Anatomic Treatment-based Classification of Diseased Lumbar Spinal Motion-segment

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ABSTRACT

Background: Multiple minimally invasive spine approaches and techniques have been developed in recent years. While the disease processes affecting the spinal motion-segment have remained largely the same, surgical treatment options have changed radically and not necessarily in an organized fashion. This is inevitable given the rapid evolution of the technology. The current diagnostic techniques, also evolving, have helped us appreciate the disease pathoanatomy in minute details. A comprehensive classification method accounting for all anatomical participants in the spinal motion-segment pathology, tailored to treatment options, is necessary. Out of many valid options, a spine surgeon should be able to choose a single surgical approach that is most appropriate for the pathoanatomy of his/her patient's disease. We feel that our classification system will help the spine surgeon make that important decision consistently, with minimal risk of overlooking a significant lesion, or disrupting a structure which is not a participant in the disease process.

Purpose of the study: To develop a comprehensive, treatment-orientated classification of degenerative lumbar spinal motionsegment disease.

Materials and Methods: Contributors to spinal motion-segment disease - intervertebral disc, facet joint, ligamentum flavum and mal-alignment were identified. The degrees of abnormalities in each of these entities were coded, and the codes were entered in a matrix from which the possible combinations of pathologic processes were generated. To test the usefulness of the classification system in clinical practice, inter- and intra-observe reliability test was performed on the system. The combined codes so created will be used in a software application along with, clinically relevant patient attributes, and attributes of available surgical options to prioritize surgical management.

A retrospective study of the 57 lumbar MRI films was carried out to determine the frequency of the occurrence of various combinations of the motion-segment disease.

Results: This classification presents 494 possible combinations of the spinal motion-segment disease. Many of the combinations are only theoretical possibilities without clinical significance. The retrospective study of the MRI films of the lumbar spine revealed 33.3% as normal motion-segments; $D_1A_0L_0F_0$ representing 8.8% of the study revealed a bulging disc and normal facet, alignment and facet joint. $D_2A_0L_0F_2$ represented 6.9% and this combination revealed intra-annular disc herniation, normal alignment, mildly thickened ligamentum flavum, and hypertrophied superior articular process of the facet joint. $D_1A_0L_1F_3$ representing 6.4% revealed bulging disc, mildly hypertrophic ligamentum and hypertrophied facet joint. For inter-observer agreement study, the Cohen's Kappa was used. Inter-observer agreement was Kappa = 0.792 (SE of Kappa =0.140, 955 CI = 0.518, 1.065

Conclusion: A treatment-orientated, standardized classification of spinal motion-segment disease is necessary in light of current multiple treatment options and availability of sophisticated pre-operative imaging techniques. Such a classification will allow standardization of treatment options for various combinations of the pathological processes. With the emergence of new technologies, surgical options can be upgraded based on a standardized classification. This in turn will help minimize confusion for those who want to learn, and facilitate growth in the minimally invasive technology. Software needs to be developed to handle the massive combination possibilities and treatment options, for ease of use by surgeons.

Introduction

The classification of a disease process requires thorough knowledge of the etiology, pathoanatomy, pathophysiology, and the knowledge of the internal and external factors which affect the process. Classification systems have improved over the years in all medical specialties, and as the understanding of the disease processes improves with the technology, so have the quality of classifications. Comprehensive classification systems elucidate, not only the aspects of a given disease, but also help craft treatment strategies.

The classification of the functional spinal motion-segment disease spectrum into three phases, as described by William Kirkaldy Willis[1], has enhanced the understanding and treatment of the spectrum of the disc and facet diseases. Disc ruptures may occur acutely in an apparently normal disc, or in a degenerated disc. Disc ruptures have been described as protrusion, prolapse and sequestrated by Spengler[2]. Topographically the herniations may be described as central, paracentral, intraforaminal or extraforaminal. Fujiwara, et al[3] and Weishaupt et al[4] have used Pathria's[5] 4-grade classification of the facet arthropathy to determine the utility of MRI as a diagnostic alternative to CT scan. Both studies confirm that CT scan is slightly more accurate in grading of facet degeneration, but in light of the superiority of MRI in diagnosing the soft tissue anomalies, MRI study is sufficient, for most part, for disc and facet disease classification. Thalgott et al[6] utilized MRI, plain X-rays and provocative discography to more thoroughly evaluate the degenerative disc disease in the anterior spinal column, and facet degeneration in the posterior spinal column. This is mainly an effort to clearly define the facet disease in the era of disc arthroplasty. Rauschning performed high quality cryosections of fresh-frozen cadavers, with the sections corresponding to CT-scan slices in sagittal, coronal, axial and oblique planes, clearly translating the scanning images to pathoanatomy of the spine[7]. Yeung, in a series of *in vivo* endoscopic transforaminal disc and facet procedures elucidates the pathophysiology of back pain through evocative discography and probing in lightly sedated patients[8].

