further, there is no literature available comparing diagnostic techniques to outcomes of therapeutic modalities. These issues are related to criterion or gold standard and methodological challenges. AHRQ criteria utilized in the evaluation (74) addresses the methodological concerns. Others also have described a multitude of other criteria to overcome methodological challenges. These include the criteria described by the American Medical Association (AMA) (75,76), Quality Assessment Studies of Diagnostic Accuracy (QUADAS) (77), and others (78,83-85). While all the criteria have individual variations, AHRQ criteria is the most widespread and comprehensive (74). Knottnerus et al (84) described several methodological challenges including the gold standard problem, spectrum and selection bias, "soft" measures (subjective phenomena), observer variability and bias, complex relations, clinical impact, sample size, and the rapid progress of knowledge.

There is no gold standard for discogenic pain. A concordantly painful disc with contiguous negative discs was considered as the gold standard for this systematic review. Both the studies (16,18) considered for inclusion in this systematic review were able to describe, in detail, concordant pain, but only one study (16) described a negative disc. The assessment of pain may be considered as a soft measure and has been challenged repeatedly (3,30,84-95). The patients' ability to consistently report pain accurately during discography along with multiple confounding factors has been extensively discussed (3,96,97). There are no studies evaluating the outcomes based on surgical treatments derived from opinions of appropriately performed thoracic provocation discography. A gold standard of tissue biopsy, which is not reliable in the case of degenerative discs, may also be inappropriate as a criterion standard for provocation discography.

The basic principles for thoracic provocation discography are to determine whether or not a thoracic disc(s) is the source of a patient's thoracic, chest wall, or upper abdominal pain. Thus, thoracic discography is performed in an attempt to provoke pain with each injection at each designated level. A local anesthetic can be used to anesthetize painful discs to further refine the identification of a concordantly painful disc. If thoracic pain is reproduced during thoracic discography, the disc or discs are responsible for at least part or all of the pain (50,53). If thoracic pain is not reproduced during thoracic discography, then the discs are excluded as potential pain generators. Disc stimulation is analogous to palpation for tenderness (50,85). The rationale for thoracic provocation discography is based on the fact that thoracic discs are innervated and therefore can elicit pain (20,53,98-105). Anatomical studies have demonstrated that intervertebral discs receive an innervation posteriorly from the sinuvertebral nerves, laterally from the vertebral nerves, and anteriorly from the sympathetic trunks (37,50,53,98-106). In addition, thoracic discs have been shown to cause chronic upper back and mid back pain (16,18). Discogenic pain has been described to be dull and aching in quality, whereas, neurogenic pain has been described to be lancinating in quality (14). Imaging studies such as radiographs, myelography, CT, CT-myelography, and MRI are inaccurate in determining if a thoracic disc is responsible for a patient's pain complaints or the presence or absence of disc pathology (20). In addition, the patterns for thoracic discogenic pain are expected to be indistinguishable from those of thoracic facet joint pain, as in the lumbar and cervical regions (53-55). Even though these pain patterns can be used to indicate the most likely segmental source of pain and, therefore, the levels at which investigations should be focused, these patterns reflect the innervation of the source of the pain, and they do not implicate a particular structure as the source. Thus, it is essential to rule out thoracic facet joint pain prior to embarking

on provocation discography. Physical examination is unable to distinguish the source of pain because shear stress applied to the thoracic spine will simultaneously stress not only the disc, but also facet joints.

The criteria developed by IASP (50) have recommended that in order to be valid, thoracic provocation discography must be subjected to anatomical controls. Consequently, the 2 diagnostic criteria for discogenic pain must be met in each and every case. The first criteria is that the provocation of the target disc reproduces the patient's pain and the second criteria is that provocation of adjacent discs does not reproduce the pain. Validity may also be enhanced by appropriate assessment of the pain including location, quality, intensity, and concordance.

In summary, extensive research is not currently available regarding the various causes of thoracic pain and the diagnosis of those causes. Some studies (65-67) have focused on the prevalence of thoracic facet joint pain, whereas there are no studies evaluating the prevalence of thoracic discogenic pain. This systematic review provides Level II-3 evidence and a 2C/weak recommendation for thoracic discography as a diagnostic tool.

Conclusion

Based on the present systematic review the strength of evidence is Level II-3 based on the AHRQ USPSTF criteria for the diagnostic accuracy for discography, with a 2C/weak recommendation with low-quality evidence, with the implication that other alternatives may be equally reasonable.

