Quantification and Classification of Lumbar Disc Degeneration

Timothy L. Tan, BS[1], Sean L. Borkowski, MS[2], Sophia Nicole Sangiorgio, PhD[2], Patricia Campbell, PhD[2], Edward Ebramzadeh, PhD[2].
[1]UCLA, Los Angeles, CA, USA, [2]Orthopaedic Hospital/UCLA, Los Angeles, CA, USA.

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Introduction: Annually, low back pain affects more than 54 million patients, many of whom require surgery. Despite efforts over the past decade to limit unnecessary imaging with evidence based guidelines, the two most common imaging modalities, X-ray and MRI, remain widely ordered, rarely resulting in definitive diagnoses. Furthermore, the most common imaging finding is nonspecific degeneration, which frequently has little correlation with clinical pain. When degeneration is found, both primary care physicians and spine specialists frequently use subjective evaluation to classify imaging changes.
As healthcare becomes more standardized and closely monitored, it is worth evaluating whether an objective classification system should be applied to classify lumbar degeneration. While multiple classification systems have been developed, primarily as research tools, for evaluating disc degeneration, it is unclear whether there is a definitive gold standard classification criteria for the two most common imaging modalities: X-ray and MRI.
In this study, a comprehensive systematic review was performed to identify available lumbar disc degeneration classification systems for X-ray, MRI, and histology, and determine their respective frequency of use.
Methods: In order to assess the lumbar classification systems, a MEDLINE search was done using the search terms “lumbar degeneration” and “classification.” Articles developing classification systems for grading of intervertebral disc degeneration using X-Ray, MRI, and histology were identified. Once found, the “related citations” option of PubMed was used for each classification criteria to identify additional articles missed using the initial search criteria. Only lumbar classification systems that evaluated the intervertebral discs were included.
Once identified, to assess the popularity of each classification system, the earliest dated article that established the specific classification system was found. Then, Google Scholar and Web of Science (WOS) were used to identify the number of times the original classification article has been cited. In addition, among the research articles that cited the original classification systems, the number of NIH funded studies (2008 - present) was identified using PubMed Central (PMC) and WOS in order to identify studies of higher quality.
Results: Fifteen grading classifications using imaging were found, including six systems for X-ray, eight systems for MRI, and one system utilizing both radiographs and MRI. Radiographic grading systems ranged in grading from 0-2 to 1-4, and were mostly based on evaluation of indirect disc features: disc height, endplate sclerosis, and osteophytes (Table 1). Of the six X-Ray classification systems, no single system could be determined to be the ‘gold standard’. Four classifications systems have each been cited more than 100 times in both Google Scholar and WOS. Among NIH funded studies citing these classification systems, only Lane et al.’s [1] classification criteria and Wilke et al.’s[2] classification criteria were used.
MRI grading scales ranged from 0-3 to 1-8, and were based on characteristics intrinsic to the disc, such as nuclear signal, disc height, and distinction between nucleus and annulus. Unlike X-Ray classification systems, Pfirrmann et al.’s[3] classification system was the dominant MRI lumbar degeneration classification system cited (Table 1). This system has been cited more than twice as many times as any other system. Additionally, only Pfirrmann’s classification has been cited by NIH funded studies since 2008.
Four unique histologically based classification criteria were developed, including three in-vitro systems, and one in-vivo system. Boos et al.[4] was the most widely used, cited 451 times according to Google Scholar and 246 times according to WOS. The next most popular system, by Gunzburg et al.[5], was only cited 93 and 54 times, according to Google Scholar and WOS, respectively. Despite the popularity of this classification system, there were only three NIH studies that used a histologically based classification criteria.
Discussion: Despite widespread use of X-Ray and MRI for diagnosis of lumbar disc degeneration, grading of radiographic results lacks standardization. For X-Ray diagnosis, six classification systems have been developed and used, however, none of these systems have been established as the ‘gold standard.’ Unlike X-Ray methods which have no clear consensus, the Pfirrmann et al.classification system appears to have been widely accepted for MRI.
These classification systems have been developed and used throughout the literature; however, currently, diagnoses from using X-Ray and MRI have a weak correlation with clinical symptoms. Specifically, studies have reported the incidence of degenerative findings in asymptomatic patients to be as high as 21% using X-Ray, and between 22% and 57% using MRI. While for X-Ray, this low specificity may be a result of technology limitations, such as the inability of x-ray films to visualize the disc directly, for MRI, this may be due to lack of sensitivity in the measurements. Regardless, comparing specificity and sensitivity measurements of X-Ray and MRI across the literature is often difficult due to the many classification systems in use.
While radiographic measurements are relied on clinically for grading degeneration, several studies have suggested increased

