X-raying of the Lumbar Spine

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Abstract: The lumbar spine consists of a series of five building blocks called vertebra, which lies between the thorax and sacrum. Degenerative change of the lumbar spine is a physiological response of the body occurring during the life of an adult. Many of these changes may be asymptomatic and this sometimes makes it difficult to detect the origin of pain. Hence, this paper presented a systematic review of the lumbar spine in the context of gross anatomy, variants, radiographic, pathophysiology and management. This review reported that the lumbar spines are remarkably strong vertebrae with highly flexible tendon, large muscles, and sensitive nerves which help to protect the spinal cord and bear the burden of the body weight. Also, it reported that the major common pathology and anomalies associated with the lumbar spines are Herniated nucleus pulposus (HNP), Radiculopathy, Spondylolisthesis and lumbosacral transitional vertebra (LSTV). Conclusively, it emphasized that although several modern techniques exist in the management of various lumbar spine pathologies, but the most reliable and safe procedure is fusion of the spine. It further recommends that prevention strategies such as healthy dietary lifestyles, reducing physical workload at workplace and public health surveillance may help to reduce the incidence of lumbar spine problems.

Keywords: Vertebrae, Lumbar Spine, Gross Anatomy, Pathophysiology, Management, Healthy Dietary Lifestyles, Physical Workload

1. Introduction

The lumbar spine is essentially a series of five building blocks called vertebra. They stack up, one on top of the other. They rest on the sacrum, the triangular bone wedged into the pelvis. The sacrum is the “base bone” of the spine. The vertebrae are separated in front by the discs. The discs are the shock absorbers of the spine. They allow motion and yet absorb impact. The back part of the spine contains the joints called the facets. These facets are the governors of spinal motion. They will allow bending forward, backward and side to side but resist rotation. They also act as door stops to prevent one vertebra from sliding forward on the one below (degenerative spondylolisthesis) [1].

The transverse processes stick out from the sides of the vertebrae and are essentially lever arms that muscles attach to. These levers allow smaller muscles to move the vertebral segments more easily. The spinous processes which project out the back of the vertebra are also lever arms. Strong ligaments attach that prevent the spine from bending too far forward and when bending backwards, these processes abut, preventing too much backwards motion. The nerves in the lumbar spine below the end of the cord are all peripheral nerves, not central nerves. Peripheral nerves in general are much more resistant to compression and can heal if injured whereas the spinal cord generally doesn’t. This fact comes into play if an injury is at a higher vs. a lower level in the lower back [2].

As always there is one exception. There is a small filamentous set of nerves called “Nervi Erigantes” in the cauda equina. These are the parasympathetic nerves that make the bowel and bladder function. These nerves come
right out of the end of the spinal cord called the "conus medularis". There is one rare emergent condition involving these nerves, usually caused by a large disc herniation called "cauda equina syndrome", generally a surgical emergency. Mechanically, everything in the lumbar spine revolves around the disc. The disc functions like a shock absorber. This structure absorbs impact and still allows for motion of the spine. It also has to have restraints to prevent damage to itself and the other spinal structures such as the nerves and facets. These requirements create some major demands [3].

X-rays of the spine may be performed to evaluate any area of the spine (cervical, thoracic, lumbar, sacral, or coccygeal). Other related procedures that may be used to diagnose spine, back, or neck problems include myelography (myelogram), computed tomography (CT scan), magnetic resonance imaging (MRI), or bone scans. One type of x-ray detector is photographic film, but there are many other types of detectors that are used to produce digital images. The x-ray images that result from this process are called radiographs. The primary clinical application of dual-energy x-ray absorptiometry (DXA or DEXA) is the measurement of bone mineral content (BMC, g) and bone mineral density (BMD, g/cm²) of the lumbar spine and proximal femur to assess risk for osteoporosis. Additional applications of DXA that are relevant to nutrition research include: (1) the determination of total body bone mineral content (TBBM, g), which can be used as an adjunct measure for the assessment of body composition using multicompartment models; (2) the independent assessment by DXA of a three-compartment model of body composition (TBBM, fat, and nonbone lean tissue); and (3) the evaluation of regional body composition [4].