Acknowledgments

The authors wish to thank the editorial board of *Pain Physician*, for review and criticism in improving the manuscript; Vidyasagar Pampati, MSc, statistician, and Tonie M. Hatton and Diane E. Neihoff, transcriptionists (Pain Management Center of Paducah), for their assistance in preparation of this manuscript.

References

1. Lindblom K. Diagnostic disc puncture of intervertebral discs in sciatica. *Acta Orthop Scandinav* 1948; 17:231-239.
2. Dandy W. Loose cartilage from intervertebral disc simulating tumor of the spinal cord. *Arch Surg* 1929; 19:660.
3. Wolfer L, Derby R, Lee JE, Lee SH. Systematic review of lumbar provocation discography in asymptomatic subjects with a meta-analysis of false-positive rates. *Pain Physician* 2008; 11:513-538.
4. Mixter WJ, Barr JS. Rupture of the intervertebral disc with involvement of the spinal canal. *N Eng J Med* 1934; 211:210-215.
5. Mixter WJ, Ayers JB. Herniation or rupture of the intervertebral disc into the spinal canal. *N Engl J Med* 1935; 213:385-395.
6. Pang WW, Mok MS, Lin ML, Chang DP, Hwang MH. Application of spinal pain mapping in the diagnosis of low back pain - analysis of 104 cases. *Acta Anaesthesiol Sin* 1998; 36:71-74.
7. Manchikanti L, Singh V, Pampati V, Damron K, Barnhill R, Beyer C, Cash K. Evaluation of the relative contributions of various structures in chronic low back pain. *Pain Physician* 2001; 4:308-316.
8. Schwarzer AC, Aprill CN, Derby R, Fortin J, Kine G, Bogduk N. The prevalence and clinical features of internal disc disruption in patients with chronic low back pain. *Spine* 1995; 20:1878-1883.
9. Bogduk N, Aprill C. On the nature of neck pain, discography and cervical zygapophysial joint blocks. *Pain* 1993; 54:213-217.
10. Yin W, Bogduk N. The nature of neck pain in a private pain clinic in the United States. *Pain Med* 2008; 9:196-203.
11. Crock HV. A reappraisal of intervertebral disc lesions. *Med J Aust* 1970; 1:983-989.
12. Ohnmeiss DD, Vanharanta H, Ekholm J. Degree of disc disruption and lower extremity pain. *Spine* 1997; 22:1600-1605.
13. Wheeler AH, Murrey DB. Chronic lumbar spine and radicular pain: Pathophysiology and treatment. *Curr Pain Headache Rep* 2002; 6:97-105.
14. Falco FJ, Zhu J, Irwin L, Onyewu CO, Kim D. Thoracic discography. In Manchikanti L, Singh V (eds). *Interventional Techniques in Chronic Spinal Pain*. ASIPP Publishing, Paducah KY, 2007, pp 553-566.
15. Simmons EH, Segil CM. An evaluation of discography in the localization of symptomatic levels in discogenic disease of the spine. *Clin Orthop* 1975; 108:57-69.
16. Schellhas KP, Pollei SR, Dorwart RH. Thoracic discography. A safe and reliable technique. *Spine* 1994; 19:2103-2109.
17. Winter RB, Schellhas KP. Painful adult thoracic Scheuermann's disease: Diagnosis by discography and treatment by combined arthrodesis. *Am J Orthop* 1996; 25:783-786.
18. Wood KB, Schellhas KP, Garvey TA, Aeppli D. Thoracic discography in healthy individuals. A controlled prospective study of magnetic resonance imaging and discography in asymptomatic and symptomatic individuals. *Spine* 1999; 24:1548-1555.
19. Guyer RD, Ohnmeiss DD. Lumbar discography. Position statement from the North American Spine Society diagnostic and therapeutic committee. *Spine* 1995; 20:2048-2059.
20. Singh V. Thoracic discography. *Pain Physician* 2004; 7:451-458.
21. Fernstrom U. A discographical study of ruptured lumbar discs. *Acta Chirurg Scand* 1960; 258:1-60.
22. Hirsch C. An attempt to diagnose level of disc lesion clinically by disc puncture.

Acta Orthop Scand 1948; 18:132-140.

