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MAGNETIC RESONANCE FINDINGS OF EXAGGERATED FLUID IN FACET JOINTS PREDICTS INSTABILITY.

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The purpose of this study was to determine the incidence of exaggerated fluid signal in lumbar facet joints on Magnetic Resonance Imaging (MRI) and evaluate the correlation of this finding with radiographic evidence of instability. One hundred and thirty-four consecutive lumbar MRIs obtained by a single surgeon over a 2-year period were selected for review. Studies were evaluated for exaggerated fluid (defined as greater than one millimeter) between the articular surfaces of the facets on axial views. Standing plain films of all patients were then evaluated to determine the incidence of spondylolisthesis for patients with and without exaggerated fluid in the facets on MRI.

Of 134 consecutive MRIs, 118 were available for review. Sixteen (13.6%) had exaggerated fluid in the facets on axial images. Only 2 of these 16 (12.5%) had spondylolisthesis appreciable on MRI at that level. In contrast, 8 of the 16 (50.0%) had spondylolisthesis at the level of exaggerated fluid when the corresponding radiographs were reviewed. Thus, spondylolisthesis was suggested in 6 of 14 cases (42.9%) when the exaggerated fluid sign was present but spondylolisthesis was not evident on the supine MRI.

In comparison, in the population without exaggerated fluid, only 1 in 102 (0.9%) showed a slip on plain film that was not observed on MRI. This difference was statistically significant ($P<0.001$). The sensitivity and specificity for this finding in detecting spondylolisthesis were 57% and 92%, respectively. The positive predictive value was 50%, and the negative predictive value was 94% when using the presence of fluid in the facets on MRI as an indicator of radiographic lumbar instability. The positive

diagnostic likelihood ratio was 7.43, and the negative diagnostic likelihood ratio was 0.46. Given a patient with fluid in the facets, the post-test probability of having spondylolisthesis was 93.0%.

In conclusion, patients with exaggerated fluid in the facets on axial MRI had a far greater likelihood of having spondylolisthesis on standing plain films than those without (odds ratio = 16.0, 95% CI, 4.44-57.60), even if this was not appreciated on the supine sagittal MRI sequences.

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Introduction

Spondylolisthesis and Lumbar Facet Joint Mechanics:

The roots of the term spondylolisthesis are of Greek origin, with *spondylo* meaning "vertebra" and *olisthesis* meaning "movement or slipping." Spondylolisthesis refers to a pathological condition in which one vertebra slips with respect to the one adjacent to it. This slip may be forward (anterolisthesis) or backward (retrolisthesis) (1).

The most well known classification system used to categorize the various forms of spondylolisthesis, known as the Wiltse classification, divides the disorder into five types: Type I (dysplastic or congenital), Type II (isthmic), Type III (degenerative), Type IV (traumatic), and Type V (pathological) (2)(3). In this study, degenerative spondylolisthesis (Type III) was the primary focus. It is a condition that primarily affects older individuals. It occurs most frequently at the L4-5 level, with 90% occurring at either L4-5 or L5-S1 (4).

In the functioning lumbar spinal unit, the intervertebral disc and facet joints function in unison to supply stability and absorb stress placed on the spine. The facet joints are diarthroidal joints and contain a joint capsule and hyaline articular cartilage which overly subchondral bone. The bony elements of this joint include the inferior articular process of the cephalad vertebra and the superior articular process of the caudal vertebra.

Adams and Hutton produced a study in 1983 delineating the function of the lumbar facet joint (5). They concluded that the facet joint limits the motion between vertebrae and protects the intervertebral discs from shear forces, excessive flexion, and axial rotation. Degeneration of the facet and intervertebral disc, in turn, leads to spinal segment instability, such as that seen in spondylolisthesis. More recent work supports this conclusion, for example that produced by Fujiwara et al. in 2000 (6). In their cadaveric study they evaluated the association between intervertebral disc degeneration and facet joint degeneration, and formulated an MRI-based grading system for the severity of facet joint degeneration. They saw that lumbar segmental instability, which was already increased due to intervertebral disc degeneration, was further increased with facet cartilage degeneration. These areas of instability or segmental movements can be appreciated on weight bearing lateral lumbar radiographs as anterior subluxation, which if significant may be categorized as anterior spondylolisthesis (7)(8)(9).

MRI studies have also looked at the degenerative process in the lumbar spine. Many point to the role of facet joint orientation and tropism as a cause for different lumbar spine pathologies. Work here indicates that increased sagittal lumbar facet orientation and greater facet tropism correlate with increased intervertebral disc degeneration and increased incidence of degenerative spondylolisthesis (10)(11)(12)(13).

Spinal stenosis often results from spondylolisthesis, as the slipped vertebrae may cause the spinal canal to decrease in cross sectional area. This may subsequently compress nerve roots and cause pain (14)(15). Patients typically present with low back pain, often radiating to the buttocks or lateral thigh, proximal weakness, and intermittent claudication symptoms (“pseudoclaudication”). Pain may be relieved with sitting or leaning forward, as lumbar flexion relieves pressure on the nerves by effectively increasing the diameter of the spinal canal and intervertebral foramen.

Imaging Options for Spondylolisthesis:

There are a variety of imaging options for patients that present with low back pain, such as that occurring with degenerative spondylolisthesis. Standing lumbar radiographs are the accepted means for assessing lumbar alignment, as these allow visualization of the lumbar spine in a functional position (16). Studies have shown that weight bearing accentuates the anterior displacement of spondylolisthesis while recumbency (i.e. elimination of the axial load) results in partial reduction of spondylolisthesis. For example, Lowe et al. found an increase of two millimeters or more in the standing versus supine roentgenograms in 13 out of 50 (26%) patients with spondylolisthesis (17). Boxall et al. found similarly significant changes in the angle of slipping between supine and standing films in 13 out of 15 (87%) patients (18).

