

Research progress of diagnosing methodology for lumbar segmental instability

A narrative review

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Abstract

Objective: Lumbar segmental instability (LSI) is due to a pathologic movement of the vertebral body on the vertebra below and often causes clinical symptoms. The study was to achieve the research progress of diagnosing methodology for lumbar segmental instability and help clinicians make treatment choices.

Methods: The data for this study were collected from the MEDLINE, Springer, Web of Science, PubMed, EMBASE, the Cochrane Central Register of Controlled Trials, Evidence Based Medicine Reviews, VIP, and CNKI. The search terms were integrated as follows: “(*lumbar instability* OR *lumbar spondylolisthesis*) and (*image* or *diagnosis*)”. Studies without clear radiographic instable criteria, case reports, letter, and basic research were excluded.

Result: In total, 39 articles published met our inclusion criteria. The various modalities were used to diagnosis LSI in these studies included radiographs, facet joint degeneration and physical examination tests.

Conclusion: Overall, there have been a variety of researches to develop the diagnosing methodology for LSI, and many have been successful, although no consensus has been reached yet. However, it is believed that the diagnosis of LSI will become easier and more accurate in the near future.

Abbreviations: DXR = dynamic X-rays, F/E = flexion-extension, LSI = lumbar segmental instability.

Keywords: diagnosing methodology, literature review, lumbar segmental instability, research progress

1. Introduction

Lumbar segmental instability (LSI) is due to a pathologic movement of the vertebral body on the vertebra below and often causes clinical symptoms. Spondylolisthesis is a main factor causing low back pain. The topic of chronic instability of the lumbar spine is subject to much debate as to the exact nature of

the problem, the correlation with symptoms, or the relevance to patient management.^[1–4] Some authors refer to the concept of instability also considering the so-called “clinical” or “functional” instability, in which no defect of the body architecture of the lumbar spine, and no excessive detectable translation or rotation are shown. So, we consider that lumbar instability is an evolving and challenging concept.^[4–9]

Previous reviews separately investigated the diagnostic accuracy or the reliability of the instability tests, but a complete vision about their diagnostic validity to detect lumbar instability is lacking. The objective of this literature review is to achieve the research progress of diagnosing methodology for lumbar segmental instability and help clinicians make treatment choices.

2. Materials and methods

2.1. Search criteria

We conducted a comprehensive computerized literature search through multiple electronic databases without date limits up until August, 2020 by using combinations of key search terms. MEDLINE, Springer, Web of Science, PubMed, EMBASE, the Cochrane Central Register of Controlled Trials, Evidence Based Medicine Reviews, VIP, and CNKI were searched for any potential studies. The search terms were integrated as follows: “(*lumbar instability* OR *lumbar spondylolisthesis*) and (*image* or *diagnosis*)”. This is a review that does not require an ethics committee review board approval and informed consent.

2.2. Inclusion and exclusion criteria

Articles for potential selection were screened using inclusion and exclusion criteria. Inclusion criteria include studies published in

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All data generated or analyzed during this study are included in this published article [and its supplementary information files].

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peer-reviewed journals in English or translated into English and studies reporting on the diagnosing methodology for lumbar spinal instability or lumbar spondylolisthesis. Studies with the following criteria were excluded: non-English; no clear radiographic instable criteria; case reports; not a full-text article (editorials or letters); basic science studies.

2.3. Study selection

All duplicated studies will be imported into Endnote X7 software and excluded before the screening. Two authors will independently scan all the records from title and abstract and all irrelevant literatures will be removed. Then, full manuscripts of all remaining studies will be further identified to check if they meet all inclusion criteria. We will note all excluded citations with specific reasons. If there are any different opinions between 2 authors, we will invite another author for consultation and final decision will be made after discussion. The detail of the study selection will be presented in a PRISMA flow diagram

2.4. Data extraction

After an initial screen of abstracts and article titles, we obtained full text articles of all potential studies. To perfect the research, 2 independent researchers reviewed and evaluated the included articles, respectively. Any different opinions were discussed until consensus was reached. Relevant data identified from each article was the type of study, level of evidence, number of patients included, examination methods, and diagnosing methodology used to assess spinal instability.