23. Malmivaara A. Disc degeneration in the thoracolumbar junctional region. Evaluation by radiography and discography in autopsy. *Acta Radiol* 1987; 28:755-760.
24. Fortin JD. Precision diagnostic disc injections. *Pain Physician* 2000; 3:271-288.
25. Collins CD, Stack JP, O'Connell DJ, Walsh M, McManus FP, Redmond OM, Ennis JT. The role of discography in lumbar disc disease: A comparative study of magnetic resonance imaging and discography. *Clin Radiol* 1990; 42:252-257.
26. El-Khoury GY, Renfrew DL. Percutaneous procedures for the diagnosis and treatment of lower back pain: Diskography, facet-joint injection, and epidural injection. *Am J Roentgenol* 1991; 157:685-691.
27. Schellhas KP, Pollei SR. The role of discography in the evaluation of patients with spinal deformity. *Orthop Clin North Am* 1994; 25:265-273.
28. Simmons JW, Emery SF, McMillin JN, Landa D, Kimmich SJ. Awake discography. A comparison study with magnetic resonance imaging. *Spine* 1991; 16: S216-S221.
29. Skubic JW, Kostuik JP. Thoracic pain syndromes and thoracic disc herniation. In Frymoyer JW (ed). *The Adult Spine: Principles and Practice*. Raven Press, New York, 1991, pp 1443-1461.
30. Walsh TR, Weinstein JN, Spratt KF, Lehmann TR, Aprill C, Sayre H. Lumbar discography in normal subjects. A controlled, prospective study. *J Bone Joint Surg Am* 1990; 72:1081-1088.
31. Weinstein J, Claverie W. Gibson S. The pain of discography. *Spine* 1998; 13:1344-1348.
32. Whitecloud TS, Seago RA. Cervical discogenic syndrome: Results of operative intervention in patients with positive discography. *Spine* 1987; 12:313-316.
33. Zucherman J, Derby R, Hsu K, Picetti G, Kaiser J, Schofferman J, Goldthwaite N, White A. Normal magnetic resonance imaging with abnormal discography. *Spine* 1988; 13:1355-1359.
34. Cloward RB. The anterior surgical approach to the cervical spine: The Cloward Procedure: Past, present, and future. The presidential guest lecture, Cervical Spine Research Society. *Spine* 1988; 13:823-827.
35. Wood KB, Garvey TA, Gundry C, Heithoff KB. Thoracic MRI evaluation of asymptomatic individuals. *J Bone Joint Surg [Am]* 1995; 77:1631-1638.
36. Bogduk N, Modic MT. Lumbar discography. *Spine* 1996; 21:402-404.
37. Bland JH. Diagnosis of thoracic pain syndromes. In Giles LGF, Singer KP (eds). *Clinical Anatomy and Management of Thoracic Spine Pain*, *Vol. 2*. Butterworth-Heinemann, Oxford, 2000, pp 145-156.
38. McInerney J, Ball PA. The pathophysiology of thoracic disc disease. *Neurosurg Focus* 2000; 9:e1.
39. Cloward RB. Anterior herniation of a ruptured lumbar intervertebral disk; comments on the diagnostic value of the diskogram. *AMA Arch Surg* 1952; 64:457-463.
40. Lindblom K. Technique and results in myelography and disc puncture. *Acta Radiol* 1950; 34:321-330.
41. Antti-Poika I, Soini J, Tallroth K, Yrjonen T, Konttinen YT. Clinical relevance of discography combined with CT scanning. A study of 100 patients. *J Bone Joint Surg Br* 1990; 72:480-485.
42. Singh V. The role of cervical discography in interventional pain management. *Pain Physician* 2004; 7:249-255.
43. Jensen MC, Brant-Zawadzki MN, Obuchowski N, Modic MT, Malkasian D, Ross JS. Magnetic resonance imaging of the lumbar spine in people without back pain. *N Engl J Med* 1994; 331:69-73.
44. Horton WC, Daftari TK. Which disc as visualized by magnetic resonance imaging is actually a source of pain? A correlation between magnetic resonance imaging and discography. *Spine* 1992; 17: S164-S171.
45. Boden SD, Davis DO, Dina TS, Patronas NJ, Wiesel SW. Abnormal magnetic-resonance scans of the lumbar spine in asymptomatic subjects. A prospective investigation. *J Bone Joint Surg Am* 1990; 72:403-408.
46. Wood KB, Blair JM, Aepple DM, Schendel MJ, Garvey TA, Gundry CR, Heithoff KB. The natural history of asymptomatic thoracic disc herniations. *Spine* 1997; 22:525-529.
47. Smith GW, Nichols P Jr. The technique of cervical discography. *Radiology* 1957; 68:718-720.
48. Buenaventura RM, Shah RV, Patel V, Benyamin R, Singh V. Systematic review of discography as a diagnostic test for spinal pain: An update. *Pain Physician* 2007; 10:147-164.
49. Shah RV, Everett C, McKenzie-Brown A, Sehgal N. Discography as a diagnostic test for spinal pain: A systematic and narrative review. *Pain Physician* 2005; 8:187-209.
50. Merskey H, Bogduk N. Thoracic discogenic pain. In *Classification of Chronic Pain. Descriptions of Chronic Pain Syndromes and Definition of Pain Terms*, 2nd ed. International Association for the Study of Pain. IASP Press, Seattle, 1994, p 116.
51. Merskey H, Bogduk N. Lumbar discogenic pain. In *Classification of Chronic Pain. Descriptions of Chronic Pain Syndromes and Definition of Pain Terms*, 2nd ed. International Association for the Study of Pain. IASP Press, Seattle, 1994, pp 180-181.
52. Merskey H, Bogduk N. Cervical discogenic pain. In *Classification of Chronic Pain. Descriptions of Chronic Pain Syndromes and Definition of Pain Terms*, 2nd ed. International Association for the Study of Pain. IASP Press, Seattle, 1994, p 108.
53. Bogduk N. Thoracic disc stimulation (provocation discography). In *Practice Guidelines for Spinal Diagnostic and Treatment Procedure*. International Spine Intervention Society (ISIS), San Francisco, 2004, pp 287-294.
54. Bogduk N. Cervical disc stimulation (provocation discography). In *Practice Guidelines for Spinal Diagnostic and Treatment Procedures*. International Spine Intervention Society (ISIS), San Francisco, 2004, pp 95-111.
55. Bogduk N. Lumbar disc stimulation (provocation discography). In *Practice Guidelines for Spinal Diagnostic and Treatment Procedures*. International Spine Intervention Society (ISIS), San Francisco, 2004, pp 20-46.
56. Laslett M, Aprill CN, McDonald B, Oberg B. Clinical predictors of lumbar provocation discography: A study of clinical predictors of lumbar provocation discography. *Eur Spine J* 2006; 15:1473-1484.
57. Laslett M, Oberg B, Aprill CN, McDonald B. Centralization as a predictor of provocation discography results in chronic low back pain, and the influence of dis-

