

North American Spine Society

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Revised

Evidence-Based Clinical Guidelines for Multidisciplinary Spine Care

Diagnosis and Treatment of Degenerative Lumbar Spondylolisthesis

Evidence-Based Clinical Guidelines for Multidisciplinary
Spine Care

Diagnosis and Treatment of Degenerative Lumbar Spondylolisthesis 2nd Edition



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Comments

Comments regarding the guideline may be submitted to the North American Spine Society and will be considered in development of future revisions of the work.

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I. Introduction

Objective

The objective of the North American Spine Society (NASS) *Clinical Guideline for the Diagnosis and Treatment of Degenerative Lumbar Spondylolisthesis* is to provide evidence-based recommendations to address key clinical questions surrounding the diagnosis and treatment of degenerative lumbar spondylolisthesis. The guideline is intended to update the original guideline on this topic, published in 2008. This guideline is based upon a systematic review of the evidence and reflects contemporary treatment concepts for symptomatic degenerative lumbar spondylolisthesis as reflected in the highest quality clinical literature available on this subject as of May 2013. The goals of the guideline recommendations are to assist in delivering optimum, efficacious treatment and functional recovery from this spinal disorder.

Scope, Purpose and Intended User

This document was developed by the North American Spine Society Evidence-based Guideline Development Committee as an educational tool to assist practitioners who treat patients with degenerative lumbar spondylolisthesis. The goal is to provide a tool that assists practitioners in improving the quality and efficiency of care delivered to these patients. The NASS *Clinical Guideline for the Diagnosis and Treatment of Degenerative Lumbar Spondylolisthesis* provides a definition of this disorder, outlines a reasonable evaluation of patients suspected to have degenerative lumbar spondylolisthesis and outlines treatment options for adult patients with this diagnosis.

THIS GUIDELINE DOES NOT REPRESENT A “STANDARD OF CARE,”

nor is it intended as a fixed treatment protocol. It is anticipated that there will be patients who will require less or more treatment than the average. It is also acknowledged that in atypical cases, treatment falling outside this guideline will sometimes be necessary. This guideline should not be seen as prescribing the type, frequency or duration of intervention. Treatment should be based on the individual patient's need and doctor's professional judgment. This document is designed to function as a guideline and should not be used as the sole reason for denial of treatment and services. This guideline is not intended to expand or restrict a health care provider's scope of practice or to supersede applicable ethical standards or provisions of law.

Patient Population

The patient population for this guideline encompasses adults (18 years or older) with a chief complaint of low back pain and/or lower extremity symptoms related to spinal stenosis and degenerative lumbar spondylolisthesis. In general, the nature of the pain and associated patient characteristics (eg, age) are more typical of a diagnosis of spinal stenosis with degenerative lumbar spondylolisthesis than discogenic low back pain, lumbar sprain/strain, or mechanical low back pain with degenerative spondylolisthesis.

II. Guideline Development Methodology

Through objective evaluation of the evidence and transparency in the process of making recommendations, it is NASS' goal to develop evidence-based clinical practice guidelines for the diagnosis and treatment of adult patients with various spinal conditions. These guidelines are developed for educational purposes to assist practitioners in their clinical decision-making processes. It is anticipated that where evidence is very strong in support of recommendations, these recommendations will be operationalized into performance measures.

Multidisciplinary Collaboration

With the goal of ensuring the best possible care for adult patients suffering with spinal disorders, NASS is committed to multidisciplinary involvement in the process of guideline and performance measure development. To this end, NASS has ensured that representatives from both operative and non-operative, medical, interventional and surgical spine specialties have participated in the development and review of NASS guidelines. To ensure broad-based representation, NASS welcomes input from other societies and specialties.

Evidence Analysis Training of All NASS Guideline Developers

All Evidence-Based Guideline Development Committee Members have completed NASS' Fundamentals of Evidence-Based Medicine Training. Members have the option to attend a one-day course or complete training via an online program. In conjunction with Qwogo Inc., a University of Alberta affiliated enterprise, NASS offers an online training program geared toward educating guideline developers about evidence analysis and guideline development. All participants in guideline development for NASS have completed the live or online training prior to participating in the guideline development program at NASS. Both trainings include a series of readings and exercises, or interactivities, to prepare guideline developers for systematically evaluating literature and developing evidence-based guidelines. The live course takes approximately 8-9 hours to complete and the online course takes approximately 15-30 hours to complete. Participants are awarded CME credit upon completion of the course.

Disclosure of Potential Conflicts of Interest

All participants involved in guideline development have disclosed potential conflicts of interest to their colleagues in accordance with NASS' Disclosure Policy for committee members (<https://www.spine.org/Documents/WhoWeAre/DisclosurePolicy.pdf>) and their potential conflicts have been documented in this guideline. NASS does not restrict involvement in guidelines based on conflicts as long as members provide full disclosure. Individuals with a conflict relevant to the subject matter were asked to recuse themselves from deliberation. Participants have been asked to update their disclosures regularly throughout the guideline development process.

Levels of Evidence and Grades of Recommendation

NASS has adopted standardized levels of evidence (*Appendix B*) and grades of recommendation (*Appendix C*) to assist practitioners in easily understanding the strength of the evidence and recommendations within the guidelines. The levels of evidence range from Level I (high quality randomized controlled trial) to Level V (expert consensus). Grades of recommendation indicate the strength of the recommendations made in the guideline based on the quality of the literature.

Grades of Recommendation:

- A: Good evidence (Level I studies with consistent findings) for or against recommending intervention.
- B: Fair evidence (Level II or III studies with consistent findings) for or against recommending intervention.
- C: Poor quality evidence (Level IV or V studies) for or against recommending intervention.
- I: Insufficient or conflicting evidence not allowing a recommendation for or against intervention.

Levels of evidence have very specific criteria and are assigned to studies prior to developing recommendations. Recommendations are then graded based upon the level of evidence. To better understand how levels of evidence inform the grades of recommendation and the standard nomenclature used within the recommendations see Appendix D.

Guideline recommendations are written utilizing a standard language that indicates the strength of the recommendation. "A" recommendations indicate a test or intervention is "recommended"; "B" recommendations "suggest" a test or intervention and "C" recommendations indicate a test or intervention "may be considered" or "is an option." "I" or "Insufficient Evidence" statements clearly indicate that "there is insufficient evidence to make a recommendation for or against" a test or intervention. Work group consensus statements clearly state that "in the absence of reliable evidence, it is the work group's opinion that" a test or intervention may be appropriate.

The levels of evidence and grades of recommendation implemented in this guideline have also been adopted by the Journal of Bone and Joint Surgery, the American Academy of Orthopaedic Surgeons, Clinical Orthopaedics and Related Research, the journal Spine and the Pediatric Orthopaedic Society of North America.

In evaluating studies as to levels of evidence for this guideline, the study design was interpreted as establishing only a potential level of evidence. As an example, a therapeutic study designed as a randomized controlled trial would be considered a potential Level I study. The study would then be further analyzed as to how well the study design was implemented and significant shortcomings in the execution of the study would be used to downgrade the levels of evidence for the study's conclusions. In the example cited previously, reasons to downgrade the results of a potential Level I randomized controlled trial to a Level II study would include, among other possibilities: an underpowered study (patient sample too small, variance too high), inadequate

randomization or masking of the group assignments and lack of validated outcome measures.

In addition, a number of studies were reviewed several times in answering different questions within this guideline. How a given question was asked might influence how a study was evaluated and interpreted as to its level of evidence in answering that particular question. For example, a randomized controlled trial reviewed to evaluate the differences between the outcomes of surgically treated versus untreated patients with lumbar disc herniation with radiculopathy might be a well designed and implemented Level I therapeutic study. This same study, however, might be classified as providing Level II prognostic evidence if the data for the untreated controls were extracted and evaluated prognostically.

Guideline Development Process

Step 1: Identification of Clinical Questions

The clinical questions from the original guideline, published in 2008, are included in this guideline update. Since 2008, an additional section addressing value in spine care has been added. Trained guideline participants were asked to submit a list of new additional clinical questions that the guideline should address in addition to the questions included in the original guideline. The lists of new questions were compiled into a master list, which was then circulated to each member with a request that they independently rank the questions in order of importance for consideration in the guideline. The questions from the previous guideline and most highly ranked new questions, as determined by the participants, served to focus the guideline.

Step 2: Identification of Work Groups

Multidisciplinary teams were assigned to work groups and assigned specific clinical questions to address. Because NASS is comprised of surgical, medical and interventional specialists, it is imperative to the guideline development process that a cross-section of NASS membership is represented on the work group. This also helps to ensure that the potential for inadvertent biases in evaluating the literature and formulating recommendations is minimized.

Step 3: Identification of Search Terms and Parameters

One of the most crucial elements of evidence analysis is the comprehensive literature search. Thorough assessment of the literature is the basis for the review of existing evidence and the formulation of evidence-based recommendations. In order to ensure a thorough literature search, NASS has instituted a Literature Search Protocol (Appendix E) which has been followed to identify literature for evaluation in guideline development. In keeping with the Literature Search Protocol, work group members have identified appropriate search terms and parameters to direct the literature search. Specific search strategies, including search terms, parameters and databases searched, are documented in the technical report that accompanies this guideline.

Step 4: Completion of the Literature Search

Once each work group identified search terms/parameters, the literature search was implemented by a medical/research librarian at InfoNOW at the University of Minnesota, consistent with

the Literature Search Protocol. Following these protocols ensures that NASS recommendations (1) are based on a thorough review of relevant literature; (2) are truly based on a uniform, comprehensive search strategy; and (3) represent the current best research evidence available. NASS maintains a search history in Endnote, for future use or reference.

Step 5: Review of Search Results/Identification of Literature to Review

Work group members reviewed all abstracts yielded from the literature search and identified the literature they will review in order to address the clinical questions, in accordance with the Literature Search Protocol. Members have identified the best research evidence available to answer the targeted clinical questions. That is, if Level I, II and or III literature is available to answer specific questions, the work group was not required to review Level IV or V studies.

Step 6: Evidence Analysis

Members have independently developed evidentiary tables summarizing study conclusions, identifying strengths and weaknesses and assigning levels of evidence. In order to systematically control for potential biases, at least two work group members have reviewed each article selected and independently assigned levels of evidence to the literature using the NASS levels of evidence. Any discrepancies in scoring have been addressed by two or more reviewers. Final ratings are completed at a final meeting of all section workgroup members including the section chair and the guideline chair. The consensus level (the level upon which two-thirds of reviewers were in agreement) was then assigned to the article.

As a final step in the evidence analysis process, members have identified and documented gaps in the evidence to educate guideline readers about where evidence is lacking and help guide further needed research by NASS and other societies.

Step 7: Formulation of Evidence-Based Recommendations and Incorporation of Expert Consensus

Work groups held web-conferences and face-to-face meetings to discuss the evidence-based answers to the clinical questions, the grades of recommendations and the incorporation of expert consensus. Work group members incorporated evidence findings from the original guideline in the guideline update. Where there was no new evidence, the work group re-reviewed the original literature and recommendation statements to ensure agreement with original findings. When new literature was found, work group members included existing evidence when updating recommendations statements.

Expert consensus was incorporated only where Level I-IV evidence is insufficient and the work group has deemed that a recommendation is warranted. Transparency in the incorporation of consensus is crucial, and all consensus-based recommendations made in this guideline very clearly indicate that Level I-IV evidence is insufficient to support a recommendation and that the recommendation is based only on expert consensus.

Consensus Development Process

Voting on guideline recommendations was conducted using a modification of the nominal group technique in which each work group member independently and anonymously ranked a recommendation on a scale ranging from 1 (“extremely inappropriate”) to 9 (“extremely appropriate”). Consensus was obtained when at least 80% of work group members ranked the recommendation as 7, 8 or 9. When the 80% threshold was not attained, up to three rounds of discussion and voting were held to resolve disagreements. If disagreements were not resolved after these rounds, no recommendation was adopted.

After the recommendations were established, work group members developed the guideline content, addressing the literature supporting the recommendations.

Step 8: Submission of the Draft Guidelines for Review/Comment

Guidelines were submitted to the full Evidence-Based Guideline Development Committee and the Research Council for review and comment. Revisions to recommendations were considered for incorporation only when substantiated by a preponderance of appropriate level evidence.

Step 9: Submission for Board Approval

Once any evidence-based revisions were incorporated, the drafts were prepared for NASS Board review and approval. Edits and revisions to recommendations and any other content were considered for incorporation only when substantiated by a preponderance of appropriate level evidence.

Step 10: Submission for Publication and National Guideline Clearinghouse (NGC) Inclusion

Following NASS Board approval, the guidelines have been slated for publication and submitted for inclusion in the National Guidelines Clearinghouse (NGC). No revisions were made after submission to NGC, but comments have been and will be saved for the next iteration.

Step 11: Review and Revision Process

The guideline recommendations will be reviewed every three to five years by an EBM-trained multidisciplinary team and revised as appropriate based on a thorough review and assessment of relevant literature published since the development of this version of the guideline.

Use of Acronyms

Throughout the guideline, readers will see many acronyms with which they may not be familiar. A glossary of acronyms is available in Appendix A.

Nomenclature for Medical/Interventional Treatment

Throughout the guideline, readers will see that what has traditionally been referred to as “nonoperative,” “nonsurgical” or “conservative” care is now referred to as “medical/interventional care.” The term medical/interventional is meant to encompass pharmacological treatment, physical therapy, exercise therapy, manipulative therapy, modalities, various types of external stimulators and injections.

III. Recommendation Summary

Comparison of 2008 and Current Guideline Recommendations

Clinical Question	2008 Guideline Recommendation	Current Guideline Recommendation <i>*See recommendation sections for supporting text</i>
Definition and Natural History		
What is the best working definition of degenerative lumbar spondylolisthesis?	An acquired anterior displacement of one vertebra over the subjacent vertebra, associated with degenerative changes, without an associated disruption or defect in the vertebral ring. Workgroup Consensus Statement	Maintained.
What is the natural history of degenerative lumbar spondylolisthesis?	The majority of patients with symptomatic degenerative lumbar spondylolisthesis and an absence of neurologic deficits will do well with conservative care. Patients who present with sensory changes, muscle weakness or cauda equina syndrome, are more likely to develop progressive functional decline without surgery. Progression of slip correlates with jobs that require repetitive anterior flexion of the spine. Slip progression is less likely to occur when the disc has lost over 80% of its native height and intervertebral osteophytes have formed. Progression of clinical symptoms does not correlate with progression of the slip.	Not addressed in guideline update. The literature to address natural history is limited and efforts to develop recommendations are often unsuccessful. Therefore, natural history questions have been eliminated from this guideline.
Diagnosis and Imaging		
What are the most appropriate historical and physical examination findings consistent with the diagnosis of degenerative lumbar spondylolisthesis?	Obtaining an accurate history and physical examination is essential to the formulation of the appropriate clinical questions to guide the physician in developing a plan for the treatment of patients with degenerative lumbar spondylolisthesis. Work Group Consensus Statement In older patients presenting with radiculopathy and neurogenic intermittent claudication, with or without back pain, a diagnosis of degenerative lumbar spondylolisthesis should be considered. Grade of Recommendation: B	In the absence of evidence to address this question, it is the work group's opinion that obtaining an accurate history and physical examination is important for the diagnosis and treatment of patients with degenerative lumbar spondylolisthesis. Formulating appropriate clinical questions is essential to obtaining an accurate history that can be used in developing a treatment plan for patients. Work Group Consensus Statement In patients with imaging evidence of degenerative lumbar spondylolisthesis, the following clinical characteristics have been reported: asymptomatic with only occasional back pain; chronic low back pain with or without radicular symptoms and with or without positional variance; radicular symptoms with or without neurologic deficit, with or without back pain; and intermittent neurogenic claudication. Study summaries are provided as background support to help further define the clinical characteristics that may be associated with a diagnosis of degenerative lumbar spondylolisthesis.

This clinical guideline should not be construed as including all proper methods of care or excluding or other acceptable methods of care reasonably directed to obtaining the same results. The ultimate judgment regarding any specific procedure or treatment is to be made by the physician and patient in light of all circumstances presented by the patient and the needs and resources particular to the locality or institution

Clinical Question	2008 Guideline Recommendation	Current Guideline Recommendation <i>*See recommendation sections for supporting text</i>
<p>What are the most appropriate diagnostic tests for degenerative lumbar spondylolisthesis?</p>	<p>The most appropriate, noninvasive test for detecting degenerative lumbar spondylolisthesis is the lateral radiograph. Grade of Recommendation: B</p> <p>The most appropriate, noninvasive test for imaging the stenosis accompanying degenerative lumbar spondylolisthesis is the MRI. Work Group Consensus Statement</p> <p>Plain myelography or CT myelography are useful studies to assess spinal stenosis in patients with degenerative lumbar spondylolisthesis. Grade of Recommendation: B</p> <p>CT is a useful noninvasive study in patients who have a contraindication to MRI, for whom MRI findings are inconclusive or for whom there is a poor correlation between symptoms and MRI findings, and in whom CT myelogram is deemed inappropriate. Work Group Consensus Statement</p>	<p>The lateral radiograph is the most appropriate, noninvasive test for detecting degenerative lumbar spondylolisthesis. Grade of Recommendation: B (Suggested)</p> <p>In the absence of reliable evidence, it is the work group’s opinion that the lateral radiograph should be obtained in the standing position whenever possible. Work Group Consensus Statement</p> <p>The most appropriate, noninvasive test for imaging stenosis accompanying degenerative lumbar spondylolisthesis is MRI. Work Group Consensus Statement</p> <p>Facet joint effusion greater than 1.5mm on supine MRI may be suggestive of the presence of degenerative lumbar spondylolisthesis. Further evaluation for the presence of degenerative lumbar spondylolisthesis should be considered, including using plain standing radiographs. Grade of Recommendation: B</p> <p>There is insufficient evidence to make a recommendation for or against the utility of the upright seated MRI in the diagnosis of degenerative lumbar spondylolisthesis. Grade of Recommendation: I (Insufficient Evidence)</p> <p>There is insufficient evidence to make a recommendation for or against the use of axial loaded MRI to evaluate the dural sac cross sectional area in patients with degenerative lumbar spondylolisthesis and spinal stenosis. Grade of Recommendation: I (Insufficient Evidence)</p> <p>Plain myelography or CT myelography are useful studies to assess spinal stenosis in patients with degenerative lumbar spondylolisthesis especially in those who have contraindications to MRI. Grade of Recommendation: B (Suggested)</p> <p>In patients with degenerative lumbar spondylolisthesis with associated spinal stenosis for whom MRI is either contraindicated or inconclusive, CT myelography is the most appropriate test to confirm the presence of anatomic narrowing of the spinal canal or the presence of nerve root impingement. Work Group Consensus Statement</p> <p>In patients with degenerative spondylolisthesis with associated spinal stenosis for whom MRI and CT myelography are contraindicated, inconclusive or inappropriate, CT is suggested as the most appropriate test to confirm the presence of anatomic narrowing of the spinal canal or the presence of nerve room impingement. Work Group Consensus Statement</p>

This clinical guideline should not be construed as including all proper methods of care or excluding or other acceptable methods of care reasonably directed to obtaining the same results. The ultimate judgment regarding any specific procedure or treatment is to be made by the physician and patient in light of all circumstances presented by the patient and the needs and resources particular to the locality or institution

Clinical Question	2008 Guideline Recommendation	Current Guideline Recommendation <i>*See recommendation sections for supporting text</i>
What are the most appropriate diagnostic or physical exam tests consistent with the diagnosis of fixed versus dynamic deformity?	Not addressed	<p>There is insufficient evidence to make a recommendation on the most appropriate diagnostic or physical exam test consistent with fixed or dynamic deformity in degenerative lumbar spondylolisthesis patients due to the lack of uniform reference standards which define instability.</p> <p>There is no universally accepted standard to diagnose fixed versus dynamic spondylolisthesis. To evaluate instability, many studies employ the use of lateral flexion extension radiographs, which may be done in the standing or recumbent position; however, there is wide variation in the definition of instability. To assist readers, the definitions for instability (when provided) in degenerative spondylolisthesis patients, are bolded below. Grade of Recommendation: I (Insufficient Evidence)</p>
Is dynamic MRI and/or dynamic CT myelography imaging (including standing imaging, imaging with axial loading) helpful in the diagnostic testing for degenerative lumbar spondylolisthesis?	Not addressed	<p>There is insufficient evidence to make a recommendation for or against the utility of dynamic MRI and dynamic CT myelography in the diagnosis of degenerative lumbar spondylolisthesis. Grade of Recommendation: I (Insufficient Evidence)</p>
Outcome Measures for Medical/Interventional and Surgical Treatment		
What are the appropriate outcome measures for the treatment of degenerative lumbar spondylolisthesis?	<p>The Zurich Claudication Questionnaire (ZCQ)/Swiss Spinal Stenosis Questionnaire (SSS), Oswestry Disability Index (ODI), Likert Five-Point Pain Scale and 36-Item Short Form Health Survey (SF-36) are appropriate measures for assessing treatment of degenerative lumbar spondylolisthesis. Grade of Recommendation: A</p> <p>The Japanese Orthopedic Association (JOA) Score and the calculated Recovery Rate may be useful in assessing outcome in degenerative lumbar spondylolisthesis. Grade of Recommendation: B</p> <p>The Shuttle Walking Test (SWT), Oxford Claudication Score (OCS), Low Back Pain Bothersome Index and Stenosis Bothersome Index are potential outcome measures in studying degenerative lumbar spondylolisthesis. Grade of Recommendation: I (Insufficient Evidence)</p>	<p>An updated literature search was not conducted. For more information on appropriate outcome measures for degenerative lumbar spondylolisthesis, the North American Spine Society has a publication entitled <i>Compendium of Outcome Instruments for Assessment and Research of Spinal Disorders</i>. To purchase a copy of the Compendium, visit https://webportal.spine.org/Purchase/ProductDetail.aspx?Product_code=68cdd1f4-c4ac-db11-95b2-001143edb1c1.</p> <p>For additional information about the Compendium, please contact the NASS Research Department at nassresearch@spine.org.</p>

Clinical Question	2008 Guideline Recommendation	Current Guideline Recommendation <i>*See recommendation sections for supporting text</i>
Medical and Interventional Treatment		
<ul style="list-style-type: none"> • Do medical/ interventional treatments improve outcomes in the treatment of degenerative lumbar spondylolisthesis compared to the natural history of the disease? • What is the role of pharmacological treatment in the management of degenerative lumbar spondylolisthesis? • What is the role of physical therapy/ exercise in the treatment of degenerative lumbar spondylolisthesis? • What is the role of manipulation in the treatment of degenerative lumbar spondylolisthesis? • What is the role of ancillary treatments such as bracing, traction, electrical stimulation and transcutaneous electrical stimulation (TENS) in the treatment of degenerative lumbar spondylolisthesis? • What is the long-term result of medical/ interventional management of degenerative lumbar spondylolisthesis? • What is the role of injections for the treatment of degenerative lumbar spondylolisthesis? 	<p>A systematic review of the literature yielded no studies to adequately address any of the medical/interventional treatment questions posed.</p> <p>Medical/interventional treatment for degenerative lumbar spondylolisthesis, when the radicular symptoms of stenosis predominate, most logically should be similar to treatment for symptomatic degenerative lumbar spinal stenosis.</p> <p>Work Group Consensus Statement</p>	<p>Not addressed in guideline update; the literature to address natural history is limited and efforts to develop recommendations are often unsuccessful. Therefore, natural history questions have been eliminated from this guideline.</p> <p>Maintained. An updated systematic review of the literature yielded no studies to adequately address any of the medical/interventional treatment questions posed (except for injections).</p> <p>There is insufficient evidence to make a recommendation for or against the use of injections for the treatment of degenerative lumbar spondylolisthesis.</p> <p>Grade of Recommendation: I (Insufficient Evidence)</p> <p>Maintained. Medical/interventional treatment for degenerative lumbar spondylolisthesis, when the radicular symptoms of stenosis predominate, most logically should be similar to treatment for symptomatic degenerative lumbar spinal stenosis.</p> <p>Work Group Consensus Statement</p>
Surgical Treatment		
<p>Do surgical treatments improve outcomes in the treatment of degenerative lumbar spondylolisthesis compared to the natural history of the disease?</p>	<p>Surgery is recommended for treatment of patients with symptomatic spinal stenosis associated with low grade degenerative spondylolisthesis whose symptoms have been refractory to a trial of medical/ interventional treatment.</p> <p>Grade of Recommendation: B</p>	<p>Not addressed in guideline update; the literature to address natural history is limited and efforts to develop recommendations are often unsuccessful. Therefore, natural history questions have been eliminated from this guideline.</p>

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Clinical Question	2008 Guideline Recommendation	Current Guideline Recommendation <i>*See recommendation sections for supporting text</i>
Does surgical decompression alone improve surgical outcomes in the treatment of degenerative lumbar spondylolisthesis compared to medical/interventional treatment alone or the natural history of the disease?	<p>Direct surgical decompression is recommended for treatment of patients with symptomatic spinal stenosis associated with low grade degenerative lumbar spondylolisthesis whose symptoms have been recalcitrant to a trial of medical/interventional treatment. Grade of Recommendation: I (Insufficient Evidence)</p> <p>Indirect surgical decompression is recommended for treatment of patients with symptomatic spinal stenosis associated with low grade degenerative lumbar spondylolisthesis whose symptoms have been recalcitrant to a trial of medical/interventional treatment. Grade of Recommendation: I (Insufficient Evidence)</p>	<p>Direct surgical decompression may be considered for the treatment of patients with symptomatic spinal stenosis associated with low grade degenerative lumbar spondylolisthesis whose symptoms have been recalcitrant to a trial of medical/interventional treatment. Grade of Recommendation: C</p> <p>There is insufficient evidence to make a recommendation for or against the use of indirect surgical decompression for the treatment of patients with symptomatic spinal stenosis associated with low grade degenerative lumbar spondylolisthesis whose symptoms have been recalcitrant to a trial of medical/interventional treatment. Grade of Recommendation: I (Insufficient Evidence)</p>
Does the addition of lumbar fusion, with or without instrumentation, to surgical decompression improve surgical outcomes in the treatment of degenerative lumbar spondylolisthesis compared to treatment by decompression alone?	<p>Surgical decompression with fusion is recommended for the treatment of patients with symptomatic spinal stenosis and degenerative lumbar spondylolisthesis to improve clinical outcomes compared with decompression alone. Grade of Recommendation: B</p>	<p>Surgical decompression with fusion is suggested for the treatment of patients with symptomatic spinal stenosis and degenerative lumbar spondylolisthesis to improve clinical outcomes compared with decompression alone. Grade of Recommendation: B</p> <p>For symptomatic single level degenerative spondylolisthesis that is low-grade (<20%) and without lateral foraminal stenosis, decompression alone with preservation of midline structures provides equivalent outcomes when compared to surgical decompression with fusion. Grade of Recommendation: B (Suggested)</p>
Does the addition of lumbar fusion, with or without instrumentation, to surgical decompression improve surgical outcomes in the treatment of degenerative lumbar spondylolisthesis compared to medical/interventional treatment alone?	Not addressed	<p>Surgical decompression with fusion, with or without instrumentation, is suggested to improve the functional outcomes of single-level degenerative spondylolisthesis compared to medical/interventional treatment alone. Grade of Recommendation: B</p> <p>There is insufficient evidence to make a recommendation for or against efficacy of surgical decompression with fusion, with or without instrumentation, for treatment of multi-level degenerative lumbar spondylolisthesis compared to medical/interventional treatment alone. Grade of Recommendation: I (Insufficient Evidence)</p>
Does the addition of instrumentation to decompression and fusion for degenerative lumbar spondylolisthesis improve surgical outcomes compared with decompression and fusion alone?	<p>The addition of instrumentation is recommended to improve fusion rates in patients with symptomatic spinal stenosis and degenerative lumbar spondylolisthesis. Grade of Recommendation: B</p> <p>The addition of instrumentation is not recommended to improve clinical outcomes for the treatment of patients with symptomatic spinal stenosis and degenerative lumbar spondylolisthesis. Grade of Recommendation: B</p>	<p>The addition of instrumentation is suggested to improve fusion rates in patients with symptomatic spinal stenosis and degenerative lumbar spondylolisthesis. Grade of Recommendation: B</p> <p>The addition of instrumentation is not suggested to improve clinical outcomes for the treatment of patients with symptomatic spinal stenosis and degenerative lumbar spondylolisthesis. Grade of Recommendation: B</p>