Degenerative change of the lumbar spine is a physiological response of the body occurring during the life of an adult. Thus, depending on the age and activities of the individual, all of the imaging techniques (radiographs, computer tomography and magnetic resonance imaging) show these changes differently. Many of these changes may be asymptomatic and unknown to the person. The presence of corresponding symptoms (mostly local back pain) is dependent on the extent and localisation of the degeneration and the underlying individual anatomy. This sometimes makes it difficult to detect the origin of pain, since the degenerative changes may be spread out (and visible) along the whole lumbar spine, but only one of them might be painful. Thus, this lacuna warrants the need for a circumspect understanding and in-depth analysis of the lumbar spine.

Several authors have given extensive information on the vertebral column and spinal cord in relation to their anatomy, functions and health problems. However, there is paucity of information or lack of robust review on the lumbar spine, which plays a pivotal role in bearing the massive weight of the body. This review therefore, adopted a systematic and extensive desktop review of the lumbar spine in the context of its gross anatomy, physiological functions, pathophysiology, radiography and management of its anomalies.

2. Literature Review of the Spinal Column

2.1. Spinal Architecture - A Primer

The spinal column is composed of 33 vertebrae. Most of the column sits on, and is therefore supported by, the "sacral base." The sacral base is the top surface of the sacrum bone, which a triangular bone is wedged in between your two hip bones in back. The sacrum bone naturally angles forward a bit, which means that right at the biomechanical foundation, the stage is set for the presence of spinal curves - all the way up the column. Below the sacrum bone is your coccyx bone, aka the tail bone.

The spinal column houses the spinal cord, which is a key structure of the central nervous system. The spinal cord runs through a hollowing in the center of the stack of spinal bones (also known as vertebral) that make up the spinal column. An upright position of the spine - as when you sit up or stand up - is technically called "posture" and/or "static spine". It is from this erect "posture" that anatomists make measurements and create references used for determining what is normal and healthy about your musculoskeletal alignment, and what needs work.

2.2. Spinal Curves

The spine is divided into the following regions: Cervical (neck), which is composed of 7 vertebrae, thoracic (mid and upper back), composed of 12 vertebrae, lumbar (low back), composed of 5 (and in some people, 6) vertebrae, the sacral (sacrum bone, which is 1 bone made of several bones fused together evolutionarily), and coccyx (tail bone, made up of 3 fused bones.)

These regions correspond to your spinal curves. Generally only the cervical, thoracic and lumbar curves are talked about to any great extent, especially when the communication is given by doctors and physical therapists to non-medical people (i.e. their patients.) Limiting the talk about spinal curves to the cervical, thoracic and lumbar is also a common practice in the media. Taken as a whole, the curves in an adult spine make an "S" shape when you look at the body from the side. From the side view, some of the curves go forward toward the front of your body and others go backward. The direction of each curve (i.e. forward or back) alternates from curve to curve; this alternation helps you maintain body posture as well as negotiate challenges to your balance. In fact, the curves are actually classified according to the direction into which they go when viewing the whole spine (body) from the side. The term that describes the neck and low back curves is lordosis. The term for the thoracic and sacral curves is kyphosis. (You've probably heard of...
kyphosis as a posture problem. But in reality, kyphosis is the general name for a type of curve, and when there's too much of it - regardless of the specific region in which it is located - it becomes a label for a problem or medical diagnosis. The same is true for "lordosis."). Called the primary curve, only the kyphotic curves (thoracic and sacral - as one big "C" shape) are present when you are born. The others develop as you acquire the ability to lift your head (cervical curve) and learn to walk (lumbar curve.) These are considered secondary curves because you develop them after you're born.

2.3. Overview of the Lumbar Spine

The lumbar spine is the area of the spinal column that comprises the low back. The lumbar spine is made of 5 vertebrae. Lumbar vertebrae are referred to by 'L,' prepended to an identifying number. The number indicates the level of the lumbar spine in which the particular vertebra is located. Each region of the spine (i.e., the cervical, thoracic, lumbar and sacral regions) has its own numbers; the bones of the lumbar spine are numbered from L-1 to L-5. The complex anatomy of the lumbar spine is a remarkable combination of these strong vertebrae, multiple bony elements linked by joint capsules, and flexible ligaments/tendons, large muscles, and highly sensitive nerves. It also has a complicated innervation and vascular supply[1, 6-8, 2]. The lumbar spine is designed to be incredibly strong, protecting the highly sensitive spinal cord and spinal nerve roots. At the same time, it is highly flexible, providing for mobility in many different planes including flexion, extension, side bending, and rotation.