ability and distress on diagnostic power. *Spine J* 2005; 5:370-380.

58. Yrjama M, Tervonen O, Vanharanta H. Ultrasonic imaging of lumbar discs combined with vibration pain provocation compared with discography in the diagnosis of internal anular fissures of the lumbar spine. *Spine* 1996; 21:571-575.
59. Ohnmeiss DD, Guyer RD, Mason SL. The relation between cervical discographic pain responses and radiographic images. *Clin J Pain* 2000; 16:1-5.
60. Hancock MJ, Maher CG, Latimer J, Spindler MF, McAuley JH, Laslett M, Bogduk N. Systematic review of tests to identify the disc, SIJ or facet joint as the source of low back pain. *Eur Spine J* 2007; 16:1539-1550.
61. Linton SJ, Hellsing AL, Hallden K. A population based study of spinal pain among 35–45-year-old individuals. *Spine* 1998; 23:1457-1463.
62. Wilson PR. Thoracic facet joint syndrome – a clinical entity? *Pain Suppl* 1987; 4:S87.
63. Dreyfuss P, Tibiletti C, Dreyer SJ. Thoracic zygapophyseal joint pain patterns: A study in normal volunteers. *Spine* 1994; 19:807-811.
64. Fukui S, Ohseto K, Shiotani M. Patterns of pain induced by distending the thoracic zygapophyseal joints. *Reg Anesth* 1997; 22:332-336.
65. Manchikanti L, Singh V, Pampati VS, Beyer CD, Damron KS. Evaluation of the prevalence of facet joint pain in chronic thoracic pain. *Pain Physician* 2002; 5:354-359.
66. Manchikanti L, Boswell MV, Singh V, Pampati VS, Damron KS, Beyer CD. Prevalence of facet joint pain in chronic spinal pain of cervical, thoracic, and lumbar regions. *BMC Musculoskelet Disord* 2004; 5:15.
67. Manchukonda R, Manchikanti KN, Cash KA, Pampati V, Manchikanti L. Facet joint pain in chronic spinal pain: An evaluation of prevalence and false-positive rate of diagnostic blocks. *J Spinal Disord Tech* 2007; 20:539-545.
68. Sehgal N, Dunbar EE, Shah RV, Colson JD. Systematic review of diagnostic utility of facet (zygapophysial) joint injections in chronic spinal pain: An update. *Pain Physician* 2007; 10:213-228.
69. Malmivaara A, Videman T, Kuosma E, Troup JDG. Facet joint orientation, facet and costovertebral joint osteoarthrosis, disc degeneration, vertebral body osteophytosis, and Schmorl's nodes in the thoracolumbar junctional region of cadaveric spines. *Spine* 1987; 12:458-463.
70. Manchikanti L, Singh V, Derby R, Schultz DM, Benyamin RM, Prager JP, Hirsch JA. Reassessment of evidence synthesis of occupational medicine practice guidelines for interventional pain management. *Pain Physician* 2008; 11:393-482.
71. Manchikanti L, Singh V, Derby R, Helm S, Trescot AM, Staats PS, Prager JP, Hirsch JA. Review of occupational medicine practice guidelines for interventional pain management and potential implications. *Pain Physician* 2008; 11:271-289.
72. Manchikanti L, Singh V, Helm S, Trescot AM, Hirsch JA. A critical appraisal of 2007 American College of Occupational and Environmental Medicine (ACOEM) practice guidelines for interventional pain management: An independent review utilizing AGREE, AMA, IOM, and other criteria. *Pain Physician* 2008; 11:291-310.