3. Results

Our initial search resulted in 86 articles. Of these, we excluded those identified as duplicate articles, editorials, letters, or basic science studies, and identified 54 full-text articles. With detailed analysis, we excluded 15 full-text articles (3 non-English; 7 could not be found and 5 with no clear radiographic instable criteria). A total of 39 full-text articles were found to be relevant for the systematic review. The various modalities used to diagnosis LSI in these studies included radiographs, facet joint degeneration and physical examination tests.

3.1. X-ray image

The execution of dynamic X-rays (DXR) in flexion and extension is the most commonly used in clinical practice and widely recognized as an effective method to detect the presence of LSI. The range of segmental vertebral mobility is relatively wide, it is widely be accepted by many authors that sagittal translation of segmental vertebral ≥ 4 mm or $\geq 8\%$ and a sagittal rotation $\geq 10^\circ$ in L1 to L5 and $\geq 20^\circ$ in L5 to S1 are pathological for LSI. Patient can evocate a greater segmental slip in the standing position compared to the recumbent position, so it may not reflect the degree of LSI sensitively and accurately.^[10–12] At the same time, its clinical significance is still controversial and there is not a unanimous consensus on this technique. *Tarpada* indicated that supine radiograph demonstrates more reduction in anterolisthesis than the extension radiograph. Incorporation of a supine lateral radiograph in place of extension radiograph can improve the understanding of segmental mobility when evaluating degenerative spondylolisthesis.^[11] *Landi* suggested that DXR in

flexion and extension performed in recumbent position (RDXR). With the patient lying along his side, it can reduces the augmented muscular tone of the paravertebral muscles in patients with low back pain or sciatic pain and might discover hypermovements hidden by antalgic contractions when investigated with DXR obtained in standing position.^[6] Among 200 patients in the study, 43 patients (32.3%) showed a hypermovement in RDXR ($P < .05$). The study drew the conclusion that the execution of RDXR has high sensibility and specificity in doubtful cases (patients suspect for LSI or with negative SDXR). *D'Andrea* reported that a new method of “Supine-prone” dynamic X-ray amination to evaluate low-grade lumbar spondylolisthesis, he found a higher degree of listhesis in 19 cases (14 I grade, 5 II grade), while there was no difference in 56 cases. The results indicated that supine-prone dynamic X-ray has a better diagnostic value than of flexion-extension (F/E) images.^[13]

Some scholars recommend that instability should be evaluated by standard upright lumbar lateral radiograph (U) with a supine sagittal magnetic resonance image (S) (combined, U/S). Liu did a prospective cohort study to investigate and compare the use of 2 diagnostic modalities in the evaluation of stability in lumbar spondylolisthesis. Overall, the mobility in US was significantly higher than that in F/E images ($7.68 \pm 5.34\%$ vs $4.90 \pm 3.82\%$ $P = .001$). The ability to identify “instability” on the basis of U/S was improved compared with that obtained using F/E X-ray.^[5] *Chen* also found that U/S MRI could find many patients with lumbar instability in kyphosis that could not be found by F/E X-ray. The U/S MRI was also less affected by the experience of the evaluator, with good consistency, and could reduce missed diagnosis.^[14] In the study of *Viswanathan*, patients diagnosed by F/E X-ray as unstable were divided into 1 group, and the patients diagnosed by U/S MRI as unstable and not meeting the criteria of F/E X-ray were divided into another group. And compare the radiographic and degeneration parameters between the 2 groups, the results showed that there was no statistical difference between these parameters of the 2 groups. It also suggests that the application of the U/S has the opportunity to distinguish a number of unstable patients from those diagnosed as stable by F/E images.^[15]