Lumbar magnetic resonance imaging (MRI) has become routine in the evaluation of many lumbar conditions. It is often used to evaluate patients with axial low back pain or lumbar-related complaints. Although standing plain films have historically been used for detection of lumbar instability, as discussed above, the increasing availability of MRI has made plain radiographs less common in the initial work up. MRI provides much information including, but not limited to, that related to disc degeneration and neural element compression (14)(19). Although such information may be helpful when evaluating soft tissue structures, this type of imaging is most frequently performed in the supine position, thus potentially limiting the ability to evaluate subtle deformities that may only be apparent in the upright, functional position (3)(20).

A report in 2001 from Bendo and Ong provides a good example of this concept (8). They encountered one case in which there was complete reduction of L4-5 degenerative spondylolisthesis, which was seen on standing plain film, when that same patient was placed supine during an MRI scan. In this case, the supine MRI was the initial study taken, and thus the spondylolisthesis was originally missed in this patient. They also observed that low-grade slips often reduce on the operating table after the administrating of anesthetic when patients are supine. As a result they stress the "importance of correlating static and dynamic imaging studies in developing a treatment plan for patients with degenerative spondylolisthesis."

Studies evaluating the use of axial loading MRI also demonstrate this point. Jayakumar et al. studied the utility of applying axial force to the spine during MRI scans (21). The authors found that this axial load (which can be likened to the force of gravity in the upright position) helped to identify occult dynamic degenerative spondylolisthesis in a patient that was not shown on conventional MRI. This concept of translational deformities that may be missed on certain types of imaging is extremely important when considering treatment options for patients with spondylolisthesis and/or and spinal stenosis. The pathology and mechanics of these different, but related, lumbar conditions require different interventions, and so appropriate diagnosis is of utmost importance.

Treatment Options for Spondylolisthesis:

Although the majority of patients with spondylolisthesis may be treated conservatively, 10% to 15% require surgical intervention (22). Surgery is suggested for spondylolisthesis when one or more of the following are present: Persistent or recurrent leg pain despite a minimum of three months of conservative treatment, progressive neurological deficit, significant reduction in quality of life, or confirmatory imaging consistent with the clinical findings. Surgical treatment can involve simple decompression, decompression and posterolateral fusion with or without instrumentation, or anterior or posterior interbody fusion (1). Several studies have shown that decompression combined with stabilization, by whatever means, significantly improves patient outcome compared to decompression alone (23)(24)(25). As stabilization of the lumbar spine is indicated in only in patients with demonstrated instability such as that seen in degenerative spondylolisthesis, detecting abnormalities in functional alignment is clearly of potential clinical interest (25)(26).

Our study was intended to evaluate a means of identifying instability through MR imaging, namely, fluid in the facet joints. Although we believe that standing plain films are the gold standard for diagnosing translational movement in spondylolisthesis, there is a trend towards increasing use of MR imaging. As a result, spondylolisthesis is often missed when surgeons are evaluating MR films for lumbar pathology such as spinal stenosis. In such cases, decompression may be performed without stabilization, which would have otherwise been deemed necessary if standing plain films had been viewed and spondylolisthesis detected.

Background Literature:

The concept of exaggerated fluid in the facet joints as an indicator of dynamic instability is one that was not firmly established prior to the initiation of our study. Several reports anecdotally mention this finding, though it was not until recently that the incidence, pathology, and mechanism of this phenomenon were more extensively evaluated and presented in publication.

The presence of high intensity signals in or around the facet joint has been discussed in studies dating back the late 1980s (27)(28)(29). These works focused on the anatomy of the facet joint and noted that high intensity signals were produced by fat pads and/or synovial fluid associated with the articular joint. However, these reports did not make a correlation between the presence of increased fluid in the facet joints and dynamic instability such as spondylolisthesis.

In 1998 Mailleux et al. produced a report that discussed 2 cases of degenerative spondylolisthesis with stenosis that was not initially detected using MRI, but that was diagnosed on standing plain film (30). They explained that this was due to reduction of the slip in the supine position during the MR imaging process. They also noted that in these same cases, “MR images of the facet joints showed unusual large areas with hypersignal on T2 weighted images suggestive of fluid collection.” The authors proposed that these fluid signals should raise the suspicion of spondylolisthesis in the functional standing examination that reduces in the supine position. They believed that this finding could be an important diagnostic tool for the translation of the spine to a more neutral position when supine (i.e. during an MRI) may lead the diagnostician to underestimate spondylolisthesis and canal stenosis. This study appears to be the first published discussion of this phenomenon to our knowledge.

In a report similar to that published by Mailleux et al., in 2001 Bendo presented a case of a 46-year-old woman who had a missed case of L4-5 spondylolisthesis because the slip was not apparent on supine MRI (8). In their work they noted that “the only hint of radiographic instability on MRI was a high signal change on the T2-weighted axial image within the facet joints at L4-5 bilaterally.” They believed that this high intensity signal should “alert the investigator to the possibility of incompetent joints and perhaps instability.”

A literature review by Apostolaki et al. that discussed MR findings of lumbar facet synovial cysts also adds to this topic (31). In this review, they noted that in 40 patients with synovial cysts, 88% had degenerative spondylolisthesis and 80% had facet fluid. Though the purpose of their work was not to evaluate fluid in the facet joints as a sign of degenerative spondylolisthesis, they did present data suggestive of a potential correlation.

More recently, Ben-Galim and Reitman discussed a “distended facet sign” on supine MRI imaging that they believe to be indicative of position dependent spinal stenosis and degenerative spondylolisthesis (20). They evaluated 6 patients with symptoms of neurogenic claudication that could not be explained by stenosis or translational deformity on supine MRI. Standing plain films and computed tomography-myelography demonstrated dynamic spondylolisthesis and stenosis, respectively, in these patients. The researches then went back to reevaluate the supine MRIs of these patients. In this process they noted hypertrophic and fluid filled facets at the level of dynamic slip.