Clinical Question	2008 Guideline Recommendation	Current Guideline Recommendation <i>*See recommendation sections for supporting text</i>
How do outcomes of decompression with posterolateral fusion compare with those for 360° fusion in the treatment of degenerative lumbar spondylolisthesis?	Because of the paucity of literature addressing this question, the work group was unable to generate a recommendation to answer this question.	There is insufficient evidence to make a recommendation for or against the use of either decompression with posterolateral fusion or 360° fusion in the surgical treatment of patients with degenerative lumbar spondylolisthesis. Grade of Recommendation: I (Insufficient Evidence)
Does 360° fusion with decompression lead to better outcomes versus 360° fusion without decompression for treatment of degenerative lumbar spondylolisthesis?	Not addressed	No evidence was found to address this question. Due to the paucity of literature addressing this question, the work group was unable to generate a recommendation to answer this question.
Do flexible fusions improve outcomes in the treatment of degenerative lumbar spondylolisthesis compared to nonoperative treatment?	Not addressed	No evidence was found to address this question. Due to the paucity of literature addressing this question, the work group was unable to generate a recommendation to answer this question.
Does the use of interspinous spacers in the treatment of degenerative lumbar spondylolisthesis improve outcomes compared to nonoperative treatment?	Not addressed	There is insufficient and conflicting evidence to make a recommendation for or against the efficacy of interspinous spacers versus medical/interventional treatment in the management of degenerative lumbar spondylolisthesis patients. Grade of Recommendation: I (Insufficient Evidence)
What is the role of reduction (deliberate attempt to reduce via surgical technique) with fusion in the treatment of degenerative lumbar spondylolisthesis?	Reduction with fusion and internal fixation of patients with low grade degenerative lumbar spondylolisthesis is not recommended to improve clinical outcomes. Grade of Recommendation: I (Insufficient Evidence)	There is insufficient evidence to make a recommendation for or against the use of reduction with fusion in the treatment of degenerative lumbar spondylolisthesis. Grade of Recommendation: I (Insufficient Evidence)
For patients undergoing posterolateral fusion, does the use of autogenous bone graft improve surgical outcomes compared to those fused with bone graft substitutes?	Not addressed	Due to the paucity of literature addressing this question, the work group was unable to generate a recommendation to answer this question. There is insufficient evidence to make a recommendation for or against the use of autogenous bone graft or bone graft substitutes in patients undergoing posterolateral fusion for the surgical treatment of degenerative lumbar spondylolisthesis. Grade of Recommendation: I (Insufficient Evidence)
Do minimally invasive surgical treatments improve outcomes in the treatment of degenerative lumbar spondylolisthesis compared to: a. conventional open decompression (laminectomy)? b. conventional (open) lumbar decompression and fusion, with or without instrumentation?	Not addressed	No evidence was found to assess the efficacy of minimally invasive surgical techniques versus open decompression alone in the surgical treatment of degenerative lumbar spondylolisthesis. While both minimally invasive techniques and open decompression and fusion, with or without instrumentation, demonstrate significantly improved clinical outcomes for the surgical treatment of degenerative lumbar spondylolisthesis, there is conflicting evidence which technique leads to better outcomes. Grade of Recommendation: I (Insufficient/Conflicting Evidence)

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Clinical Question	2008 Guideline Recommendation	Current Guideline Recommendation <i>*See recommendation sections for supporting text</i>
What is the long-term result (four+ years) of surgical management of degenerative lumbar spondylolisthesis?	Decompression and fusion is recommended as a means to provide satisfactory long-term results for the treatment of patients with symptomatic spinal stenosis and degenerative lumbar spondylolisthesis. Grade of Recommendation: C	Decompression and fusion may be considered as a means to provide satisfactory long-term results for the treatment of patients with symptomatic spinal stenosis and degenerative lumbar spondylolisthesis. Grade of Recommendation: C
Which patient-specific characteristics influence outcomes (and prognosis) in the treatment (surgical or any) of degenerative lumbar spondylolisthesis?	Not addressed	<p>There is insufficient evidence to make a recommendation for or against the influence of a nonorganic pain drawing on the outcomes/prognosis of treatments for patients with degenerative lumbar spondylolisthesis. Grade of Recommendation: I (Insufficient Evidence)</p> <p>There is insufficient evidence to make a recommendation regarding the influence of age and three or more comorbidities on the outcomes of patients undergoing treatment for degenerative lumbar spondylolisthesis. Grade of Recommendation: I (Insufficient Evidence)</p> <p>There is insufficient evidence to make a recommendation regarding the influence of symptom duration on the treatment outcomes of patients with degenerative lumbar spondylolisthesis. Grade of Recommendation: I (Insufficient Evidence)</p> <p>There is insufficient evidence to make a recommendation regarding the influence of obesity (BMI >30) and its impact on treatment outcomes in patients with degenerative lumbar spondylolisthesis. Grade of Recommendation: I (Insufficient Evidence)</p>
What is the effect of postsurgical rehabilitation including exercise, spinal mobilization/manipulation or psychosocial interventions on outcomes in the management of degenerative lumbar spondylolisthesis (compared to patients who do not undergo postsurgical rehabilitation)?	Not addressed	There was no evidence found to address this question. Due to the paucity of evidence, a recommendation cannot be made regarding the effect of postsurgical rehabilitation the outcomes of patients undergoing surgical treatment for degenerative lumbar spondylolisthesis.
Value of Spine Care		
What is the cost-effectiveness of the surgical treatment of degenerative lumbar spondylolisthesis compared to nonoperative management (consider with and without fusion separately)?	Not addressed	There was no evidence found to address this question. Due to the paucity of evidence, a recommendation cannot be made regarding the cost-effectiveness of surgical treatment compared to nonoperative treatment for the management of patients with degenerative lumbar spondylolisthesis.
What is the cost-effectiveness of minimal access-based surgical treatments of degenerative lumbar spondylolisthesis compared to traditional open surgical treatments?	Not addressed	There is insufficient evidence to make a recommendation for or against the cost-effectiveness of minimal access-based surgical treatments compared to traditional open surgical treatments for degenerative lumbar spondylolisthesis. Grade of Recommendation: I (Insufficient Evidence)

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IV. Definition of Degenerative Lumbar Spondylolisthesis

Original Guideline Question:

What is the best working definition of degenerative lumbar spondylolisthesis?

An acquired anterior displacement of one vertebra over the subjacent vertebra, associated with degenerative changes, without an associated disruption or defect in the vertebral ring. Maintained from original guideline

Work Group Consensus Statement

The literature search revealed several reports that describe variants of degenerative spondylolisthesis in which the degree of anterior displacement is measurably affected by the posture and position of the patient. These observations on position dependent deformities may have significant implications for the pathophysiology and natural history of degenerative spondylolisthesis; however, no longitudinal studies have yet addressed this issue.

Degenerative spondylolisthesis is an anatomic finding. The clinical symptoms of degenerative spondylolisthesis, however, are varied. Patients with degenerative lumbar spondylolisthesis can be asymptomatic. They can also present with back pain, or with neurogenic claudication and/or radicular pain, with or without axial back pain. Therefore, the work group agreed upon this anatomic definition, but also evaluated the relevant literature inclusive of the variations of clinical presentation.

V. Recommendations for Diagnosis and Treatment of Degenerative Lumbar Spondylolisthesis

A. Diagnosis and Imaging

Original Guideline Question:

What are the most appropriate historical and physical examination findings consistent with the diagnosis of degenerative lumbar spondylolisthesis?

In the absence of evidence to address this question, it is the work group's opinion that obtaining an accurate history and physical examination is important for the diagnosis and treatment of patients with degenerative lumbar spondylolisthesis. Formulating appropriate clinical questions is essential to obtaining an accurate history that can be used in developing a treatment plan for patients. *Maintained from original guideline with minor word modifications*

Work Group Consensus Statement

In patients with imaging evidence of degenerative lumbar spondylolisthesis, the following clinical characteristics have been reported: asymptomatic with only occasional back pain; chronic low back pain with or without radicular symptoms and with or without positional variance; radicular symptoms with or without neurologic deficit, with or without back pain; and intermittent neurogenic claudication. The summaries below are provided as background support to help further define the clinical characteristics that may be associated with a diagnosis of degenerative lumbar spondylolisthesis.

Studies obtained from updated literature search:

Chen et al¹ conducted an age- and sex-matched case-control study to identify the predisposing factors of degenerative lumbar spondylolisthesis. A total of 66 women, aged 45 to 64 years, with a first time lumbar spondylolisthesis diagnosis were compared to 66 controls. A physiatrist confirmed the grade of the anterior displacement of the lumbar spine according to Neuman's classification and assessed the anthropometric parameters from the lateral view of L-spine radiograph and KUB, which included angles of the lumbar and sacral spine. In the case group, most parameters, including disc height, body height, and angles tended to be lower than those in the control group, whereas the length of the transverse process of L5 (TPL), the width of the transverse process of L5 (TPW) and TP-AREA were higher than the control group. The differences in disc height, lumbar index, sacral inclination angle, sacral horizontal angle and transverse

processes between the two groups were statistically significant ($p < 0.05$). Using multivariate logistic regression analysis, this study suggests that antero-inferior disc height and lumbar index are independent variables of predisposing factors of degenerative lumbar spondylolisthesis.

Pearson et al² conducted a retrospective analysis of data from the Spine Patient Outcomes Trial (SPORT) to compare baseline characteristics and the surgical and nonoperative outcomes between degenerative spondylolisthesis and spinal stenosis patients. The degenerative spondylolisthesis cohort included 601 patients and the spinal stenosis cohort included 634 patients. Primary outcome measures included the SF-36 bodily pain, physical function scores and the Oswestry Disability Index (ODI). Comparison of baseline characteristics between the degenerative spondylolisthesis and spinal stenosis groups revealed statistically significant differences. The degenerative spondylo-

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listhesis group included a higher proportion of women (69% vs 39%, $p < 0.001$) and was about 18 months older (66.1 vs 64.6 years, $p < 0.021$) than the spinal stenosis group. Fewer degenerative spondylolisthesis patients reported heart (20% vs 26%, $p < 0.021$) or bowel (7% vs 14%, $p < 0.001$) problems compared to spinal stenosis patients, while more reported depression (16% vs. 11%, $p < 0.009$). There were no significant differences on any of the primary (SF-36 BP, PF or ODI) or secondary (Stenosis Bothersome Index or Low Back Pain) outcome measures at baseline between the 2 diagnostic groups. In addition, degenerative spondylolisthesis patients were found to have similar levels of disability when compared to spinal stenosis patients. This study suggests that degenerative spondylolisthesis patients tended to be female, older, with more depression and similar levels of disability, but less heart and bowel problems when compared to spinal stenosis patients.

Studies included in original guideline:

Cauchioux et al³ described a study in which the diagnostic evaluation of 26 patients with degenerative spondylolisthesis included plain radiographs and myelography. The study included 26 patients with nerve root compression secondary to degenerative slip, with 80% reporting back pain, 46% reporting primary chronic sciatica and 54% reporting primary neurogenic claudication. Sciatica tended to occur in older patients and neurogenic claudication in younger subjects. In critique of this study, this is a characterization of a subset of patients with degenerative lumbar spondylolisthesis referred for evaluation of neurological symptoms. These data offer background for the neurological symptoms associated with degenerative lumbar spondylolisthesis.

Fitzgerald et al⁴ conducted a study of 43 patients with symptomatic spondylolisthesis which examined various parameters. It is unclear if the patients represented a consecutive or nonconsecutive series. In addition to a description of plain radiographic findings of the spine, as well as concomitant hip arthritis, the authors provided a detailed description of the presentation (symptom) pattern of the patients. In summary, they found that 34 patients had back pain without leg pain and signs of nerve root compression, 5 cases with leg pain with or without back pain with signs of nerve root compression and four cases in which patients reported neurogenic claudication. As a diagnostic history and physical examination study, the study presents a spectrum of symptoms and signs in patients with degenerative lumbar spondylolisthesis.

Matsunaga et al⁵ conducted a prospective observational study to determine the clinical course of nonsurgically managed patients with degenerative spondylolisthesis as well as the indications for surgery. A total of 145 nonsurgically managed patients with degenerative spondylolisthesis were examined annually for a minimum of 10 years. Lumbar rheumatism, with or without pain in the lower extremities was a common complaint at initial examination. Conservative treatment for these patients consisted of brace wearing, use of antiinflammatory drugs and/or lumbar exercises. Twenty-nine (83%) of the 35 patients who had neurological symptoms, such as intermittent claudication or vesicorectal disorder, at initial examination and refused surgical treatment experienced neurological deterioration.

Postacchini et al⁶ performed a retrospective study which reported on the clinical features of 77 patients with degenerative lumbar spondylolisthesis. Within these patients, 18% reported chronic low back pain as the only symptom; 12% had lower extremity symptoms felt to be nonvertebral in origin (eg, hip arthritis) and reported no low back pain; 47% had radicular symptoms and low back pain; and 23% reported only radicular symptoms. Radiculopathy presented as pain alone, pain and sensory symptoms or pain and sensorimotor changes. Lasegue test was negative in almost all cases. The most common neurological signs were absent ankle jerks, weak extensor hallucis longus (EHL), weak anterior tibialis or loss of knee jerk reflex. The authors reviewed five clinical patterns and three radiographic patterns as defined by Fitzgerald and MacNab. Clinical patterns included the following:

1. no symptoms, occasional back pain;
2. chronic low back pain with no radicular symptoms;
3. radicular symptoms with no root compression, with or without back pain;
4. radicular symptoms with neurologic deficit; or
5. intermittent claudication.

Radiological findings included slight central stenosis, lateral root canal stenosis or combined central and root canal stenosis. The authors concluded that degenerative lumbar spondylolisthesis is not always symptomatic. Patients may complain of low back pain, but the etiology is uncertain. Patients largely complain of radicular symptoms or intermittent claudication, which is secondary to an associated stenosis.

Rosenberg et al⁷ conducted a retrospective study which characterized symptoms in 200 consecutive patients with degenerative lumbar spondylolisthesis. Back, buttock or thigh pain were the principal complaints in a large majority of patients. Of the 200 patients, 61 had leg symptoms. Some patients described gait abnormalities. Seven patients had sacral nerve root symptoms. Acute radiculopathy occurred in 19 instances and a disc herniation was confirmed on myelography. Symptoms included aching, pulling, weakness, heaviness, numbness or burning. Lower extremity symptoms could be unilateral, bilateral or alternating. Neurogenic claudication was uncommon. Examination of the patients demonstrated that many were supple and able to touch toes, 10% had back spasms and 42% had neurologic deficits, primarily L5 with decreased sensation in the lateral thigh or inability to walk on heels. Atrophy occurred occasionally and 20% had altered deep tendon reflexes.

Vogt et al⁸ described a retrospective, cross-sectional study of 788 women greater than 65 years of age enrolled in the Study of Osteoporotic Fractures. The presence of olisthesis (degenerative spondylolisthesis and retrodisplacement) was defined as greater than 3mm of translational change. Of the women enrolled in the study, 29% had anterior olisthesis (degenerative spondylolisthesis) and 14% had retrolisthesis. Ninety percent of degenerative spondylolisthesis and 88% of retrolisthesis occurred at one level. Prevalence was not associated with smoking status, diabetes or oophorectomy. Unlike retrolisthesis, degenerative spondylolisthesis was not associated with back pain. This study suggests that degenerative spondylolisthesis is relatively common in elderly Caucasian women and does not correlate with back pain.

Future Directions For Research

The work group identified the following potential studies that would generate meaningful evidence to assist in identifying the most appropriate historical and physical examination findings consistent with the diagnosis of degenerative lumbar spondylolisthesis:

Recommendation #1:

Sufficiently-powered observational studies evaluating the predictive value of physical examination tests in diagnosing degenerative lumbar spondylolisthesis.

Recommendation #2:

Large multicenter registry database studies are needed to better understand the importance of certain patient characteristics or clinical presentation associated with the diagnosis of degenerative lumbar spondylolisthesis.

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Original Guideline Question:

What are the most appropriate diagnostic tests for degenerative lumbar spondylolisthesis?

The lateral radiograph is the most appropriate, noninvasive test for detecting degenerative lumbar spondylolisthesis. *Maintained from original guideline with minor word modifications*

Grade of Recommendation: B (Suggested)

In the absence of reliable evidence, it is the work group's opinion that the lateral radiograph should be obtained in the standing position whenever possible. *New consensus statement*

Work Group Consensus Statement

Study obtained from updated literature search:

Cabraja et al¹ analyzed the images of 100 symptomatic patients with low-grade spondylolisthesis who underwent surgical fusion to test the hypothesis that in symptomatic patients, imaging in the standing and recumbent position that is done as part of the routine diagnostics with CT and radiography reveals a higher sagittal translation (ST) and sagittal rotation (SR) compared to lumbar flexion-extension radiographs in the standing position. To determine the ST and SR in the standing and recumbent position, the authors compared the images taken in the recumbent position in the CT with images taken in the standing position during the routine plain radiography. ST and SR were measured on the dynamic radiographs by subtraction from flexion to extension; on the plain radiographs (standing position) and on the CT (recumbent supine position) by subtraction from plain standing position and supine recumbent position, respectively. Results indicated that the absolute values of measurement of ST differed significantly ($p=0.001$) with 2.3 ± 1.5 mm in standing flexion-extension radiograph and 4.0 ± 2.0 mm in the standing and recumbent radiograph. The analysis of

the relative value showed an ST of $5.9 \pm 3.9\%$ in standing flexion-extension radiograph and $7.8 \pm 5.4\%$ in standing and recumbent radiograph and also differed significantly ($p = 0.008$). The vertebral anterior translation was highest during flexion and lowest during recumbent supine position. The measurement of ST in the recumbent supine position showed an absolute value of 4.6 ± 2.5 mm and differed significantly from ST in the standing flexion-extension position ($p = 0.001$) and standing and recumbent position ($p = 0.045$). The analysis of the relative value showed an ST of $9.2 \pm 5.7\%$ in radiography in the flexion and recumbent spine position. This differed significantly from standing flexion-extension ($p = 0.0062$), but did not reach the level of significance when comparing the relative values with the standing and recumbent position ($p = 0.062$). The measurement of SR revealed no significant differences between standing flexion-extension, standing and recumbent position and flexion in a recumbent position; however there was at least a trend that standing flexion-extension evokes a greater SR than standing and recumbent position ($p = 0.051$). The authors concluded that in symptomatic patients with a low-grade spondylolisthesis,

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radiography in the standing and recumbent position evokes a greater ST than the standing flexion-extension radiograph in most patients. In critique, it is unclear if these patients were consecutive and there was no subgroup analysis separating the results of the 17 patients with isthmic spondylolisthesis patients. This study offers Level III diagnostic evidence that for evaluation of ST in symptomatic patients with degenerative spondylolisthesis, imaging in the standing and recumbent position appears to be more suitable than flexion-extension, while a pathological SR is better identified in flexion-extension radiographs in the standing position.

Studies included in original guideline:

Brown et al² reported findings from a retrospective study of patients with degenerative spondylolisthesis, which examined a number of different parameters, including diagnostic features on plain radiographs. These patients were selected from a review of 2,348 consecutive charts of patients with low back pain; 132 (5.6%) had radiographic evidence of degenerative spondylolisthesis. Of patients included in the study, 88 were female and 44 were male. The average age was 63.5 years for the female group and 65.2 years for the male group. Seventy-eight percent had back pain with proximal leg referral lasting between one week and 40 years; 17% had instability symptoms (eg, catch in the back, tiredness in back, inability to walk one hour, limitation of forward bend, inability to lift weights, back pain with coughing or sneezing, significant back pain with twisting). In critique, this study does not present peer-reviewed data. There was no comparison of diagnostic tests. As the study was performed in the early 1980s, the primary radiographic modality was plain radiographs. These data offer Level III diagnostic evidence that plain radiographs are a useful test for identifying patients with degenerative spondylolisthesis.

Cauchioux et al³ conducted a diagnostic evaluation on 26 patients with degenerative spondylolisthesis using plain radiographs and myelography. The study included 26 patients with nerve root compression secondary to degenerative slip, with 80% reporting back pain, 46% reporting chronic sciatica and 54% reporting neurogenic claudication. Sciatica tended to occur in the older patient and neurogenic claudication in the younger subjects. Myelography was performed in 17 patients to detect nerve root/cauda equina compression. Although not supported by statistical analysis, the authors claimed that lateral recess stenosis was “most important.” In critique of this study, the authors did not state whether patients were consecutively selected; thus, it was assumed that they were nonconsecutive patients. The study did not include comparison of diagnostic modalities. Admittedly, in the mid to late 1970s, plain radiograph and myelography were the most advanced imaging methods available. By default, they would have been considered gold standard diagnostic tests for degenerative spondylolisthesis and spinal stenosis. These data offer Level III diagnostic evidence that plain radiographs and myelography are useful diagnostic tests for this disorder.

Fitzgerald et al⁴ described a study of 43 patients with symptomatic spondylolisthesis. It is unclear if the patients represented a consecutive or nonconsecutive series. In addition to a description of plain radiographic findings of the spine, as well as concomitant hip arthritis, the authors provided a detailed descrip-

tion of the presentation (symptom) pattern of the patients. In summary, they found that 34 patients had back pain without leg pain and signs of nerve root compression, 5 cases with leg pain with or without back pain with signs of nerve root compression and four cases in which patients reported neurogenic claudication. As a diagnostic study, the primary imaging method was plain radiographs; however, plain myelography was also performed in 7 of the 9 patients with neurological symptoms. In critique of this study, one must presume that the patients were not consecutively enrolled. The only two imaging methods used were plain radiographs and myelography, which were not uniformly performed in all patients. This study provides Level III diagnostic evidence that plain radiographs and myelography are useful modalities with which to diagnose and evaluate degenerative spondylolisthesis in the lumbar spine.

Kanayama et al⁵ conducted a case series of 19 patients with symptomatic degenerative lumbar spondylolisthesis who were candidates for instrumented lumbar arthrodesis and decompression. Patients were assessed according to radiographic parameters including disc angle, range of motion (ROM), percent slip, percent posterior height, which were then compared with distraction stiffness in the operating room. The authors concluded that disc angle in flexion and ROM were highly correlated with distraction stiffness. Patients with segmental kyphosis with flexion showed lower stiffness compared to those with lordosis in flexion. In critique of this study, it assessed an intraoperative and nonvalidated test. The clinical application of such a test remains unknown. Although the study presents potential Level II diagnostic evidence, the authors failed to mention whether the patients were consecutively assigned, thus the study was downgraded to Level III evidence. The study provides Level III diagnostic evidence that standing flexion and extension radiographs are predictive of instability.

Postacchini et al⁶ described a study of 77 patients with degenerative spondylolisthesis in which flexion-extension radiographs, CT and/or MRI, and myelography were obtained. The various findings were reported. Dynamic radiographs “showed hypermobility of L4 in approximately half of the cases.” Myelography revealed neural structure compression in the spinal canal in all cases in which it was performed. (Note: myelography may have only been performed if patients had neurologic symptoms.) CT was useful for assessing the facet joint. MRI, CT and myelography were useful in identifying stenosis in patients with neurological symptoms. In critique, the diagnostic studies were applied inconsistently across patients. Not all patients received all studies, preventing comparison between diagnostic modalities. This article presented comprehensive descriptions of the findings with each of the diagnostic modalities. These data offer Level III diagnostic evidence of the utility of dynamic radiographs, CT, MRI and myelography for evaluation of degenerative spondylolisthesis.

The most appropriate, noninvasive test for imaging the stenosis accompanying degenerative lumbar spondylolisthesis is MRI. Maintained from original guideline

Work Group Consensus Statement

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Based on NASS' Clinical Guideline for Diagnosis and Treatment of Degenerative Lumbar Spinal Stenosis (2011)⁷, MRI is suggested as the most appropriate, noninvasive test to confirm the presence of anatomic narrowing of the spinal canal or the presence of nerve root impingement in patients with history and physical examination findings consistent with degenerative lumbar spinal stenosis (Grade B Recommendation). This Work Group Consensus has been made with the understanding that the symptoms of degenerative lumbar spondylolisthesis are related to the presence of anatomic narrowing or nerve root impingement, which are similar to imaging findings in lumbar spinal stenosis.

Facet joint effusion greater than 1.5mm on supine MRI may be suggestive of the presence of degenerative lumbar spondylolisthesis. Further evaluation for the presence of degenerative lumbar spondylolisthesis should be considered, including using plain standing radiographs.

New recommendation statement

Grade of Recommendation: B

Studies obtained from updated literature search:

In a retrospective radiographic review, Chaput et al⁸ evaluated the association between facet joint effusion seen on MRI and spondylolisthesis seen on standing lateral flexion-extension (SLFE) radiographs in patients with degenerative spondylolisthesis. A total of 193 patients were studied, including 139 without degenerative spondylolisthesis and 54 with degenerative spondylolisthesis. Degenerative spondylolisthesis was considered present if anterior translation of L4 on L5 was >5% on SLFE films. When reviewing radiographic indicators for degenerative spondylolisthesis, degenerative spondylolisthesis patients were more likely to have synovial cysts ($p < 0.0001$), higher osteoarthritis grade ($p < 0.0001$) and larger effusions ($p < 0.0001$) compared to nondiseased patients. After adjusting for age and osteoarthritis grade, every 1mm increase in effusion increased the odds of having degenerative spondylolisthesis by 5.6 fold (OR=5.6). An effusion > 1.5mm was not found in the negative degenerative spondylolisthesis group. Using facet effusion as the only variable in univariate logistic regression, the probability of having spondylolisthesis when 1mm effusion was present on MRI was 29.6%, 60.3% when 2mm of effusion was present and 84.6% when 3mm of effusion was present. This study provides Level II diagnostic evidence that an effusion >1.5 mm is predictive of degenerative spondylolisthesis and the increasing size of the effusion may be correlated to the increased probability of degenerative spondylolisthesis.

In a prospective diagnostic study, Caterini et al⁹ analyzed supine weight-bearing flexion-extension lumbosacral radiographs and lumbosacral MRI for 52 patients with low back pain and/or radiculopathy to determine the incidence of increased fluid in the lumbar facet joints seen on the supine axial T2 MRI and to evaluate whether this finding is correlated with radiographic evidence of lumbar instability. The patients had a mean age of

64.7 years. Results indicated that in 12 patients (23.1%) in the series, radiographic signs of degenerative lumbar spondylolisthesis were present, and in 10 of these 12, the degenerative spondylolisthesis was not evident on the sagittal MRI; in 8 cases out of 12, degenerative spondylolisthesis was present at L4–L5, and in the remaining 4 cases at L3–L4. Among these 12 patients with radiographic signs of degenerative spondylolisthesis, the MRI showed exaggerated fluid in the facet joints at the corresponding level in 8 patients (66%). Facet joint effusion was evident on MRI (range 1.5–3mm) in 7 patients (13.4%), but no radiographic signs of corresponding lumbar instability were found. Altogether, 15 patients (28.8%) presented with increased lumbar facet joint fluid on the axial T2 MRI. According to their conclusions, the authors observed a statistical correlation between increased fluid in the lumbar facet joints on the supine axial T2 MRI and degenerative spondylolisthesis seen on standing lateral flexion-extension lumbosacral radiographs. In critique of this study, the investigators did not incorporate a blinded evaluation, there was no control group of asymptomatic patients, and statistical analysis comparing patients with degenerative spondylolisthesis and increased facet fluid to those without degenerative spondylolisthesis and increased facet fluid was not performed. This potential Level II study has been downgraded to level III due to these limitations. This study provides Level III diagnostic evidence that increased facet fluid as seen on MRI may be associated with degenerative spondylolisthesis.