In recent years, a new kind of semiautomatic X-ray radiography device (vertebral motion analysis system, VMA) is developed to aid diagnosis the LSI. In addition to taking standard F/E X-rays, it also includes various body positions assisted by the system, such as upright position and reclining position. Through the built-in program of the system, the patient can be photographed in a more standardized process, and more accurate analysis can be achieved. The result indicated that the VMA system had an overall improvement in specificity, sensitivity, consistency and negative predictive value compared to traditional F/E X-ray.^[17]

3.2. Facet joint degeneration on CT and MRI

As the degeneration of the facet joints is coupled with intervertebral disc degeneration, both of which are important contributors to lumbar instability. Several studies have attempted to address the relationship between lumbar instability and facet joint degeneration.^[16,17]

CT examination of patients with LSI can often reveal a vacuum phenomenon in the lumbar facet joints. Some literatures have studied the relationship between vacuum facet phenomenon and lumbar segmental instability. *Sun* indicated that there was a linear

correlation between the degree of segmental motion and the width of vacuum facet phenomenon in patients with degenerative spondylolisthesis at L4-5. Vacuum facet phenomenon detected on CT images of patients with degenerative spondylolisthesis are highly predictive of segmental instability.^[18]

Previous studies have demonstrated that there is a high statistically significant correlation between exaggerated fluid in facet joints and lumbar instability in the MRI image. Fluid collections within the lumbosacral facets detected on MR images are indicative of segmental instability in patients with lumbar spondylolisthesis.^[19,20] *Chaput* indicated that large (>1.5 mm) facet effusions were highly predictive of degenerative spondylolisthesis at L4 to 5 in the absence of measurable anterolisthesis on supine MRI. A clinically measurable facet effusion (≥ 1 mm) suggests the need for F/E images to diagnose degenerative spondylolisthesis that can be missed with supine positioning on MRI.^[21] *Cho* selected 94 patients with degenerative spondylolisthesis who underwent decompression surgery. Patients were divided into 2 groups by the presence of lumbar instability and measured degeneration status of intervertebral discs and facet joints and distance of facet fluid signal on T2 axial MRI on each groups. The study drew the conclusion that high signal in facet joints on T2 MRI images can be a useful factor suggestive of lumbar instability and the identification of fluid signal in the facet joints on MRI should raise the suspicion for lumbar instability.^[17] *Lattig* found that the difference in the % slip measured on X-ray and on MRI was $\geq 3\%$ and facet joint effusion is clearly correlated with spontaneous reduction of the extent of slippage in the supine position compared to the upright position. Also, the greater the difference in right and left facet effusion, the higher the likelihood of having a rotational translation.^[9] We examined the reliability of radiological findings in predicting segmental instability in 112 patients who had degenerative disease of the lumbar spine. Multivariate regression analysis revealed that facet opening was the strongest predictor for instability followed by spondylolisthesis, MRI grade and subchondral sclerosis.^[22]

3.3. Physical examination tests

Although the clinical features of lumbar instability lack specificity, it is of great significance in the diagnosis of symptomatic LSI. With the exception of the active hip abduction test, aberrant movement pattern, prone instability test, passive lumbar extension test, and lumbar extension load test can be considered sufficiently reliable for clinical use.^[23–26] A prospective cohort study was proposed by *Hicks* to develop a clinical prediction rule to predict treatment response to a stabilization exercise program for patients with LSI.^[27] The most important variables were age, straight-leg raise, prone instability test, aberrant motions, lumbar hypermobility, and fear-avoidance beliefs. The best rule for predicting success was the presence of 3 or more of the 4 variables. *Abbott* provided evidence reporting the validity of manual tests for the detection of abnormal sagittal planar motion. The results indicated that PAIVMs (passive accessory intervertebral motion tests) and PPIVMs (passive physiological intervertebral motion tests) were highly specific, but not sensitive. This research also indicated that manual clinical examination procedures have only moderate validity for detecting segmental motion abnormality.^[28] *Denteneer* did a systematic review to provide a comprehensive overview of 30 clinical tests associated with functional LSI and motor control impairment, and to investigate their intrarater and interrater

reliability. 3 clinical tests had been concluded to have an adequate reliability: the prone instability test, aberrant movement pattern, and Beighton Scale.^[29]