While all these studies teach us a lot about the pathology of the spine, there is lack of a comprehensive classification system for the purpose of determining treatment options. The severity of the disease process affecting each anatomical entity within the motion-segment needs to be clearly delineated and classified to understand how the disease evolved to that stage, to understand how the processes produce patient's symptoms, and use that information to craft treatment options to precisely address the offending pathologic entity, while incurring minimal collateral damage to normal tissues. The classification system presented here, describes the pathoanatomy of the degenerative disease of the lumbar spine, as seen on the imaging studies – specifically the MRI, and CT scan, and attempts to tailor the treatment strategies to surgically benefit the patient, and minimize the need for subsequent interventions. Software application which combines the imaging classification, unique clinical attributes of patient and attributes of the surgical options is envisioned for this classification so that the appropriate surgery, out of all the available options, may be prioritized and offered to patients. The power of software allows the surgeon to have a complex but easy-to-use classification, to produce a consistent surgical approach to the spinal motion-segment disease. The classification also attempts to delineate the disease combinations which current minimally invasive approaches alone cannot address adequately or safely. It also explores pathologic combinations where a hybrid approach of minimally invasive and open approaches may be used to minimize surgical trauma, while offering the patient maximum surgical benefit in the safest possible fashion. With current trends in the development of the technology, such a classification offers an opportunity for standardizing treatment options for the given presentations, as well as comparing the effectiveness of the different available treatment options. Furthermore, lack of a universally accepted comprehensive classification of the motionsegment disease and lack of standardized treatment protocols may have encouraged payers to deny compensation for minimally invasive spine procedures, and thereby hampered the development of the technology.

Materials and Methods: The degenerative disease of the spinal motion-segment is classified by identifying and grading the disease severity of each component of the spinal motion-segment (Table 1). The structural components identified are the disc, facet, spinal alignment, and the facet joints. The disc disease is graded "D_0, D_1, D_2, D_3 and D_4, with D_0 being normal and the D_4 showing a collapsed disc with posterior osteophytosis. The facet is graded F_0, F_1, F_2, F_3, and F_4. The ligament flavum is classified L_0, L_1, L_2, L_3, L_4, and the alignment is classified as A_0, A_1, A_2, A_3, and A_4.

A = Alignment	D = Disc	F = Facet	L = Ligamentum Flavum (LF)

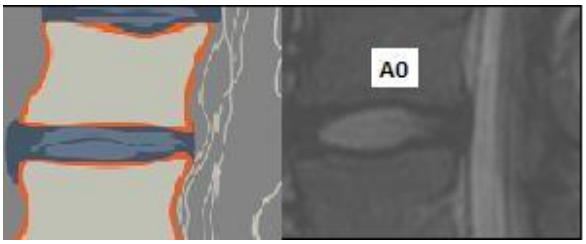
A_0 = Normal A_1= Retrolisthesis A_2 = Grade II spondylolisthesis A_3 = Grade 4 spondylolisthesis A_4= Grade 3 & Spondylolisthesis	D0 = Normal disc D1 = Global bulging disc D2 = Contained herniation D3 = Free frag herniation D4 = Disc osteophytes (in canal)	F_0 = Normal facet F_1 = IAP hypertrophy F_2 = SAP hypertrophy F_3 = IAP & SAP hypertrophy F_4 = IAP & SAP hypertrophy & synovial cyst. Key: IAP = Inferior Articular Process SAP = Superior Articular Process	L0 = Normal L1= Minimal hypertrophy of LF L2= Moderate hypertrophy of the LF L3= Severe hypertrophy of the LF L4 = Calciified/ossified

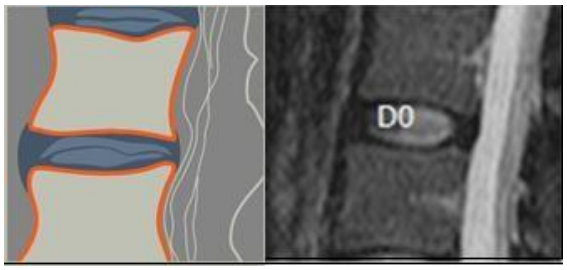
TABLE 1: Grading the disease stages of the spinal alignment, intervertebral disc disease, facet degeneration and ligamentum flavum (LF) hypertrophy