Similar to the other authors already discussed above, Ben-Galim and Reitman believed that the mechanics of this phenomenon was due to positional translation in the standing versus supine position.

Kim and Wang also recently discussed fluid signal in the facets (32). In this study they identified four types of facet joint synovial architecture on T2-weighed MRI scans. They then correlated the four types of facet joint synovial architecture with “hot” joints on SPECT scans. They reported that these four grades likely represent a continuum of facet degeneration, ranging from a normal to an obliterated joint. They found that one subtype, Grade 2 or “mottled,” often had increased synovial fluid, and they regarded this type of facet as an intermediate step in the progression of joint degeneration. Although they did not note that fluid in the facets was indicative of instability, they did find that it was highly predictive of a “hot” facet joint on single photon emission computed tomography.

Purpose

The purpose of this study was to determine the incidence of the MRI finding of exaggerated fluid signal in lumbar facet joints, and evaluate for the potential correlation of this finding with evidence of instability on upright radiographs. We hypothesized that a positive correlation would exist between those patients with exaggerated fluid in the facet and those with instability. At the initiation of the study, this was the first time that the relative incidence of subtle instability with and without this finding had been evaluated to our knowledge.

Methods

Approval was obtained by our institution's Human Investigations Committee on June 15, 2005. Following approval, all lumbar MRIs obtained by a single surgeon (Jonathan N. Grauer, MD) at a single institution (Yale University) from January 2003 to June 2005 were selected for retrospective review. Given these parameters, 134 consecutive patients were selected from the surgeon's database. Studies were excluded if any of following criteria were met: 1) Scans were technically limited (e.g., due patient movement or incomplete axial imaging); 2) Scoliosis great enough to obscure the axial images was noted; 3) Instrumentation was present; 4) Focal deformity secondary to trauma was noted. Each of these conditions, if present, would prevent proper evaluation of the architecture of the facet joint on axial views.

The MRIs were reviewed by two observers together: one spine surgeon (Jonathan N. Grauer, MD) and one musculoskeletal radiologist (Lee D. Katz, MD). At the beginning of the study, the medical student (Kimberly A. Schinnerer) assigned each patient a random identification number, which was the only means by which the two reviewers could identify the subjects. There was no knowledge of plain film findings at the time of this review of MRIs.

All MRIs were obtained on a General Electric Signa 1.5T (Waukesha, WI) scanner. We evaluated the T2-weighed axial and sagittal images, and the digital images were viewed using Synapse v 3.0 software (Fuji) in a systematic fashion. For sagittal images, findings of dark discs, loss of disc height, disc bulges, Modic changes, and anterolisthesis (measured in millimeters) were noted at each vertebral level from L1-2 to L5-S1. Anterolisthesis was measured from the posterior inferior corner of the superior vertebra to the posterior superior corner of the inferior vertebra. The findings were recorded by the medical student after agreement of the two reviewers. This method was meant to model a clinic environment, with the two reviewers essentially functioning as one.

Specific attention was then directed at evaluating the presence of exaggerated fluid in the facet joints on axial images. Each facet joint was independently evaluated (right and left separately). A joint was noted to be normal if there was no more than a physiologic amount of fluid, which was defined as a fluid signal of less than 1 millimeter between the articular processes (measured as a straight line, perpendicular to the apparent joint line). A joint was noted to have an abnormal amount of fluid (“exaggerated”) if that which was observed was greater than 1 millimeter (Figure 1). All of the above data was recorded onto a standard form that was used for each subject. At the end of each reading session, this information was entered into an Excel spreadsheet for data analysis.

Next, upright plain films were evaluated for all subjects. By the primary surgeon’s routine, these were standing AP, lateral, flexion and extension views. The same methods used to blind the readers during the MRI evaluations were used again in this portion of the study. Each patient was assigned a random identification number that was known only by the medical student. These images were evaluated for anterolisthesis (measured in millimeters in a similar fashion as described above). Finally, the data involving fluid in the facets was used to determine if a correlation exists between the described finding and spondylolisthesis.

We additionally assessed the intraobserver variability of evaluating MRIs for exaggerated fluid in the facets in this study. A subset of 10 MRIs was chosen by the medical student, which was reviewed by the study group a second time in order to assess intraobserver variability. A kappa value was calculated from the findings, and was interpreted as follows: <0 = no agreement; 0.0-0.19 = poor agreement; 0.20-0.39 = fair agreement; 0.40-0.59 moderate agreement; 0.60-0.79 = substantial agreement; 0.80-1.00 = almost perfect agreement (35).

All statistical analysis was performed by the medical student using Excel in additional to manual calculations.

Results

Of the 134 patients available for review, sixteen were excluded from the study (11.9%). Four were excluded because their MRI scans were technically limited (2 due to patient movement and 2 due to incomplete axial imaging). Three were excluded due to scoliosis, 4 due to instrumentation, 1 due to scoliosis and instrumentation, and 3 as a result of focal traumatic deformities. All of these situations inhibited proper evaluation of the facet architecture. One hundred and eighteen patients were left for inclusion in the study.

Of this population of 118 patients, 107 (90.7%) exhibited disc dehydration at one or more levels (20.3% at L1-2, 25.4% at L2-3, 41.5% at L3-4, 67.0% at L4-5, and 64.4% at L5-S1). Loss of disc height was seen in 84 patients (71.2%) in the study population (18.6% at L1-2, 17.0% at L2-3, 19.5% at L3-4, 37.3% at L4-5, and 44.0% at L5-S1). Forty five (38.1%) showed Modic changes (2.5% at L1-2, 6.8% at L2-3, 6.8% at L3-4, 15.3% at L4-5, and 21.2% at L5-S1). In 94 patients (79.9%) bulging disc(s) were identified (9.3% at L1-2, 17.0% at L2-3, 17.0% at L3-4, 48.3% at L4-5, 43.2% at L5-S1). This data has been included in Table 1.