73. Berg AO, Allan JD. Introducing the third U.S. Preventive Services Task Force. *Am J Prev Med* 2001; 20:21-35.
74. West S, King V, Carey TS, Lohr KN, McKoy N, Sutton SF, Lux L. *Systems to Rate the Strength of Scientific Evidence*, Evidence Report, Technology Assessment No. 47. AHRQ Publication No. 02-E016. Rockville, MD: Agency for Healthcare Research and Quality, 2002. www.thecre.com/pdf/ahrq-system-strength.pdf
75. Reid MC, Lachs MS, Feinstein AR. Use of methodological standards in diagnostic test research. Getting better but still not good. *JAMA* 1995; 274:645-651.
76. Lijmer JG, Mol BW, Heisterkamp S, Bonsel GJ, Prins MH, van der Meulen JH, Bossuyt PM. Empirical evidence of design-related bias in studies of diagnostic tests. *JAMA* 1999; 282:1061-1066.
77. Whiting P, Rutjes A, Reitsma J, Bossuyt P, Kleijnen J. The development of QUADAS: A tool for the quality assessment of studies of diagnostic accuracy included in systematic reviews. *BMC Med Res Methodol* 2003; 3:25.
78. Bossuyt PM, Reitsma JB, Bruns DE, Gatsonis CA, Glasziou PP, Irwig LM, Lijmer JG, Moher D, Rennie D, de Vet HC; Standards for Reporting of Diagnostic Accuracy. Towards complete and accurate reporting of studies of diagnostic accuracy: The STARD initiative. *Clin Chem* 2003; 49:1-6.
79. Guyatt G, Gutterman D, Baumann MH, Addrizzo-Harris D, Hylek EM, Phillips B, Raskob G, Lewis SZ, Schünemann H. Grading strength of recommendations and quality of evidence in clinical guidelines. Report from an American College of Chest Physicians Task Force. *Chest* 2006; 129:174-181.
80. Fluke M. To the Editor. Thoracic discography: A safe and reliable technique. *Spine* 1995; 20:1740.
81. Schellhas KP. In response to thoracic discography: A safe and reliable technique. *Spine* 1995; 20:1740-1741.
82. Weinstein JN, Walsh TR, Spratt KF, Lehman TR, Sayre H. Lumbar discography: A controlled, prospective study of normal volunteers to determine the false-positive rate. *Orthopaedic Transactions* 1989; 13:647-648.
83. Deeks JJ. Systematic reviews in health care: Systematic reviews of evaluations of diagnostic and screening tests. *BMJ* 2001; 323:157-162.
84. Knottnerus JA, van Weel C, Muris JW. Evaluation of diagnostic procedures. *BMJ* 2002; 324:477-480.
85. Saal JS. General principles of diagnostic testing as related to painful lumbar spine disorders. *Spine* 2002; 27:2538-2545.
86. Derby R, Kim BJ, Lee SH, Chen Y, Seo KS, Aprill C. Comparison of discographic findings in asymptomatic subject discs and negative discs of chronic LBP patients: Can discography distinguish asymptomatic discs among morphologically abnormal discs? *Spine J* 2005; 5:389-394.
87. Schellhas KP, Smith MD, Gundry CR, Pollei SR. Cervical discogenic pain. Prospective correction of magnetic resonance imaging and discography in asymptomatic subjects and pain sufferers. *Spine* 1996; 21:300-311.
88. Klafta LA Jr, Collis JS Jr. The diagnostic inaccuracy of the pain response in cervical discography. *Cleveland Clin Q* 1969; 36:35-39.
89. Cohen S, Hurley RW. The ability of diagnostic spinal injections to predict