There is insufficient evidence to make a recommendation for or against the utility of the upright seated MRI in the diagnosis of degenerative lumbar spondylolisthesis. *New recommendation statement*

Grade of Recommendation: I (Insufficient Evidence)

Study obtained from updated literature search:

Ferreiro-Perez et al¹⁰ evaluated the differences in imaging findings between recumbent and upright-sitting MRI of the cervical and lumbosacral spine. A total of 89 patients were included in the analysis, including 45 lumbosacral spine patients and 44 cervical spine patients. When determining pathology, degenerative spondylolisthesis was seen in 13 patients, including 11 anterior and 2 posterior. Anterior spondylolisthesis was only seen on the upright-sitting examination in 4 patients (31%). Anterior spondylolisthesis was comparatively greater in degree on the upright-seated study in 7 patients (54%). Posterior spondylolisthesis was comparatively greater in degree on the recumbent examination in 2 patients (15%). The authors suggest that the upright-seated MRI was found to be superior to recumbent MRI. In critique of this study, the sample size was small, it was unclear which patients received which type of MRI and statistical analysis of results was not performed. Due to these limitations, this potential Level III study has been downgraded to a Level IV. This study provides Level IV diagnostic evidence that upright-seated MRI may be superior to recumbent MRI of the spine in cases of anterior spondylolisthesis. The seated upright MRI may make an

terior spondylolisthesis more visible when compared to supine MRI.

There is insufficient evidence to make a recommendation for or against the use of axial loaded MRI to evaluate the dural sac cross sectional area in patients with degenerative lumbar spondylolisthesis and spinal stenosis. *New recommendation statement*

Grade of Recommendation: I (Insufficient Evidence)

Study obtained from updated literature search:

Ozawa et al¹¹ compared the dural sac cross sectional area (DCSA) in patients with degenerative spondylolisthesis versus patients with spinal stenosis (without degenerative spondylolisthesis) on axially loaded MR imaging. All patients had neurogenic intermittent claudication and leg pain or numbness and associated neurologic signs. Lumbar spinal canal narrowing was radiographically confirmed on cross-sectional imaging in all patients. For the comparative analysis in this study, the patients with >3mm spondylolisthesis were assigned to the degenerative spondylolisthesis group, while the other patients were assigned to the spinal stenosis group. A total of 88 patients were included in the study, including 40 with degenerative spondylolisthesis patients. All patients received MR imaging. After conventional MR imaging, axial loading was applied by using an external commercially available nonmagnetic compression device. The DCSA was measured from the L2-3 to L5-S1 on the axial image. The measurement was performed three times and the mean value was calculated and used for analysis in this study. Results indicated that a >15-mm² change in the DCSA was found in 8 patients (16.7%) in the spinal stenosis group and 25 patients (62.5%) in the degenerative spondylolisthesis group. In the degenerative spondylolisthesis group, patients with a >15-mm² change had a significantly larger DCSA on conventional MR imaging ($58 \pm 26 \text{ mm}^2$) than those with a <15 mm² change ($41 \pm 18 \text{ mm}^2$) ($p=0.028$), while the axial loaded MR imaging showed no significant difference between the patients with a >15 and a <15-mm² change in the DCSA ($p=0.897$). The authors conclude that DCSA in patients with degenerative spondylolisthesis is more likely to be decreased by axial loading than in those with spinal stenosis. Axial loaded MRI may be a more useful tool for the assessment of spinal canal narrowing in patients with degenerative spondylolisthesis than those with spinal stenosis without spondylolisthesis. In critique, use of a 15mm² criterion as significant change in DCSA is not a universally accepted diagnostic standard; therefore, this study has been downgraded from Level II to III. This study provides Level III diagnostic evidence that axially loaded MRI may reveal more severe stenosis in patients with degenerative spondylolisthesis than might be apparent on conventional MRI.

Plain myelography or CT myelography are useful studies to assess spinal stenosis in patients with degenerative lumbar spondylolisthesis especially in those who have contraindications to MRI. *Maintained from original guideline*

Grade of Recommendation: B (Suggested)

Studies included in original guideline:

Cauchioux et al³ conducted a diagnostic evaluation of 26 patients with degenerative spondylolisthesis which included plain radiographs and myelography. Specifically, the authors stated that they made the diagnosis based on the “presence of a slip of one vertebra on the vertebra below in the absence of a defect of the pars interarticularis.” The study included 26 patients with nerve root compression secondary to degenerative slip, with 80% reporting back pain, 46% reporting chronic sciatica and 54% reporting neurogenic claudication. Sciatica tended to occur in the older patient and neurogenic claudication in the younger subject. Myelography was performed in 17 patients to detect nerve root/cauda equina compression. Although not supported by statistical analysis, the authors claimed that lateral recess stenosis was “most important.” In critique of this study, the authors did not state whether patients were consecutively selected, thus it was assumed that they were nonconsecutive patients. There was no comparison of diagnostic modalities. Admittedly, in the mid- to late-1970s, plain radiographs and myelography were the most advanced imaging methods available. By default, they would have been considered gold standard diagnostic tests for degenerative spondylolisthesis and spinal stenosis. These data offer Level III diagnostic evidence that plain radiographs and myelography are useful diagnostic tests for this disorder.

Fitzgerald et al⁴ described a study of 43 patients with symptomatic spondylolisthesis. It is unclear if the patients represented a consecutive or nonconsecutive series. In addition to a description of plain radiographic findings of the spine, as well as concomitant hip arthritis, the authors provided a detailed description of the presentation (symptom) pattern of the patients. In summary, they found that 34 patients had back pain without leg pain and signs of nerve root compression, five cases with leg pain with or without back pain with signs of nerve root compression, and four cases in which patients reported neurogenic claudication. As a diagnostic study, the primary imaging method was plain radiographs. However, plain myelography was also performed in 7 of the 9 patients with neurological symptoms. In critique of this study, one must presume that the patients were not consecutively enrolled. The only 2 imaging methods used were plain radiographs and myelography, which were not uniformly performed in all patients. This study provides Level III diagnostic evidence that plain radiographs and myelography are useful modalities with which to diagnose and evaluate degenerative spondylolisthesis in the lumbar spine.

Postacchini et al⁶ described a study of 77 patients with degenerative spondylolisthesis in which flexion-extension radiographs, CT and/or MRI, and myelography were obtained. The various findings were reported. Dynamic radiographs “showed

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hypermobility of L4 in approximately half of the cases.” Myelography revealed neural structure compression in the spinal canal in all cases in which it was performed. (Note: myelography may have only been performed if patients had neurologic symptoms.) CT was useful for assessing the facet joint. MRI, CT and myelography were useful in identifying stenosis in patients with neurological symptoms. In critique, the diagnostic studies were applied inconsistently across patients. Not all patients received all studies, preventing comparison between diagnostic modalities. This article presented comprehensive descriptions of the findings with each of the diagnostic modalities. These data offer Level III diagnostic evidence of the utility of dynamic radiographs, CT, MRI and myelography for evaluation of degenerative spondylolisthesis.

Rosenberg et al¹² conducted a retrospective study which characterized 200 consecutive patients with degenerative lumbar spondylolisthesis. This cohort contained a subgroup of 39 patients with severe unremitting symptoms; 29 underwent myelography and showed an hourglass constriction of the dura at the level of slippage. Seven patients also had a protrusion. Surgical findings included absence of epidural fat, pale pulseless dura and decreased capacity of the spinal canal. In critique of this study, data were collected retrospectively and tests were not uniformly applied across patients. However, from the diagnostic perspective, this small subgroup of 29 patients provides a consecutive series of patients that was retrospectively analyzed. These subgroup data provide Level II diagnostic evidence that myelography is useful in identifying stenosis in patients with degenerative spondylolisthesis and neurological symptoms.

Satomi et al¹³ reported findings from a retrospective case series of patients with degenerative spondylolisthesis who were evaluated with CT myelography in order to plan the optimal surgical procedure. CT myelograms were compared with plain radiographic myelograms to evaluate the sites of dural compression. Patients who underwent anterior lumbar interbody fusion (ALIF) were included in Group A. Patients were selected for the posterior decompression group (Group B) if their imaging showed displacement at 2 or more discs, had CT myelographic findings indicating lateral stenosis or were deemed inappropriate candidates for ALIF due to age. Group A consisted of 27 patients; discography was performed in 22. Based on the novel CT myelogram classification used in the study, 38% of these patients had stage 3 stenotic changes. Group B consisted of 14 patients, 5 of whom underwent fusion. Of these patients, 4 reported back pain; neurogenic intermittent claudication was more severe in Group B. Discography was performed in 2 patients. Based on myelogram classification used in the study, 62% of these patients had stage 3 stenotic changes. Stenosis over two disc space levels was present in 92% of these patients. The authors concluded that information on CT myelography was useful for identifying pathologic processes and for planning surgery. In critique of this study, the authors did not evaluate a list of diagnostic criteria a priori. The authors failed to indicate whether patients were selected consecutively. These data offer Level III diagnostic evidence that CT myelography is a useful imaging study for this disorder.

In patients with degenerative lumbar spondylolisthesis with associated spinal stenosis for whom MRI is either contraindicated or inconclusive, CT myelography is suggested as the most appropriate test to confirm the presence of anatomic narrowing of the spinal canal or the presence of nerve root impingement.

New Consensus Statement

Work Group Consensus Statement

In patients with degenerative spondylolisthesis with associated spinal stenosis for whom MRI and CT myelography are contraindicated, inconclusive or inappropriate, CT is suggested as the most appropriate test to confirm the presence of anatomic narrowing of the spinal canal or the presence of nerve room impingement.

New Consensus Statement

Work Group Consensus Statement

Based on NASS' *Clinical Guideline for Diagnosis and Treatment of Degenerative Lumbar Spinal Stenosis* (2011)⁷, CT was demonstrated to be an effective diagnostic tool to detect degenerative lumbar spinal stenosis. As many patients included in the review had degenerative spondylolisthesis, it is logical to conclude that CT would be useful in this group as well. However, only one disease-specific study was found, necessitating reference to the NASS *Clinical Guideline on Lumbar Spinal Stenosis* to support this consensus statement.

Study included in original guideline:

Rothman et al¹⁴ conducted a retrospective review of the CT findings of 150 patients with degenerative spondylolisthesis. The authors described the pathological findings, which included canal stenosis, facet overgrowth, joint-capsule hypertrophy, ligamentum flavum enlargement and gas within the facet joints. All patients were examined on GE 8800 CT scanners using axial scans of 5mm-thick sections at every 3mm spacing (2mm overlap), with sagittal and coronal reformats. The authors found only 19% had subluxation greater than 6mm. Severe facet degeneration with marked hypertrophy, erosive changes or gas within an irregular joint was noted in 91 patients. Severe canal stenosis was detected in 15 patients due to narrowing of the central canal secondary to a combination of subluxation, facet bony overgrowth, joint-capsule hypertrophy, ligamentous hypertrophy, bulging and end plate osteophyte formation. Foraminal stenosis was observed in 38 patients. Anterior soft tissue bulge/herniation of greater than 5mm was present in only three patients. The authors concluded that CT is useful in evaluating the severity of stenosis in patients with symptomatic degenerative spondylolisthesis. Stenosis is frequently secondary to soft tissue changes and facet hypertrophy, and does not always correlate with the

severity of slip. In critique, this was a study of nonconsecutive patients, radiological findings were not correlated with clinical signs or symptoms, and no gold standard was employed. The data offers Level IV diagnostic evidence that CT is a useful modality in the diagnosis of stenosis in patients with degenerative spondylolisthesis.

Future Directions for Research

The work group recommends prospective, appropriately powered studies to better assess the utility of supine recumbent, axial loaded and positional MRI in the detection and evaluation of stenosis in the setting of degenerative lumbar spondylolisthesis.

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New Guideline Question:

What are the most appropriate diagnostic or physical exam tests consistent with the diagnosis of fixed versus dynamic deformity?

There is insufficient evidence to make a recommendation on the most appropriate diagnostic or physical exam test consistent with fixed or dynamic deformity in degenerative lumbar spondylolisthesis patients due to the lack of uniform reference standards which define instability.

There is no universally accepted standard to diagnose fixed versus dynamic spondylolisthesis. To evaluate instability, many studies employ the use of lateral flexion extension radiographs, which may be done in the standing or recumbent position; however, there is wide variation in the definition of instability. To assist the readers, the definitions for instability (when provided) in degenerative spondylolisthesis patients, are bolded below.

Grade of Recommendation: I (Insufficient Evidence)

In a prospective diagnostic study, Caterini et al¹ analyzed supine weight-bearing flexion–extension lumbosacral radiographs and lumbosacral MRI for 52 patients with low back pain and/or radiculopathy to determine the incidence of increased fluid in the lumbar facet joints seen on the supine axial T2 MRI and to evaluate whether this finding is correlated with radiographic evidence of lumbar instability. The patients had a mean age of 64.7 years. **Degenerative spondylolisthesis was considered positive when the vertebral slippage was greater than 4.5 mm or greater than 15% of the width of the vertebral body on flexion x-rays.** In 12 patients (23.1%) in the series, radiographic signs of degenerative lumbar spondylolisthesis were present, and in 10 of these 12, the degenerative spondylolisthesis was not evident on the sagittal MRI. In 8 cases out of 12, degenerative spondylolisthesis was present at L4–L5, and in the remaining 4 cases at L3–L4. Among these 12 patients with radiographic signs of degenerative spondylolisthesis, the MRI showed exaggerated fluid in the facet joints at the corresponding level in 8 patients (66%). Facet joint effusion was evident on MRI (range 1.5–3mm) in 7 patients (13.4%), but no radiographic signs of corresponding

lumbar instability were found. Altogether, 15 patients (28.8%) presented with increased lumbar facet joint fluid on the axial T2 MRI. The authors observed a statistical correlation between increased fluid in the lumbar facet joints on the supine axial T2 MRI and degenerative spondylolisthesis seen on standing lateral flexion–extension lumbosacral radiographs. In critique of this study, the investigators did not incorporate a blinded evaluation, there was no control group of asymptomatic patients and statistical analysis comparing patients with degenerative spondylolisthesis and increased facet fluid to those without degenerative spondylolisthesis and increased facet fluid was not performed. This potential Level II study has been downgraded to III due to these limitations. This study provides level III diagnostic evidence that increased facet fluid may be associated with degenerative spondylolisthesis on lateral plain films even when not evident on MRI.

In a retrospective radiographic review, Chaput et al² evaluated the association between facet joint effusion found on MRI and spondylolisthesis found on standing lateral flexion–extension (SLFE) radiographs in patients with degenerative

spondylolisthesis. A total of 193 patients were studied, including 139 without degenerative spondylolisthesis and 54 with degenerative spondylolisthesis. **Degenerative spondylolisthesis was considered present if anterior translation of L4 on L5 was >5% on SLFE films.** When reviewing radiographic indicators for degenerative spondylolisthesis, it was found that degenerative spondylolisthesis patients were more likely to have synovial cysts ($p < 0.0001$), higher osteoarthritis grade ($p < 0.0001$) and larger effusions ($p < 0.0001$) compared to nondiseased patients. After adjusting for age and osteoarthritis grade, every 1mm increase in effusion increased the odds of having degenerative spondylolisthesis by 5.6 fold (OR=5.6). An effusion > 1.5mm was not found in the negative degenerative spondylolisthesis group, and the authors suggest that an effusion > 1.5mm is highly predictive of degenerative spondylolisthesis. Using facet effusion as the only variable in univariate logistic regression, the probability of having spondylolisthesis when 1mm effusion was present on MRI was 29.6%, 60.3% when 2mm of effusion was present and 84.6% when 3mm of effusion was present. This study provides Level II diagnostic evidence that there is a probability of progressive spondylolisthesis with increasing facet joint effusion size, even if spondylolisthesis is not evident on supine MRI. MRI findings of large facet effusion and synovial cysts are suggestive of degenerative spondylolisthesis.

Hammouri et al³ conducted a retrospective radiographic review to assess use of lateral dynamic flexion-extension radiographs in the initial evaluation of patients with degenerative lumbar deformities. Anteroposterior and lateral lumbar radiographs were taken with the patients in their natural posture. Flexion and extension lumbar films were taken by asking the patient to achieve his or her maximum effort at flexion and extension in the standing position. **The measurement of spondylolisthesis was made by determining the relative AP distance between the posterior borders of adjacent vertebral bodies. A minimum measurement of 2mm was used to achieve this definition.** In review of the spondylolisthesis patients, 67 (20%) patients had anterolisthesis and 46 (13%) had retrolisthesis, including 54% at L4-5 and 31% at L5-S1. Only 2 out of 342 patients had new findings on flexion/extension not visible on anteroposterior and lateral lumbar radiographs. Fifteen patients had change in degree of listhesis with flexion/extension/ anteroposterior/lateral lumbar radiograph, without any change in their Meyerding grade. This study provides Level II diagnostic evidence that standing lateral extension films are not indicated in patients who do not demonstrate a degenerative spondylolisthesis on standing radiograph.

Cho et al⁴ assessed the correlation between the degree of L4-5 spondylolisthesis on plain flexion-extension radiographs and the corresponding amount of L4-5 facet fluid visible on MR images. Only patients diagnosed with L4-5 degenerative spondylolisthesis (DS) and who had both lumbosacral flexion-extension radiographs and MR images available for review were eligible for this study. The authors did not provide a specific definition for a positive diagnosis of degenerative spondylolisthesis. Dynamic motion index (DMI) was measured using the lateral lumbosacral plain radiograph and calculated as the percentage of the degree of anterior slippage seen on flexion versus that seen on extension. Axial T2-weighted MR images of the L4-5 facet

joints were analyzed for the amount of facet fluid using the image showing the widest portion of the facets. The facet fluid index was calculated from the ratio of the sum of the amounts of facet fluid found in the right plus left facets over the sum of the average widths of the right plus left facet joints. Facet fluid was noted on MR images in 29 of 54 patients (53.7%) with a mean DMI of 6.349 ± 2.726 . Patients without facet fluid on MR imaging had a mean DMI of 1.542 ± 0.820 . The difference between the mean DMI's of patients with and without facet fluid on MR imaging was statistically significant ($p < 0.001$). In the patients who exhibited facet fluid on MRI, there was a positive linear association between the facet fluid index and DMI (Pearson correlation coefficient 0.560, $p < 0.01$). In the subgroup of 29 patients with L4-5 DS and facet fluid on MR images, flexion-extension plain radiographs showed anterolisthesis in 10 (34.5%) patients, but corresponding MR images did not show anterolisthesis. The authors conclude that there is a linear correlation between the degree of segmental motion seen on flexion-extension plain radiography in patients with DS at L4-5 and the amount of L4-5 facet fluid on MR images. If L4-5 facet fluid is seen on MR images in DS patients, a corresponding anterolisthesis on weight-bearing flexion-extension lateral radiographs should also been seen. In critique of this study, it is unclear whether the patients included were consecutive. This study provides Level III diagnostic evidence that when facet fluid is present, the use of weight-bearing flexion-extension plain radiography will prevent the clinician from missing the anterior slippage caused by a hypermobile segment of the lumbar spine not visualized on a supine MR image.

D'Andrea et al⁵ evaluated the use of the supine-prone position in performing dynamic x-ray examination in patients with low grade spondylolisthesis. **Segmental lumbar instability was defined as translation movement exceeding 3 mm from flexion to extension and supine to prone.** A total of 75 patients had a standard lateral x-ray films in the supine position, and then in the prone position. At supine-prone examination, the authors observed 46 patients with grade I spondylolisthesis versus only 32 positive cases at standard dynamic examination, 29 versus 24 grade I-II spondylolisthesis, and the 19 negative results, prior observed, disappeared. Nineteen patients had new diagnosis of spondylolisthesis, 19 had higher grade of spondylolisthesis and 56 had no change in diagnosis. In critique, it is unclear whether the patients were consecutive and how many patients had a diagnosis of degenerative spondylolisthesis. This study provides Level III diagnostic evidence that using the supine-prone position for performing a dynamic x-ray examination is simple, safe and economically effective in diagnosis lumbar spinal instability in patients with degenerative spondylolisthesis.

In a retrospective radiographic study, Lattig et al⁶ evaluated whether facet joint effusion seen on supine MRI was an indicator of increased abnormal motion in patients with degenerative spondylolisthesis and rotational translation. The sample included 160 patients with degenerative spondylolisthesis and varying degrees of narrowing of the spinal canal who had undergone decompression only or decompression with instrumented fusion. All patients had preoperative upright x-ray films in AP and lateral views and supine MRI. A cut off value of >3% was arbitrarily chosen to represent the threshold for a real difference.

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The imaging studies were assessed for the following parameters: percent of slippage, absolute value of facet joint effusion, facet angles, degree of facet degeneration and spinal canal central narrowing, disc height, presence of facet cysts and the presence of rotational translation in the AP x-ray study. Results indicated that both mean and maximum facet joint effusion were significantly greater ($p = 0.0001$) in the group with $>3\%$ MRI-x-ray slip difference than in the $<3\%$ group. In the group with $<3\%$ MRI-x-ray slip difference, there was a significantly lower proportion of facet joint cysts ($p = 0.045$) and a lower mean facet joint angle ($p = 0.04$) compared to the group with $>3\%$ slip difference. According to findings, the extent of effusion correlated significantly with the relative slippage difference between standing and supine positions ($r = 0.64, p < 0.001$). The extent of the left/right difference in effusion was also found to be associated with the presence of rotational translation (RT $1.31 \pm 0.8\text{mm}$ vs. no-RT $0.23 \pm 0.17\text{mm}$, $p < 0.0001$). The authors suggest that in degenerative spondylolisthesis, facet joint effusion on MRI and reduction in slip between standing x-ray and supine MRI should be used in surgical decision making. This study provides Level III diagnostic evidence that there is a significant correlation between the extent of effusion of the facet joints on MRI and the difference in the degree of slippage between the standing and lying positions in patients with degenerative spondylolisthesis.

Ozawa et al⁷ compared the dural sac cross sectional area (DCSA) in patients with degenerative spondylolisthesis and spinal stenosis on axially loaded MR imaging. All patients had neurogenic intermittent claudication and leg pain or numbness with associated neurologic signs and had radiographically confirmed lumbar spinal canal narrowing on cross-sectional imaging. **For the comparative analysis in this study, the patients with $>3\text{mm}$ spondylolisthesis were assigned to the degenerative spondylolisthesis group, while the other patients were assigned to the spinal stenosis group.** A total of 88 patients were included in the study, including 40 with degenerative spondylolisthesis patients. All patients received MR imaging. After conventional MR imaging, axial loading was applied by using an external commercially available nonmagnetic compression device. The DCSA was measured from the L2/3 to L5/S1 on the axial image. The measurement was performed three times and the mean value was calculated and used for analysis in this study. Results indicated that a $>15\text{mm}^2$ change in the DCSA was found in 8 patients (16.7%) in the spinal stenosis group and 25 patients (62.5%) in the degenerative spondylolisthesis group. In the degenerative spondylolisthesis group, patients with a $>15\text{mm}^2$ change had a significantly larger DCSA on conventional MR imaging ($58 \pm 26 \text{mm}^2$) than those with a $<15\text{mm}^2$ change ($41 \pm 18 \text{mm}^2$) ($p = 0.028$), while the axial loaded MR imaging showed no significant difference between the patients with a >15 and a $<15\text{mm}^2$ change in the DCSA ($p = 0.897$). The authors conclude that DCSA in patients with degenerative spondylolisthesis is more likely to be decreased by axial loading than in those with spinal stenosis and that axial loaded MRI may be a more useful tool to provide valuable imaging findings for the assessment of spinal canal narrowing in patients with degenerative spondylolisthesis than those with spinal stenosis. In critique, use of a 15mm^2 criterion as significant change in DCSA is not a universally accepted diagnostic standard; therefore, this study has been

downgraded from Level II to III. This study provides Level III diagnostic evidence that axially loaded MRI may reveal more severe stenosis in patients with degenerative spondylolisthesis than might be apparent on conventional MRI.

Tokuhashi et al⁸ analyzed the utility of the treadmill provocation test in evaluating clinical lumbar instability. A total of 82 patients were included in the study, including 18 degenerative spondylolisthesis patients, 17 herniated lumbar disc patients, 10 isthmic spondylolisthesis patients and 37 canal stenosis patients. The treadmill exercise began at a speed of 0.6 mile/hr and gradually accelerated up to 1.8 mile/hr at different rates depending on the patient's age and symptoms. The symptoms elicited by the treadmill exercise, such as low-back pain, pain of the lower extremities and intermittent claudication, were analyzed and divided into groups. The 0 group had no symptoms after 10 minutes; the 1+ group reproduced symptoms after treadmill exercise with the same distances of walking that formally elicited symptoms on a flat road; the 2+ group reproduced symptoms after far less exercise; and the 3+ group were unusually and severely induced symptoms that had not occurred when the patient was walking on a flat road. The authors utilized radiographs to compare the symptoms after treadmill exercise to the segmental abnormality of the lumbar spine on radiographs. Results indicated that symptoms were elicited at a relatively higher rate in patients with degenerative spondylolisthesis. The dynamic abnormality of segmental movement was evaluated as translational movement over 3mm anteriorly or posteriorly, or abnormal tilting movement on the flexion-extension radiograph. Patients with instability/movement on flexion-extension radiograph did not correlate with treadmill provocation. The reproduction rates of symptoms after treadmill exercise were more affected in the clinical symptomatic instability than in the findings of abnormal structure or movement on the radiograph. In critique, this study had a small sample size, it is unclear whether the patients were consecutive **and it's important to note that this study is evaluating clinical instability, not radiographic instability.** This study provides Level III diagnostic evidence that the treadmill provocation test can be useful in evaluating the lumbar spine.

Ferreiro-Perez et al⁹ evaluated the differences in imaging findings between recumbent and upright-sitting MRI of the cervical and lumbosacral spine. A total of 89 patients were included in the analysis including, 45 lumbosacral spine patients and 44 cervical spine patients. When determining pathology, degenerative spondylolisthesis was seen in 13 patients, including 11 anterior and 2 posterior; however, the authors' definition of degenerative spondylolisthesis was not provided. Anterior spondylolisthesis was only seen on the upright-sitting examination in 4 patients (31%). Anterior spondylolisthesis was comparatively greater in degree on the upright-seated study in 7 patients (54%). Posterior spondylolisthesis was comparatively greater in degree on the recumbent examination in 2 patients (15%). The authors suggest that the upright-seated MRI was found to be superior to recumbent MRI. In critique of this study, the sample size was small, it was unclear which patients received which type of MRI, and statistical analysis of results was not performed. Due to these limitations, this potential Level III study has been downgraded to a Level IV. This study provides Level IV diagnostic evidence that upright-seated MRI may be superior to recumbent MRI of

the spine in cases of anterior spondylolisthesis. The seated upright MRI may make anterior spondylolisthesis more visible when compared to supine MRI; however, the significance of this finding is unclear.

Friberg et al¹⁰ conducted a radiographic analysis to study the dynamic behavior of the lumbar spine segments when subject to traction and compression. A total of 117 patients were included in the study; however, only 7 patients had the diagnosis of degenerative spondylolisthesis. Patients were examined for segmental translatory instability using a new method in which lateral spot radiographs of the lumbosacral spine were taken during axial traction and compression. Axial compression of the spine was brought about by positioning the patient to stand erect with a sac filled with 20kg of sand. The lumbar spine was subjected to gravitational traction by patients suspended from a horizontal bar. The compressive force consisted of the weight of the entire torso, compressive preloads, and the extra load of 20kg. During the evaluation, every patient could carry the 20kg load without difficulty during the radiographic tests, but one female patient was unable to hang from the bar because of a stiff and painful shoulder. As a sign of instability, distinct movement was found in patient with degenerative spondylolisthesis of L4. **The mean amount of malalignment was 8mm (SD=1.3mm). The mean amount of translatory movement at the spondylolisthetic level, measured on traction-compression radiography, was 6.2mm (SD=1.7mm).** In critique, the degenerative spondylolisthesis sample size was small, there was no clear comparison with a control group and the gold standard of lateral flexion-extension x-ray films were not used. This potential Level III study provides Level IV diagnostic evidence that traction-compression radiography of the lumbar spine can be used to assess for translational instability.