Anterolisthesis was noted by MRI in 13 of the 118 patients (11.0%): 6 at L4-5, 5 at L5-S1, and 2 at both L4-5 and L5-S1. On standing plain film, anterolisthesis was noted in 14 of the 118 patients (11.9%): 2 at L3-4, 7 as L4-5, 4 at L5-S1, and 1 at both L4-5 and L5-S1.

Sixteen of the 118 MRIs reviewed had exaggerated fluid in the facets on axial images (13.6%). Intraobserver variability for this observation had a kappa value of 0.62

(substantial agreement). Only 2 of these 16 (12.5%) had spondylolisthesis appreciable on the MRI at the levels where fluid was found.

When the corresponding radiographs were reviewed, 8 of the 16 (50.0%) patients with exaggerated fluid in the facets on axial MRI images were positive for spondylolisthesis at that level on standing plain film. Two of these 8 were the cases where spondylolisthesis was also detected on MRI. Thus, spondylolisthesis was suggested in 6 of 14 cases (42.9%) when the fluid sign was present but spondylolisthesis was not evident on the routine supine MRI study. There was one patient with exaggerated fluid in the facets for which we were not able to obtain plain films, and thus this patient was excluded from the study. As a result, the values we have calculated could underestimate the proportion for which a slip would have been seen on plain film for this patient population.

When we evaluated the population without fluid signals, 5 had spondylolisthesis that was detected on MRI and x-ray, 1 on x-ray alone, and 3 had slips that were seen on MRI only. As discussed above in the Introduction, we believe that the gold standard for diagnosing dynamic instability is upright plain films. As such, the rate of spondylolisthesis in the patients without the fluid signal was 5.9% (6 of 102), as these were the only films where spondylolisthesis was diagnosed on x-ray. Furthermore, using parallel reasoning as above, spondylolisthesis was detected on plain film in 1 of 102 patients (0.9%) where it was not evident on routine supine MRI study in this population. The difference in incidence of spondylolisthesis on plain film that was not evident on MRI in the exaggerated fluid and non-exaggerated fluid groups was statistically significant ($P<0.001$).

The sensitivity and specificity for this finding in detecting spondylolisthesis were 57% and 92%, respectively. The positive predictive value was 50%. The negative predictive value was 94%. The positive diagnostic likelihood ratio was 7.43. In other words, for every 1% of subjects who were not diagnosed with spondylolisthesis on plain film but did have fluid in the facets on MRI, 7.43% that were diagnosed with spondylolisthesis did have fluid in the facets on MRI. The negative diagnostic likelihood ratio was 0.46. The odds ratio was 16.0 (95% CI, 4.44-57.60). Given that the prevalence of spondylolisthesis in this population was 11.9%, we used this value as the pre-test probability of having spondylolisthesis. Given a patient with fluid in the facets on MRI in our study population, the post-test probability of having spondylolisthesis was 93.0%.

Discussion

Review of Proposed Mechanism:

When an intact functional spinal unit is loaded, the facet joints resist the majority of the shear force, while the disc is primarily subjected to the compression (5). As with other synovial joints, osteoarthritis in the facet joint involves deterioration of the cartilage, subchondral sclerosis, osteophyte formation, and accumulation of fluid within the joint. As the facets wear, the vertebral body may settle forward (34)(35).

In the upright, loaded posture, the slip is most pronounced and facet joints contact one another as they limit the slip from progressing farther. In the supine position, however, the unstable spinal segment is unloaded and is therefore able to reduce posteriorly and return to a more neutral alignment. Consequently, the articular processes move away from one another with passive correction of the vertebral deformity. This creates a potential space within the facet joint. When viewed on T2-weighted MRI, this space may be identified as an exaggerated fluid signal. An example of this is shown (Figure 2).

Summary of Results:

In this study, 16 (13.6%) of the MRIs reviewed had fluid in the facets on axial images. Eight (50%) were positive for spondylolisthesis at that level on plain film, two of which had spondylolisthesis that was also evident on MRI at that level as well. Using standing plain films as the gold standard for diagnosing spondylolisthesis, a slip was suggested in 6 of 14 cases (42.9%) when the fluid sign was present but spondylolisthesis was not evident on the routine supine MRI study. In comparison, in the population of patients without the fluid sign, only 1 in 102 (0.9%) showed a slip on plain film that was not observed on MRI. The difference in incidence of spondylolisthesis on plain film that was not evident on MRI in the exaggerated fluid and non-exaggerated fluid groups was statistically significant ($P<0.001$).

The sensitivity and specificity for this finding in detecting spondylolisthesis were 57% and 92%, respectively. The positive predictive value was 50% and the negative predictive value was 94% when using the presence of fluid in the facets on MRI as an indicator of radiographic lumbar instability. The positive diagnostic likelihood ratio was 7.43, and the negative diagnostic likelihood ratio was 0.46. Patients with exaggerated fluid in the facets on axial MRI had a far greater likelihood of having spondylolisthesis on standing plain films than those without (odds ratio = 16.0, 95% CI, 4.44-57.60). We used the incidence of spondylolisthesis in our population (11.7%) as the pre-test probability of having spondylolisthesis. Given a patient with fluid in the facets on MRI in our study population, the post-test probability of having spondylolisthesis was 93.0%.

One way to interpret these values would be to say that our finding is relatively good at ruling in spondylolisthesis. In our patient population, if a patient is found to have exaggerated fluid in the facet joints on supine MRI, it is fairly likely this patient will have spondylolisthesis on standing plain film. At the same time, the negative predictive value for our finding is quite high, and thus the absence of fluid in the facets is also helpful for ruling out spondylolisthesis. It is important to note here that our finding is not meant as a substitution for obtaining standing plain films, rather it is intended to highlight the situations in which the MRI findings warrant further radiographic investigation for instability.