Below the lumbar spine is the sacrum and below that, is the tailbone, or coccyx. The coccyx is the very last bone of the spine. As with almost all of the other spinal vertebrae, a bone in the lumbar spine is made of front and back "elements." In front, the vertebral body provides support by stacking on top of the bone below it, and by supporting the one above it. (The 5th lumbar vertebra sits on top of the sacrum bone at the sacral base.) A bony ring with several pieces and areas attaches to the vertebral body in back[9, 10]. These pieces do a number of jobs, from providing attachment sites for ligaments and muscles, to making arches through which the spinal cord and spinal nerve roots pass, and forming joints that help maintain the spine's upright integrity.

2.4. Lumbar Lordosis

Each area of the spine is curved, and the lumbar region is no exception. Curves alternate directions in the spine to help provide balance and support for movement. In the cervical (neck) and lumbar spines, the curve goes towards the front of the body when you look at a side view. This is called a lordosis. A normal lordosis has a degree of curve that is not excessive, but experts don't really know what that measurement is, exactly. Lumbar lordosis - the forward curve in the low back - is a key element of posture, good or bad. Along with the cervical and thoracic curves, it's a normal feature of the human spine.

But when it comes to definitively measuring lumbar lordosis, spine physicians do not agree on exactly what "normal" is, report Chernukha and associates in their 1998 study (published in Spine) entitled "Lumbar Lordosis Measurement."

2.4.1. Lumbar Lordosis Angles for the Rest of Us - Confused Yet

Not only that, but there's no one way to measure nor interpret a lumbar lordosis. Been and associates, in their 2014 research entitled "Lumbar Lordosis," and published in Spine, reviewed 120 studies that looked at factors associated with measuring the angle of a lumbar lordosis, and how to determine normal values. They found that positioning during testing, as well as the number of spinal bones included in the measurement can cause variations in results.

And as if this weren't confusing enough, they say that lots of things - from age, gender, ethnicity, engagement in sports and physical activity, and how much strength and flexibility you have and your body mass index (a height to weight ratio that's used to determine your relative degree of underweight, normal weight overweight, obesity, etc.) - can affect the results of a lordosis test. So there are many reasons why no one can really tell you what normal lordosis is in terms of numbers and angles. But for those of us who wish to be pro-active about addressing our posture issues, this can be frustrating: How bad is it really? What angle should we go for when working to reduce our excessive lordosis?

One bit of definitive information about measuring lordosis, Been and associates did find is that most accurate position for taking the x-ray is in standing with the shoulders flexed at a 30 angle, and arms supported.

2.4.2. Lordosis Measurement for Math Geeks

If you are a math geek, you may be wondering what system of interpretation is used to translate the x-ray film into an angle measurement that expresses how much lordosis a person has. It turns out that a number of tools are used - from determining Cobb angle (from a side view x-ray) to using centroid, tangential radiologic assessment of lumbar lordosis (TRALL) and/or Harrison posterior tangent line-drawing methods. But not all are suitable; one must fit the tool to the task. Studies conducted by Harrison et. al.
2.5. Functions of the Lumbar Spines

The lumbar vertebrae are very important in supporting the upper body in an upright position. They have an increased body size compared to the other vertebrae for this reason. They also contain a small portion of the spinal cord and other nervous tissue and provide protection of these.