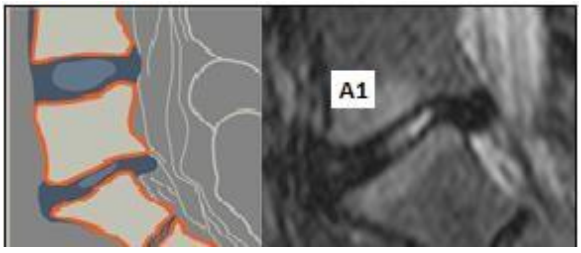
	D_0 (normal disc)	**D_1 (global bulge)**	**D_2 (Intraannular herniation)**	**D_3 (Extraannular herniation)**	**D_4 (Disc osteophytes)**	
F_0 (Normal facet = normal foraminal height & AP diameter)	$D_0A_0L_0F_0$	D_I $A_0L_1F_0$	$D_2A_0L_2F_O$	$D_3A_0L_3F_0$	$D_4A_0L_4F_0$	**A_0 (Normal alignment)**
F_1 (IAP hypertrophy = ↓ lat recess AP diameter)	$D_0L_0A_0F_1$	$D_1L_1A_1F_1$	$D_2A_1L_2F_1$	$D_3A_1L_3F_1$	$D_4A_1L_4F_1$	**A_1 (Retrolisthesis = ↓ disc height, global bulge)**
F_2 (SAP hypertrophy = ↓ foraminal height & AP diameter)	$D_0A_2L_0F_2$	$D_1A_2L_1F_2$	$D_2A_2L_2F_2$	$D_3A_2L_3F_2$	$D_4A_2L_4F_2$	**A_2 (Grade I listhesis = Mild to moderate central and foraminal stenosis)**
F_3 (S&IAP hypertrophy = ↓ Foraminal height & foraminal/lat recess AP diameter)	$D_0A_3L_0F_3$	$D_1A_3L_1F_3$	$D_2A_3L_2F_3$	$D_3A_3L_3F_3$	$D_4A_3L_4F_3$	**A_3 (Grade II listhesis = moderate to severe central & foraminal stenosis)**
F_4 (S&IAP hyper + cyst =↓ foraminal, height & foraminal/lat recess ± central	$D_0A_4L_0F_4$	$D_1A_4L_1F_4$	$D_2A_4L_2F_4$	$D_3A_4L_3F_4$	$D_4A_4L_4F_4$	**A_4 (Grade III&IV listhesis = extreme central and foraminal stenosis)**

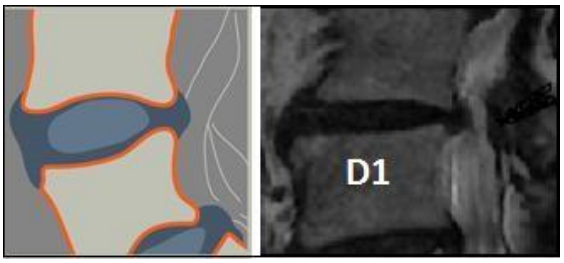
AP diameter)						
	L_0 (normal LF)	**L_1 (mild LF hypertrophy)**	**L_2 (moderate LF hypertrophy)**	**L_3 (severe LF hypertrophy)**	**L_4 (Calcified, hypertrophied LT**	

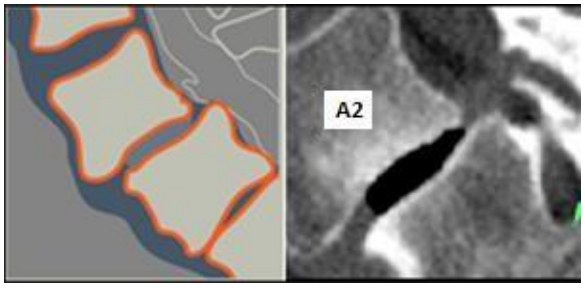
TABLE 2

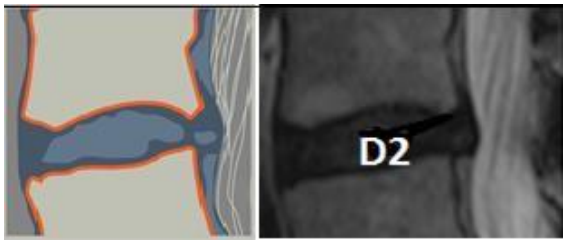


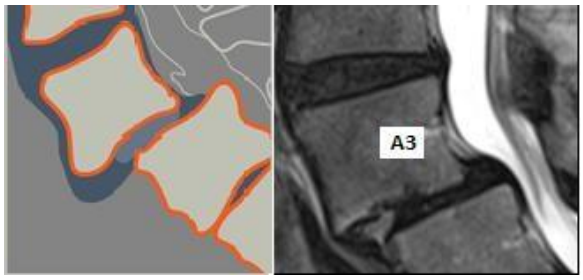


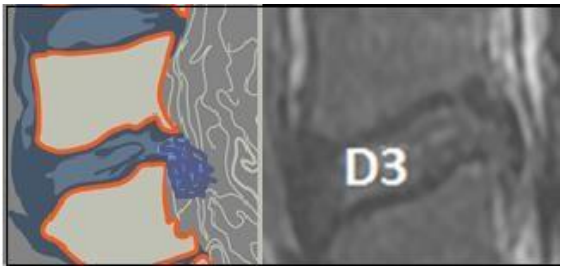












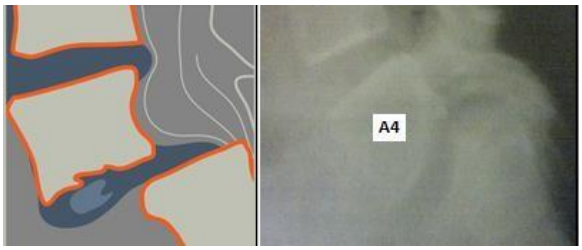


Figure 1:
A_0 = normal alignment;
A_1 = retrolisthesis;
A_2 = grade 1 spondylolisthesis;
A_3 = grade II spondylolisthesis;
A_4= grade III & IV spondylolisthesis.