sensitivity and accuracy in detecting degeneration using histology, as histology provides assessment at the microscopic level. Despite widespread use of histology, only four distinct classification systems have been developed specifically for grading degeneration. Of these, the system proposed by Boos et al. appears to be the most readily accepted. Most studies evaluating intervertebral discs using histology identify specific features without the use of a grading system. Moreover, these features are often unrelated to degeneration and of unknown clinical significance.

While histology may be limited clinically, the potential benefits of histology in preclinical studies using cadaveric specimens cannot be ignored. Furthermore, because of its increased sensitivity, histology may be a useful tool to serve as a benchmark for current imaging modalities and developing diagnostic techniques e.g. positional MRI.

Significance: Due to the lack of objective sensitivity measurements, despite improving technologies, the clinical relationship between radiographic findings and pain remains unclear. As a first step towards improving this understanding, more research must be done to establish objective, uniform, and reliable imaging and histological grading classification systems for clinical and research studies alike.

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Table 1. Lumbar Disc Degeneration Grading Systems

Type	Author	Year	Plane	Scale	Criteria	Times Cited NIH	WOS	GS
Xray	Kellgren	1952	Lat; AP	0-2	spacing; lipping; sclerosis; erosion; movement	0	164	195
Xray	Gordon	1991	Unknown	1-4	sclerosis; narrowing; osteophytes	0	105	185
Xray	Lane	1993	Lat	0-3	joint space narrowing; osteophytes; sclerosis	3	150	160
Xray	Mimura	1994	Lat; AP	1-4	disc height; osteophytes; endplate sclerosis	0	127	210
Xray	Madan	2003	Lat; AP	0-3	disc height; osteophytes; endplate sclerosis; Schmorl's nodes; vacuum phenomenon	0	NA	15
Xray,MRI	Thalgott	2004	Ax, Lat	A-F	sclerosis; osteophytes	0	NA	42
Xray	Wilke	2006	Lat; AP	0-3	height loss; osteophyte formation; diffuse sclerosis	1	32	54
MRI	Schneiderman	1987	Sag	1-4	disc height; signal intensity; pattern	0	130	246
MRI	Butler	1990	Sag	1-4	disc space; borders of annulus and nucleus; herniation; signal intensity	0	159	295
MRI	Tertti	1991	Sag	1-3	signal intensity	0	109	176
MRI	Gunzburg	1992	Sag	0-3	nuclear signal	0	54	93
MRI	Southern	2000	Ax; Sag; Cor	1-4	signal intensity; disc space narrowing	0	20	52
MRI	Pfirrmann	2001	Sag	1-5	disc structure; distinction of nucleus and annulus; signal intensity; height	27	394	656
MRI	Askar	2004	Ax; Sag	1-4	disc height reduction; radial tears; annular shape	0	7	13
MRI	Griffith	2007	Sag	1-8	nucleus signal intensity; nucleus/annulus distinction; height	0	32	65
Histo	Gunzburg	1992	Sag	0-3	rim lesions; annular tears; bulging; quantity of nuclear material; endplates	3	54	93
Histo	Berlemann	1998	Sag	1-4	annulus; nucleus; endplate; margin changes	11	NA	63
Histo	Boos	2002	Sag	0-22	chondrocyte proliferation; mucous degeneration; cell death; tear and cleft formation; granular changes	21	246	451
Histo	Weiler	2011	N/A	0-15	chondrocyte proliferation; mucous degeneration; cell death; tear and cleft formation; granular changes	0	NA	2

Lat, Lateral; AP, Anterior-Posterior; Sag, Sagittal; Ax, Axial; Cor, Coronal; WOS, Web of Science; GS, Google Scholar

26.