First lumbar nerve

The first lumbar spinal nerve (L1) originates from the spinal column from below the lumbar vertebra 1 (L1). The two terminal branches of this nerve is the iliohypogastric and the ilioinguinal nerves. L1 supplies many muscles, either directly or through nerves originating from L1. They may be innervated with L1 as single origin, or be innervated partly by L1 and partly by other spinal nerves. The muscles are: quadratus lumborum (partly) and iliopsoas muscle (partly)

Second lumbar nerve

The second lumbar spinal nerve (L2) originates from the spinal column from below the lumbar vertebra 2 (L2). L2 supplies many muscles, either directly or through nerves originating from L2. They may be innervated with L2 as single origin, or be innervated partly by L2 and partly by other spinal nerves. The muscles are: quadratus lumborum (partly) and iliopsoas (partly)

Third lumbar nerve

The third lumbar spinal nerve (L3) originates from the spinal column from below the lumbar vertebra 3 (L3). L3 supplies many muscles, either directly or through nerves originating from L3. They may be innervated with L3 as single origin, or be innervated partly by L3 and partly by other spinal nerves. The muscles are: quadratus lumborum (partly), iliopsoas (partly) and obturator externus (partly)

Fourth lumbar nerve

The fourth lumbar spinal nerve (L4) originates from the spinal column from below the lumbar vertebra 4 (L4). L4 supplies many muscles, either directly or through nerves originating from L4. They are not innervated with L4 as single origin, but partly by L4 and partly by other spinal nerves. The muscles are: quadratus lumborum, gluteus medius muscle, gluteus minimus muscle, tensor fasciae latae, obturator externus, inferior gemellus and quadratus femoris

Fifth lumbar nerve

The fifth lumbar spinal nerve 5 (L5) originates from the spinal column from below the lumbar vertebra 5 (L5). L5 supplies many muscles, either directly or through nerves originating from L5. They are not innervated with L5 as single origin, but partly by L5 and partly by other spinal nerves. The muscles are: gluteus maximus muscle mainly S1, gluteus medius muscle, gluteus minimus muscle, tensor fasciae latae, tibialis anterior, tibialis posterior, extensor digitorum brevis and extensor hallucis longus.


3.1. Bones

The lumbar vertebrae, numbered L1-L5, have a vertical height that is less than their horizontal diameter. They are composed of the following 3 functional parts:

- The vertebral body, designed to bear weight
- The vertebral (neural) arch, designed to protect the neural elements
- The bony processes (spinous and transverse), which function to increase the efficiency of muscle action

The lumbar vertebral bodies are distinguished from the thoracic bodies by the absence of rib facets. The lumbar vertebral bodies (vertebrae) are the heaviest components, connected together by the intervertebral discs. The size of the vertebral body increases from L1 to L5, indicative of the increasing loads that each lower lumbar vertebra absorbs. Of note, the L5 vertebra has the heaviest body, smallest spinous process, and thickest transverse process.

The intervertebral discal surface of an adult vertebra contains a ring of cortical bone peripherally termed the epiphysial ring. This ring acts as a growth zone in the young while anchoring the attachment of the annular fibers in adults. A hyaline cartilage plate lies within the confines of this epiphysial ring. Each vertebral arch is composed of 2 pedicles, 2 laminae, and 7 different bony processes (1 spinous, 4 articular, 2 transverse) (see the following image), joined together by facet joints and ligaments.

![Figure 1. Lumbar vertebrae are characterized by massive bodies and robust spinous and transverse processes. Their articular facets are oriented somewhat parasagittally, which is thought to contribute the large range of anteroposterior bending possible between lumbar vertebrae. Lumbar vertebrae also contain small mammillary and accessory processes on their bodies. These bony protuberances are sites of attachment of deep lumbosacral muscles.](image-url)

The pedicle, strong and directed posteriorly, joins the
arch to the posterolateral body. It is anchored to the cephalad portion of the body and function as a protective cover for the caudaequina contents. The concavities in the cephalad and caudal surfaces of the pedicle are termed vertebral notches. Beneath each lumbar vertebra, a pair of intervertebral (neural) foramina with the same number designations can be found, such that the L1 neural foramina are located just below the L1 vertebra. Each foramen is bounded superiorly and inferiorly by the pedicle, anteriorly by the intervertebral disc and vertebral body, and posteriorly by facet joints. The same numbered spinal nerve root, recurrent meningeal nerves, and radicular blood vessels pass through each foramen. Five lumbar spinal nerve roots are found on each side.

The broad and strong laminae are the plates that extend posteromedially from the pedicle. The oblong shaped spinous processes are directed posteriorly from the union of the laminae. The 2 superior (directed posteromedially) and inferior (directed anterolaterally) articular processes, labeled SAP and IAP, respectively, extend cranially and caudally from the point where the pedicles and laminae join. The facet or zygapophyseal joints are in a parasagittal plane. When viewed in an oblique projection, the outline of the facets and the pars interarticularis appear like the neck of a Scottie dog.