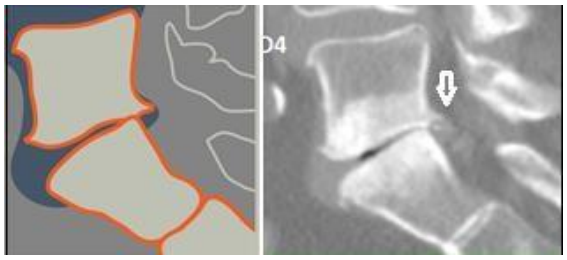
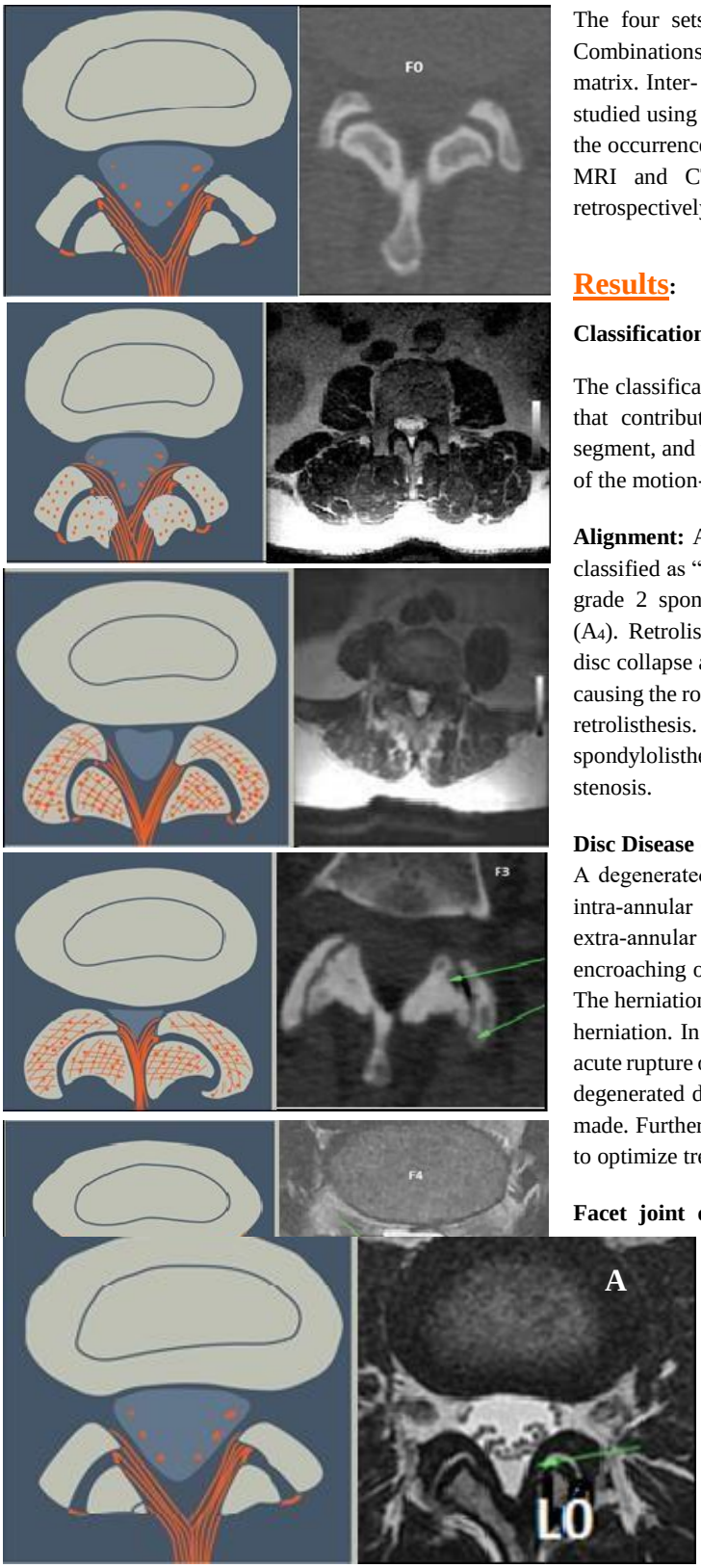


Figure 2:
D_0 = normal disc;
D_1 = global bulge;
D_2 = intra-annular disc herniation;
D_3 = extra-annular disc herniation;
D_4 = posterior disc osteophytes.