surgical outcomes. *Pain Med* 2007; 105:1756-1775.

90. Derby R, Lee SH, Kim BJ, Chen Y, Aprill C, Bogduk N. Pressure-controlled lumbar discography in volunteers without low back symptoms. *Pain Med* 2005; 6:213-221.
91. Carragee EJ, Alamin TF, Carragee JM. Low-pressure positive discography in subjects asymptomatic of significant low back pain illness. *Spine* 2006; 31:505-509.
92. Carragee EJ, Chen Y, Tanner CM, Hayward C, Rossi M, Hagle C. Can discography cause long-term back symptoms in previously asymptomatic subjects? *Spine* 2000; 25:1803-1808.
93. Carragee EJ, Barcohana B, Alamin T, van den Haak E. Prospective controlled study of the development of lower back pain in previously asymptomatic subjects undergoing experimental discography. *Spine* 2004; 29:1112-1117.
94. Derby R. Lumbar discometry. *Newsletter of International Spine Injection Society* 1993; 1:8-17.
95. Derby R, Howard MW, Grant JM, Lettice JJ, Van Peteghem PK, Ryan DP. The ability of pressure-controlled discography to predict surgical and nonsurgical outcomes. *Spine* 1999; 24:364-371; discussion 371-362.
96. Shin D, Kim H, Jung J, Sin D, Lee J. Diagnostic relevance of pressure-controlled discography. *J Korean Med Sci* 2006; 21:911-916.
97. Manchikanti L, Singh V, Pampati VS, Fellows B, Beyer C, Damron K, Cash KA. Provocative discography in low back pain patients with or without somatization disorder: A randomized prospective evaluation. *Pain Physician* 2001; 4:227-239.
98. Fagan A, Moore R, Vernon Roberts B, Blumbergs P, Fraser R. The innervation of the intervertebral disc: A quantitative analysis. *Spine* 2003; 28:2570-2576.
99. Ashton IK, Roberts S, Jaffray DC, Polak JM, Eisenstein SM. Neuropeptides in the human intervertebral disc. *J Orthop Res* 1994; 12:186-192.
100. Roofe PG. Innervation of annulus fibrosis and posterior longitudinal ligament. *Arch Neurol Psych* 1940; 44:100-103.
101. Malinsky J. The ontogenetic development of nerve trigeminations in the intervertebral discs of man. *Acta Anat* 1959; 38:96-113.
102. Roberts S, Eisenstein SM, Menage J, Evans EH, Ashton IK. Mechanoreceptors in intervertebral discs. *Spine* 1995; 24:2645-2651.
103. Freemont AJ, Watkins A, Le Maitre C, Baird P, Jeziorska M, Knight MT, Ross ER, O'Brien JP, Hoyland JA. Nerve growth factor expression and innervation of the painful intervertebral disc. *J Pathol* 2002; 197:286-292.
104. Burke JG, G Watson RW, Conhyea D, McCormack D, Dowling FE, Walsh MG, Fitzpatrick JM. Human nucleus pulposus can respond to a pro-inflammatory stimulus. *Spine* 2003; 28:2685-2693.
105. Stilwell DL. The nerve supply of the vertebral column and its associated structures in the monkey. *Anat Rec* 1956; 125:139-169.
106. Kuslich SD, Ulstrom CL, Michael CJ. The tissue origin of low back pain and sciatica: A report of pain response to tissue stimulation during operation on the lumbar spine using local anesthesia. *Orthop Clin North Am* 1991; 22:181-187.