Between the superior and inferior articular processes, 2 transverse processes are projected laterally that are long, slender, and strong. They have an upper tubercle at the junction with the superior articular process (mamillary process) and an inferior tubercle at the base of the process (accessory process). These bony protuberances are sites of attachments of deep back muscles.

The lumbar spine has an anterior, middle, and posterior column that is pertinent for lumbar spine fractures (see the following images).

Figure 2. Drawing of 2 lumbar segments viewed from an oblique angle. The outline of the facets and the pars interarticularis has the appearance of the neck of a Scottie dog.
Figure 3. Lower spine, anterior view.
Figure 4. Lumbar vertebrae are characterized by massive bodies and robust spinous and transverse processes. Their articular facets are oriented somewhat parasagittally, which is thought to contribute the large range of anteroposterior bending possible between lumbar vertebrae. Lumbar vertebrae also contain small mammillary and accessory processes on their bodies. These bony protuberances are sites of attachment of deep lumbosacral muscles.

3.2. Lumbar Spine Musculature

Four functional groups of muscles govern the lumbar spine and can be divided into extensors, flexors, lateral flexors, and rotators. Synergistic muscle action from both the left and right side muscle groups exist during flexion and extension of the L-spine. (See the image below.)

Extensors
The extensor muscles are arranged in 3 layers. The largest group of intrinsic back muscles and primary extensor is the erector spinae (or sacrospinalis). In the lower L-spine, the erector spinae appears as a single muscle. At the upper lumbar area, it divides into 3 vertical columns of muscles (iliocostalis, longissimus, spinalis). Located posterolateral to the vertebral column, they have a common origin from a thick tendon that is attached to the sacrum, the lumbar spinous processes, and the iliac crest. The iliocostalis is the most lateral, and the spinalis (smallest muscle) is the most medial. The longissimus (largest muscle) inserts onto the skull base, whereas the iliocostalis inserts onto the angles of the ribs and transverse processes of the lower cervical vertebrae. As these muscles ascend up the vertebral column, they divide regionally depending on where the muscle attaches superiorly.

A 3-layered fasciculated muscle, the transversospinal muscle group, lies deep to the erector spinae and originates on the mammillary processes in the lumbar spine. In the sacrum, it originates from the laminar area just medial to the posterior sacral foramina, from the tendinous origins on the erector spinae, and the medial surface of the posterior superior iliac spine (PSIS). Each fascicle is directed superomedially toward the inferior and medial margin of the lamina and adjacent spinous process. The superficial layer attaches from 3-4 levels above, the intermediate layer attaches 2 levels above, and the deep layer attaches 1 level above. The transversospinal muscle group acts both as an L-
spine extensor and a rotator.

A multitude of small, segmental muscles are the deepest layer of the lumbar extensors. They can be divided into 2 groups, both innervated by the dorsal rami of spinal nerves. The levatorescostarum are not typically present in the lumbar spine. The second group contains the interspinales and intertransversarii. The interspinales consists of short fasciculi attached between the spinous processes of contiguous vertebrae. The intertransversarii consist of 2-3 slips of muscles, which pass between adjacent transverse processes. They are postural stabilizers and increase the efficiency of larger muscle group action.

**Forward flexors**

Flexors of the L-spine are divided into an iliothoracic (extrinsic) group and a femorospinal (intrinsic) group. The iliothoracic group is made up of the abdominal wall muscles: rectus abdominis, external abdominal oblique, internal abdominal oblique, and the transversusabdominis. The femorospinal group is made up of the psoas major and iliacus muscles. The psoas major originates from multiple areas: the anterior surface and lower border of transverse processes of L1-L5, from the bodies and discs of T12-L5. It inserts on to the lesser trochanter of the femur and is innervated by direct fibers of the lumbar plexus (L1-L3). Its primary action is hip and trunk flexion.