The four sets of the grading are placed in a matrix (Table 2). Combinations of the disease severity are computed as shown in the matrix. Inter- and intra-observer reliability of the classification was studied using the kappa coefficient. To determine the prevalence of the occurrence of the combinations in clinical situations, analysis of MRI and CT scan films in our database was carried out, retrospectively.

Results:

Classification:

The classification system described here identifies anatomic entities that contribute to the degenerative processes of spinal motion-segment, and these include intervertebral disc; facet joint; alignment of the motion-segment; and the ligamentum flavum:

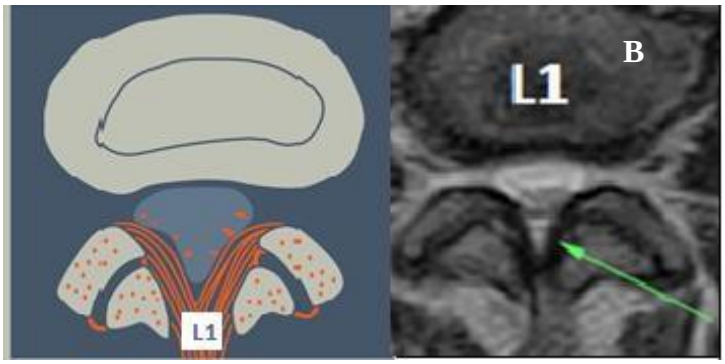
Alignment: As shown in Figure 1a – 1e, normal alignment is sub-classified as "A_0", retrolisthesis (A_1); grade1 spondylolisthesis (A_2); grade 2 spondylolisthesis (A_3); and grade 3&4 spondylolisthesis (A_4). Retrolisthesis, in the degenerative cascade signify primarily disc collapse and relatively well maintained facet articular cartilage, causing the rostral vertebra to slide caudally and posteriorly, creating retrolisthesis. Depending on the degree of slippage, degenerative spondylolisthesis may cause both spinal canal and foraminal stenosis.

Disc Disease (Figures 2a – e)**:** The normal disc is classified as "D_0". A degenerated and globally bulging disc is classified as "D_1". An intra-annular (contained) disc rupture is classified as "D_2", and an extra-annular rupture as "D_3". The degenerate disc with osteophytes encroaching on spinal and/or foraminal canals is classified as "D_4". The herniation may be central, paracentral and intra-/extra-foraminal herniation. In this classification, no distinction is made between an acute rupture of an apparently normal disc and a rupture of previously degenerated disc, or the topographical location of the disc lesion is made. Further classification of the disc pathology will be necessary to optimize treatment options.

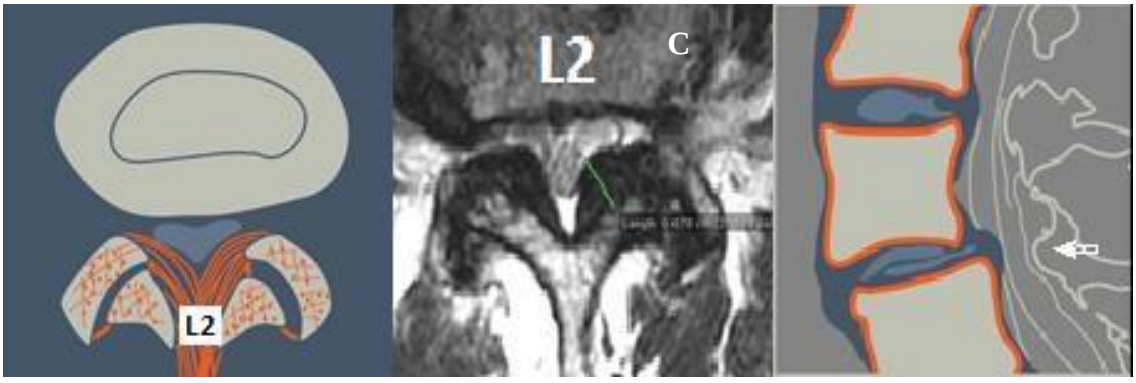
Facet joint disease (Figure 3a – e): The normal facet joint is classified as "F_0". When the inferior articular process is hypertrophied, this is classified as "F_1". It causes encroachment on the central spinal canal along with the ligamentum flavum, and deforms the sides of the triangular dural sac to trefoil configuration. The enlarged inferior articular process also encroaches on the lateral recess. The hypertrophied superior articular process is classified as "F_2". The enlargement of the superior articular process contributes to the narrowing of the foraminal canal,

subarticular space and, significantly, blunts the base angles of the triangular dural sac on the axial MRI slice. When both the inferior and superior articular processes are hypertrophied (as often is the case) they are classified as "F_3" and when the pathology is associates with synovial cyst, it is classified as "F_4". The synovial cyst may be intra- or extra-canal.