Applicability of Results:

The intraobserver variability for evaluating fluid in the facets had a kappa value of 0.62 (substantial agreement) which signifies that our reviewers were consistent in their assessments. Interobserver variability, on the other hand, is important for determining whether identifying fluid in the facet joints may be repeated by diagnosticians other than our two reviewers with similar results. This was not studied formally in our project.

A study by Mulconrey et al. in 2006 does evaluate interobserver reliability in the interpretation of diagnostic lumbar MRIs (36). In their study interobserver variability was determined using kappa values in a similar fashion to our study, and interobserver reliability was evaluated and compared with a “group consensus.” The readers were orthopedists and radiologists, also similar to our study. In addition, they used reviewers with a wide variety of background experience in reading MRIs. They interpreted the MRIs for degenerative discs, spondylolisthesis, and Modic changes. They found high kappa values in the identification of degenerative disc, spondylolisthesis, and Modic changes (0.773, 0.728, and 0.669, respectively), and thus concluded that MRI interpretation of the lumbar spine is comparable between specialties.

Although fluid in the facet joints was not evaluated in their study, we believe that the ability to evaluate the three designated findings of Mulconrey’s work is of the same diagnostic difficulty as evaluating fluid in the facets. As a result, we feel that their study may demonstrate the potential ability of our finding to be used by various clinicians reading lumbar MRIs. In the future, though, our findings will best be supported with evidence of interobserver reliability in detecting fluid in the facets on MRI.

Limitations:

There are limitations to our study. Most notable, this study evaluated a population presenting to a single spine surgeon and thus is subject to unintended selection bias. It represents a single cohort which we believe is typical of patients presenting to a spine surgical practice (Table 1). However, differences in patient populations may sway the results observed in a population such as this. Thus, as with any study of limited cohort size, it cannot be deemed a true representative sample. In addition, our results cannot be applied to any patients that would have been categorized under our exclusion criteria (i.e. those with scoliosis great enough to obscure the axial images, instrumentation, or focal deformity secondary to trauma). Finally, we did not record the type of spondylolisthesis that was present for each case of spondylolisthesis. We have suggested that the degenerative form of spondylolisthesis supports the proposed mechanism of our finding, although it is also possible that the lytic form could have similarly significant findings. As such, it would be important to study the types of spondylolistheses present and the relative incidence of fluid in the facets in each subgroup to prove the validity of our explanation.

Review of Recent Literature: Rihn et al.

This finding of fluid in the facet joints has been previously suggested, but the relative incidence of subtle instability in patients with and without this finding had never been evaluated in an objective fashion to our knowledge at the time of initiation of our study. Since then, two reports have been published describing the same phenomenon, with similar results.

In 2007, Rihn et al. performed a retrospective radiographic study in order to analyze the association between fluid in the facets in the lumbar spine and instability detected on a flexion radiograph (37). In their words, "based on previous biomechanical studies that demonstrate the importance of facet integrity in lumbar spinal stability, [] a lumbar spinal segment with degenerative, fluid-filled facets would demonstrate instability." These authors explain that the fluid is a result of degeneration of the synovial facet joint, which like other arthritic synovial joints (such as the knee, hip, etc.) is easily detectable using MRI. Unlike T1-weighted sequences which are helpful for evaluating normal anatomy, T2-weighted sequences highlight extracellular free water and thus are useful when evaluating facet fluid.

While our study looked at all patients presenting to a spine surgeon, their patient population included 51 patients with degenerative lumbar disease who underwent laminectomy plus arthrodesis or laminectomy alone at L4-5 over a 2 year period. Patients were required to have preoperative MRI as well as AP and weight-bearing flexion-extension lateral lumbar radiographs available for review. Patients with prior surgery, or lumbar disease other than degenerative (trauma, infection, tumor, etc.) were excluded. After exclusions, they evaluated all patients for fluid in the facets on MRI.

They calculated a “facet fluid index,” which was defined as the ratio of the width of fluid in each facet (bilateral) to the sum of the width of both facets (bilateral).

In their study group, 23 (45%) of patients did not have fluid in the facets on MRI, while 28 (55%) did. This percentage is much larger than that found in our study, which is likely due to the fact their study group consisted of a population with already diagnosed degenerative disease, while our population was all those presenting to a spine surgeon regardless of diagnosis.

Of the patients with no facet fluid, 4 of 23 (17.4%) had instability noted on the flexion lumbar radiograph, and 19 of 23 (82.6%) had no instability noted. In contrast, in those patients with facet fluid on the MRI, 23 of 28 (82.1%) had instability and 5 of 28 (17.9%) had no instability on flexion lumbar radiograph. In addition, in those 28 patients that had fluid in the facet joints, there was a significant positive linear correlation between the facet fluid index and the percentage radiographic slip. They calculated a positive predictive value of 82% and negative predictive value of 83% when using the presence of L4-5 facet fluid on MRI as an indicator of radiographic lumbar instability. Finally, they concluded that patients with facet fluid had a far greater likelihood of having instability than those without facet fluid (odds ratio = 21.9%; 95% CI, 5.1-93.0). Their study was performed with a high interobserver and intraobserver reliability.

An important point of commentary in their report, which we have also discussed above, is that MRI alone should not be used to diagnose lumbar instability. In their study they found that 15% of patients with radiographic evidence of instability did not have facet fluid present on MRI. Furthermore, 19% of patients with facet fluid on MRI did not have evidence of instability. As are result, they conclude that weight bearing flexion-extension radiographs are still essential for complete assessment of lumbar instability

The main limitation that the authors focus on in their discussion is that their definition of instability does not take into account other forms of instability such as rotational instability (which they note is common in patients with degenerative lumbar disease). As such, it is possible that there were incidences of lumbar instability in this study population which were not detected on the flexion films. Alternative means of diagnosing instability, such as traction-compression radiographs, dynamic MRI, or three-dimensional dynamic computed tomography may not have missed these potential cases. The authors did not elect to use these forms of diagnostic imaging as plain AP and flexion radiographs and static MRI were the only means that were readily available at their institution. Additionally, they explained, plain film and static MRI are the most commonly used modalities in current clinical practice to asses the lumbar spine for degenerative disease and instability, making them the best options for this type of study.