**Lateral flexors**

True lateral flexion is normally a combination of side bending and rotation. Normally, side bending is brought about by ipsilateral contraction of the oblique and transversus abdominal muscles and quadratuslumborum. Of these, only unilateral contraction of the quadratuslumborum can bring about pure lateral flexion and elevation of the ilium, whereas bilateral contraction produces some lumbar extension. The quadratuslumborum is attached below to the iliolumbar ligament and to the adjacent part of the iliac crest above the lower anterior surface of the 12th rib and to the apexes of the L1-4 transverse processes.

**Rotators**

Rotation of the lumbar spine is brought about by the unilateral contraction of muscles that follow an oblique direction of pull; the more oblique the course, the more important the rotational effect. Most of the extensors and lateral flexors follow an oblique course and produce rotation when their primary component has been neutralized by antagonist muscle groups.

The transversospinal muscle group, innervated by the dorsal rami of spinal nerves, is deep to the erector spine muscle and runs obliquely (superomedially) from the transverse processes to the spinous processes. As a group, they act to extend the vertebral column. But, when contracted unilaterally, they cause the trunk to rotate in the contralateral direction. They are divided into 3 groups: the semispinales, multifidus, and rotatoreslumborum muscles. The rotatoreslumborum are small, irregular, and variable muscles connecting the superoposterior part of the transverse process of the vertebra below to the inferolateral border of the lamina of the vertebra above.

### 3.3. Lumbar Spine Vasculature

**Arterial**

Lumbar vertebrae are contacted anterolaterally by paired lumbar arteries that arise from the aorta, opposite the bodies of L1-L4. Each pair passes anterolaterally around the side of the vertebral body to a position immediately lateral to the intervertebral canal and leads to various branches. The periosteal and equatorial branches supply the vertebral bodies. Spinal branches of the lumbar arteries enter the intervertebral foramen at each level. They divide into smaller anterior and posterior branches, which pass to the vertebral body and the combination of vertebral arch, meninges, and spinal cord, respectively.

These arteries give rise to ascending and descending branches that anastomose with the spinal branches of adjacent levels. Nutrient arteries from the anterior vertebral canal travel anteriorly and supply most of the red marrow of the central vertebral body. The larger branches of the spinal branches continue as radicular or segmental medullary arteries, distributed to the nerve roots and to the spinal cord, respectively.

Up to age 8 years, intervertebral discs have a good blood supply. Thereafter, their nutrition is dependent on diffusion of tissue fluids through 2 routes: (1) the bidirectional flow from the vertebral body to the disc and vice versa and (2) the diffusion through the annulus from blood vessels on its surface. As adults, the discs are generally avascular structures, except at their periphery.

**Venous**

The venous drainage parallels the arterial supply. Venousplexuses are formed by veins along the vertebral column both inside and outside the vertebral canal (internal/epidural and external vertebral venous plexuses). Both plexuses are sparse laterally but dense anteriorly and posteriorly. The large basivertebral veins form within the vertebral bodies, emerge from the foramen on the posterior surfaces of the vertebral bodies, and drain into the internal vertebral venous plexuses, which may form large longitudinal sinuses. The intervertebral veins anastomose with veins from the cord and venousplexuses as they accompany the spinal nerves through the foramen to drain into the lumbar segmental veins.

### 3.4. Innervation of the Lumbar Spine Structures

Lumbar spinal nerves give off one or more recurrent meningeal branches, known as the sinuvertebral nerves. These branches originate from the autonomic nervous system, paravertebral plexuses, and overlying muscles distal to the DRG. The sinuvertebral nerves reenter the vertebral canal and carry with them sensory and sympathetic efferent fibers. Similar to the spinal branches of lumbar arteries, each nerve divides into ascending and descending branches to supply the periosteum, PLL, and outer annularlaminae.

The ALL is richly innervated by nerve fibers from the sympathetic system. The sinuvertebral nerves are also sensory to the meninges and the walls of the vertebral venousplexuses. They furnish the vasomotor fibers that regulate...
blood flow in the arteries and internal vertebral venous plexuses. The sinuvertebral nerves extend to communicate with branches from radicular levels both above and below the level of entry, as well as the contralateral side, making it difficult to localize pain from involvement of these nerves [12]. Anatomically, the ventral and dorsal (anterior and posterior) rami arise from the spinal nerve, just as it exits the foramen. The ventral primary ramus participates in the formation of the lumbosacral plexus and also provides a few nerve endings to the adjacent superficial annulusfibrosus of intervertebral discs. Otherwise, discs are considered non-innervated structures.