Ligamentum flavum: Normal ligamentum flavum is classified as "L0". As the motion-segment loses height secondary to degeneration the interlaminar space becomes narrow and the ligamentum folds into the spinal canal and thickens. The minimal, moderate, and severe hypertrophy and in-folding of ligamentum are classified as "L1", "L2" and "L3", respectively. The ligamentum is classified as "L4", if it is calcified. (Figure 4).



494 possible combinations can be computed from the matrix in Table 2. Many of these are theoretical possibilities. The retrospective study of lumbar MRI included 220 lumbar spinal motion-segments of 54 patients, by the senior author showed the most prevalent combination of the motion-segment disease as shown in Table 3. Age range was 16 to 87 years (mean age 47.3 years). There were 30 male and 24 female patients. The study was undertaken to determine the frequency of the common pathologic combinations in clinical context. Table 3 shows 14 of the most common combinations of the spinal motion-segment disease.



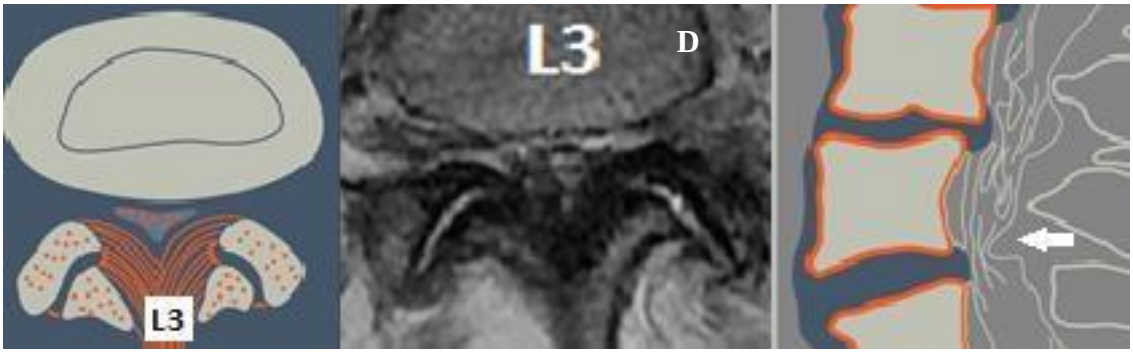


Figure 4: a – normal LF (L_0); b – mildly hypertrophied LF (L_1); c – moderately hypertrophied (L_2); d – severely hypertrophied LF (L_3); d - calcified LF (L_4)

As expected, the normal motion-segments, $D_0A_0L_0F_0$, are the most common combination (33.3%). Of the diseased combinations, $D_1A_0L_0F_0$, representing 8.8% of the current population is the commonest. This combination represents

CODE	%	Pathologic Process
$D_0A_0L_0F_0$	33.3	Normal disc, normal alignment, normal ligamentum flavum, normal facet joint
$D_1A_0L_0F_0$	8.8	Degenerative global bulging disc, normal alignment, normal LF, and normal facet joint
$D_2A_0L_0F_2$	6.9	Intra-annular disc herniation, normal alignment, normal LF, and hypertrophy of superior articular process
$D_1A_0L_1F_3$	6.4	Global bulging disc, normal alignment, mild hypertrophY LF, hypertrophic superior & inferior articular processes
$D_1A_0L_1F_0$	3.9	Global disc bulge, normal alignment, mild hypertrophy of LF, normal facet joint
$D_2A_0L_1F_0$	2.5	Intra-articular disc herniation, normal alignment, mild hypertrophy of LF,
$D_3A_0L_0F_0$	2.5	Extra-annular disc herniation, normal alignment, normal LF, normal facet joint
$D_1A_0L_0F_3$	2	Global disc bulge, normal alignment, normal LF, Superior and inferior articular processes
$D_1A_1L_0F_0$	2	Global disc bulge, retrolisthesis, normal LF, normal facet joint.
$D_2A_0L_0F_3$	2	Intra-discal herniation, normal alignment, normal LF, Superior and inferior articular processes
$D_2A_0L_1F_3$	2	Intra-annular herniation, normal alignment, mild LF hypertrophy, superior and inferior process hypertrophy
$D_1A_1L_1F_1$	3	Global disc bulge, retrolisthesis, mile LF hypertrophy, superior and inferior process hypertrophy
$D_1A_2L_1F_3$	3	Global disc bulge, grade I spondylolisthesis, mild LF hypertrophy, superior and inferior process hypertrophy

degenerate, globally bulging disc, without structurally obvious abnormality of the other members of the motionsegment on the magnetic resonance imaging scans. The commonest combinations in which all the four components of the motion-segments are involved represent 6% of the current population and they are $D_1A_1L_1F_1$, $D_1A_2L_1F_3$, and $D_1A_2L_1F_3$.