Review of Recent Literature: Chaput et al.

The second study that adds to our research was published by Chaput et al. in 2007 (38). Thus study also evaluated the significance of fluid signal in the facets in relation to degenerative spondylolisthesis. The purpose of their study was to “define MRI findings at the facet joints that may suggest abnormal sagittal plane translation seen on standing lateral flexion-extension radiographs.”

Similar to our work, their patient population was obtained by evaluating all patients seen at an orthopedic spine service over a two year period. After exclusions, a total of 193 patients’ films were retrospectively analyzed at the L4-5 spinal level. Exclusion criteria were comparable to ours, although they also excluded patients with plain films and MRIs taken more than one year apart, skeletal dysplasia, or history of inflammatory arthritis.

The authors defined a facet effusion as a “measurable, curvilinear, high intensity signal within the facet joint, which closely matched that of cerebrospinal fluid on the axial T2 images.” The amount of fluid was measured perpendicularly to the apparent joint line, and the largest value was noted as the “effusion size.” They also evaluated each facet with respect to osteoarthritis using a classification system defined by Weishaupt et al. (39). In this system facet joints are graded I through III, with Grade I representing mild degenerative changes and Grade III representing severe degenerative disease of the facet joint.

In their study, 139 (72%) of patients did not have degenerative spondylolisthesis, while 54 (28%) did. Thus, their study population had over 100% more patients with spondylolisthesis than our study population (11%). The most likely explanation for this disparity is due to differences in severity of lumbar degenerative disease in the two patient populations. One would think that since we looked at multiple lumbar levels, rather than only looking at L4-5, we would have a higher percentage of patients with diagnosed spondylolisthesis (as L5/S1 is also a common level for spondylolisthesis). As a result, the best explanation must be that the dissimilarity is a result of the differing cohorts.

The median facet joint effusion was 0.83 mm for the population without degenerative spondylolisthesis and was 1.05 mm for those with spondylolisthesis ($P<0.0001$). Over 40% of the patients without spondylolisthesis had no measurable facet joint effusion versus only 20% (11 patients) in the population with spondylolisthesis. Interestingly, all but one of the 11 with spondylolisthesis on plain film but no fluid on MRI had a slip that was easily measurable on MRI. For all patients with and without spondylolisthesis, those with osteoarthritis of Grade II or less had larger joint effusions than those with Grade III osteoarthritis.

The authors then conducted a univariate logistic regression using only facet effusion as a variable. Here they noted that the probability of having spondylolisthesis when a 1 mm effusion was found was 29.6%. For a 2 mm effusion the value rose to 60.3%, and for a 3 mm effusion it was 84.6%. After adjusting for age and osteoarthritis grade, every 1-mm increase in effusion increased the odds of having spondylolisthesis by approximately 5.6-fold.

Twelve (22.2%) of the patients in this study who were diagnosed with spondylolisthesis on standing plain film did not show evidence of a slip on supine MRI. The authors note that this suggests a more “mobile degenerative spondylolisthesis,” and they provided data to support this argument. The median effusion for this group of patients with spondylolisthesis on plain film but not on MRI was 1.94 mm. This value is over twice the size of the median effusion for the other 42 patients who had spondylolisthesis appreciable on plain film and MRI, which was 0.90 mm ($P<0.0131$). Additionally, only one patient in this subset who had spondylolisthesis that was not evident on MRI had an effusion of <0.9 mm.

In their publication, the authors present an excellent description of facet joint degeneration and how it relates to the above findings. They site Kirkaldy-Willis's division of the process of degeneration into three phases (4). In this description, the first phase is dysfunction of discoligamentous structures with limited anatomic disruption. In the second phase instability begins, and decreased disc height, loosening of facet capsules and ligaments, and articular alterations are all seen. This, in turn, can lead to increased translational and rotational movement. As the degenerative process continues, osteophyte formation and fibrosis lead to stiffness and eventual re-stabilization. The authors comment that "theoretically, as the degenerative process progresses from the phase of instability to the phase of restabilization, there should be a decrease in facet joint effusion."

Their data reinforce this suggestion, as both those patients with and without spondylolisthesis demonstrated significantly smaller effusion size with the more advanced Grade III osteoarthritis compared with those of Grade II or I. They point out that several cases of degenerative spondylolisthesis in the older population of their study (>70 years old) did not have a significant effusion on MRI, though they did shown signs of Grade III degenerative changes with large osteophytes. As a result, they suggest that the instances of degenerative spondylolisthesis in the elderly population with extensive arthritis were more likely to be appreciable on MRI and less likely to have a significant effusion. This is because their spondylolisthesis had reached the phase of relative stability in the degenerative process described above (i.e., the slip does not change significantly between the supine and standing positions, and thus an exaggerated fluid signal does not appear on supine MRI). Instead, there are large osteophytes associated with the facet joint.

They also suggest that this explains why there is such a small difference in median millimeters of facet effusion between those with spondylolisthesis versus those without (0.83 mm versus 1.05 mm) in their study. If only those patients where the slip was not measurable on MRI but was apparent on standing plain film were examined (i.e., those with translational movement), the mean measurement of facet effusion was 1.94 mm. This subset represents those with a higher degree of instability, where the fluid in the facets collects as a result of the translational movement of the lumbar spine segment in the supine position.