The dorsal primary ramus divides into medial, intermediate, and lateral branches just after it gives off an ascending facet branch to the dorsal aspect of the joint immediately above. The intermediate and lateral branches course laterally on the transverse process and supply the erector spinae muscles. Each medial branch of the posterior primary ramus participates in the innervation of 3 facet joints: one branch innervates the facet joint above the level, the second branch innervates at that level, and the third branch descends caudally to the level below. See the following image.

Figure 6. Innervation of the facet joints; dorsal ramus innervation (medial and lateral branches). MAL23 = mamillo-accessory ligament bridging the mamillary and accessory processes of L2 and L3; Z-joint = zygapophyseal joint.
4. Radiographic/ X-ray Positioning of the Lumbar Spine

**Figure 7.** Lumbar Spine Radiographic Anatomy.

**Figure 8.** Oblique view of the lumbar spine.
Figure 9. Adult Lumbar Spine - Lateral View.

Lumbar Spine - Lateral

Table 1. Details of the Radiographic positioning of the Lumbar Spine (Lateral Position) of Adult Human shown in Fig [9].

<table>
<thead>
<tr>
<th>Name of projection</th>
<th>Lumbar Spine – Lateral</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area Covered</td>
<td>T12 - Sacrum, intervertebral foramina L1 to L4, vertebral bodies, intervertebral joints, spinous processes, and L5 to S1 junction, entire sacrum may be visualized</td>
</tr>
<tr>
<td>Pathology shown</td>
<td>Fractures, spondylolisthesis, bone lesions, osteoporosis, foreign bodies.</td>
</tr>
<tr>
<td>Radiographic Anatomy</td>
<td>Lumbar Spine Radiographic Anatomy</td>
</tr>
<tr>
<td>IR Size &amp; Orientation</td>
<td>35 x 43 cm larger patient</td>
</tr>
<tr>
<td>Film / Screen Combination</td>
<td>Regular (CR and DR as recommended by manufacturer)</td>
</tr>
<tr>
<td>Bucky / Grid</td>
<td>Moving or Stationary Grid</td>
</tr>
<tr>
<td>Filter</td>
<td>No</td>
</tr>
<tr>
<td>Exposure</td>
<td>80 kVp x 40 mAs or breathing technique 80 kVp x 40 mA with 2 seconds exposure time</td>
</tr>
<tr>
<td>FFD / SID</td>
<td>100cm</td>
</tr>
<tr>
<td>Central Ray</td>
<td>CR perpendicular to long axis of spine</td>
</tr>
<tr>
<td>Collimation</td>
<td>Larger patient - centre to iliac crest (L4-5)</td>
</tr>
<tr>
<td></td>
<td>Smaller patient - centre to L3 (lower costal margin) (4cm above iliac crest)</td>
</tr>
<tr>
<td></td>
<td>Inferior to Superior - collimate to film size</td>
</tr>
<tr>
<td>Markers</td>
<td>Lateral borders closely collimate (light field will appear small due to the patient being close to the X-ray tube)</td>
</tr>
<tr>
<td>Shielding</td>
<td>Superior and Lateral Marker orientation AP</td>
</tr>
<tr>
<td>Gonadal</td>
<td>Position patient lateral recumbent</td>
</tr>
<tr>
<td></td>
<td>Cushion for patients head and knees flexed</td>
</tr>
<tr>
<td></td>
<td>Align mid coronal plane to CR and midline of table / grid</td>
</tr>
<tr>
<td></td>
<td>Radiolucent support may be placed under waist to get the spine parallel to table</td>
</tr>
<tr>
<td>Positioning</td>
<td>Ensure pelvis and torso are in a true lateral position</td>
</tr>
<tr>
<td></td>
<td>CR perpendicular to long axis of spine</td>
</tr>
<tr>
<td></td>
<td>Larger patient - centre to iliac crest (L4-5)</td>
</tr>
<tr>
<td></td>
<td>Smaller patient - centre to L3 (lower costal margin) (4cm above iliac crest)</td>
</tr>
<tr>
<td></td>
<td>Suspend respiration on expiration or use breathing technique</td>
</tr>
</tbody>
</table>
5. Healthy and Degenerative Lumbar Spine