TABLE 3

Discussion:

A treatment-orientated classification of spinal motionsegment degenerative disease is necessary in light of the many emerging treatment options, and the availability of sophisticated preoperative imaging techniques which reveal fine details of the pathologic processes of the spinal motionsegment. The classification described herein is a preliminary publication which will allow standardization of treatment options for the various combinations of the pathological processes. Inter- and intra-observer reliability study was performed on the system agreements of both studies were very good. Once the necessary software application has been developed, the authors will subject the classification to prospective clinical study. The unique feature of this classification is the fact that grouping of the disease entities is avoided; instead, codes are used to label combinations of grades of structural abnormalities are seen on the images such as the MRI scans. Since the natural history of the disease evolution is not expected to change, and that treatment options evolve rapidly with new technologies, it is the view of the authors that the classification can be applied universally and that new technologies can be added to the repertoire of treatment options without changing the classification system. New surgical options can be assigned to an appropriate combination in this classification based on relevant clinical setting, attributes of the available surgical options, and cost of treatment, with the aid of an appropriate software application. This in turn will help minimize confusion for those who want to learn the available techniques, ease communication between spine professionals across the globe, and cut down the cost of treatment by assigning the least invasive and most effective treatment options.

Glassman et al, recognizing the deficiencies of the current classification systems, and the confusion regarding the best treatment of the various spinal disease processes, made a commendable effort to classify spinal conditions based on the clinical findings and imaging studies. They created a matrix consisting of symptoms, structural pathoanatomy, and compressive pathoanatomy[9]. However, noting the complexity of spinal disease and clinical presentations, the authors made compromises by simplifying the pathoanatomical categorization and symptomatic profile, to render the classification usable in clinical practice. It is, however, the view of this article's authors that such an approach fails to clearly define the disease spectra which require different treatment options in the current state of technology. On the contrary, it is the view of the authors that all the minute differences in the stages of a given pathologic process should be clearly shown and treatment option assigned. The authors believe that in the era of software technology and lesser and lesser invasive treatment options, we should not shy away from complex classification systems. It is hoped that such a system may actually encourage innovations of the least form of surgical interventions.

Bae et al, in analyzing the national trend of management of lumbar spinal stenosis concluded that national consensus for the surgical management of lumbar spinal stenosis is lacking. In light of the increased use of fusion technology and the associated increase in the use of resources, they concluded further research in needed to determine the optimal surgical management for patients with spinal stenosis[10].

Table 3 shows the prevalence of disease combinations of the spinal motion-segment. If the patient fails comprehensive non-operative measures, the most appropriate surgical option must be offered, based not only on the images and symptoms, but also on the patient's unique characteristics including age, body mass index, co-morbid status, attributes of each

surgical options, and cost of treatment. Such a complex consideration demands deployment of software technology to prioritize treatment options based on these factors, and the authors are currently committed to the development of such an application. Given the appropriate considerations regarding the patient characteristics, the following would be the examples of surgical options for different classifications. Combination $D_0A_0L_0F_0$, shown in Table 3 represents 33.3% of the studied sample, and is normal, hence, do not need treatment. $D_1A_0L_0F_0$ (8.8%) represents a degenerative global disc bulge, with the other members of the motion-segment being normal. The presenting symptoms may be axial pain, radicular symptoms or a combination of both axial and radicular symptoms. If the patient fails to respond to comprehensive non-operative treatment including activity modification, pain medicines, non-steroidal anti-inflamatory medications, physical therapy and appropriate therapeutic injections, based on the symptoms complex, specific patient's attributes, and additional diagnostic studies such as discography, the surgical options include percutaneous transforaminal endoscopic decompression, endoscopic transforaminal decompression and fusion, or similar approaches based on the patient's unique features. $D_2A_0L_0F_2$ (6.9%) represents an intra-annular disc rupture. Again, if the non-operative regime fails, the authors' preference in this situation most likely be endoscopic transforaminal decompression if symptoms are mainly radicular. Depending on the pathology and the topographic location of the lesion, placement of the portal and the choice of the tools needed for the procedure are determined. If there is significant foraminal stenosis by the hypertrophied superior articular process, foraminoplasty in addition to removal of the herniated disc is imperative. Other options for the treatment are, endoscopic interlaminar, mini-open interlaminar, and open laminotomy/laminonoplasty/laminectomy approach to decompress the nerve. If acute radicular symptoms are superimposed on chronic axial pain, the endoscopic transforaminal decompression, interbody fusion and percutaneous pedicle screw implantation[11] would be the authors' preferred option for a relatively young patient. $D_1A_2L_1F_3$ (2%) representing a bulging disc, grade II spondylolisthesis, mild hypertrophy of the ligamentum flavum, and hypertrophy of the facet joint may be amenable to ETDIF (endoscopic tranforaminal decompression, interbody fusion, and percutaneous pedicle screw implantation), alternatively a hybrid approach including open decompression and percutaneous interbody fusion and pedicle screw implantation may be preferred, to avoid neural injury if stenosis is severe. In an elderly person with stenosis due to $D_1A_0L_0F_3$ (2%), posterior interspinous/interlaminar dynamic stabilizer may be a preferred minimally invasive option[12]. Currently, the commonly used MIS options for decompression, fusion, and instrumention include MISTansforaminal lumbar interbody fusion[13,14], direct lateral lumbar interbody fusion[15,16,17], pre-sacral interbody fusion[18,19], and interlaminar fusion and instrumentation. These are examples of what the surgeon may choose to do with different combinations of the pathology, but as stated earlier, the authors are working on comprehensive software application where all the patients attributes, attributes of the various surgical options, and the classification will be considered to prioritize the treatment options.