In the review of *Ferrari*, the passive lumbar extension test is the most accurate single physical examination test for determining LSI due to its highest sensitivity, specificity and consistency, but it is still not as good as F/E X-ray.^[30] However, result of *Rathod's* study is opposite, the sensitivity and specificity of the passive lumbar extension test are poor, while the rolling test performance is better. A new Lumbar rocking test was recommended with 95.56% sensitivity and 93.47% positive predictive value.^[31] Other researchers believe that low midline sill sign is a better physical examination method for LSI. Lack of repeated verification, it is difficult to evaluate its value.^[8,32]

4. Discussion

A variety of causes such as degenerative disease of discs and/or facet joints, spinal deformity, lesions of muscle and/or fascia and even psychological factors is thought to give rise to low back pain. Segmental instability is merely the biomechanical failure of a lumbar segment and does not necessarily correlate with the degree of pain. Previous studies, however, have mostly identified instability using flexion/extension radiographs and have not presented biomechanical measurements including the neutral zone, which is the key to identifying instability. To my best knowledge, this study the first to research the progress of diagnosing methodology for LSI. With this objective in mind, we conducted a systematic literature search to guarantee the comprehensiveness of the studies included. Given the evidence provided by this study, accurate imaging and characterization of LSI is absolutely crucial to the development of a proper treatment plan.

In the exploration of how to diagnose lumbar instability more accurately, we found that the improvement of the F/E X-ray examination position and the adoption of U/S MRI were effective supplements to the traditional F/E X-ray examination, which could improve the accuracy of diagnosis rate of LSI. The use of computer-aided system for auxiliary photography is also an idea, which can reduce the errors caused by patients' nonstandard posture. It also obtains obvious progress in sensitivity, specificity, consistency, and other aspects. The facet joint effusion found by lumbar MRI is a good indicator for predicting LSI, and even helpful for determining the severity of lumbar instability. The change in the width of facet joint space may be another effective indicator for predicting LSI, but it needs further research to prove. Lumbar rotator center is helpful for the identification of LSI and nonspecific chronic low back pain as well as asymptomatic population. The intraoperative assessment system is difficult to be used for preoperative diagnosis, but the sensitivity and specificity of other diagnostic or examination methods can be evaluated, which is worthy of more researchers to use and improve.^[20,21,24]

Many researchers are trying to include the patient's clinical symptoms into the diagnosis of LSI. Among all kinds of physical experiment, prone instability test and passive lumbar extension test are most valuable. But, there are also many researchers got the opposite conclusion, it is mainly caused by physical examination test operators on the operation and interpretation of subjective error. So for, strict and standardized procedures, strict operation personnel training and clear criteria are very important.^[19,22,25]

In general, the physical examination tests or assessment questionnaire are supposed to be an important means of auxiliary diagnosis of LSI, because they are simple and economical. Both in operation and results interpretation, there is the shortcoming of physical examination that the subjective error is bigger, so the research conclusions are controversial and the repeatability is poor. For CPR, PLET or PIT test, different researchers for their opinions tend to vary wildly, so they are far from can be applied for clinical applications. Moreover, due to the large number of physical examination tests, most of them are only involving in 1 study, which cannot be compared horizontally. This is also an important problem. The diagnosis of LSI by physical examination or evaluation questionnaire is a promising direction, but efforts should be made in clarifying the detailed procedures of physical examination, standardizing the training of physical examiners and standardizing the interpretation of results.

5. Conclusion

Overall, there have been a variety of researches to develop the diagnosing methodology for LSI, and many have been successful, although no consensus has been reached yet. However, it is believed that the diagnosis of LSI will become easier and more accurate in the near future

Author contributions

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