McGregor et al¹¹ conducted a radiographic study to investigate patterns of intervertebral mobility (using flexion-extension positions in open MRI) in subjects with spondylolisthesis to determine the level of spinal instability. In this case-control study, 29 patients, including 15 with a diagnosis of isthmic spondylolisthesis and 14 with a diagnosis of degenerative spondylolisthesis, were enrolled and compared with a preexisting database of 12 patients with no history of back pain (controls). The motion characteristics of these patients in flexed and extended positions were investigated using open MRI of known precision. In all of the subjects, the level of resting pain, grade of slip, and level of defect were evaluated. No mobility differences of angular or translatory motion were found between the spondylolisthesis (degenerative or isthmic) group and asymptomatic controls. It is unclear how patients were recruited to this study and whether there was consecutive enrollment. The authors concluded that there is no evidence to support that subjects with spondylolisthesis will have an unstable spine. This study provides Level IV diagnostic evidence that the presence of degenerative spondylolisthesis does not lead to hypermobility. Additionally, this study suggests that dynamic MRI may not be able to differentiate between dynamic and fixed deformity.

In a case-control study, Oishi et al¹² assessed which factors determined whether the involved disc levels were restabilized (from initial assessment to the time of surgery) or remained unstable at the time of operation in 195 consecutive Japanese patients with degenerative lumbar spondylolisthesis. Patients who

had received laminectomy with or without fusion for progressed degenerative spondylolisthesis, defined as slip percentage >10% at lateral flexion position with spinal canal stenosis, were included in the study. **Sagittal plane unstable motion was defined according to the criteria that translatory displacement was >4mm (translatory hypermobility) or rotatory displacement was >10° (rotatory hypermobility).** The following 9 parameters were investigated retrospectively as the candidate factors to determine whether the affected segments were restabilized or not at the time of operation: age, sex, BMI, disc level, grade of disc degeneration, grade of disc spur formation, facet effusion size, length of facet spur formation and angle between facets. Radiographic measurements were taken by x-ray, CT and MRI. Multiple regression analysis for all candidate factors (except for sex and disc level) indicated that translatory displacement significantly correlated with facet effusion size positively ($p < 0.001$), and that rotatory displacement significantly correlated with facet effusion size positively ($p < 0.001$) and with age ($p = -0.042$) and grade of disc degeneration ($p = -0.033$) negatively. Logistic regression analysis for all candidate factors demonstrated that increased facet effusion size (OR 1.656, 95% CI 1.182–2.321) was the only independent factor for the presence of unstable motion at the time of operation. This study provides Level IV diagnostic evidence that facet effusion size is correlated to translational instability (translatory displacement >4mm).

Future Directions For Research

The work group identified the following potential studies that would generate meaningful evidence to assist in defining the most appropriate diagnostic or physical exam tests consistent with the diagnosis of fixed versus dynamic deformity in patients with degenerative lumbar spondylolisthesis:

Recommendation #1:

Future studies are needed to establish a consistent, universally agreed upon reference standard for instability with a confirmed validated clinical relevance.

Recommendation #2:

The diagnosis of instability needs to be further validated by correlation with symptom severity, prognosis and response to treatment.

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New Guideline Question:

Is dynamic MRI and/or dynamic CT myelography imaging (including standing imaging, imaging with axial loading) helpful in the diagnostic testing for degenerative lumbar spondylolisthesis?

There is insufficient evidence to make a recommendation for or against the utility of dynamic MRI and dynamic CT myelography in the diagnosis of degenerative lumbar spondylolisthesis.

Grade of Recommendation: I (Insufficient Evidence)

Huang et al¹ investigated the effect of axial loading on spine and spinal canal morphology in patients with degenerative spondylolisthesis of L4–5 and evaluated the correlation between morphologic changes and disability and physical functioning. A total of 32 consecutive cases with degenerative L4–5 spondylolisthesis, grade 1–2, intermittent claudication and low back pain without sciatica were included in this study. All patients underwent unloaded and axially loaded MRI of the lumbosacral spine in supine position to elucidate the morphological findings and to measure the parameters of MRI, including disc height (DH), sagittal translation (ST), segmental angulation (SA), dural sac cross-sectional area (DCSA) at L4–5, and lumbar lordotic angles (LLA) at L1–5 between the unloaded and axially loaded condition. Each patient's disability was evaluated by the Oswestry Disability Index (ODI) questionnaire and physical functioning (PF) was evaluated by the Physical Function scale. Comparisons and correlations were done to determine which parameters were critical to the patient's disability and PF. The morphologies of the lumbar spine changed after axially loaded MRI. In 6 patients, the authors observed adjacent segment degeneration (4 at L3–L4 and 2 at L5–S1) coexisting with degenerative spondylolisthe-

sis of L4–L5 under axially loaded MRI. The mean values of the SA under preload and postload were 7.14° and 5.90° at L4–L5 (listhetic level), respectively. The mean values of the LLA under preload and postload were 37.03° and 39.28°, respectively. There were significant correlations only between the ODI, PF, and the difference of SA, and between PF and the postloaded LLA. The changes in SA (L4–L5) during axial loading were well correlated to the ODI and PF scores. In addition, the LLA (L1–L5) under axial loading was well correlated to the PF of patients with degenerative L4–L5 spondylolisthesis. The authors conclude that axially loaded MRI is a useful tool for study of the anatomical changes of the spinal canal of the lumbar spine. It can also aid diagnosis of instability, or occult spinal disorders, such as equivocal herniated discs or stenosis, by simulating the upright position under normal gravity. This study provides Level IV prognostic evidence that axially loaded MRI using the Dynawell device demonstrates morphological changes in patients with symptomatic degenerative spondylolisthesis and that segmental angulation at L4-5 was correlated with physical disability (ODI).

In a study by McGregor et al², authors conducted a radiographic study to investigate patterns of intervertebral mobility

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(using flexion-extension positions in open MRI) in subjects with spondylolisthesis to determine level of spinal instability. Twenty-nine patients, including 15 with a diagnosis of isthmic spondylolisthesis and 14 with a diagnosis of degenerative spondylolisthesis, were enrolled and compared with a preexisting database of 12 patients with no history of back pain (controls). The motion characteristics of these patients in flexed and extended positions were investigated using open MRI. In all of the subjects, the level of resting pain, grade of slip and level of defect were evaluated. No mobility differences of angular or translatory motion were found between the spondylolisthesis (degenerative or isthmic) and asymptomatic controls. In critique of this study, it is unclear how patients were recruited, whether there was consecutive enrollment and a clear subgroup analysis was not included. This study provides Level IV diagnostic evidence that the presence of degenerative spondylolisthesis does not lead to hypermobility. A spondylolytic defect may not lead to detectable instability or hypermobility in the lumbar spine on dynamic MRI.

Ozawa et al³ compared the dural sac cross sectional area (DCSA) in patients with degenerative spondylolisthesis and spinal stenosis on axially loaded MR imaging. All patients had neurogenic intermittent claudication and leg pain or numbness with associated neurologic signs and had radiographically confirmed lumbar spinal canal narrowing on cross-sectional imaging. For the comparative analysis in this study, the patients with >3mm spondylolisthesis were assigned to the degenerative spondylolisthesis group, while the other patients were assigned to the spinal stenosis group. A total of 88 patients were included in the study, including 40 with degenerative spondylolisthesis patients. All patients received MR imaging. After conventional MR imaging, axial loading was applied by using an external commercially available nonmagnetic compression device. The DCSA was measured from the L2-3 to L5-S1 on the axial image. The measurement was performed three times and the mean value was calculated and used for analysis in this study. Results indicated that a >15mm² change in the DCSA was found in 8 patients (16.7%) in the spinal stenosis group and 25 patients (62.5%) in the degenerative spondylolisthesis group. In the degenerative spondylolisthesis group, patients with a >15mm² change had a significantly larger DCSA on conventional MR imaging ($58 \pm 26\text{mm}^2$) than those with a <15mm² change ($41 \pm 18\text{mm}^2$) ($p=0.028$), while the axial loaded MR imaging showed no significant difference between the patients with a >15 and a <15mm² change in the DCSA ($p=0.897$). The authors conclude that DCSA in patients with degenerative spondylolisthesis is more likely to be decreased by axial loading than in those with spinal stenosis. Axial loaded MRI may be a more useful tool to provide valuable imaging findings for the assessment of spinal canal narrowing in patients with degenerative spondylolisthesis than those with spinal stenosis. In critique, use of a 15mm² criterion as significant change in DCSA is not a universally accepted diagnostic standard; therefore, this study has been downgraded from Level II to III. This study provides Level III diagnostic evidence that axially loaded MRI may reveal more severe stenosis in patients with degenerative spondylolisthesis than might be apparent on conventional MRI.

Future Directions for Research

The work group recommends prospective, appropriately powered studies to better assess the utility of dynamic MRI and/or CT myelography in the diagnostic testing for degenerative spondylolisthesis.

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B. Outcome Measures for Medical/Interventional and Surgical Treatment

Original Guideline Question:

What are the appropriate outcome measures for the treatment of degenerative lumbar spondylolisthesis?

An updated literature search was not conducted. For more information on appropriate outcome measures for degenerative lumbar spondylolisthesis, the North American Spine Society has a publication entitled *Compendium of Outcome Instruments for Assessment and Research of Spinal Disorders*. To purchase a copy of the Compendium, visit https://webportal.spine.org/Purchase/ProductDetail.aspx?Product_code=68cdd1f4-c4ac-db11-95b2-001143edb1c1.

For additional information about the Compendium, please contact the NASS Research Department at nassresearch@spine.org.

C. Medical and Interventional Treatment

An updated systematic review of the literature yielded no studies to adequately address any of the medical/interventional treatment questions from the original guideline posed below:

- What is the role of pharmacological treatment in the management of degenerative lumbar spondylolisthesis?
- What is the role of physical therapy/exercise in the treatment of degenerative lumbar spondylolisthesis?
- What is the role of manipulation in the treatment of degenerative lumbar spondylolisthesis?
- What is the role of ancillary treatments such as bracing, traction, electrical stimulation and transcutaneous electrical stimulation (TENS) in the treatment of degenerative lumbar spondylolisthesis?
- What is the long-term result (4+ years) of medical/interventional management of degenerative lumbar spondylolisthesis?

Results from the Spine Patient Outcomes Research Trial (SPORT), a research trial analyzing nonoperative and surgical treatment effects in patients with degenerative spondylolisthesis associated with spinal stenosis, are summarized below. Due to the uncontrolled nonoperative protocol, lack of nonoperative treatment details and high treatment cross-over rate of the SPORT Trial at 4 years, the work group is cautioned to use this trial as support for a recommendation for or against the role of long term efficacy of any specific medical/interventional treatment for the management of degenerative lumbar spondylolisthesis. However, given the paucity of nonoperative treatment evidence from the original and current guideline literature searches, the work group included the summary below as background information.

Weinstein et al^{1,2} compared the surgical and nonsurgical outcomes in patients enrolled in either a randomized or observational cohort of the Spine Patient Outcomes Research Trial (SPORT). All patients in the trial had neurogenic claudication or radicular leg pain with associated neurologic signs, spinal stenosis shown on cross-sectional imaging and degenerative spondylolisthesis shown on lateral radiographs obtained with the patient in a standing position. Investigators enrolled 304 patients in the randomized cohort and 303 in the observational cohort. Pre-enrollment nonoperative care was not specified, but included physical therapy (68%), epidural injections (55%), chiroprac-

tic care (25%), anti-inflammatory medications (63%) and opioid analgesics (30%). Going forward, the nonoperative protocol was “usual recommended care,” which included, at least, active physical therapy, education and counseling with instructions regarding home exercise, and nonsteroidal anti-inflammatory drugs if the patient could tolerate them. In the randomized cohort, 159 patients were assigned to surgery and 145 were assigned to nonsurgical treatment. Of the 145 patients assigned to receive nonoperative care, 54% underwent surgery by 4 years. In the observational cohort, 173 initially chose surgery and 130 initially chose nonsurgical care. Of the 130 patients who initially chose nonoperative treatment, 33% underwent surgery by 4 years. Patients were evaluated over 4 years using the SF-36 for bodily pain and physical function scores and the modified Oswestry Disability Index. Results indicated that patients enrolled in the nonoperative treatment group experienced modest improvement from baseline over a period of four years. In patients with neurogenic claudication, the SF-36 score improved 12.9 points, SF-36 physical function score improved 8.3 points, and the Oswestry Disability Index decreased 7.4 points. Additionally, results from a post hoc analysis of SPORT,³ analyzing whether the duration of symptoms (less than or more than one year) affect outcomes after the treatment of degenerative spondylolisthesis, suggest that symptom duration does not impact nonoperative or surgical treatment success for patients with this disease.

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Original Guideline Question: What is the role of injections for the treatment of degenerative lumbar spondylolisthesis?

There is insufficient evidence to make a recommendation for or against the use of injections for the treatment of degenerative lumbar spondylolisthesis. *New recommendation statement*

Grade of Recommendation: I (Insufficient Evidence)

New study retrieved from the updated literature search:

Klessinger et al⁴ conducted a retrospective case-series study of 40 patients to determine if radiofrequency neurotomy is an effective treatment option for patients with low back pain and degenerative spondylolisthesis. An electronic medical record system was used to identify all patients in a single spine center with a positive MRI diagnosis of degenerative spondylolisthesis who had received lumbar radiofrequency neurotomy during a 3-year period. Most of the patients (82.1%) were tested before the neurotomy with controlled medial branch blocks; the other patients only had single medial branch blocks before radiofrequency neurotomy. A radiofrequency neurotomy was only considered after positive testing (at least 80% pain relief). Injections were performed with fluoroscopic visualization using bupivacaine (0.25%). Patients had a mean age of 67.8 years, were mostly women, had Grade 1 or 2 spondylolisthesis according to Meyerding grades, and included in the analysis only if they had at least 3 months treatment follow-up. The authors did not uti-

lize a validated outcome measurement tool to evaluate treatment success. According to their criteria, treatment response was considered positive if at least a 50% reduction in pain was achieved. A pain reduction of at least 50% and satisfying results for the patients in the radiofrequency group for a minimum of 3 months was achieved in 26 patients (65%). Eight of these patients had a minimum of 50% pain relief; 18 had a minimum of 80%. Eleven patients did not respond to radiofrequency neurotomy. In addition, 3 patients with a positive response to radiofrequency neurotomy, but with pain relief lasting only one month, were treated as negative successes. All patients with pain relief of 3 months had continuing pain relief at a mean follow-up of 18.6 months. This study provides level IV therapeutic evidence that degenerative facet joints represent one possible pain generator in patients with degenerative spondylolisthesis. Radiofrequency neurotomy may lead to pain reduction in a subset of patients with degenerative spondylolisthesis who have symptomatic facet joint pain diagnosed by controlled medial branch nerve blocks.

Medical/interventional treatment for degenerative lumbar spondylolisthesis, when the radicular symptoms of stenosis predominate, most logically should be similar to treatment for symptomatic degenerative lumbar spinal stenosis. *Consensus Statement maintained from original guideline*

Work Group Consensus Statement

Treatment recommendations and the supporting evidence are available in the NASS clinical guideline *Diagnosis and Treatment of Degenerative Lumbar Spinal Stenosis* (2011)⁵ available on the NASS website at www.spine.org.

Future Directions For Research

The work group identified the following suggestions for future studies which would generate meaningful evidence to assist in further defining the role of medical treatment for degenerative lumbar spondylolisthesis.

Recommendation #1:

Future outcome studies of degenerative lumbar spondylolisthesis should include results specific to each of the medical/interventional treatment methods, presenting results stratified by patient symptomatology (eg, axial back pain only, combination of axial back pain and radiculopathy).

Recommendation #2:

Although the review was devoid of studies examining the benefits of physical therapy with a directional preference (eg, avoiding extension) in patients with degenerative lumbar spondylolisthesis, this appears to be an area of growing interest. Ac-

cordingly, the work group suggests that a randomized controlled study comparing the benefits of physical therapy with directional preference versus non-preferential therapy for the treatment of degenerative lumbar spondylolisthesis would be useful. Ideally the directional preference study would also address inter-rater reliability as there is some evidence in low back pain literature that clinician training in mechanical diagnosis and treatment affects the clinician's ability to identify directional preference and symptomatic patterns within the exam.⁶⁻⁷

Recommendation #3:

The work group recommends the undertaking of large multicenter registry database studies with long term follow-up evaluating the outcomes of various medical/interventional treatments for the management of degenerative lumbar spondylolisthesis.

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D. Surgical Treatment

Original Guideline Question:

Does surgical decompression alone improve surgical outcomes in the treatment of degenerative lumbar spondylolisthesis compared to medical/interventional treatment alone?

Direct surgical decompression may be considered for the treatment of patients with symptomatic spinal stenosis associated with low grade degenerative lumbar spondylolisthesis whose symptoms have been recalcitrant to a trial of medical/interventional treatment. *Updated recommendation statement*

Grade of Recommendation: C

Study obtained from updated literature search:

Murat et al¹ conducted a prospective case series of 84 patients with degenerative spondylolisthesis to evaluate the efficacy of bilateral decompression using a unilateral approach. Patients had a mean age of 62 years old, had lower back pain with or without sciatica, neurogenic claudication that had not improved after at least 6 months of conservative treatment and a radiological diagnosis of Grade I degenerative spondylolisthesis and lumbar stenosis. The surgical technique involved the midline approach, with special attention given to maintaining stability of the supraspinous ligaments and spinous processes. Patients were followed for a minimum of 24 months and evaluated via Visual Analog Scale (VAS), Oswestry Disability Index (ODI) and Neurogenic Claudication Outcomes Score (NCOS). Results indicated that neural and dynamic slip percentages did not significantly change after surgery. Spinal canal size increased from 50.6 to 102.8 (p<0.001). The ODI decreased significantly in both the early and late follow-up evaluations, and good to excellent results were obtained in 64 cases. The NCOS demonstrated improvement in late follow-up results (p<0.001). Among all of the treated spine levels, 4 patients experienced accidental durotomy; however, these durotomies were not associated with noticeable postoperative morbidity. One patient experienced a wound infection requiring antibiotic therapy, and one patient required secondary fusion due to progressively increasing back pain. While this study doesn't directly address the efficacy of medical/interventional treatment alone, it does provide Level IV therapeutic evidence that bilateral decompression via a unilateral approach is a safe and effective treatment option for degenerative

spondylolisthesis patients whose symptoms did not improve after at least 6 months of conservative treatment.

Study included in original guideline:

Matsudaira et al² conducted a retrospective comparative study of patients with spinal stenosis and grade I degenerative spondylolisthesis. Eighteen patients underwent decompressive laminoplasty without fusion and 16 patients, who served as the control group, were treated conservatively. All patients received a trial of conservative therapy, which included medication and nerve blocks, for at least three months prior to surgery. At a minimum of 2 years follow-up, decompressive laminoplasty patients showed significantly better improvements in Japanese Orthopaedic Association (JOA) scores than the conservative treatment group (p<0.001). The L4-5 range of motion showed no change in the conservative treatment group, whereas it showed a significant decrease in the decompressive laminoplasty group (9.1±4.5 to 9.1±4.3 vs. 11.1±3.8 to 9.3±4.0, p=0.0443). The L4-5 angle on flexion also showed no change in the conservative treatment group, whereas posterior enlargement tended to decrease in the decompressive laminoplasty group (p=0.0671). In critique of this study, the sample size was modest, particularly considering there were only 16 patients in the medical/interventional group. This paper provides Level III therapeutic evidence that decompressive surgery alone in the form of a decompressive laminoplasty results in better outcomes than conservative treatment in patients with spinal stenosis and Grade I degenerative spondylolisthesis.

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There is insufficient evidence to make a recommendation for or against the use of indirect surgical decompression for the treatment of patients with symptomatic spinal stenosis associated with low grade degenerative lumbar spondylolisthesis whose symptoms have been recalcitrant to a trial of medical/interventional treatment.

Maintained from original guideline

Grade of Recommendation: I (Insufficient Evidence)

The updated literature search did not retrieve new evidence to support a recommendation for the use of indirect surgical decompression over medical/interventional treatment in patients with spinal stenosis and low grade degenerative lumbar spondylolisthesis. The Anderson study, included in the original guideline, was the only study retrieved that addressed the clinical question and is summarized below.

Study included in original guideline:

Anderson et al³ performed a subgroup analysis of 75 patients with Grade I degenerative spondylolisthesis who were originally included in the pivotal randomized controlled trial comparing the X-STOP device and medical/interventional treatment for spinal stenosis with neurogenic claudication that was relieved by flexion and sitting. Although examined prospectively, this subgroup was not appropriated to surgical and medical/interventional treatment in a truly randomized fashion. Forty-two patients had the X-STOP device placed, while 33 had medical/interventional treatment that included at least one epidural steroid injection, medications and physical therapy as needed. Only 70 of 75 patients had a minimum of 2-year follow-up. Of patients in the X-STOP group, 63% had significant improvements in the Zurich Claudication Questionnaire (ZCQ) score, while 12% in the medical/interventional group had significant improvements. In critique of this study, although labeled by the authors as a randomized controlled trial, it was not such for patients with degenerative spondylolisthesis. Patient numbers were relatively low. In support of their findings, there was a low attrition rate (7% at 2-year follow-up). Furthermore, the investigators utilized a validated outcome instrument, the ZCQ. This study offers Level III therapeutic evidence that an interspinous distraction device that provides indirect decompression leads to better outcomes in patients with spinal stenosis and Grade I degenerative spondylolisthesis than does medical/interventional treatment. Although use of the interspinous spacers in the setting of listhesis has been associated with high complication rates.^{4,5}

Future Directions for Research

Due to the lack of clarity of the ideal candidate for decompression alone, a large scale randomized controlled trial may be logistically and ethically difficult to perform. The work group acknowledges that previously published high profile studies (SPORT trials) demonstrated the intrinsic difficulties in conducting RCTs

comparing surgical to medical/interventional treatment in the North American patient population. It is unlikely that higher quality data are achievable for the comparison of surgical and medical/interventional treatment.

A greater number of nonindustry-sponsored, independent, retrospective or prospective studies need to be done to further investigate a potentially effective and minimally invasive means (interspinous spacers) of decompressing the spinal canal in patients with symptomatic spinal stenosis and degenerative lumbar spondylolisthesis.

In addition, with increased focus on and use of data registries, the work group recommends the undertaking of large multi-center registry database studies with long term follow-up evaluating the outcomes of both surgical and medical/interventional treatment outcomes in the management of degenerative lumbar spondylolisthesis.

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Original Guideline Question:

Does the addition of lumbar fusion, with or without instrumentation, to surgical decompression improve surgical outcomes in the treatment of degenerative lumbar spondylolisthesis compared to treatment by decompression alone?

Surgical decompression with fusion is suggested for the treatment of patients with symptomatic spinal stenosis and degenerative lumbar spondylolisthesis to improve clinical outcomes compared with decompression alone. *Maintained from original guideline with minor word modifications*

Grade of Recommendation: B

For symptomatic single-level degenerative spondylolisthesis that is low-grade (<20%) and without lateral foraminal stenosis, decompression alone with preservation of midline structures provide equivalent outcomes when compared to surgical decompression with fusion. *New recommendation statement*

Grade of Recommendation: B (Suggested)**Studies obtained from updated literature search:**

Aihara et al¹ conducted a prospective, comparative study of 50 consecutive patients to compare decompression with fusion to microendoscopic decompression (MED) for the treatment of degenerative lumbar spondylolisthesis. The first 17 patients underwent decompression with fusion and the next 33 patients underwent MED. In the fusion group, 14 patients had slippage at L4 and 3 patients had slippage at both L3 and L4. In the MED group, 21 patients had slippage at L4, 7 patients had slippage at L3, one patient at L5, and 4 patients at both L3 and L4. Before the operation, plain radiographs of the lumbosacral spine were taken in all patients to measure the intervertebral angle between the adjacent vertebral end-plates at the operative level as seen on the lateral flexion-extension radiographs and to measure the percentage of slipping at the level of the slip. These radiographs were repeated at follow-up, which ranged from 25 to 40 months for both groups. Clinical outcomes were also evaluated using the Japanese Orthopaedic Association Back Pain Evaluation Questionnaire (JOABPEQ), which consists of 5 functional scores selected from the Roland Morris Disability Questionnaire and SF-36. Operation time, blood loss and postoperative hospitalization were significantly less in the MED group ($p=0.0000431$, $p=0.00000859$, $p=0.00141$, respectively). As measured by the JOABPEQ, the degrees of improvement for low-back pain, lumbar function, walking ability, social life function and mental

health were greater in patients in the MED group compared to the fusion group; however, the differences were not statistically significant between groups. Degree of improvement in lumbar function was significantly greater in the decompression with fusion group compared to the MED group in regard to the percentage of slipping in neutral position among those with over 20% slipping ($p=0.0396$). Although not statistically significant, degrees of improvement in low-back pain, walking ability, social life function and mental health were greater in the decompression and fusion group compared to the MED group among those with over 20% slippage. Postoperative complications included one patient with transient foot drop and 2 patients with pseudarthrosis in the decompression and fusion group and 2 patients with transient urinary retention in the MED group. No major internal complications or surgical site infections were observed. This study provides therapeutic Level II evidence that decompression with fusion and MED for the treatment of degenerative lumbar spondylolisthesis result in similar outcomes for lower grade slips. When the slippage exceeds 20%, posterior decompression and fusion with pedicular screws may be the preferred surgical treatment.

In a retrospective comparative study, Kleinstueck et al² examined whether the outcomes of surgery for degenerative lumbar spondylolisthesis varied depending on the predominant baseline symptoms and the treatment administered. A total of 213 pa-

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tients underwent surgical treatment including 56 with decompression alone and 157 with decompression and fusion. Patients were followed for 12 months and outcomes were evaluated using the multidimensional Core Outcome Measures Index (COMI) questionnaire. At 12 months, there was greater reduction in back pain, leg pain and neurological deficit in the decompression and fusion group compared to the decompression alone group ($p=0.04$). Using the global outcome measure of either “good” or “poor,” 86.2% of patients in the decompression and fusion group had a good outcome compared to 70.4% of patients in the decompression-only group ($p=0.01$). Multivariable regression analysis suggested that decompression and fusion was a significant predictor for the 12 month COMI and Global outcomes. An odds ratio of 2.6 was calculated favoring decompression and fusion over decompression alone. The level of back pain and leg pain, and the category of the main problem at baseline had no significant influence on outcome. There were no statistically significant differences in complication rates between the groups. In the decompression only group 7 of 56 patients experienced surgical complications, including 2 bleeding in spinal canal, 2 dura lesion, one wound infection, one continuing back pain and one wound dehiscence. In the decompression and fusion group, 14 of 157 experienced complications, including one bleeding in spinal canal, 3 bleeding outside spinal canal, 6 dural tears, 2 wound infections and 2 necrotic wounds. In critique of this study, there was a statistically significant difference in age between the two groups, with an average age of 73 years \pm 8 in the decompression alone group and 67.4 years \pm 9.4 in the decompression and fusion group ($p<0.0001$). Although multivariate regression analysis suggested that increased age was not an independent predictor of poor outcome, the favored results in the decompression and fusion group should be interpreted cautiously as the analysis may have not accounted for all variables associated with morbidity in older aged individuals. This study provides Level III therapeutic evidence that instrumented fusion and decompression may provide superior outcomes to decompression alone in patients under 70 years old regardless of baseline symptoms.