Several studies have looked at the roles of the structures of spinal motion-segment in the development of spinal stenosis. Haig AJ et al[20], concluded although the ligamentum flavum appears to get thicker with age, other factors, including clinical diagnosis, pain, and function, do not appear to relate to the ligamentum flavum width. Our study of lumbar MRI study of spinal motion-segment reveals wide variation in the absolute anteroposterior thicknesses of the ligamentum flavum in normal motion-segments, without any evidence of encroachment on the spinal canal dimensions. Conversely, an otherwise thin ligamentum flavum has been found to encroach on the spinal canal diameter. It is, therefore, important to carefully study the configuration of the dural sac, the inferior articular process and the ligamentum flavum, to determine if the latter is contributing to stenosis. The trefoil deformity of the dural sac on the axial view of the spine MRI suggests a posterolateral compression, and this can be due to the hypertrophy of the ligamentum if the inferior articular process (IAP) is not enlarged. Conversely, the ligamentum may not be thickened but the inferior articular process is hypertrophied, producing the posterolateral compression, leading to the trefoil deformity of the sac. On the other hand, both the IAP and the ligamentum may be thickened, each contributing to the deformity. The predominantly superior articular process (SAP) hypertrophy compresses the dural sac from ventrolateral direction. This produces a rounded trapezoidal configuration of the dural sac by compressing the sides of the sac ventrally, pushing the contents of the sac dorsally, producing a dome of the dural sac posteriorly. For the purpose of this classification, therefore, the degree of the ligamentum flavum thickening, the hypertrophy of IAP, and the pattern of dural sac deformation were considered together to determine the role of ligamentum flavum in the pathoanatomy. Liu HX, et al[21], observed there is a close relationship between the severity of facet joint osteoarthritis

and ligamentum flavum thickness. While defining the cortical margins of the articular processes are difficult on the MRI as compared to plain CT scan, its ability to reveal the pathology of the soft tissues including the disc, the facet capsule, synovial cyst and the ligamentum makes MRI the authors' preferred mode of study to determine the severity of spinal stenosis. Drew et al[22], demonstrated only moderate agreement between four surgeons who studied plain CT scan of patients regarding the presence or absence of spinal stenosis. The agreement was poor with regards to the assessment of the severity of stenosis. Riew et al[23] compared the utility of CT-Myelogram alone, MRI alone, and CTmyelogram and MRI together in pre-operative planning and found the plans generated from CT-myelogram alone was similar to the one generated from the combined studies. They concluded CT-myelogram was more useful in surgical planning than MRI alone. For the purpose of this classification, MRI study is necessary to for the grading of the various entities in the motion-segment. Singh *et al*[24] performed dynamic MRI study on 45 patients and noted foraminal area decreased significantly in extension compared with flexion and neutral on MRI. Lumbar disc bulge migration and angular motion at each level contributed independently to the decrease in foraminal area in extension, whereas translational motion had no effect. Data from such dynamic MRI studies will increase the accuracy of grading in this classification.

Conclusion:

The preliminary classification system described here for degenerative spinal motion-segment disease is comprehensive and identifies specific abnormalities of the disc, facet joint, ligamentum flavum, and spinal alignment. The analysis of 204 motions segments shades light on the most common pathologic processes which require surgical intervention. The authors plan to expand on this database. The classification attempts to assign treatment options to different disease combinations to help standardize surgical management of spinal motion-segment in an era of rapid technologic transition to less invasive spine surgery. By detailed grading of diseased motion-segment, the authors hope targeted surgical approach will minimize trauma; reduce blood loss, reduce operative time, shorten hospital stay, reduce convalescence, and reduce cost of treatment to the patient and society. The authors plan to produce software application which will take into account all the relevant attributes of the patient, the grading of the disease combination, the attributes of the different surgical options and, based on all the information provide list of options in a prioritized form. The authors will be publishing similar comprehensive classification for disc pathology alone. The authors envision, using the two classifications systems in conjunction to render even more refined approach to the treatment of the spine.

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