In conclusion, the authors propose that "large (>1.5 mm) facet effusions are highly suggestive of degenerative spondylolisthesis at L4-5 in the absence of measureable anterolisthesis on supine MRI." They present recommendations for simple criteria for obtaining standing lateral flexion-extension films to determine the existence of degenerative spondylolisthesis. First they set forth that patients with a measurable slip on MRI can be assumed to have spondylolisthesis as this group always had a measurable slip on plain film in their cohort. We also set forth similar parameters in our conclusion, as we saw that these patients had cases of spondylolisthesis that would not have been missed on supine MRI, regardless of whether or not we found fluid in the facets. Secondly, they define “clinically measurable” effusions as those larger than 1 mm, as we did in our study, and recommend that the presence such effusions warrants standing lateral flexion-extension films. By applying these two criteria to the patient population in their study, only 1 case of spondylolisthesis would have been missed out of 54 (1.8%).

In the conclusion section, the authors reference the potential benefit of using dynamic MRI, and note that it may have detected some of the missed spondylolistheses in the study. They also comment, though, that standing plain films are much more readily available at this time and it is unknown if dynamic MRI would eliminate the need to obtain them.

The limitations of this study include the fact that the findings were limited to the L4-5 spinal segment. The authors explain that too few patients had degenerative spondylolisthesis at the L3-4 and L5-S1 levels to allowing for meaningful comparisons. In addition, the study excluded a variety subjects and thus it would be incorrect to attempt to apply their conclusions to patients with spondylolysis, lytic spondylolisthesis, scoliosis, previous surgery, bony abnormalities, or inflammatory conditions. As with our study, the results cannot be used for the general population either, for this cohort does not reflect the prevalence of degenerative spondylolisthesis in the general population. All patients that were included were referred to an orthopedic spine clinic for back or lower extremity pain. As such, their results may overestimate the prevalence of spondylolisthesis and possibly the association between facet effusions and spondylolisthesis in the general population.

The Future: Functional MRI:

An interesting point to note, although not formally studied in our project, is that the fluid signal on supine MRI may be seen to a lesser extent when the patient stands. In the upright position, the alignment partially slips back due to the dynamic instability and the potential space between the facets is reduced. The fluid is most likely disbursed around the joint in this position, and as such it is not seen as an isolated collection between the articular surfaces. An example MRI of a patient in an upright as well as supine position demonstrates this concept (Figure 3).

In the future, studies that can further examine the use to functional MRI to explain this pathomechanism will be important. As already mentioned in the Introduction section, studies evaluating the use of axial loading MRI provide noteworthy results. Jayakumar et al. applied axial force to the spine during MRI scans and found that this helped to identify occult dynamic degenerative spondylolisthesis versus using conventional MRI (21).

A study by Vitzthum et al. in 2000 is another good example (26). The authors examined the relationship of different structures of the lumbar spine during interventional movement examination in a MR scanner. They used clinically healthy volunteers as well as patients with degenerative disorders of the lumbar spine, all of which underwent vertical open MR imaging.

In the 50 healthy volunteers the authors recorded characteristic angles of the facet joints, and three functional patterns of lumbar spine motion were identified. In the 50 patients with degenerative disorders, the range of motion was increased in the degenerative spinal segments. In addition signs of neural compression were increased under spinal motion. As such, they found that dynamic examinations using open MR imaging may help define spinal segmental instability and provide objective numerical data on segment mobility. At this point, the cost and availability of functional MRI limit its clinical use, although it could be an important component to the study of dynamic lumbar instability in the future.

Conclusion:

In conclusion, attention to exaggerated fluid signals in the facet joints significantly increases the likelihood of detecting spondylolisthesis in this patient population versus using MRI alone. We believe that it is an important addition to the diagnostic evaluation of patients for whom detection of such findings may alter patient management. For our primary surgeon's practice, this is most germane to the preoperative patient. A patient with evidence of spinal stenosis, as well as dynamic instability on lumbar imaging, would likely benefit from stabilization in addition to decompression. In contrast, in a patient with only spinal stenosis who lacks evidence of dynamic instability, decompression alone may be sufficient.

It is important to reiterate that we do not believe that the finding of fluid in the facets should take the place of obtaining upright plain films. Rather, this finding should highlight the need to obtain plain films in order to better assess instability. Our primary surgeon routinely obtains upright radiographs for all preoperative patients, as it remains an important factor in pre-surgical evaluation for this patient group.

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Tables and Figures

Table 1: Descriptive Statistics of Patient Population in Percentages

	Dark Disc	Disc height loss	Modic Changes	Disc Bulge
L1-2	20.3	18.6	2.5	9.3
L2-3	25.4	17.0	6.8	17.0
L3-4	41.5	19.5	6.8	17.0
L4-5	67.0	37.3	15.3	48.3
L5-S1	64.4	44.0	21.2	43.2

Figure 1: Axial T2 MRI examples of patients noted as having increased fluid within the facet joints (A), as well as those deemed to be within normal limits (B).