Park et al³ retrospectively compared the outcomes of patients undergoing either decompression alone or decompression with fusion and fixation for the treatment of degenerative spondylolisthesis. A total of 45 patients underwent surgical treatment after being unresponsive to conservative treatment for 3 or more months, including 20 unilateral laminectomy and bilateral decompression (ULBD) patients and 25 decompression and instrumented fusion patients. All patients had stable Grade I, single level degenerative spondylolisthesis with translation $<$ 5mm. Patients were followed for a minimum of 3 years and outcomes were assessed using the numeric rating scale (NRS) for back and leg pain, the Oswestry Disability Index (ODI), the physical component summary (PCS), the mental component summary (MCS), and Short Form 36 (SF-36). Radiological outcomes were analyzed by determining changes in slippage, disc height translation, and angular difference on simple and dynamic x-ray films. Results suggested that there was a statistically significant greater decrease in the mean NRS for back pain in the fusion group (6.6 ± 2.4 to 2.4 ± 1.88) compared to the ULBD group (2.8 ± 3.10 to 1.2 ± 2.20 , $p=0.0001$). However, it is important to note that fusion patients had much higher preoperative and postoperative back pain scores compared to ULBD patients; therefore, the sig-

nificance of this finding is questionable. There was no significant difference in the mean ODI, SF-36 PCS, SF-36 MCS and NRS of leg pain between the groups. Excellent or good outcomes occurred in 13 ULBD and 14 fusion group patients based on Odom's criteria. In the ULBD group, 3 patients had residual pain and 3 had recurrent pain. The 3 patients with residual pain had nonquantified preoperative foraminal narrowing. Complaints of recurrent pain occurred 1, 1.5 and 2 years after surgery. Those with recurrent pain had unilaterally more collapsed discs on the painful side on preoperative AP radiograph. In comparison, no patients in the fusion group had residual pain and 5 had recurrent pain and intermittent radiculopathy. Radiologically, the ULBD group showed a $2.1 \pm 3.10\%$ change in mean slippage, a 0.15 ± 1.58 mm change in mean translation, a 0.91 ± 4.48 degrees change in mean angular difference and a -1.83 ± 1.69 mm change in mean disc height. In the fusion the mean reductions in upper and lower disc heights were 1.38 ± 1.10 mm and 1.19 ± 0.80 mm, respectively. In critique, the sample size of this study was small and the diagnostic methods used for the initial diagnosis of degenerative lumbar spondylolisthesis were vaguely described; however, the group did not feel that these were sufficient reasons to downgrade the study. In conclusion, this study provides Level III therapeutic evidence that in patients with stable degenerative lumbar spondylolisthesis, results of unilateral laminectomy and bilateral decompression may be similar to instrumented fusion for functional outcomes and lower extremity pain scores.

Kim et al⁴ compared the cost effectiveness of decompression with and without instrumented fusion in patients undergoing surgical treatment for degenerative spondylolisthesis. The primary study outcome was the incremental cost/utility ratio (ICR) expressed as the differential cost per relative gain in quality-adjusted life-year (QALY). A total of 115 patients underwent surgery, including 57 in the decompression group and 58 in the decompression with fusion group. Patients were included in the study if postoperative data, including SF-6D health utility scores, hospital cost/case rates and revision rates were available for at least one year after surgery. A Markov Cost Model was developed for a 10-year period with a one-year cycle for a hypothetical cohort of 1,000 surgical candidates undergoing decompression only or decompression with fusion. Average costs for these surgeries over a period of 4 years was captured and calculated in the Markov model. The average cost used for the cohort simulation was \$18,161 per case for decompression with instrumented fusion and \$5,243 per case for decompression alone. All costs were represented in 2010 Canadian dollars. The authors suggest that for a specific subpopulation of degenerative lumbar spondylolisthesis patients (ie, those with leg-dominant pain and stable spondylolisthesis), decompression alone and decompression plus fusion are almost similar in clinical effectiveness with a slight advantage for fusion. However, this small advantage comes at a large cost (\$185,878/QALY gained compared with decompression alone) that makes it unfavorable in the context of health-care decision making with limited resources. Due to the limited clinical outcomes provided in the study's results, this study has been included to provide background support only and has been not assigned a level of evidence grade to provide support to the recommendation.

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Studies from original guideline:

Bridwell et al⁵ described a prospective, comparative study of 44 surgically treated patients with degenerative lumbar spondylolisthesis followed for a minimum of two years. Of the 44 patients, 9 underwent laminectomy alone, 10 had laminectomy and non-instrumented fusion and 24 had laminectomy and instrumented fusion (18 single-level, 6 two-level). Patients were radiographically assessed and a functional assessment was conducted by asking whether they felt their ability to walk distances was worse (-), the same (0) or significantly better (+). Of the 44 patients, 43 were followed for 2 years or more. The authors determined that instrumented fusion had higher fusion rates than noninstrumented fusion ($p=0.002$). The authors further observed greater progression of spondylolisthesis in patients treated with laminectomy alone (44%) and in laminectomy without instrumented fusion (70%) compared to patients who received laminectomy with instrumented fusion (4%, $p=0.001$). A higher proportion of the patients without slippage progression reported that they were helped by the surgery than those whose slippage progressed postoperatively ($p<0.01$). In critique, this was a small study in which selection bias entered into the randomization process, reviewers were not masked to patient treatment and validated outcome measures were not utilized. Because of these weaknesses, this potential Level II study was downgraded to Level III. This study provides Level III therapeutic evidence that instrumented fusion patients had less chance of progressive slippage postoperatively than laminectomy alone or noninstrumented fusions and a higher proportion of patients with stable or unchanged spondylolisthesis reported greater improvement after surgery.

Herkowitz et al⁶ conducted a prospective, comparative study of 50 patients with degenerative lumbar spondylolisthesis to determine if concomitant intertransverse process arthrodesis provided better results than decompression alone. Clinical outcomes were assessed using a rudimentary outcome scale (excellent, good, fair, poor) with a mean follow-up of 3 years. Preoperative and postoperative plain radiographs of the lumbosacral spine were also taken. The authors reported that of the 25 patients treated with decompression and fusion, 11 reported excellent results, 13 good, one fair and zero poor. Of the 25 patients treated with decompression alone, 2 reported excellent results, 9 good, 12 fair and 2 poor. Improved results in the patients who had an arthrodesis concomitantly with decompression were significant by the Fisher exact test ($p=0.0001$). The authors concluded that in patients who had a concomitant arthrodesis, the results were significantly better with respect to relief of low back pain and lower limb pain. In critique, this was a small study which did not utilize validated clinical outcome measures or describe baseline characteristics of the groups. Because of these weaknesses, this potential level II study was downgraded to Level III. This study offers Level III therapeutic evidence that decompression with arthrodesis in patients with degenerative lumbar spondylolisthesis provides significantly better relief of low back pain and leg pain than decompression alone.

Mardjetko et al⁷ performed a meta-analysis of primarily Level III studies. The objective of the study was to analyze the published data on degenerative spondylolisthesis to evaluate the feasibility of its use as a literature control to compare with the historical cohort pedicle screw study data. The authors conducted a

comprehensive literature search to identify studies published in English peer-reviewed journals between 1970 and 1993 addressing degenerative spondylolisthesis with radicular leg pain or neurogenic claudication. Inclusion criteria included a minimum of 4 cases reviewed and reporting of the primary outcome variable of fusion in articles in which this was part of the treatment. Clinical outcome variables of back pain, leg pain, function, neurogenic claudication and global outcome scores were recorded when available. A total of 25 papers representing 889 patients were accepted for inclusion. Twenty-one were retrospective, nonrandomized and uncontrolled. One paper was retrospective and nonrandomized, but compared 2 different treatments. Three prospective, randomized studies were included. The primary outcome variable, fusion, was determined by each author. The most constant clinical outcome variable reported was pain with 16 papers reporting pain only, 6 papers reporting pain and function, and 2 papers reporting patient-determined outcomes. Patient function was reported in 6 papers and referred to the presence or absence of neurogenic claudication. In addition to these clinical outcomes, four papers reported a global evaluation. Two used Kaneda's rating system and two used the Japanese Orthopedic Association (JOA) score. Excellent and good results were reassigned as satisfactory; poor results were classified as unsatisfactory. The authors reported that in the decompression alone category, 11 papers representing 216 patients accepted for inclusion in the decompression category. Sixty-nine percent of patients had a satisfactory outcome. The incidence of worsened postoperative slip was 31% but was not associated with a poorer clinical result in the majority of patients. In the category of decompression with fusion and no instrumentation, 6 papers qualified for inclusion. In one paper, only fusion data were broken out for the diagnosis of degenerative spondylolisthesis and were used just for this outcome variable. Ninety percent of the patients in this category had a satisfactory outcome; 86% achieved solid spinal fusion. With regard to clinical outcome, the difference between patients treated with decompression without fusion (69% satisfactory) and those treated with decompression and fusion without instrumentation (90% satisfactory) was statistically significant ($p<0.0001$). In the decompression with fusion and pedicle screws category, 5 studies met the inclusion criteria. Fusion status was analyzed in 101 patients. Eighty-five patients were analyzed with respect to clinical outcome. One paper did not separately analyze clinical data, but did so for fusion data; therefore, only fusion data were included. The proportionally weighted fusion rates for this group were 93%. When comparing the fusion without instrumentation group to the fusion with pedicle screw group, there was not a statistically significant increase in fusion rate ($p=0.08$). Analysis of the clinical outcomes reveals an 86% satisfactory rating for the pedicle screw group. This compares favorably to the 69% satisfactory rate in the decompression without fusion group ($p<0.0001$). In the anterior spinal fusion category, three papers presenting the results for 72 patients who received anterior spinal fusion for the treatment of degenerative spondylolisthesis were included. Pooling the data from these three studies yielded a 94% fusion rate with an 86% rate of patient satisfaction. The authors concluded that the meta-analysis results support the clinical impression that, in the surgical management of degenerative lumbar spondylolisthesis,

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spinal fusion significantly improves patient satisfaction. In critique of this study, only 3 Level II studies were reviewed and data was very heterogeneous. This paper offers Level III therapeutic evidence that the addition of fusion with or without instrumentation to decompression improves clinical outcomes.

Martin et al⁸ conducted a systematic review designed to identify and analyze comparative studies that examined the surgical management of degenerative lumbar spondylolisthesis, specifically the differences in outcomes between fusion and decompression alone, and between instrumented fusion and noninstrumented fusion. Relevant randomized controlled trials (RCTs) and comparative observational studies were identified in a comprehensive literature search (1966 to June 2005). The inclusion criteria required that a study be an RCT or comparative observational study that investigated the surgical management of degenerative lumbar spondylolisthesis by comparing:

1. fusion to decompression and/or
2. instrumented fusion to noninstrumented fusion.

A minimum one-year follow-up was required. Studies also had to include at least 5 patients per treatment group. A study was excluded if it included patients who had received previous spine surgery or patients with cervical injuries, spinal fractures, tumors or isthmic spondylolisthesis. A study was also excluded if it was not possible to analyze patients with degenerative spondylolisthesis separately from another included patient population or if it was not clearly a comparative study. Data from the included studies were extracted by 2 independent reviewers using a standard data abstraction sheet. The data abstraction sheet identified the following information:

1. patient population's age, sex, symptoms and degree of spondylolisthesis;
2. type of decompression, fusion, instrumentation, bone graft material, and preoperative and postoperative treatment;
3. study design and methodological quality using the Cochrane RCT/CCT/Crossover Studies Checklist, modified by the additional criterion that observational studies state the use of a consecutive series of patients; and
4. study outcomes.

The main abstracted outcomes were clinical outcome, reoperation rate and solid fusion status. An attempt was made to compare patient-centered, validated and disease-specific outcomes, complications and spondylolisthesis progression, but because of heterogeneity in reporting these outcomes in the primary studies, no pooled analysis could be performed on these outcomes. When appropriate, a study's clinical outcome rating scale was altered to match a dichotomous rating scale of "satisfactory" or "unsatisfactory" clinical outcome, and results were entered into Review Manager 4.2 for weighted grouped analyses. The authors reported that 8 studies were included in the fusion versus decompression alone analysis, including two RCTs. Limitations were found in the methodologies of both RCTs and most of the observational studies. Grouped analysis detected a significantly higher probability of achieving a satisfactory clinical outcome with spinal fusion than with decompression alone (relative risk, 1.40; 95% confidence interval, 1.04–1.89; $P < 0.05$). The clinical benefit favoring fusion decreased when analysis was

limited to studies where the majority of patients were reported to be experiencing neurologic symptoms such as intermittent claudication and/or leg pain. Six studies were included in the instrumented fusion versus noninstrumented fusion analysis, including three RCTs. The use of adjunctive instrumentation significantly increased the probability of attaining solid fusion (relative risk, 1.37; 95% confidence interval, 1.07–1.75; $P < 0.05$), but no significant improvement in clinical outcome was recorded (relative risk, 1.19; 95% confidence interval, 0.92–1.54). There was a nonsignificant trend towards a lower repeat operation rate in the fusion group compared with both decompression alone and instrumented fusion. The authors concluded there is moderate evidence that fusion may lead to a better clinical outcome compared with decompression alone. Evidence that the use of adjunctive instrumentation leads to improved fusion status and less risk of pseudarthrosis is also moderate. No conclusion could be made about the clinical effectiveness of instrumented fusion versus noninstrumented fusion. In critique of this study, it was a systematic review of studies ranging down to Level III, and is thus classified as a Level III systematic review. Limitations were found in the methodologies of all RCTs, specifically in the pseudorandomization, absence of masking and/or the lack of validated outcome measures to assess clinical outcomes. This paper offers Level III therapeutic evidence that fusion leads to a better clinical outcome compared with decompression alone and the use of adjunctive instrumentation leads to improved fusion status and less risk of pseudarthrosis. Their data does not demonstrate any difference in clinical outcomes between instrumented and noninstrumented fusions.

Matsudaira et al⁹ described a retrospective, comparative study of 55 patients with spinal stenosis and Grade I degenerative lumbar spondylolisthesis. Of the 55 patients, 20 underwent laminectomy plus posterolateral fusion and pedicle screw instrumentation (Group 1), 19 underwent laminoplasty alone (Group 2) and 16 refused surgery and received medical/interventional treatment (Group 3). One patient in each surgical group was lost to follow-up. Outcomes were assessed by the Japanese Orthopedic Association (JOA) score, along with radiographic evaluation at minimum 2-year follow-up. The authors reported that alleviation of symptoms was noted in the fusion and laminoplasty groups but not in the medical/interventional treatment group. No statistically significant difference in clinical improvement was noted between the fusion and laminoplasty groups. The percent slip increased significantly in groups 2 and 3, whereas spondylolisthesis was stabilized in Group 1. The authors concluded that decompression with preservation of the posterior elements can be useful in treating patients with symptomatic lumbar spinal stenosis resulting from Grade I degenerative spondylolisthesis. In critique of this study, the numbers were small, patients were not randomized and no clearly defined indications for specific treatment selections were included. This paper offers Level III therapeutic evidence that decompression with posterolateral fusion and instrumentation, as well as laminoplasty alone yield improved outcomes in the treatment of symptomatic lumbar spinal stenosis resulting from Grade I degenerative spondylolisthesis as compared with medical/interventional treatment alone.

Future Directions for Research

Because of the lack of clarity of the ideal candidate for decompression alone, a large scale randomized controlled trial may be logistically and ethically difficult to perform in comparison to decompression and fusion.

The work group recommends the undertaking of large multicenter registry database studies with long term follow-up evaluating the outcomes of various surgical techniques, including decompression with and without fusion, for the surgical treatment of degenerative lumbar spondylolisthesis. It will be important for these databases to be populated with comprehensive demographic and radiographic detail in order to appropriately distinguish various cohorts.

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New Guideline Question:

Does the addition of lumbar fusion, with or without instrumentation, to surgical decompression improve surgical outcomes in the treatment of degenerative lumbar spondylolisthesis compared to medical/interventional treatment alone?

Surgical decompression with fusion, with or without instrumentation, is suggested to improve the functional outcomes of single-level degenerative lumbar spondylolisthesis compared to medical/interventional treatment alone.

Grade of Recommendation: B

There is insufficient evidence to make a recommendation for or against efficacy of surgical decompression with fusion, with or without instrumentation, for treatment of multi-level degenerative lumbar spondylolisthesis compared to medical/interventional treatment alone.

Grade of Recommendation: I (Insufficient Evidence)

In a retrospective comparative study, Matsudaira et al¹ compared the surgical and medical management of Japanese patients undergoing treatment for Grade I lumbar degenerative spondylolisthesis. A total of 53 patients were included in the study, including 19 patients treated with decompression laminectomy with posterolateral fusion and pedicle screw instrumentation, 18 patients treated with decompression alone and 16 control patients treated with conservative therapy after refusing surgical treatment. All patients had undergone a trial of conservative therapy, which included medication and nerve blocks, for at least 3 months before being offered surgery. Clinical outcomes were evaluated according to the Japanese Orthopedic Association Score (JOA). At 2-years follow-up, the JOA score of subjective symptoms showed no significant improvement compared to baseline measurements in the control patients, but significant improvement in symptoms in the surgical groups ($p < 0.0001$). The total JOA score did not improve in the control group (17.3 pre vs 17.1 post), but significantly improved in the decompression and fusion group (14.1 pre vs 21.7 post, $p < 0.0001$) and the decompression only group (13.4 pre vs 23.4 post, $p < 0.0001$). The degree of improvement was significantly greater in the surgical groups compared to the control group ($p < 0.001$), but there were no significant differences in scores between the surgical groups. When evaluating radiographic findings, the slippage increased significantly in the decompression only and control groups compared to the decompression and instrumented fusion groups. The difference in percent slip between flexion and

extension showed little change in the decompression only and control group, but was almost eliminated in the decompression and instrumented fusion group. In critique, the diagnostic methods used to diagnosis degenerative spondylolisthesis are vaguely described, the medical/interventional treatment was not standardized, and the sample size was small. This study provides level III therapeutic evidence that patients with single level spinal stenosis due to Grade I degenerative spondylolisthesis show significantly greater alleviation of symptoms when treated with decompression and instrumented fusion compared to a control group.

Weinstein et al² evaluated the surgical and nonsurgical outcomes in patients enrolled in either a randomized or observational cohort of the Spine Patient Outcomes Research Trial (SPORT). All patients in the trial had neurogenic claudication or radicular leg pain with associated neurologic signs, spinal stenosis shown on cross-sectional imaging, and degenerative spondylolisthesis shown on lateral radiographs obtained with the patient in a standing position. Investigators enrolled 304 patients in the randomized cohort and 303 in the observational cohort. Treatment was standard decompressive laminectomy, with or without fusion, or usual nonsurgical care, which included at least physical therapy, education or counseling on home exercises, and nonsteroidal anti-inflammatory agents, if tolerated. In the randomized cohort, 6% underwent decompression only, 21% underwent fusion without instrumentation and 73% underwent fusion with instrumentation. In the observational

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cohort, 5% received decompression only, 21% received fusion without instrumentation, and 74% underwent fusion with instrumentation. In the randomized cohort, 159 patients were assigned to surgery and 145 were assigned to nonsurgical treatment. In the observational cohort, 173 initially chose surgery and 130 initially chose nonsurgical care. The one year cross-over rates were high in the randomized cohort (approximately 40% in each direction), but moderate in the observational cohort (17% to surgery and 3% to non-surgical care). Patients were evaluated over 2 years using the SF-36 for bodily pain and physical function scores and the modified Oswestry Disability Index. It is important to note that in the randomized cohort, only 6% received decompression only, 21% received fusion without instrumentation and 73% received fusion with instrumentation. Results suggest that there were no significant differences in treatment effects between the randomized and observational surgical cohorts. For the nonsurgical group, treatment effects at 2 years were 1.5 for SF-36 bodily pain (95% confidence interval [CI], -4.2 to 7.3; $P = 0.52$), 1.9 for physical function (95% CI, -3.7 to 7.5; $P = 0.71$), and 2.2 for the Oswestry Disability Index (95% CI, -2.3 to 6.8; $P = 0.68$). Combined treatment effects for the surgical groups at 2 years were 18.1 for SF-36 bodily pain (95% CI, 14.5 to 21.7), 18.3 for physical function (95% CI, 14.6 to 21.9), and -16.7 for the Oswestry Disability Index (95% CI, -19.5 to -13.9). The authors suggest that patients with degenerative spondylolisthesis and spinal stenosis treated surgically showed substantially greater improvement in pain and function after 2 years compared to nonsurgical patients.

In a follow-up analysis of SPORT, Weinstein et al³ reported the treatment effects after 4 years. An as-treated analysis combining the randomized and observational cohorts that adjusted for potential confounders demonstrated that the clinically relevant advantages of surgery that had been previously reported through 2 years were maintained at 4 years, with treatment effects of 15.3 (95% confidence interval, 11 to 19.7) for bodily pain, 18.9 (95% confidence interval, 14.8 to 23) for physical function, and -14.3 (95% confidence interval, -17.5 to -11.1) for the Oswestry Disability Index. In critique, conservative treatments were not controlled, there was high-cross over rates in the SPORT Trial, and some groups had less than 80% follow-up at 4 years. These 2 studies provide Level II therapeutic evidence that in patients undergoing treatment for degenerative spondylolisthesis, decompression and fusion provided greater improvement in pain, function and patient satisfaction outcomes compared to medical management after 2- and 4-years follow-up.

Park et al⁴ conducted a post hoc retrospective subgroup analysis of SPORT to compare multilevel spinal stenosis outcomes to single level spinal stenosis outcomes, including a subset of patients with spondylolisthesis, against those who did not have surgery ("usual nonoperative care"). Outcomes were measured by Bodily Pain and Physical Function scales of the Medical Outcomes Study 36-item Short-Form General Health Survey (SF-36) and the modified Oswestry Disability Index at 6 weeks, 3 months, 6 months, one year and 2 years. Secondary outcome measures included the stenosis bothersomeness index, leg pain bothersomeness, low back pain bothersomeness and patient satisfaction. In the degenerative spondylolisthesis group, only patients with one level of spondylolisthesis were included and

treatment included decompression with or without fusion or standard nonoperative care. A total of 607 degenerative spondylolisthesis patients were enrolled in the study, including 304 into the randomized cohort and 303 in the observational cohort. Of these groups, 328 patients received surgical treatment. The authors do not discuss the specific number of patients enrolled in the nonoperative care group; however, through deduction, one may assume that 279 patients were initially enrolled in this group. Results suggest that the surgical outcomes were significantly better at 2 years in the single-level degenerative spondylolisthesis patients compared to those with multilevel spinal stenosis. Surgical treatment demonstrated significant treatment improvement over nonoperative measures within each subgroup of degenerative spondylolisthesis patients. This study provides Level III therapeutic evidence that patients with concomitant degenerative spondylolisthesis and single-level stenosis have better surgical outcomes than those with additional levels of stenosis. In these patients, decompression and fusion of stenotic levels improves outcomes compared to nonoperative management.

Mardjetko et al⁵ performed a meta-analysis of literature from 1970-1993 to evaluate the outcomes of surgical fusion treatment for degenerative spondylolisthesis. The studies included in this analysis were primarily Level III or IV studies. Prior to undertaking the review, the authors identified a null hypothesis that posterior decompression with posterolateral spinal fusion (PLSF) performed with pedicular instrumentation demonstrates equivalent fusion rates and clinical outcomes to alternative techniques of PLSF without instrumentation or controlled instrumentation. In review of the articles, the authors accepted 11 papers for the decompression without fusion category representing 216 patients. Results from these surgical decompression procedures suggested that 69% of patients had a satisfactory outcome. Six papers, representing 74 patients, met inclusion for decompression with fusion without instrumentation. Results suggested that 90% of patients had a satisfactory outcome and 86% achieved a solid spinal fusion. Four papers, representing 138 patients, were included in the decompression with fusion with control device category with 90% of patients achieving a satisfactory outcome. In the decompression with fusion with pedicle screws category, including 5 studies representing 101 patients, 93% of patients had successful fusion rates. The pooling of three studies in the anterior spinal fusion category, representing 72 patients, suggested a 94% fusion rate with an 86% patient satisfaction rate. When comparing the pooled results, the authors found a statistically significant difference in satisfactory clinical outcomes between the decompression without fusion and decompression and fusion without instrumentation (69% vs. 90%, $p < 0.0001$), fusion rates between the fusion/no instrumentation group and fusion with control device group (86% vs. 96%, $p = 0.009$), and satisfactory outcome rates of the decompression without fusion compared to decompression with fusion with pedicle screws groups (69% vs. 86%, $p < 0.0001$). The authors suggest that in patients undergoing the surgical management of degenerative spondylolisthesis, spinal fusion significantly improves patient satisfaction and the adjunctive spinal instrumentation enhances fusion rates. In critique of this study, the groups were very heterogeneous for comparison purposes and the studies included

were primarily retrospective and of lower quality. In addition, this study doesn't evaluate the efficacy of fusion and decompression versus medical/interventional treatment for the management of degenerative lumbar spondylolisthesis. However, it does provide background information on the effectiveness of adding lumbar fusion to decompression procedures. This potential Level III study provides Level IV therapeutic evidence that the addition of fusion to decompression results in satisfactory outcomes and the use of adjunctive spinal instrumentation increases fusion success.

Surgical decompression with fusion, with or without instrumentation, has been shown to improve the functional outcomes of single-level degenerative spondylolisthesis in patients with a BMI > 30 compared to medical/interventional treatment alone with an understanding that the risk of surgical complications increases. Although this clinical question was not developed to address the impact of obesity (BMI > 30) on treatment outcomes, the work group felt it was important to include the findings below from a post hoc analysis of SPORT. As addressing this question was not the primary intent of the work group, the literature search was not designed to address obesity. The summary below is included for information purposes only.

In another post hoc retrospective subgroup analysis of SPORT, Rihn et al⁶ evaluated the impact of obesity on the treatment outcomes for lumbar stenosis and degenerative spondylolisthesis patients. In the cohort of degenerative spondylolisthesis patients, there were 376 patients with a BMI of less than 30 (non-obese) and 225 patients with a BMI more than 30 (obese). It is important to note that in addition to obesity, obese patients had a significantly higher incidence of comorbidities, including hypertension, diabetes, and stomach problems ($p < 0.001$). A higher proportion of obese patients underwent instrumented fusion and fewer underwent decompression alone compared to nonobese patients. The incidence of intraoperative complications was significantly lower in the obese patient group; however, there was a trend toward increase rate of wound infection in the obese patients compared to nonobese patients (5% vs. 1%, $p = 0.051$). At 4-year follow-up, there was a significantly higher rate of reoperation in the obese patient group compared to the nonobese group (20% vs. 11%, $p = 0.013$). At four year follow-up in the nonoperative group, obese patients had SF-36 physical function scores that worsened from baseline by a mean of 3.5 compared to a mean improvement of 13.9 points in the non-obese group ($p < 0.001$). The treatment effect for the SF-36 Physical Function score was significantly higher for the obese surgical patient group compared to nonoperative obese patient group (25.6 vs. 14, $p = 0.004$) suggesting that surgery has a significantly greater benefit over nonsurgical treatment of degenerative spondylolisthesis in obese patients. This study provides Level III therapeutic evidence that decompression and fusion in patients with BMIs greater than 30 with degenerative spondylolisthesis may prove beneficial due to the poor progress they make with nonoperative therapy. However, risk of infection and reoperation after four years is greater compared to nonobese surgical patients.

Future Directions for Research

The work group recommends the undertaking of large prospective studies or multicenter registry database studies with

long-term follow-up comparing the outcomes of various surgical techniques, including decompression with fusion (with or without instrumentation) to medical/interventional treatments for the management of single level and multi-level degenerative lumbar spondylolisthesis.

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*Original Guideline Question:***Does the addition of instrumentation to decompression and fusion for degenerative lumbar spondylolisthesis improve surgical outcomes compared with decompression and fusion alone?**

The addition of instrumentation is suggested to improve fusion rates in patients with symptomatic spinal stenosis and degenerative lumbar spondylolisthesis. Maintained from original guideline with minor word modifications

Grade of Recommendation: B

The addition of instrumentation is not suggested to improve clinical outcomes for the treatment of patients with symptomatic spinal stenosis and degenerative lumbar spondylolisthesis. Maintained from original guideline with minor word modifications

Grade of Recommendation: B (Suggested)

The updated literature search did not retrieve any new evidence that would provide additional support in addressing this clinical question; therefore, the work group maintains the above guideline recommendations from the original guideline.

Articles from original guideline:

Bridwell et al¹ described a prospective comparative study of 44 surgically treated patients with degenerative lumbar spondylolisthesis followed for a minimum of 2 years. Of the 44 patients, 9 underwent laminectomy alone, 10 had laminectomy and non-instrumented fusion and 24 had laminectomy and instrumented fusion (18 single-level, 6 two-level). Patients were radiographically assessed and a functional assessment was conducted by asking whether they felt their ability to walk distances was worse (-), the same (0) or significantly better (+). Of the 44 patients, 43 were followed for 2 years or more. The authors reported that instrumented fusion had higher fusion rates than noninstrumented fusion ($p=0.002$) and observed greater progression of spondylolisthesis in patients treated with laminectomy alone and laminectomy without instrumented fusion compared to patients who received laminectomy with instrumented fusion ($p=0.001$). A higher proportion of the patients without slippage progression reported that they were helped by the surgery than those whose slippage progressed postoperatively ($p<0.01$). In critique, this was a small study in which selection bias entered into the randomization process, reviewers were not masked to patient treatment and validated outcome measures were not utilized. Because of these weaknesses, this potential Level II study was downgraded to Level III. This study provides Level III therapeutic evidence that addition of instrumentation to fusion results

in higher fusion rates and subjective improvement in walking distance when compared with fusion alone.

Fischgrund et al² conducted a randomized comparative study of 76 consecutive patients with symptomatic spinal stenosis associated with degenerative lumbar spondylolisthesis who underwent posterior decompression and posterolateral fusion. Patients were randomized into a transpedicular fixation group or noninstrumented group with a study objective to determine whether instrumentation improves clinical outcomes and fusion rates. Outcomes were assessed at 2-year follow-up using a five-point visual analog scale (VAS) and an operative result rating (excellent, good, fair, poor) based on examiner assessment of pain and functional level. The authors reported that of the 76 patients included in the study, 68 (89%) were available at 2-year follow-up. Clinical outcome with a rating of excellent or good was achieved in 76% of instrumented patients and 85% of noninstrumented patients ($p=0.45$). Successful arthrodesis was achieved in 82% of instrumented versus 45% of noninstrumented patients ($p=0.0015$). The authors found that successful fusion did not correlate with clinical outcome ($p=0.435$). The authors concluded that for single-level degenerative lumbar spondylolisthesis, use of instrumentation may lead to a higher fusion rate, but clinical outcome showed no improvement in low back pain and lower limb pain with their nonvalidated outcome measures. In critique of this study, the follow-up may have been too short

to detect the effects of pseudarthrosis in this nonmasked study. Validated outcome measures were not utilized to assess clinical outcomes. Because of these weaknesses, this potential Level II study was downgraded to Level III. This study offers Level III therapeutic evidence that the addition of instrumentation to posterolateral fusion for the treatment of degenerative lumbar spondylolisthesis increases the likelihood of obtaining a solid arthrodesis, but does not correlate with improved clinical outcomes at 2-year follow-up.

Kimura et al³ described a retrospective, comparative study of 57 patients with Grade I or II L4-5 degenerative lumbar spondylolisthesis. Group A consisted of 28 patients who underwent decompression and posterolateral fusion without instrumentation. Group B was comprised of 29 patients who had decompression and posterolateral fusion with pedicle screw instrumentation. Following surgery, Group A was immobilized with bed rest and a cast for 4-6 weeks, whereas Group B was mobilized much more quickly. Outcomes were assessed using the Japanese Orthopedic Association (JOA) scores and radiographs with mean follow-up in Group A of 6 years and in Group B of 3 years. The authors indicated that patients in Group A (noninstrumented) reported 72.4% satisfaction rate, with an 82.8% fusion rate. Patients in Group B (instrumented) reported an 82.1% satisfaction rate, with a 92.8% fusion rate. The authors did not find any significant differences in outcomes between the 2 groups, except that Group B (instrumented) had less low back pain. In critique of this study, patients were not randomized and there was varying duration of follow-up between groups. Although there was a trend toward improved satisfaction and fusion rates with instrumentation, with the numbers available no significant difference was detected. This paper offers Level III therapeutic evidence of no significant benefit with the addition of instrumentation for L4-5 degenerative lumbar spondylolisthesis.

Mardjetko et al⁴ performed a meta-analysis of primarily Level III studies. The objective of the study was to analyze the published data on degenerative spondylolisthesis to evaluate the feasibility of its use as a literature control to compare with the historical cohort pedicle screw study data. The authors conducted a comprehensive literature search to identify studies published in English peer-reviewed journals between 1970 and 1993 addressing degenerative spondylolisthesis with radicular leg pain or neurogenic claudication. Inclusion criteria included:

1. a minimum of four cases reviewed, and
2. reporting of the primary outcome variable of fusion in articles in which this was part of the treatment.

Clinical outcome variables of back pain, leg pain, function, neurogenic claudication and global outcome scores were recorded when available. A total of 25 papers representing 889 patients were accepted for inclusion. Twenty-one were retrospective, nonrandomized and uncontrolled. One paper was retrospective and nonrandomized, but compared 2 different treatments. Three prospective, randomized studies were included. The primary outcome variable, fusion, was determined by each author. The most constant clinical outcome variable reported was pain with 16 papers reporting pain only, 6 papers reporting pain and function and 2 papers reporting patient-determined outcomes. Patient function was reported in 6 papers and referred to the presence or absence of neurogenic claudication. In addition to

these clinical outcomes, 4 papers reported a global evaluation. Two used Kaneda's rating system and two used the Japanese Orthopedic Association (JOA) score. Excellent and good results were reassigned as satisfactory; poor results were classified as unsatisfactory. In the decompression alone category, the authors reported 11 papers representing 216 patients were accepted for inclusion. Sixty-nine percent of patients had a satisfactory outcome. The incidence of worsened postoperative slip was 31%, but was not associated with a poorer clinical result in the majority of patients. In the category of decompression with fusion and no instrumentation, 6 papers qualified for inclusion. In one paper, only fusion data were broken out for the diagnosis of degenerative spondylolisthesis and were used just for this outcome variable. Ninety percent of the patients in this category had a satisfactory outcome; 86% achieved solid spinal fusion. With regard to clinical outcome, the difference between patients treated with decompression without fusion (69% satisfactory) and those treated with decompression and fusion without instrumentation (90% satisfactory) was statistically significant ($P < 0.0001$). In the decompression with fusion and pedicle screws category, 5 studies met the inclusion criteria. Fusion status was analyzed in a total of 101. Eighty-five patients were analyzed with respect to clinical outcome. One paper did not separately analyze clinical data, but did so for fusion data; therefore, only fusion data were included. The proportionally weighted fusion rates for this group were 93%. When comparing the fusion without instrumentation group to the fusion with pedicle screw group, there was not a statistically significant increase in fusion rate ($P = 0.08$). Analysis of the clinical outcomes reveals an 86% satisfactory rating for the pedicle screw group. This compares favorably to the 69% satisfactory rate in the decompression without fusion group ($P < 0.0001$). In the anterior spinal fusion category, three papers presenting the results for 72 patients who received anterior spinal fusion for the treatment of degenerative spondylolisthesis were included. Pooling the data from these 3 studies yielded a 94% fusion rate with an 86% rate of patient satisfaction. The authors concluded that the meta-analysis results support that spinal fusion significantly improves patient satisfaction in patients undergoing surgical treatment for degenerative lumbar spondylolisthesis. In critique of this study, only 3 Level II studies were reviewed and data was very heterogeneous. This paper offers Level III therapeutic evidence that addition of instrumentation to fusion does not result in improved clinical outcome or fusion rate.

Martin et al⁵ conducted a systematic review designed to identify and analyze comparative studies that examined the surgical management of degenerative lumbar spondylolisthesis, specifically the differences in outcomes between fusion and decompression alone, and between instrumented fusion and noninstrumented fusion. Relevant randomized controlled trials (RCTs) and comparative, observational studies were identified in a comprehensive literature search (1966 to June 2005). The inclusion criteria required that a study be an RCT or comparative observational study that investigated the surgical management of degenerative lumbar spondylolisthesis by comparing:

1. fusion to decompression and/or
2. instrumented fusion to noninstrumented fusion.

A minimum one-year follow-up was required. Studies also

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had to include at least 5 patients per treatment group. A study was excluded if it included patients who had received previous spine surgery, or patients with cervical injuries, spinal fractures, tumors or isthmic spondylolisthesis. A study was also excluded if it was not possible to analyze patients with degenerative spondylolisthesis separately from another included patient population, or if it was not clearly a comparative study. Data from the included studies were extracted by two independent reviewers using a standard data abstraction sheet which identified the following information:

1. patient population's age, sex, symptoms and degree of spondylolisthesis;
2. type of decompression, fusion, instrumentation, bone graft material, and preoperative and postoperative treatment;
3. study design and methodological quality using the Cochrane RCT/CCT/Crossover Studies Checklist, modified by the additional criterion that observational studies state the use of a consecutive series of patients; and
4. study outcomes.

Clinical outcome, reoperation rate and solid fusion status were the main outcomes evaluated. An attempt was made to compare patient-centered, validated and disease-specific outcomes, complications and spondylolisthesis progression, but pooled analysis could not be performed due to heterogeneity in how outcomes were reported. When appropriate, a study's clinical outcome rating scale was altered to match a dichotomous rating scale of "satisfactory" or "unsatisfactory," and these results were entered into Review Manager 4.2 for weighted group analysis. The authors reported that 8 studies were included in the fusion versus decompression alone analysis, including two RCTs. Limitations were found in the methodologies of both RCTs and most of the observational studies. Grouped analysis detected a significantly higher probability of achieving a satisfactory clinical outcome with spinal fusion than with decompression alone (relative risk, 1.40; 95% confidence interval, 1.04–1.89; $P < 0.05$). The clinical benefit favoring fusion decreased when analysis was limited to studies where the majority of patients were reported to be experiencing neurologic symptoms such as intermittent claudication and/or leg pain. Six studies were included in the instrumented fusion versus noninstrumented fusion analysis, including three RCTs. The use of adjunctive instrumentation significantly increased the probability of attaining solid fusion (relative risk, 1.37; 95% confidence interval, 1.07–1.75; $P < 0.05$), but no significant improvement in clinical outcome was recorded (relative risk, 1.19; 95% confidence interval, 0.92–1.54). There was a non-significant trend towards a lower repeat operation rate in the fusion group compared with both decompression alone and instrumented fusion. The authors concluded there is moderate evidence that fusion may lead to a better clinical outcome compared with decompression alone, and the use of adjunctive instrumentation may lead to improved fusion status and less risk of pseudarthrosis. Conclusions regarding the clinical effectiveness of instrumented versus noninstrumented fusion could not be made. In critique of this study, it was a systematic review of studies ranging down to Level III, and is thus classified as a Level III systematic review. Limitations were found in the methodologies of all RCTs, specifically in the pseudorandomiza-

tion, absence of masking and/or the lack of validated outcome measures to assess clinical outcomes. This paper offers Level III therapeutic evidence that the use of adjunctive instrumentation leads to improved fusion rates, but failed to show a statistically significant improvement in clinical outcomes.

Future Directions for Research

The work group recommends the undertaking of large prospective studies or multicenter registry database studies with long-term follow-up to compare the postoperative outcomes of decompression and fusion with and without adjunctive use of instrumentation in the management of degenerative lumbar spondylolisthesis.

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Original Guideline Question:

How do outcomes of decompression with posterolateral fusion compare with those for 360° fusion in the treatment of degenerative lumbar spondylolisthesis?

For the purposes of this guideline, the work group defined “360° fusion” as a procedure involving interbody fusion.

There is insufficient evidence to make a recommendation for or against the use of either decompression with posterolateral fusion or 360° fusion in the surgical treatment of patients with degenerative lumbar spondylolisthesis. *Maintained from original guideline*

Grade of Recommendation: I (Insufficient Evidence)

New article from updated literature search:

In a retrospective comparative study, Ha et al¹ evaluated the effects of posterior lumbar interbody fusion (PLIF) after posterolateral fusion (PLF) on patients undergoing surgical treatment for degenerative spondylolisthesis. Forty patients, who underwent single level decompression and posterior instrumentation at L4-5, were followed for at least 2 years. The patients were divided into 4 groups: the stable PLF group (S-PLF, n=13); the stable PLF with additional PLIF group (S-PLIF, n=11); the unstable PLF group (U-PLF, n=8); and the unstable PLF with additional PLIF group (U-PLIF, n=8). Clinical and radiographic comparisons were carried out between the S-PLF and S-PLIF groups and between the U-PLF and U-PLIF groups. The Visual Analog Scale (VAS) and Oswestry Disability Index (ODI) questionnaires were administered preoperatively and at the final follow-up to compare the severity of pain and its effect on the patients' lives. Radiographic assessments, including plain radiography with dynamic flexion and extension standing lateral radio-

graphs, were also taken. In the U-PLF group, the VAS decreased by 2.6%±1.9%, and in the U-PLIF group, the VAS decreased by 5.9%±1.8%; the difference between the groups was statistically significant (p=0.004). Thus, in the unstable group, the U-PLIF group had a significantly greater improvement in the VAS than the U-PLF group. In the U-PLF group, the ODI decreased by 22.0%±16.1%, and in the U-PLIF group, the ODI decreased by 42.3%±17.9%; the difference between the groups was statistically significant (p=0.032). In the unstable group, the U-PLIF group had a significantly higher improvement in the ODI than the U-PLF group. The degree of slip did not change between stable and unstable groups with the addition of PLIF; however, disc height did change significantly in both groups. This study suggests that preoperative segmental instability may be a criterion for determining whether an additional PLIF would be beneficial in the treatment of degenerative spondylolisthesis. In critique of this study, the sample size was small, initial diagnostic methods were vaguely described, and there was limited description of patient

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characteristics. Without statistical analysis comparing the differences of patient characteristics between groups, it is difficult to determine the impact of confounding on the outcomes. This potential Level III study provides Level IV therapeutic evidence that the addition of PLIF to unstable segments may improve the surgical outcome for degenerative spondylolisthesis and appears to improve disc height.

Article from original guideline:

Rousseau et al² conducted a retrospective comparative study of 24 consecutive patients undergoing decompression and transpedicular fixation to treat symptomatic degenerative lumbar spondylolisthesis. Of the 24 patients, 8 also underwent posterior lumbar interbody fusion (PLIF). Outcomes were assessed using the Beaujon scoring system with a mean follow-up of 2.87 years. The authors reported that the Beaujon score was improved in all 24 patients ($p < 0.001$) and fusion was successful in all cases. Preoperative leg pain and the addition of PLIF were significantly correlated with greater improvement ($\rho = 0.016$ and $\rho = 0.003$), respectively. The authors concluded that posterior decompression and fusion is successful in treating degenerative lumbar spondylolisthesis and that the additional circumferential fusion yields significant improvement in functional outcomes. In critique, this study was retrospective with a small sample size of nonrandomized patients. Of the 24 patients included, only 8 underwent PLIF. In addition, of the 24 patients included in the study, only 18 (75%) were available for follow-up beyond 2 years and it is unclear how many of the 8 PLIF patients remained in this subset. Because of these deficiencies, this potential Level III study was downgraded to Level IV. This study provides Level IV therapeutic evidence that posterior decompression and fusion is successful in treating degenerative lumbar spondylolisthesis and that additional circumferential fusion results in slightly better outcomes than posterior decompression and fusion alone.

Future Directions for Research

The work group identified the following suggestions for future studies which would generate meaningful evidence to assist in further evaluating the efficacy of surgical techniques, including posterolateral fusion and 360° fusion, for the treatment of degenerative lumbar spondylolisthesis.

Recommendation 1:

The work group recommends the undertaking of a retrospective analysis comparing instrumented posterolateral fusion to decompression with 360° (circumferential) instrumented fusion in patients with degenerative lumbar spondylolisthesis.

Recommendation 2:

The work group recommends the undertaking of large multicenter registry database studies with long term follow up comparing the outcomes of surgical treatments, including instrumented posterolateral fusion to decompression with 360° (circumferential) instrumented fusion, in patients with degenerative lumbar spondylolisthesis.

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This clinical guideline should not be construed as including all proper methods of care or excluding or other acceptable methods of care reasonably directed to obtaining the same results. The ultimate judgment regarding any specific procedure or treatment is to be made by the physician and patient in light of all circumstances presented by the patient and the needs and resources particular to the locality or institution

*New Guideline Question:***Does 360° fusion with decompression lead to better outcomes versus 360° fusion without decompression for treatment of degenerative lumbar spondylolisthesis?**

No evidence was found to address this question. Due to the paucity of literature addressing this question, the work group was unable to generate a recommendation to answer this question.

Future Directions For Research

The work group recommends the undertaking of a registry database study that would provide outcomes data comparing 360° fusion with and without decompression in patients undergoing surgical treatment for degenerative lumbar spondylolisthesis.

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*New Guideline Question:***Do flexible fusions improve outcomes in the treatment of degenerative lumbar spondylolisthesis compared to nonoperative treatment?**

For the purposes of this guideline, the work group defined “flexible fusion” as a procedure involving dynamic stabilization without arthrodesis.

No evidence was found to address this question. Due to the paucity of literature addressing this question, the work group was unable to generate a recommendation to answer this question.

Although no studies were found to directly address this question, the work group included the case-series summaries below as background support to demonstrate the safety and effectiveness of flexible fusions in single-armed studies.

Payyazi et al¹ conducted a prospective case series study of 6 patients with degenerative spondylolisthesis to evaluate the efficacy of the Dynesys posterior dynamic stabilization system. Patients were followed over 2 years and outcomes were evaluated by VAS, ODI and radiographic measurements. Results suggest that the stabilization system led to significant decreases in VAS and ODI clinical scores after stabilization ($p < 0.05$). Over the 24-month follow-up period, mean flexion, extension, left, and right lateral bending of the motion segments were noted to be 1.0°, 2.4°, 0.6° and 0.6° or less, respectively. There were no statistically significant changes in the degree of motion. The authors suggest that the Dynesys dynamic instrumentation system stabilizes degenerative spondylolisthesis and may prevent further progression of listhesis.

In a retrospective case series, Lee et al² evaluated the outcomes of 65 patients who underwent surgical treatment with an interspinous soft stabilization (ISS) and tension band system for Grade I degenerative spondylolisthesis. Patients were evaluated via VAS, ODI and radiographic assessment after a mean follow-up of 72.5 months. The patients were divided according to the postsurgical clinical improvements into the optimal ($n = 44$) and suboptimal groups ($n = 21$), and the radiological intergroup differences were analyzed. Multiple linear regression analysis was performed to determine the impact of the radiological factors on the clinical outcomes. Radiologically, total lumbar lordosis (TLL) and segmental lumbar lordosis (SLL) were significantly improved only in the optimal group, resulting in significant intergroup differences in TLL ($p = 0.023$), SLL ($p = 0.001$), and the L1 tilt ($p = 0.002$). All of these measures were closely associated with postoperative segmental lumbar lordosis, which also was the most influential radiological variable for the clinical parameters. The study results suggest that dynamic stabilization outcomes were correlated with radiographic improvement and may be an alternative to fusion surgery for Grade I degenerative

spondylolisthesis patients who do not require fixation or reduction.

Onda et al³ conducted a retrospective case series of 31 patients who underwent decompression and stabilization with a graf stabilization system. Of the 31 patients enrolled, 23 had a diagnosis of degenerative spondylolisthesis. Patients were follow-up over 5 years and outcomes were assessed using Japanese Orthopedic Association (JOA) and ODI outcome measures. Results indicated that there was significantly better clinical improvement from preoperatively to postoperatively in JOA and VAS scores (6.1 preoperatively vs 2.2 postoperatively and 14.8 preoperatively vs 23.3 postoperatively, respectively). In patients with degenerative spondylolisthesis, the Graf System resulted in motion inhibition only in flexion ($p < 0.05$). The mobility indicating a difference in the spondylolisthesis between flexion and extension was significantly reduced in relation to the inhibition of that in flexion ($p < 0.05$). Study results indicate that Graf stabilization may be associated with satisfactory clinical outcomes in patients undergoing surgery for degenerative spondylolisthesis.

Schaeren et al⁴ conducted a prospective case series to evaluate whether posterior dynamic stabilization in situ with Dynesys can maintain enough stability to prevent progression of spondylolisthesis in long-term follow-up. Patients were followed-up at a mean of 52 months using VAS and radiographic measurements. Results indicated that pain on VAS and walking distance significantly improved ($p < 0.001$) at 2 years and remained unchanged at 4 years follow-up. Radiographically, spondylolisthesis did not progress and the motion segments remained stable. At 2 year follow-up, anterior and posterior disc height had significantly increased from 2.9 to 3.5mm ($p = 0.02$). At 4 years follow-up, anterior and posterior disc height did not show significant alteration ($p = 0.02$ and 0.05). At 4 years follow-up, 47% of the patients showed some degeneration at adjacent levels. Overall, patient satisfaction remained high as 95% would undergo the same procedure again. Study results suggest that dynamic stabilization with Dynesys may be associated with satisfactory clinical and radiographic outcomes after 4 years in patients undergoing surgery for degenerative spondylolisthesis.

This clinical guideline should not be construed as including all proper methods of care or excluding or other acceptable methods of care reasonably directed to obtaining the same results. The ultimate judgment regarding any specific procedure or treatment is to be made by the physician and patient in light of all circumstances presented by the patient and the needs and resources particular to the locality or institution

In a prospective case series of 26 patients, Schanake et al⁵ evaluated whether elastic stabilization with the Dynesys system provided enough stability to prevent further progression of spondylolisthesis as well as instability after decompression for spinal stenosis with degenerative spondylolisthesis. Minimum follow-up was 2 years. Results indicated that the mean pain score on VAS decreased significantly from 80 to 23 (range 0–82) ($p < 0.00001$). The mean walking distance improved significantly from 250 m to over 1000 m (range 100 to infinite) ($p < 0.00001$). Radiographically, overall progression of spondylolisthesis at follow-up was 2.1% and was not significant ($p=0.056$). Study results suggest that the use of dynamic stabilization with Dynesys may be associated with satisfactory clinical and radiographic outcomes after 2 years in patients undergoing surgery for degenerative spondylolisthesis.

Future Directions for Research

The work group identified the following suggestions for future studies which would generate meaningful evidence to assist in further evaluating the role of flexible fusions and medical/interventional treatment in the management of degenerative lumbar spondylolisthesis patients.

Recommendation 1:

The work group recommends the undertaking of large multicenter registry database studies with long term follow up comparing the outcomes of surgical treatment, including flexible fusions, to medical/interventional treatment in the management of degenerative lumbar spondylolisthesis patients.

Recommendation 2:

The work group recommends the undertaking of a prospective study comparing long term outcomes of flexible fusions to medical/interventional management in the treatment of degenerative lumbar spondylolisthesis.

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New Guideline Question:

Does the use of interspinous spacers in the treatment of degenerative lumbar spondylolisthesis improve outcomes compared to medical/interventional treatment?

There is insufficient and conflicting evidence to make a recommendation for or against the efficacy of interspinous spacers versus medical/interventional treatment in the management of degenerative lumbar spondylolisthesis patients.

Grade of Recommendation: I (Insufficient Evidence)

Although one study showed clinical benefit of using interspinous spacers over medical/interventional treatments, 2 studies demonstrated that there may be increased risk of spinous process fracture and reoperation with the surgical use of interspinous spacers.

Anderson et al¹ reported subgroup analysis data from a large, randomized controlled trial dealing with spinal stenosis. The subgroup analysis evaluated 75 patients with Grade I degenerative spondylolisthesis and spinal stenosis with neurogenic claudication who were treated with either the X-STOP device or medical/interventional treatment. The medical/interventional group received at least one epidural steroid injection, medications and physical therapy. Outcomes were evaluated by the Zurich Claudication Questionnaire (ZCQ), SF-36 and radiographic assessment. At 2-years follow-up, there were statistically significant improvements in the ZCQ score and patient satisfaction in those treated with X-STOP; however, there were no statistically significant improvements in the medical/interventional group. Overall success occurred in 63.4% of X-STOP device treated patients compared to only 12.9% of medical/interventional patients ($p < 0.05$). In critique of this study, the cohort of 75 patients was derived from a larger pool of candidates with spinal

stenosis (and not necessarily spondylolisthesis) that were randomized into the X-STOP treatment group and medical/interventional group. Additionally, medical treatments administered to the medical/interventional patients were not controlled. Due to these limitations, this study has been downgraded from Level II to III. This potential Level II study offers Level III therapeutic evidence that interspinous distraction device for indirect decompression may lead to better outcomes at 2 years in patients with spinal stenosis and Grade I degenerative spondylolisthesis compared to nonoperative treatment.

In a prospective case series, Kim et al² examined the risk factors associated with early spinous process fracture after interspinous process spacer surgery (IPS). Of the 38 total patients included in the study, 20 patients had degenerative spondylolisthesis, which was observed prior to surgery. Postoperatively, patients underwent repeat CT imaging within 6 months of surgery and serial radiographs at 2 weeks, 6 weeks, 3 months, 6 months and one year. Eleven of 20 patients (55%) with spondylolisthesis experienced a fracture within 6 months of surgery. The 18 patients without spondylolisthesis did not experience a fracture. This difference was strongly significant ($p = 0.0001$; OR, 29.00; 95% CI, 4.11–infinity). The authors concluded that degenerative spon-

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dyololsthesis appears strongly associated with the occurrence of spinous process fracture after IPS surgery. While the Anderson study discusses the benefits of using IPS, this study suggests that there are risks. In critique, this single-armed study's sample size was small. This study provides Level IV therapeutic evidence that IPS placement increases the risk of spinous process fracture when used in degenerative spondylolisthesis patients.

In a retrospective case series, Verhoof et al³ examined the effectiveness of the X-STOP interspinous distraction device in the treatment of symptomatic degenerative lumbar spinal stenosis caused by degenerative spondylolisthesis. A cohort of 12 consecutive patients were evaluated over a period of two years. The primary endpoint of this study was secondary surgical intervention of the lumbar spine. Results suggested that reoperation for recurrent symptoms was performed in 7 patients (58%) within 24 months. The authors suggest that the X-STOP interspinous distraction device showed an extremely high failure rate, defined as surgical reintervention, after short-term follow-up in patients with spinal stenosis caused by degenerative spondylolisthesis. X-STOP is not recommended for the treatment of lumbar spinal stenosis with degenerative spondylolisthesis and is considered a contraindication in these patients. This study provides Level IV therapeutic evidence that the use of X-STOP in unstable degenerative spondylolisthesis patients may result in a high rate of short-term reoperations.

Future Directions for Research

The work group identified the following suggestions for future studies which would generate meaningful evidence to assist in further evaluating the role of interspinous spacers and medical/interventional treatment in the management of degenerative lumbar spondylolisthesis patients.

Recommendation 1:

The work group recommends the undertaking of large multicenter registry database studies with long term follow up comparing the outcomes of surgical treatment with interspinous spacers to medical/interventional treatment in the management of degenerative lumbar spondylolisthesis patients.

Recommendation 2:

The work group recommends that the future analysis of interspinous spacers in the treatment of single level degenerative spondylolisthesis should include a group treated with decompression with or without fusion in addition to medical management as patients have benefited from this therapy.

Recommendation 3:

The work group recommends that future analysis of interspinous spacers should include longer term outcome analysis to investigate whether complication rates fall within acceptable limits.

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Original Guideline Question:

What is the role of reduction (deliberate attempt to reduce via surgical technique) with fusion in the treatment of degenerative lumbar spondylolisthesis?

There is insufficient evidence to make a recommendation for or against the use of reduction with fusion in the treatment of degenerative lumbar spondylolisthesis. Revised wording, but Recommendation Grade maintained

Grade of Recommendation: I (Insufficient Evidence)

The updated literature search did not retrieve new evidence to support a recommendation for or against the use of reduction with fusion; therefore, the work group maintains the original guideline's "Insufficient Recommendation" grading. Although reduction and fusion can be performed, the evidence reviewed does not substantiate any improvement in clinical outcomes and reduction may increase the risk of neurological complications.

Studies included in original guideline:

Bednar et al¹ described a retrospective consecutive case series of 56 patients with degenerative spondylolisthesis and symptoms of back pain and/or stenosis treated with bilateral foraminotomies, reduction and instrumented fusion. The procedure had a 7% major complication rate. Outcomes measures were the Visual Analog Scale (VAS), Oswestry Disability Index (ODI) and radiographs. Of the 56 patients, 42 were available for follow-up at an average of 33 months (range 14-53 months). Of the 42 patients, 82% experienced relief of leg pain, 75% experienced improvement in low back pain, and 77% experienced significant improvement in their ODI scores (average preoperatively of 56% versus average of 26% postoperatively). Only 38 patients were available for late review of X-ray studies at an average of 33 months. Average preoperative slip was 16%, and of the 38 patients available at late review, 75% had perfect reduction. Of the 38 patients, 16% had minor loss of reduction. Outcome measures (VAS and ODI) were not compared based on the presence or absence of a perfect reduction. In critique, this is a moderately small, retrospective review of a consecutive case series of surgical patients from one surgeon with no comparison group and with less than 80% follow-up. This paper offers Level IV therapeutic evidence that limited bilateral foraminotomies with instrumented reduction and fusion for symptomatic degenerative spondylolisthesis and stenosis is as effective as laminectomy and in situ fusion without as much operative exposure of neural structures.