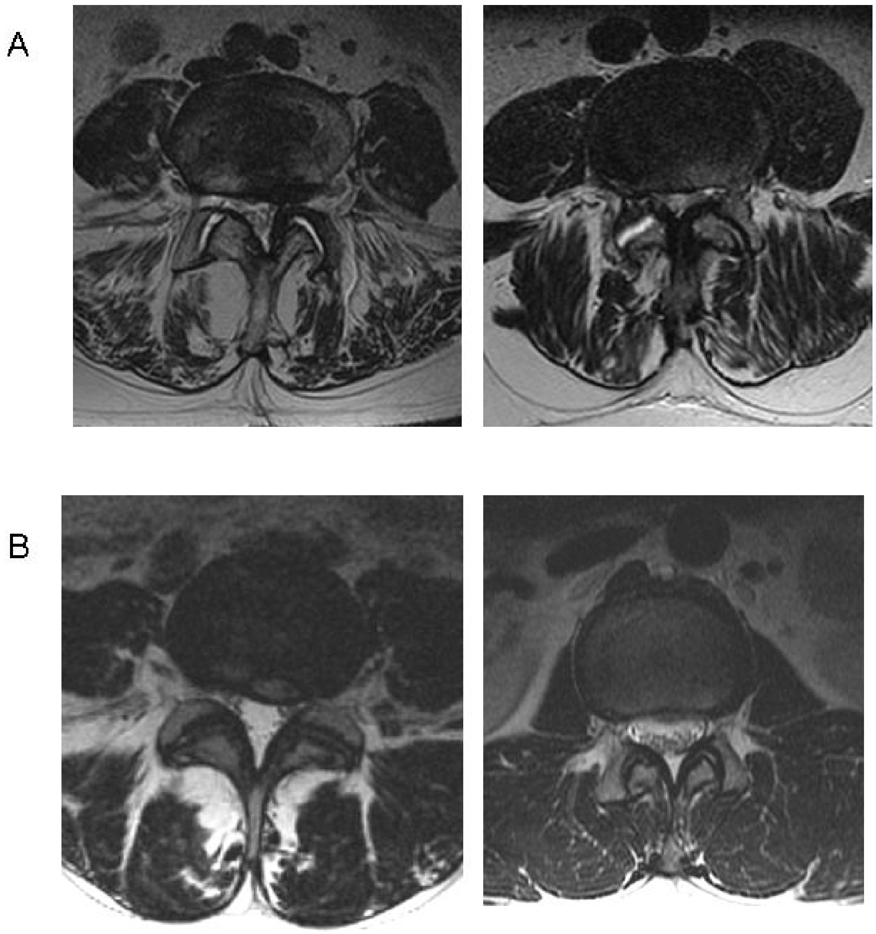

Figure 2: Case example of fluid in facet joints. **(A)** Mid-sagittal T2 MRI image of the lumbar spine. Degenerative changes are noted at L4-5 and possibility of a subtle L4-5 spondylolisthesis is raised, but not entirely clear. **(B)** Axial T2 MRI image through the L4-5 level demonstrating fluid signal within the facet joint (arrow). **(C, D)** Flexion and extension lateral radiographs of the same patient showing the L4-5 degenerative spondylolisthesis (arrows). This highlights the finding which was not well seen on supine MRI imaging, but which was suggested by the exaggerated fluid in the facet joints of that study.

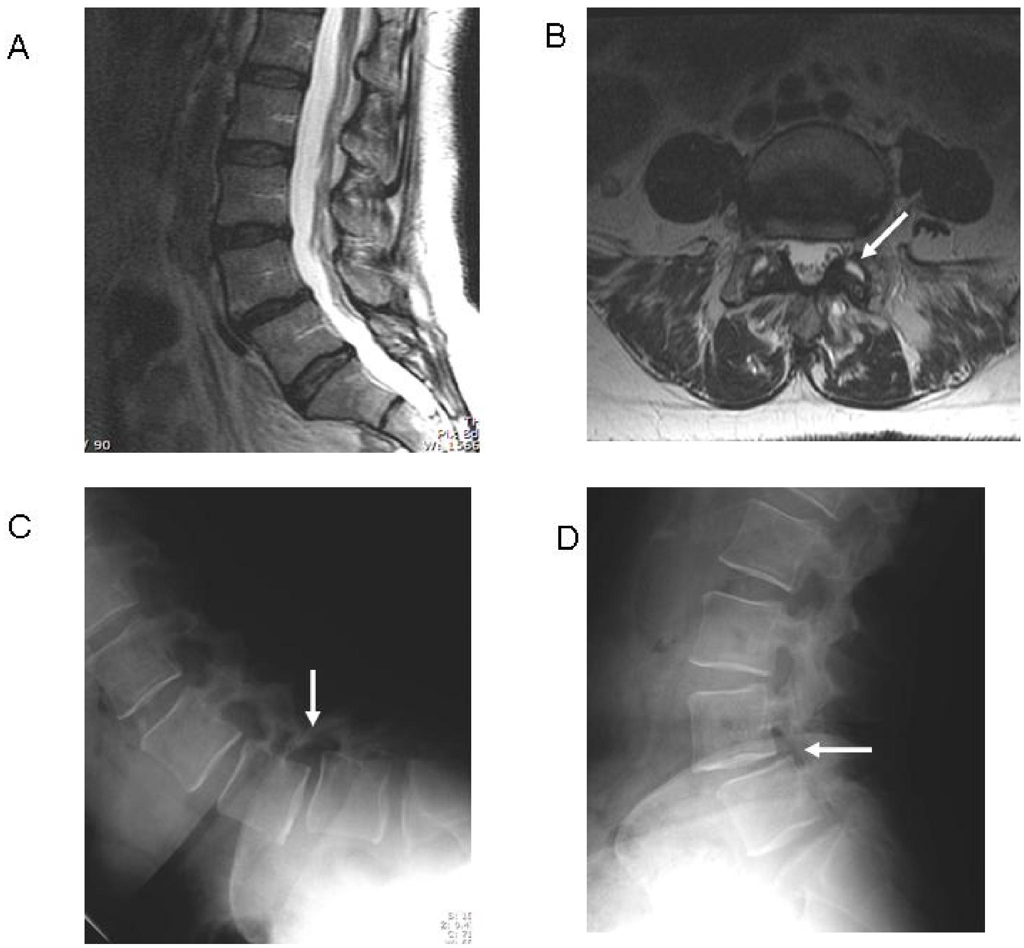

Figure 3: Additional images of the patient presented in the Figure 2 case example. These images are from a separate MRI obtained in the standing position (FONAR scanner). The sagittal image (A) demonstrates the L4-5 spondylolisthesis which was noted on standing films, but not supine MRI. The axial image through the L4-5 level (B) demonstrates that the exaggerated fluid in the facets which was seen on the supine imaging of this patient is no longer visible.