Lee et al² reported on a prospective case series of 52 consecutive patients with objectively defined unstable degenerative spondylolisthesis who underwent reduction and fusion without

decompression using the Fixater Interne pedicle fixation device. Forty-seven patients had low back pain, 40 patients had radicular pain and 36 patients had intermittent claudication. Follow-up was at a minimum of 12 months (range 12-16 months). Subjective measurement of success was classified as excellent, good, fair and poor for pain. An excellent or good outcome was considered satisfactory and a fair or poor outcome was considered unsatisfactory. A satisfactory outcome (excellent and good results) occurred in 42 of 47 patients with complaints of back pain, 37 of 40 patients with radicular pain and 31 of 36 patients with claudication. The authors commented that only 2 groups, based on their findings, are not good candidates for this procedure: (1) those with a positive Lasegue's sign and (2) those with borderline instability. In critique of this study, this was a prospective case series, which lacked a comparison group, and validated outcome measures were not used. This paper presents Level IV therapeutic evidence that patients with degenerative spondylolisthesis who do not have borderline instability or a positive Lasegue's sign can undergo reduction, fixation and fusion without decompression.

Sears et al³ reviewed a prospective case series of 34 patients with degenerative spondylolisthesis who underwent decompression, reduction, internal fixation and fusion. Twenty-five patients had a one-level fusion and 9 patients had a 2-level fusion. Of the 34 patients, 32 had surgery to relieve leg pain. Outcome measures included the VAS, Low Back Pain Outcome Score (LBOS), SF-12 and patient satisfaction questionnaire. Preoperative and postoperative measurement of slip by radiograph were also recorded. Mean preoperative slip was 20% (range was 12% to 33%). Follow-up occurred at a mean of 21.2 months (range 12 to 32 months),

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with no dropouts. Significant improvements ($p < .001$) occurred in mean VAS and LBOS scores. Ninety-one percent of the patients considered their results excellent or good on the subjective satisfaction rating. Radiograph analysis revealed mean slip reduction from 20.2% to 1.7% and focal lordosis (available in only 17 of 34 patients) increased from 13.1 to 16.1 degrees. Both of these findings were clinically significant. Three of the 34 patients had postoperative nerve root irritation, with 2 of these persisting up to the time of final report. There were no procedure-related complications were reported postoperatively, but one patient required adjacent level decompression and fusion 12 months after surgery. In critique, this is a small prospective case series on nonconsecutive patients with degenerative spondylolisthesis with no comparison group. This paper offers Level IV therapeutic evidence that reduction of a degenerative spondylolisthesis with internal fixation and posterior lumbar interbody fusion can provide good deformity correction with few complications and good short-term patient outcomes on validated patient outcome measures.

Future Directions For Research

The work group recommends the undertaking of comparative studies and multicenter registry database studies evaluating reduction spondylolisthesis to fusion in situ.

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New Guideline Question:

For patients undergoing posterolateral fusion, does the use of autogenous bone graft improve surgical outcomes compared to those fused with bone graft substitutes?

Due to the paucity of literature addressing this question, the work group was unable to generate a recommendation to answer this question.

There is insufficient evidence to make a recommendation for or against the use of autogenous bone graft or bone graft substitutes in patients undergoing posterolateral fusion for the surgical treatment of degenerative lumbar spondylolisthesis.

Grade of Recommendation: I (Insufficient Evidence)

Vaccaro et al¹ conducted a randomized controlled trial comparing OP-1 (rhBMP-7) with iliac crest autograft in patients with symptomatic degenerative spondylolisthesis and spinal stenosis treated with decompression and uninstrumented posterolateral arthrodesis. All patients had failed at least 6 months of nonoperative treatment, including physical therapy, lumbar epidural injections, anti-inflammatory medications, and activity modifications for their spinal symptoms. A total of 335 patients were randomized in 2:1 fashion to receive either OP-1 Putty or autograft in the setting of an uninstrumented posterolateral arthrodesis. Out of the 335 patients, 295 patients were actually treated. A total of 208 patients received OP-1 Putty and 87 received autograft. The OP-1 putty consisted of 3.5 mg of rhOP-1 formulated with bovine-derived collagen and carboxymethylcellulose to create a powdered mixture and was reconstituted at the time of surgery with the addition of saline. Patients in the autograft group received corticocancellous bone harvested from the posterior iliac crest. After surgery, patients were evaluated clinically and radiographically at 6 weeks, and at 3, 6, 9, 12, 24, and at a minimum of 36 months. Clinical assessments consisted of an evaluation of subjective pain and function using the Oswestry Low Back Pain Disability (ODI) questionnaire, the Visual Analog Scale (VAS), neurologic evaluation, and functional outcome assessment via completion of the Short-Form 36 (SF-36) outcomes survey. Imaging consisted of anteroposterior (AP), lateral, and flexion-extension radiographs. Regarding imaging findings, there were no statistical differences between the study groups in terms of angular or translational motion at either 24 or 36 months follow-up. One hundred seven of 143 (74.8%) of the OP-1 Putty patients and 41 of 53 (77.4%) of the autograft patients had presence of new bone on CT scan. Bridging bone was detected in 56% of patients in the OP-1 Putty group and 83% (p=0.001) of patients in the autograft group. At 24 months, 74.5% of OP-1 subjects and 75.7% of autograft subjects had a >20% improvement from baseline in ODI. At 36+ months, 68.6% of OP-1 subjects and

77.3% of autograft subjects had a >20% improvement from baseline in ODI. There were no statistical differences between the groups at either time point (p=0.839 at 24 months, p=0.201 at 36+ months). Mean operative time for the OP-1 Putty group was significantly shorter than the autograft group (144 minutes for the OP-1 Putty group vs 164 minutes for the autograft group, p<0.006). Mean operative blood loss was also significantly lower for the OP-1 Putty group than the autograft group (309 cc vs. 471 cc, p<0.00004). There were no differences in the mean length of stay after surgery (p=0.529). This study provides level I therapeutic evidence that OP-1 putty is a safe and effective alternative to autograft in the setting of uninstrumented posterolateral spinal arthrodesis.

The studies below were retrieved in the literature search, but did not meet the guideline's inclusion criteria as they are either mixed diagnosis or do not include sub-group analysis of degenerative lumbar spondylolisthesis patient outcomes. However, as this is an area of interest to many, the work group included the studies below as background information.

In a randomized controlled trial, Alexander et al² compared the efficacy of calcium sulfate pellets plus bone obtained from decompression with fresh autologous iliac crest bone in posterolateral lumbar and lumbosacral spinal fusion with decompression. Patients acted as their own controls with one side acting as the intervention side (decompression bone plus an equal volume of calcium sulfate pellets) and the other side as the control side (autologous posterior iliac crest bone of equal volume to test material). Thirty-two patients suffering from either degenerative disc disease or spondylolisthesis completed a one-year follow-up. Outcome assessment was conducted via blinded radiographic evaluation at 6 and 12 months after surgery. The radiologist utilized 2 methods for reviewing the radiographs. Method A involved viewing the posteroanterior radiograph with the lateral

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radiograph as the reference for the presence of new bone mass. If new bone was apparent, the mass on that side was compared with the mass on the other side. The side with the larger mass was noted and the side with the smaller mass was graded as a percentage of the larger side as follows: 0 to 24%, 25 to 49%, 50 to 74%, 75 to 100% or equal. Method B also involved comparing the sides for new bone mass. If new bone mass was apparent, the outline of this mass on either side was obtained and these outlines provided area measurements, which were quantified by placing outlines over graph paper and totaling the 1mm² areas within the outlines, allowing comparison between the lines. The authors considered the bone mass formation at the site of test material placement to be “equivalent” to the bone mass at the control site if the test material bone mass was in the category of 75% to 100% of, equal to, or better than the control side. Results from Method A suggested that 88% of patients at 12 months produced bone formation at the test site graded as equivalent to the control site. Method B indicated that the bone mass formation was equal for both graft sites. The test material increased bone formation an average of 9.18 cm² and the control material increased bone formation an average of 6.44cm² from 6-12 months after fusion surgery. The authors suggest that the use of calcium sulfate pellets plus decompression bone provides equivalent bone formation to the use of autologous iliac crest bone.

Delawi et al³ conducted a multicenter prospective randomized controlled trial to evaluate the safety and feasibility of osteogenic protein (OP-1) compared to iliac crest autograft in patients undergoing decompression and one level lumbar spine instrumented posterolateral fusions for either degenerative or isthmic spondylolisthesis. The OP-1 material consisted of 3.5 mg lyophilized rhOP-1 in 1 g of collagen type I combined with locally obtained bone during laminectomy. Thirty-four patients were included in this study and completed follow-up, including 21 patients with a diagnosis of degenerative spondylolisthesis (10 OP-1 Group; 11 Autograft Group) and 13 with a diagnosis of isthmic spondylolisthesis (8 OP-1 Group; 5 Autograft Group). The primary outcome measure was fusion rate one year after surgery based on blinded computed tomography assessment by a spinal surgeon and radiologist resident. Clinical assessments were conducted preoperatively and at 6 weeks and 3, 6 and 12 months postoperatively using the Visual Analog Scale (VAS) and Oswestry Disability Index (ODI). In addition, adverse events, including any untoward medical occurrence in a patient, were documented. Results indicated that fusion rates were not statistically significantly different between the treatment groups. Fusion rates of 63% were found in the OP-1 Group and 67% in the control/Autograft Group (p=0.95). ODI scores improved significantly in both groups compared to preoperative assessment (p<0.001); however, there were no significant differences in mean ODI scores between the groups at any study point (p=0.52). VAS scores at the donor site were only measured in the autograft group and therefore are unavailable for comparison. In addition, adverse events were experienced by 17 (50%) of patients; however, there were no statistically significant differences in adverse event rates between the treatment groups (p=0.48). The authors suggest that OP-1 is a safe and effective alternative for iliac crest autograft in instrumented single-level posterolateral fusions of the lumbar spine.

Korvessis et al⁴ conducted a randomized clinical trial and radiological study to compare the surgical outcomes of instrumented posterolateral lumbar and lumbosacral fusion using either coralline hydroxyapatite (CH), Group A; or iliac bone graft (IBG), Group B; or both, Group C. A total of 57 patients who suffered from symptomatic degenerative lumbar spinal stenosis, including 19 in Group A, 18 in Group B and 20 in Group C, participated in the study and underwent decompression and fusion with bone graft, bone graft substitute or both. According to the documented technique, autologous IBG was applied bilaterally in Group A; in Group B, IBG was applied on the left side and hydroxyapatite mixed with local bone and bone marrow was applied on the right side; and in Group C, hydroxyapatite mixed with local bone and bone marrow was applied bilaterally. Patients were followed up to 4 years postoperatively, with a minimal observation of 3 years, and outcomes were evaluated with the SF-36, Oswestry Disability Index (ODI), Roland-Morris (R-M) survey, Visual Analogue Scale (VAS) for pain severity, and plain roentgenograms and CT scan evaluated the evolution of the fusion. Preoperative ODI scores improved postoperatively in all groups up to the 2-year follow-up with Group A improving 41±27%, Group B improving 47±39% and Group C improving 43±28%; however, there were no significant changes measured after 2 years. R-M scores were also improved up to the 2-year follow-up with Group A improving 47±43%, Group B improving 60±46%, and Group C improving 55±28%. Thereafter, there were no significant changes in any group. VAS scores were significantly improved in all groups with a peak at 2 years postoperatively. VAS scores improved from 8.1±1.2 to 4.7±3.6 in Group A; 8±1.7 to 3.5±3.1 in Group B, and 7±2 to 3.7±2.7 in Group C. The authors suggest that the use of autologous IBG results in superior fusion results when compared to fusion using CH.

McGuire et al⁵ conducted a systematic literature review of articles published through January 2011, including the Alexander² and Korvessis⁴ studies, to compare the fusion rate, functional outcomes, and safety of local bone graft plus bone extender compared with iliac crest bone graft in posterolateral spinal fusion procedures. After review of 20 potential citations, the authors identified 3 articles meeting inclusion criteria, including 2 studies discussed above and provided as support in addressing this clinical question. All 3 randomized controlled trials included patients with a diagnosis of degenerative disc disease, spondylolisthesis, spinal stenosis or deformity. Fusion rates were high across studies and there were no significant differences between treatment groups in fusion rates, functional outcomes, or quality of life. This systematic review suggests that local bone graft plus bone extender and iliac crest bone graft used in posterolateral spinal fusion procedures have similar fusion rates, functional outcomes, and quality of life scores.

FDA Indications and Warnings

For informational purposes only, the work group has provided the following links to the FDA website to inform readers of the indications and warnings that may be associated with the use of autograft and bone graft substitutes.

Autogenous Bone Graft

<http://www.fda.gov/downloads/AdvisoryCommittees/CommitteesMeetingMaterials/MedicalDevices/MedicalDevicesAdvisoryCommittee/OrthopaedicandRehabilitationDevicesPanel/UCM254662.pdf>

Recombinant Human Bone Morphogenetic Protein

<http://www.fda.gov/MedicalDevices/safety/alertsandnotices/publichealthnotifications/ucm062000.htm>

Infuse Bone Graft

http://www.accessdata.fda.gov/cdrh_docs/pdf/P000054c.pdf

Future Directions for Research

The work group identified the following suggestions for future studies, which would generate meaningful evidence to assist in further defining the role autogenous bone graft and bone graft substitutes in the surgical treatment of patients with degenerative lumbar spondylolisthesis:

Recommendation #1:

A multicenter registry database study evaluating the morbidity of bone graft (and type of bone graft) versus autograft in patients undergoing surgical treatment for degenerative lumbar spondylolisthesis.

Recommendation #2:

A comparative cost-analysis study to evaluate the cost-effectiveness of bone graft (and type of bone graft) versus autograft in patients undergoing surgical treatment for degenerative lumbar spondylolisthesis.

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New Guideline Question:

Do minimally invasive surgical treatments improve outcomes in the treatment of degenerative lumbar spondylolisthesis compared to:

- a. conventional open decompression (laminectomy)?**
- b. conventional (open) lumbar decompression and fusion, with or without instrumentation?**

No evidence was found to assess the efficacy of minimally invasive surgical techniques versus open decompression alone in the surgical treatment of degenerative lumbar spondylolisthesis.

While both minimally invasive techniques and open decompression and fusion, with or without instrumentation, demonstrate significantly improved clinical outcomes for the surgical treatment of degenerative lumbar spondylolisthesis, there is conflicting evidence which technique leads to better outcomes.

Grade of Recommendation: I (Insufficient/Conflicting Evidence)

Harris et al¹ conducted a retrospective comparative study of 51 total patients undergoing 2 types of fusion surgeries with bilateral decompression for the treatment of degenerative spondylolisthesis with spinal stenosis. Patients underwent either fusion using a standard, midline open technique (open group, n=21) or fusion using a mini-open technique, with a small, central incision for the decompression and bilateral paramedian incisions for the posterolateral fusion and placement of cannulated pedicle screws (mini-open group, n=30). All patients in this retrospective review had documented preoperative and postoperative Visual Analog Scale (VAS) and Oswestry Disability Index (ODI) scores. Postoperative anteroposterior (AP) fluoroscopic images and lateral radiographs were also taken at 12 month after surgery. The mean preoperative VAS score was 7.58 in the open group and 7.78 in the mini-open group ($P = .74$). By 3-month follow-up, mean VAS score had improved to 2.68 in the open group and 2.89 in the mini-open group. By one-year follow-up, this score had improved to 2.38 in the open group and 2.32 in the mini-open group. The improvement at 3 months and one year after surgery was statistically significant ($p < 0.05$); however, there were no statistically significant differences in improvement between the groups at either follow-up periods ($p = 0.95$). Both groups' mean preoperative ODI score was 45.7 (consistent with severe disability). By 3-month follow-up, mean ODI score had improved to 27.2 (moderate disability) in the mini-open group and 19.0 (minimal disability) in the open group. By one-year follow-up, mean ODI score had improved further, to 6.4 (minimal disability) in the open group and 13.9 (minimal disability) in the

mini-open group. Similar to pain scores, the improvement in disability at 3 months and one year after surgery was statistically significant ($p < 0.05$); however, there were no statistically significant differences in improvement between the groups at either follow-up periods ($p = 0.19$). Radiological review found only 2 fusion failures. In the open group, one patient showed isolated radiolucency around one of the L4 pedicle screws, as well as lack of bridging posterolateral bone graft on the AP radiograph. In the mini-open group, one patient showed radiolucency around one of the L5 screws, as well as lack of bridging bone between the L4 and L5 transverse processes. The authors conclude that the standard open fusion and decompression and less invasive fusion techniques are equally effective in providing statistically significant improvement in leg pain (VAS scores) and function (ODI scores) at 3-month and one-year follow-ups. This study provides Level III therapeutic evidence that open exposure decompression and fusion (traditional midline incision) and minimally invasive mini-open exposure (3 small incisions) are effective surgical treatment options with equivalent short-term and medium-term outcomes for patients with degenerative lumbar spondylolisthesis.

In a prospective comparative study, Kotani et al² compared the clinical outcomes of degenerative spondylolisthesis with spinal stenosis patients undergoing MIS posterolateral fusion (PLF), n=43, to patients undergoing conventional PLF, n=37. There were no statistically significant differences in gender, age, vertebral level and degree of spondylolisthesis between the groups. Patients were evaluated over a period of at least 2

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years using the Japanese Orthopaedic Association (JOA) score, Oswestry-Disability Index (ODI), Roland-Morris Questionnaire (RMQ), the visual analogue scale of low back pain (LBP VAS), and the surgical complication rate. Fusion status was evaluated by radiograph studies and CT scans at the final follow-up visit. Results indicated that the average operation time was statistically equivalent between the 2 groups. Intraoperative blood loss was significantly less ($p < 0.01$) in the MIS-PLF group (181 ml) when compared to the open-PLF group (453 ml). The postoperative bleeding on day one was also significantly less ($p < 0.01$) in the MIS-PLF group (210 ml) when compared to the open-PLF group (406 ml). There were no statistically significant differences between the average preoperative and follow-up JOA scores in the MIS-PLF Group, 11.1 and 23.5 vs Open-PLF Group, 12.6 and 22.8. The recovery rates of the JOA score were 63.1 and 59.9% in each group, respectively. The average preoperative ODI values were statistically equivalent, 52.0 and 48.9 for each group, respectively. Two weeks after surgery, the MIS-PLF group's ODI value reduced significantly. There was a statistically significant difference in ODI values between the 2 groups at 2 weeks postoperatively ($p < 0.01$). At 3 months, the MIS-PLF group demonstrated a further decrease to an average of 13.2; however, the average score for the open-PLF group remained 32.1. This difference was statistically significant ($p < 0.001$) and was maintained at 6, 12 and 24 months postoperatively ($p < 0.01$). There was a statistical difference of RMQ value at 2 weeks between the 2 groups, 12.2 in the MIS-PLF group and 13.7 in the Open-PLF group ($p < 0.01$). At 3 months, MIS-PLF group showed a further decrease to 5.1; however, the Open-PLF group remained at 10.9 ($p < 0.01$). This difference was maintained until 6, 12 and 24 months postoperatively ($p < 0.01$). The LBP VAS on day 3 in the MIS-PLF group was statistically lower than that in the open-PLF group ($p < 0.02$). Radiological evaluation via x-ray films and CT scans demonstrated that solid fusion was achieved in 42 out of 43 cases (98%) in the MIS-PLF group and in all 37 cases (100%) in the open-PLF group. Statistically, there was no difference in fusion success between the groups. The authors suggest that the MIS-PLF utilizing percutaneous pedicle screw fixation serves as an alternative technique to the conventional open approach. In critique, the number of patients who completed follow-up was not addressed and patients had the option to choose their treatment; thus, adding potential bias to the study. Due to these reasons, this potential Level II study has been downgraded to a Level III. This study provides Level III therapeutic evidence that the MIS-PLF procedure is demonstrated to have better short-term and medium-term clinical outcomes when compared to conventional open-PLF in patients undergoing surgical treatment for degenerative spondylolisthesis with spinal stenosis.

In a retrospective comparative study, Mori et al³ evaluated 53 patients with degenerative lumbar spondylolisthesis who underwent either spinous process-splitting (SPS) open pedicle screw fusion (PSF) ($n=27$) or conventional open PSF ($n=26$) for a single-level instrumented posterior lumbar decompression and fusion. Radiographic and clinical outcomes were assessed using MRI, the Japanese Orthopedic Association (JOA) score, the Roland-Morris disability questionnaire (RDQ), and the visual analog scale (VAS) for low back pain and low back discomfort at one to 3 years after surgery. Results indicated that there

were no statistically significant differences between the groups for JOA, RDQ, or VAS scores for low back pain and low back discomfort at follow-up. However, one year after the surgery, the average VAS score for low back pain in the SPS open PSF group was significantly lower than that in the conventional open PSF group (1.5 ± 1.6 and 2.8 ± 2.3 , respectively, $p < 0.05$). The average multifidus atrophy ratios at the fusion level in the SPS open PSF group were significantly greater than those in the conventional open PSF group at one and 3 years after surgery (0.98 ± 0.08 vs 0.87 ± 0.07 and 0.96 ± 0.11 vs 0.84 ± 0.07 , respectively, $p < 0.01$). At the one-year postoperative follow-up, the multifidus atrophy ratio significantly correlated with the VAS score for discomfort in the low back ($p < 0.05$). The authors suggest that SPS open PSF was less damaging to the paraspinal muscle than the conventional open PSF and resulted in improved clinical outcomes and less low back discomfort at one year after the surgery. This study provides Level III therapeutic evidence that the minimally invasive SPS and PSF surgical technique may result in better surgical outcomes when compared to the conventional open PSF technique.

Adogwa et al⁴ conducted a retrospective study to compare surgical and functional outcomes of patients undergoing either minimally invasive (MIS) or open transforaminal lumbar interbody fusion (TLIF) for Grade I degenerative spondylolisthesis. Patients were excluded if they were above 70 years of age. Thirty patients were included in the analysis, including 15 in the MIS-TLIF and 15 in the open TLIF. Outcomes were assessed at 2 years via visual analog scale (VAS), low-back disability (ODI), Euro-Qol-5D, occupational disability, and narcotic use. No patients within the analysis were excluded or lost to follow-up. Overall, the mean age was 50 ± 9.6 years and included 18 women and 12 men. Interbody fusion was performed at L4 to L5 in 19 (63%) patients and L5 to S1 in 11 (37%) patients. All cases were single-level fusions. Results indicated that the median interquartile range (IQR) length of surgery was shorter for open-TLIF cases versus MIS-TLIF procedures, 210 versus 300 minutes ($p=0.008$). The median (IQR) estimated blood loss during surgery was greater for open-TLIF versus MIS-TLIF procedures, 295 versus 200 mL ($p=0.09$). Median (IQR) length of hospitalization after surgery was significantly less for MIS-TLIF versus open-TLIF, 3.0 versus 5.0 days ($p=0.001$). For all patients, the median IQR of the duration of postoperative narcotic use was 3 (1.4 to 4.6) weeks and median (IQR) time to return to work was 13.9 (2.2 to 25.5) weeks. MIS-TLIF patients used narcotics for about 2 weeks compared to 4 weeks for patients in the open-TLIF group ($p=0.008$). Return to work time was also shorter for MIS-TLIF versus open-TLIF, 8.5 weeks versus 17.1 weeks ($p=0.02$). MIS-TLIF versus open TLIF patients showed similar 2-year improvement in VAS for back pain, VAS for leg pain, Oswestry disability index, and EuroQol-5D scores. The authors suggest that MIS-TLIF may allow for shorter hospital stays, reduced postoperative narcotic use, and accelerated return to work resulting in less direct medical costs and indirect costs of lost work productivity associated with TLIF procedures. This study provides Level III therapeutic evidence that both minimally invasive and open TLIF provide long-term improvement in pain and disability and the minimally invasive technique may allow for an accelerated recovery and return to work time.

Future Directions For Research

The work group recommends the undertaking of randomized controlled trials or prospective studies comparing the efficacy and durability of minimally invasive (MIS) to open techniques. It is important to note that MIS recommendations are complicated by the lack of a consistent definition of what constitutes MIS; therefore, the work group recommends that MIS is clearly and consistently defined in any future studies evaluating the efficacy of MIS surgical techniques.

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Original Guideline Question:
What is the long-term result (4 or more years) of surgical management of degenerative lumbar spondylolisthesis?

Decompression and fusion may be considered as a means to provide satisfactory long-term results for the treatment of patients with symptomatic spinal stenosis and degenerative lumbar spondylolisthesis.

Maintained from original guideline with minor word modifications

Grade of Recommendation: C

Studies obtained from updated literature search:

Schaeren et al¹ conducted a prospective case-series of 26 consecutive patients with symptomatic spinal stenosis and degenerative spondylolisthesis to evaluate whether posterior dynamic stabilization in situ with the Dynesys System can maintain enough stability to prevent progression of spondylolisthesis. Patients were followed-up at a mean of 52 months using VAS and radiographic measurements. At 2 and 4 years follow-up, pain according to VAS assessment and walking distance significantly improved ($p < 0.001$). Plain and functional radiographs showed that spondylolisthesis did not progress and the motion segments remained stable. At 2 year follow-up, anterior and posterior disc height had significantly increased from 2.9 to 3.5mm ($p = 0.02$). At 4 years follow-up, anterior and posterior disc height did not show significant alteration ($p = 0.02$ and 0.05). Some degeneration at adjacent levels was seen in 47% of patients at 4 years follow-up. Patient satisfaction was high and 95% responded that they would undergo the same procedure again. This study provides level IV therapeutic evidence that dynamic stabilization with Dynesys may be associated with satisfactory clinical and radiographic outcomes after 4 years in patients undergoing surgery for degenerative spondylolisthesis.

In a retrospective case-series study, Toyoda et al² evaluated clinical and radiologic outcomes in patients who underwent microsurgical bilateral decompression using a unilateral approach. A total of 57 patients were included in the analysis, including 27 with lumbar spinal stenosis, 20 with degenerative spondylolisthesis, and 10 with degenerative lumbar scoliosis. Patients were followed for a minimum of 5 years and the mean follow-up time was 6 years. Clinical outcomes were evaluated by the Japanese Orthopaedic Association (JOA) score. Complications, rate of reoperation, and radiographic changes after surgery on plain radiograph were also evaluated. The mean blood loss per level was 113.4 ± 74.8 mL, and the mean operative time per level was 134.2 ± 28.7 minutes. The mean JOA score was 13.8 ± 3.6 points before surgery, but improved to 24.9 ± 3.1 points at 3 months, 25.6 ± 2.5 points at 1 year, and 22.6 ± 4.7 points at latest follow-up. The mean rate of improvement was 71.5% at 3 months, 73.5% at one year, and 57.9% at latest follow-up. Four patients required

reoperation due to complications including 2 degenerative spondylolisthesis and 2 degenerative lumbar scoliosis patients. For patients with degenerative spondylolisthesis, the mean rate of improvement at 3 months was 72.3% and 64.1% at the last follow-up. The preoperative percentages of slippage in patients degenerative spondylolisthesis was $13.2\% \pm 5.9\%$, whereas the degrees of progression of slippage at latest follow-up was $2.4\% \pm 4.7\%$. This study provides Level IV therapeutic evidence that MIS decompression yields satisfactory outcomes at 5 years.

In a retrospective case-series study, Tsutsumimoto et al³ evaluated the long-term surgical outcomes of patients with lumbar canal stenosis and Grade I degenerative spondylolisthesis undergoing uninstrumented posterolateral lumbar fusion (PLF) to determine whether the fusion status influences the long-term operative results of PLF. Nine patients were lost to follow-up; therefore, the final analysis included 42 patients. Fusion status was assessed via plain radiographs and clinical outcomes were evaluated using Japanese Orthopaedic Association (JOA) scores. The average preoperative JOA score was 13.2 (range 3-20 points) and 23.5 (range 11-29 points) at the final follow-up. At the final follow-up, the percent recovery was greater than 3 in 69.0% (29/42) of the patients. Nonunion developed in 26.2% (11/42) of the patients. At one and 3-year follow-up, there was no statistically significant difference in the overall percent recovery between the union and nonunion groups (3.5 ± 0.8 vs 3.4 ± 0.7 , $p = 0.515$, and 3.4 ± 0.8 vs 3.1 ± 1.2 , $P = 0.508$, respectively). However, the union group's percent recovery was significantly better at 5-year and final follow up compared to that of the non-union group (3.5 ± 0.7 vs 2.5 ± 1.0 , $p = 0.006$ and 3.3 ± 0.9 vs 2.2 ± 1.2 , $P = 0.008$, respectively). The overall fusion rate achieved by PLF was 74%. Regression analysis revealed that fusion status and the presence of comorbidity were significant risk factors for percent recovery at follow-up. This study provides Level IV therapeutic evidence that fusion status following PLF influences the long-term but not short-term operative results and that improved clinical outcomes are sustained long term in the treatment of patients with lumbar canal stenosis with degenerative spondylolisthesis.

In a retrospective review, Turunen et al⁴ assessed the long-term clinical outcome (at least 10 years), late complications, reoperations and postoperative patient satisfaction in patients with different indications for posterolateral fusion. A total of 106 patients were included in the study, including 31 with degenerative spondylolisthesis (Group 1), 33 with isthmic spondylolisthesis (Group 2), 22 with postdiscectomy syndrome (Group 3), and 20 with postlaminectomy syndrome (Group 4). Clinical outcomes were evaluated by an independent orthopedic surgeon, the Oswestry Disability Index (ODI) and the Visual Analog Scale (VAS) questionnaires. The degenerative spondylolisthesis patients (Group 1) showed the greatest improvements in ODI and VAS values compared to the other groups (47.0 vs. 26.4, $p < 0.001$ and 6.3 vs. 4.1, $p < 0.001$, respectively). In addition, 28 of 31 patients reported experiencing either excellent or good long term results. This study provides Level IV therapeutic evidence that posterolateral fusion provides satisfactory long term outcomes in patients suffering from degenerative lumbar spondylolisthesis.

Studies included in original guideline:

Booth et al⁵ described a presumably retrospective study of 41 patients with neurogenic claudication from spinal stenosis and spondylolisthesis who were followed for a minimum of 5 years after a laminectomy and instrumented fusion. At final follow-up, there were no new neurological deficits, no recurrent stenosis at the level of surgery and no symptomatic pseudarthroses. Three patients underwent surgery for adjacent level stenosis, which took place 4 to 12 years after the index procedure. Clinical outcomes were available in 36 patients: 83% reported high satisfaction, 86% reported reduced back and leg pain, and 46% had increased function at follow-up that ranged from 5 to 10.7 years. In critique of this study, it had small patient numbers and there was a considerable amount of attrition (less than 80% follow-up). Of 49 consecutive patients operated during the study interval, 41 were available for follow-up (8 patients died) and only 36 had clinical outcomes measured. Attrition from death, however, is expected in the affected population. This retrospective case series provides Level IV therapeutic evidence that laminectomy and instrumented fusion for stenosis from degenerative spondylolisthesis provides a high rate of satisfaction and pain relief and moderately increased function at long-term follow-up.

Kornblum et al⁶ conducted a follow-up study on 47 of 58 patients who had originally been part of a randomized controlled trial comparing instrumented versus noninstrumented fusion for spinal stenosis and degenerative spondylolisthesis. This study's cohort consisted only of the noninstrumented cases, which were followed for a minimum of 5 years. Clinical outcomes were analyzed based on the presence of solid fusion (22 patients) or a pseudarthrosis (25 patients). A statistically greater percentage of patients had good or excellent results in patients with solid fusion (86%) versus pseudarthrosis (56%). Importantly, 5 of the pseudarthrosis patients and 2 of the fusion patients had undergone a second procedure. In critique of this study, the authors used a less frequently implemented outcomes instrument, the Swiss Spinal Stenosis (SSS) Questionnaire, making it difficult to compare directly to other studies in which the ODI or ZCQ were used. Despite these minor limitations, as a prospective case series, the data offer Level IV therapeutic (>80% follow-

up) evidence that laminectomy and attempted fusion results in longstanding symptom improvement for spinal stenosis from degenerative spondylolisthesis. Furthermore, this study suggests that those patients who achieved solid fusion have statistically better long-term outcomes than those with pseudarthroses for noninstrumented fusions.

Future Directions for Research

The work group identified the following suggestions for future studies, which would generate meaningful evidence to assist in further defining the role of surgical treatment for degenerative lumbar spondylolisthesis:

Recommendation #1:

Future long-term studies of the effects of surgical interventions for patients with symptomatic spinal stenosis and degenerative lumbar spondylolisthesis should include a comparison group undergoing best current medical management techniques, when ethically feasible. Continued follow-up of patients already enrolled in ongoing prospective comparative studies will yield higher quality data regarding the relative efficacy of surgery compared to medical/interventional treatments.

Recommendation #2:

Future long-term outcome studies, such as multicenter registry database studies, are necessary to compare different surgical techniques for the treatment of patients with symptomatic spinal stenosis and degenerative lumbar spondylolisthesis.

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*New Guideline Question:***Which patient-specific characteristics influence outcomes (and prognosis) in the treatment (surgical or any) of degenerative lumbar spondylolisthesis?**

There is insufficient evidence to make a recommendation for or against the influence of a nonorganic pain drawing on the outcomes/prognosis of treatments for patients with degenerative lumbar spondylolisthesis.

Grade of Recommendation: I (Insufficient Evidence)

Andersen et al¹ investigated whether pain drawings predicted outcome in patients undergoing lumbar spinal fusion. The study also assessed the differences between spondylolisthesis patients and patients with degenerative disease as well as between patients with or without radicular pain. Patients over the age of 60 were excluded to make the patient population more comparable to other studies. One hundred thirty-five patients, including 28 spondylolisthesis patients, undergoing lumbar spinal fusion were followed for at least one year and evaluated using the Dallas Pain Questionnaire (DPQ), Low Back Pain Rating Scale (LBPRS) pain index and patient satisfaction. Pain drawings were composed by outlining each patient's front, back and area under feet. Patients were asked to indicate where their pain was occurring on the drawing. Six different symbols denoting different levels of pain were used for the following: dull/aching, burning, numbness, pins and needles, stabbing/cutting and muscular cramps. Based on visual results, pain drawings were classified as organic or nonorganic. Pain drawings were correlated to outcomes to determine their predictive value. Results indicated that 90 pain drawings were deemed organic (67%) and 45 were deemed nonorganic pain drawings (33%). In the sub-set of spondylolisthesis patients, patients with an organic pain drawing had a greater improvement in all outcome scores, including DPQ daily activity, work/leisure, anxiety/depression, social interest and LBPRS, compared with those with a nonorganic pain drawing; however, this difference was not observed to the same extent in patients operated for degenerative disease. Nonorganic pain drawings were associated with poorer outcomes in patients with low back pain and radicular symptoms, however, not in patients without radicular symptoms. This study provides Level IV prognostic evidence that spondylolisthesis patients with an organic pain drawing had a greater improvement in outcome scores compared with those with a nonorganic pain drawing.

There is insufficient evidence to make a recommendation regarding the influence of age and three or more comorbidities on the outcomes of patients undergoing treatment for degenerative lumbar spondylolisthesis.

Grade of Recommendation: I (Insufficient Evidence)

Kalanthi et al² conducted a retrospective study of degenerative spondylolisthesis patients undergoing posterior lumbar fusion to determine rates of in-patient complications and complex disposition for and evaluate the association of demographic variables. The Nationwide Inpatient Sample (NIS) administrative data was used to retrieve data from 66,601 patients with diagnostic and procedure codes specifying posterior lumbar fusion for acquired spondylolisthesis. Variables assessed included age, sex, race, number of comorbidities, hospital size and time period of procedure. Multivariate analysis revealed an association between age and complex disposition. The reference group was defined as the age Group 45 to 64 years. The likelihood of complex disposition was significantly higher for patients in the age Group 65 to 84 (OR: 5.8, $p < 0.0001$), but less likely in younger groups. Patients with 3 or more comorbidities were twice as likely to have complex disposition, regardless of age, when compared with those with no comorbidities ($p < 0.0001$). This study provides Level II prognostic evidence that increasing age and the presence of three or more comorbidities may increase the risk of a postoperative complex disposition in patients with degenerative spondylolisthesis.

There is insufficient evidence to make a recommendation regarding the influence of symptom duration on the treatment outcomes of patients with degenerative lumbar spondylolisthesis.

Grade of Recommendation: I (Insufficient Evidence)

Radcliff et al³ retrospectively reviewed data from the Spine Outcomes Research Trial (SPORT) study to determine whether the duration of symptoms affects outcomes after the treatment of spinal stenosis (SS) or degenerative spondylolisthesis (DS). The SPORT study compared the surgical and nonsurgical outcomes in patients enrolled in either a randomized or observational cohort. All patients in the trial had neurogenic claudication or radicular leg pain with associated neurologic signs, spinal stenosis shown on cross-sectional imaging, and degenerative spondylolisthesis shown on lateral radiographs obtained with the patient in a standing position. Treatment was standard decompressive laminectomy, with or without fusion, or usual nonsurgical care, which included at least physical therapy, education or counseling on home exercises, and nonsteroidal anti-inflammatory agents, if tolerated. Investigators enrolled 304 patients in the randomized cohort and 303 in the observational cohort. In the randomized cohort, 159 patients were assigned to surgery and 145 were assigned to nonsurgical treatment. Of the 145 patients assigned to receive nonoperative care, 54% underwent surgery by 4 years. In the observational cohort, 173 initially chose surgery and 130 initially chose nonsurgical care. Of the 130 patients who initially chose nonoperative treatment, 33% underwent surgery by four years. Patients were evaluated over 4 years using the SF-36 for bodily pain and physical function scores and the modified Oswestry Disability Index. An as-treated analysis comparison was made between patients with SS with 12 or fewer months' (n = 405) and those with more than 12 months' (n = 227) duration of symptoms. A comparison was also made between patients with DS with 12 or fewer months' (n = 397) and those with more than 12 months' (n = 204) duration of symptoms. Primary and secondary outcomes were measured at baseline and at regular follow-up time intervals up to 4 years. The difference in improvement among patients whose surgical or nonsurgical treatment began less than or greater than 12 months after the onset of symptoms was measured. In addition, the difference in improvement with surgical versus nonsurgical treatment (treatment effect) was determined at each follow-up period for each group. Results indicated that the primary and secondary outcome measures within the DS group did not differ according to symptom duration and suggests that there was no difference in the treatment outcome of patients with degenerative spondylolisthesis according to symptom duration. This study provides Level II prognostic evidence that suggests that symptom duration does not impact nonoperative or surgical treatment success for patients with degenerative lumbar spondylolisthesis.

There is insufficient evidence to make a recommendation regarding the influence of obesity (BMI >30) and its impact on treatment outcomes in patients with degenerative lumbar spondylolisthesis.

Grade of Recommendation: I (Insufficient Evidence)

In another post hoc retrospective subgroup analysis of SPORT, Rihn et al⁴ evaluated the impact of obesity on the treatment outcomes for lumbar stenosis and degenerative spondylolisthesis patients. In the cohort of degenerative spondylolisthesis patients, there were 376 patients with a BMI of less than 30 (non-obese) and 225 patients with a BMI more than 30 (obese). It is important to note that in addition to obesity, obese patients had a significantly higher incidence of comorbidities, including hypertension, diabetes and stomach problems (p<0.001). A higher proportion of obese patients underwent instrumented fusion and less underwent decompression alone compared to non-obese patients. The incidence of intraoperative complications was significantly lower in the obese patient group; however, there was a trend toward increase rate of wound infection in the obese patients compared to nonobese patients (5% vs. 1%, p=0.051). At 4 year follow-up, there was a significantly higher rate of reoperation in the obese patient group compared to the nonobese group (20% vs. 11%, p=0.013). At 4 year follow-up in the nonoperative group, obese patients had SF-36 physical function scores that worsened from baseline by a mean of 3.5 compared to a mean improvement of 13.9 points in the non-obese group (p<0.001). The treatment effect for the SF-36 Physical Function score was significantly higher for the obese surgical patient group compared to nonoperative obese patient group (25.6 vs. 14, p=0.004) suggesting that surgery has a significantly greater benefit over nonsurgical treatment of degenerative spondylolisthesis in obese patients. This study provides Level II prognostic evidence the risk of infection and reoperation 4 years after surgical treatment is greater in obese patients compared to non-obese surgical patients.

Future Directions for Research

The work group recommends the undertaking of population-based observational studies, such as a multicenter registry data studies, to examine the clinical characteristics associated with poor medical/interventional or surgical treatment in patients with degenerative lumbar spondylolisthesis.

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*New Guideline Question:***What is the effect of postsurgical rehabilitation including exercise, spinal mobilization/manipulation or psychosocial interventions on outcomes in the management of degenerative lumbar spondylolisthesis (compared to patients who do not undergo postsurgical rehabilitation)?**

There was no evidence found to address this question. Due to the paucity of evidence, a recommendation cannot be made regarding the effect of postsurgical rehabilitation the outcomes of patients undergoing surgical treatment for degenerative lumbar spondylolisthesis.

Future Directions For Research

The work group recommends the undertaking of observational studies to evaluate the effect of various postsurgical rehabilitation strategies on patients with degenerative lumbar spondylolisthesis.

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E. Value of Spine Care

New Guideline Question:

What is the cost-effectiveness of the surgical treatment of degenerative lumbar spondylolisthesis compared to medical/interventional treatment (consider with and without fusion separately)?

There was no evidence found to address this question. Due to the paucity of evidence, a recommendation cannot be made regarding the cost-effectiveness of surgical treatment compared to medical/interventional treatment for the management of patients with degenerative lumbar spondylolisthesis.

Future Directions For Research

The work group recommends the undertaking of cost-analysis studies evaluating the long term cost-effectiveness of surgical treatments versus medical/interventional treatment in patients undergoing treatment for degenerative lumbar spondylolisthesis.

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New Guideline Question:

What is the cost-effectiveness of minimal access-based surgical treatments of degenerative lumbar spondylolisthesis compared to traditional open surgical treatments?

There is insufficient evidence to make a recommendation for or against the cost-effectiveness of minimal access-based surgical treatments compared to traditional open surgical treatments for degenerative lumbar spondylolisthesis.

Grade of Recommendation: I (Insufficient Evidence)

In a retrospective cost-effectiveness comparative study of patients undergoing surgical treatment for Grade 1 degenerative spondylolisthesis, Parker et al¹ assessed the cost and cost utility of minimally invasive transforaminal lumbar interbody fusion (MIS-TLIF) vs open-TLIF. Fifteen patients received surgical treatment with MIS-TLIF and 15 other patients underwent open-TLIF. Independent investigators not involved in the patients' care conducted phone interviews to assess preoperative and 2-year postoperative pain, disability and quality of life. At 2 years postsurgery, information on duration of narcotic use and time to return to work was collected via phone interview as part of a standard of care protocol. Patient-assessed questionnaires included Visual Analog Scale (VAS) for low back pain and leg pain, the Oswestry Disability Index (ODI), and EuroQuol-5D (EQ-5D). QALY was used to measure the treatment effectiveness and the incremental cost-effectiveness ratio (ICER) was calcu-

lated by the difference in the mean total costs between cohorts, divided by the difference in mean QALYs. The analysis indicated that the MIS-TLIF versus the open-TLIF cohorts were similar at baseline. Mean preoperative health state values significantly improved for both the MIS-TLIF and open-TLIF cohorts by two years after surgery. The total mean QALYs gained for MIS-TLIF patients was 0.50 (95% CI, 0.37-0.63) and 0.41 (95% CI, 0.14-0.68) for open-TLIF patients. The total two year mean costs were \$35,996 for the MIS-TLIF treated patients and \$44,727 for the open-TLIF treated patients (p=0.18). Treatment groups were similar in use of oral steroids (33% MIS vs. 20% open, p=0.68) but differed significantly in the mean duration of narcotics (MIS: 2.6 weeks vs. open: 6.5 weeks, p=0.008). MIS-TLIF patients had accelerated return to work times versus open-TLIF patients (8.3 vs. 16.3 weeks, p=0.02). During the 2-year study period, indirect costs accounted for a substantial proportion of total costs in both

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groups (32.8% of cost for MIS-TLIF patients and 41.2% of costs for open-TLIF patients). When all costs were considered, MIS-TLIF versus open-TLIF was associated with a nonsignificant trend of mean 2-year cost savings of \$8,731 per patient while providing similar QALYs gained (ICER). Two-year cost and utility gained were similar for both techniques. The authors suggest that MIS-TLIF is a cost reducing surgical treatment for patients with Grade I degenerative lumbar spondylolisthesis. In critique, this study may have been too small to show a difference. In addition, open surgery can be done with posterolateral fusion only with similar results to TLIF, but for reduced cost, whereas MIS is more dependent on TLIF to accomplish goals of decompression and fusion. This study provides Level III economic and decision analysis evidence that there is no statistical difference in the cost of MIS-TLIF compared to open-TLIF.

In a follow-up analysis using the same 30 patients as above, Parker et al² evaluated 100 patients undergoing TLIF for degenerative lumbar spondylolisthesis were evaluated. Fifty patients underwent MIS-TLIF and the other 50 patients underwent open-TLIF. Preoperative, 3-month and 2-year postoperative pain, disability and quality of life were assessed via phone interview by an independent investigator not involved in care. Patient-assessed questionnaires included Visual Analog Scale (VAS) for low back pain and leg pain, Oswestry Disability Index (ODI), Short-Form (SF)-12 health survey with mental (MCS) and physical (PCS) component scores, Zung depression index and EuroQol-5D (EQ-5D). Cost-effectiveness metrics evaluated included QALY, direct hospital costs, two year resource use and direct costs, indirect costs and incremental cost-effectiveness ratio (ICER). Length of hospitalization and time to return to work were less for MIS-TLIF versus open TLIF ($p=0.006$ and $p=0.03$, respectively). MIS-TLIF versus open TLIF demonstrated similar improvement in patient-reported outcomes assessed. MIS-TLIF was associated with a reduced total 2-year cost versus open-TLIF, \$38,563 versus \$47,858 ($p=0.03$). MIS vs open TLIF was associated with a reduction in mean hospital cost of \$1758, indirect cost of \$8474, and total 2-year societal cost of \$9295 ($p=0.03$) but similar 2-year direct health care cost and quality-adjusted life years gained. In critique, open surgery can be done with posterolateral fusion only with similar results to TLIF, but for reduced cost, whereas MIS is more dependent on TLIF to accomplish goals of decompression and fusion. This choice of comparison could affect final analysis. This study provides Level III economic and decision analysis evidence that MIS-TLIF versus open-TLIF was associated with reduced costs over 2 years while providing equivalent improvement in clinical outcomes.

Kim et al³ conducted a comparative cost-effectiveness study to determine the relative cost-utility of decompression with and without concomitant instrumented fusion for patients with degenerative lumbar spondylolisthesis. All consecutive patients ($n=150$) with a primary diagnosis of degenerative lumbar spondylolisthesis were assessed. The primary outcome was the incremental cost/utility ratio (ICUR) expressed as the differential cost per relative gain in quality-adjusted life-year (QALY). A Markov model with 10-year follow-up was also developed to compare costs and outcomes of the two operative strategies. The cost-utility of decompression with fusion and decompression alone at 10 years post-intervention was \$3,281/QALY and \$1,040/QALY,

respectively. Compared with decompression alone, decompression plus instrumented fusion was associated with an improvement in quality of life at value of \$185,878 per QALY. Because this study does not directly answer this comparative question, the work group did not assign it a level of evidence. However, it does provide background information on the cost of open surgical techniques and has been included for educational reference. The authors suggest that for a specific subpopulation of degenerative lumbar spondylolisthesis patients, decompression alone and decompression and fusion are almost similar in clinical effectiveness with a slight advantage for fusion.

Future Directions for Research

The work group recommends the undertaking of cost-analysis studies evaluating the long term cost-effectiveness of minimally invasive surgeries vs conventional surgery in patients with degenerative lumbar spondylolisthesis. It is important to note that MIS recommendations are complicated by the lack of a consistent definition of what constitutes MIS; therefore, the work group recommends that MIS is clearly and consistently defined in any future studies evaluating the role and cost-effectiveness of MIS surgical techniques.

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VI. Appendices

A. Acronyms

CI	confidence interval
COS	clinical outcome score
CT	computed tomography
DCSA	dural sac cross sectional area
DH	disc height
EBM	evidence-based medicine
EMG	electromyography
ESI	epidural steroid injection
GROC	Global Rating of Change
JOA	Japanese Orthopaedic Association
LLA	lumbar lordotic angles
LR	likelihood ratio
MED	Microendoscopic decompression
MR	magnetic resonance
MRI	magnetic resonance imaging
NASS	North American Spine Society
NCOS	Neurogenic Claudication Outcome Score
NSAIDs	nonsteroidal anti-inflammatory drugs
ODI	Oswestry Disability Index
PDS	pain and disability score
PLIF	Posterior lumbar interbody fusion
PLF	Posterolateral fusion
PPV	positive predictive value
QALY	quality adjusted life years
QST	quantitative sensory testing
RDQ	Roland-Morris Disability Questionnaire
RCT	randomized controlled trial
SR	sagittal rotation
ST	sagittal translation
SLFE	standing lateral flexion-extension radiograph
SLR	straight leg raise
SEP	somatosensory evoked potentials
SNRB	selective nerve root block
TENS	transcutaneous electrical nerve stimulation
VAS	visual analog scale

B. Levels of Evidence for Primary Research Question¹

Types of Studies				
	Therapeutic Studies – Investigating the results of treatment	Prognostic Studies – Investigating the effect of a patient characteristic on the outcome of disease	Diagnostic Studies – Investigating a diagnostic test	Economic and Decision Analyses – Developing an economic or decision model
Level I	<ul style="list-style-type: none"> High quality randomized trial with statistically significant difference or no statistically significant difference but narrow confidence intervals Systematic review² of Level I RCTs (and study results were homogenous³) 	<ul style="list-style-type: none"> High quality prospective study⁴ (all patients were enrolled at the same point in their disease with ≥ 80% follow-up of enrolled patients) Systematic review² of Level I studies 	<ul style="list-style-type: none"> Testing of previously developed diagnostic criteria on consecutive patients (with universally applied reference “gold” standard) Systematic review² of Level I studies 	<ul style="list-style-type: none"> Sensible costs and alternatives; values obtained from many studies; with multiway sensitivity analyses Systematic review² of Level I studies
Level II	<ul style="list-style-type: none"> Lesser quality RCT (eg, < 80% follow-up, no blinding, or improper randomization) Prospective⁴ comparative study⁵ Systematic review² of Level II studies or Level I studies with inconsistent results 	<ul style="list-style-type: none"> Retrospective⁶ study Untreated controls from an RCT Lesser quality prospective study (eg, patients enrolled at different points in their disease or <80% follow-up) Systematic review² of Level II studies 	<ul style="list-style-type: none"> Development of diagnostic criteria on consecutive patients (with universally applied reference “gold” standard) Systematic review² of Level II studies 	<ul style="list-style-type: none"> Sensible costs and alternatives; values obtained from limited studies; with multiway sensitivity analyses Systematic review² of Level II studies
Level III	<ul style="list-style-type: none"> Case control study⁷ Retrospective⁶ comparative study⁵ Systematic review² of Level III studies 	Case control study ⁷	<ul style="list-style-type: none"> Study of non-consecutive patients; without consistently applied reference “gold” standard Systematic review² of Level III studies 	<ul style="list-style-type: none"> Analyses based on limited alternatives and costs; and poor estimates Systematic review² of Level III studies
Level IV	Case series ⁸	Case series	<ul style="list-style-type: none"> Case-control study Poor reference standard 	Analyses with no sensitivity analyses
Level V	Expert Opinion	Expert Opinion	Expert Opinion	Expert Opinion

1. A complete assessment of quality of individual studies requires critical appraisal of all aspects of the study design.
2. A combination of results from two or more prior studies.
3. Studies provided consistent results.
4. Study was started before the first patient enrolled.
5. Patients treated one way (eg, cemented hip arthroplasty) compared with a group of patients treated in another way (eg, uncemented hip arthroplasty) at the same institution.
6. The study was started after the first patient enrolled.
7. Patients identified for the study based on their outcome, called “cases” (eg, failed total arthroplasty) are compared to those who did not have outcome, called “controls” (eg, successful total hip arthroplasty).
8. Patients treated one way with no comparison group of patients treated in another way.

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C. Grades of Recommendations for Summaries or Reviews of Studies

- A: Good evidence (Level I Studies with consistent finding) for or against recommending intervention.
- B: Fair evidence (Level II or III Studies with consistent findings) for or against recommending intervention.
- C: Poor quality evidence (Level IV or V Studies) for or against recommending intervention.
- I: Insufficient or conflicting evidence not allowing a recommendation for or against intervention.

D. Linking Levels of Evidence to Grades of Recommendation

Grade of Recommendation	Standard Language	Levels of Evidence	
A	Recommended	Two or more consistent Level I studies	
B	Suggested	One Level I study with additional supporting Level II or III studies	Two or more consistent Level II or III studies
C	May be considered; is an option	One Level I, II or III study with supporting Level IV studies	Two or more consistent Level IV studies
I (Insufficient or Conflicting Evidence)	Insufficient evidence to make recommendation for or against	A single Level I, II, III or IV study without other supporting evidence	More than one study with inconsistent findings*

*Note that in the presence of multiple consistent studies, and a single outlying, inconsistent study, the Grade of Recommendation will be based on the level of consistent studies.

E. Protocol for NASS Literature Searches

One of the most crucial elements of evidence analysis to support development of recommendations for appropriate clinical care or use of new technologies is the comprehensive literature search. Thorough assessment of the literature is the basis for the review of existing evidence, which will be instrumental to these activities. It is important that all searches conducted at NASS employ a solid search strategy, regardless of the source of the request. To this end, this protocol has been developed and NASS-wide implementation is recommended.

NASS research staff will work with the requesting parties and the NASS-contracted medical librarian to run a comprehensive search employing at a minimum the following search techniques:

1. A comprehensive search of the evidence will be conducted using the following clearly defined search parameters (as determined by the content experts). The following parameters are to be provided to research staff to facilitate this search.

- Time frames for search
- Foreign and/or English language
- Order of results (chronological, by journal, etc.)
- Key search terms and connectors, with or without MeSH terms to be employed
- Age range
- Answers to the following questions:
 - o Should duplicates be eliminated between searches?
 - o Should searches be separated by term or as one large package?
 - o Should human studies, animal studies or cadaver studies be included?

This search will encompass, at minimum, a search of Medline/PubMed, EMBASE, and Cochrane Library. Additional databases may be searched depending upon the topic.

2. Search results with abstracts will be compiled by the medical librarian in Endnote software. The medical librarian typically responds to requests and completes the searches within two to five business days. Results will be forwarded to the research staff, who will share it with the appropriate NASS staff member or requesting party(ies). (Research staff has access to EndNote software and will maintain a database of search results for future use/documentation.)

3. NASS staff shares the search results with an appropriate content expert (NASS Committee member or other) to assess relevance of articles and identify appropriate articles to review.

4. NASS research staff will work with LoansomeDoc library to obtain requested full-text articles for review.

5. NASS members reviewing full-text articles should also review the references at the end of each article to identify additional articles which should be reviewed, but may have been missed in the search.

Following this protocol will help ensure that NASS recommendations are (1) based on a thorough review of relevant literature; (2) are truly based on a uniform, comprehensive search strategy; and (3) represent the current best research evidence available. Research staff will maintain a search history in EndNote for future use or reference.

VII. Bibliography

(All citations from 2008 and 2013 literature searches)

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This clinical guideline should not be construed as including all proper methods of care or excluding or other acceptable methods of care reasonably directed to obtaining the same results. The ultimate judgment regarding any specific procedure or treatment is to be made by the physician and patient in light of all circumstances presented by the patient and the needs and resources particular to the locality or institution

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