5.1. The Healthy Lumbar Spine

The lumbar spine is the part of the spine located between the pelvis and the thoracic cage. It consists of five lumbar vertebrae. Each vertebra comprises a vertebral body and a vertebral arch that is connected to the corresponding vertebral body by two pedicles. The bony attachments are posterior: the spinous processes (the bone you can feel down the centre of your back), the paired transverse and the articular processes. The transverse processes serve as attachments for muscles, while the articular processes represent the posterior bilateral joints connecting each vertebra to its adjacent vertebrae. This enables motion of the corresponding intervertebral disc on the anterior part of the spine.

The intervertebral discs, joint capsules and ligaments hold the vertebrae together and control the range of segmental motion. The posterior wall of the vertebra, the bony arch and the yellow ligament extending from one arch to the next form a tube (spinal canal) containing the end of the spinal cord and the spinal nerves. Each segment has two lateral openings through which the corresponding nerve roots exit to the periphery.

5.2. Pathology of the Lumbar Spine

Degenerative changes of the lumbar spine

The main functions of the lumbar spine are to protect the spinal nerves and to facilitate most of the trunk's motion. The five lumbar vertebral bodies maintain distance and transmit loads from the thorax to the pelvis and serve as muscle attachments. Motion and load create adaptive tissue changes during life. These changes include loss of tissue elasticity, growth of osteophytes and calcification of ligaments. As a result, the structures around the spinal canal increase in volume, thereby reducing the available space for the nerve roots in the canal or the outlets for the roots.

This effect is sometimes emphasized by anterior vertebral slippage (degenerative spondylolisthesis) due to insufficiency by wear and tear of the vertebral facets. The narrowing of the spinal canal is referred to as spinal stenosis.
5.3. Lumbar Spine: Common Pathology and Interventions

Herniated nucleus pulposus (HNP), also referred to as a herniated disc, is a common spine pathology that occurs approximately 95% of the time at the L4-L5 or L5-S1 level [13, 14]. Peak incidence of HNP is between 30 and 55 years of age [15]. The majority of herniated discs occur in a posterolateral direction, compressing the ipsilateral nerve root as it exits from the dural sac. Thus, a left L5-S1 disc herniation compresses the left S1 nerve root. The nucleus pulposus is posterior in the annulus and the posterior longitudinal ligament (PLL) is midline, creating a somewhat weak point in the annulus on either side of the PLL. The nucleus pulposus first herniates into tears in the annulus fibrosus. It may eventually break through enough of the annulus to cause bulging. If the process continues, disc material may separate and migrate.

Radiculopathy is pain, paresthesias or both in the distribution of a nerve root. In this case, it is caused by nerve root irritation from an HNP. Each nerve root has a specific area of motor and sensory distribution. The radicular pain is often described as shooting or stabbing. There may be paresthesias in the same distribution. Sciatica is radicular pain in the L5 or S1 distribution. Patients typically describe deep buttocck, posterior or posterolateral thigh pain that may or may not extend below the knee, into the lower leg and lateral foot. The pain is often aggravated by coughing, sneezing, or straining. It may also be aggravated by certain positions, such as sitting or standing. The pain usually subsides with rest.

Although most recover without surgery, patients with large midline lumbar HNPs may suffer significant neurological impairment. Caudaequina syndrome is caused by any large space-occupying mass, such as a large central HNP, located in the spinal canal at the level of the caudaequina. The caudaequina is the lumbar and sacral nerve roots extending from the lowest part of the spinal cord. It fills the thecal sac from approximately L2 to S1. Symptoms include urinary retention or incontinence, saddle anesthesia, progressive leg or foot weakness—often bilateral—or bowel incontinence. Although caudaequina syndrome is rare, neurologic compromise from this syndrome is severe and represents a surgical emergency [16, 17]. It is important to note that a central HNP does not necessarily cause caudaequina syndrome. In fact, as with other HNPs, the patient can be totally asymptomatic with a central HNP, have back pain only, and have unilateral or bilateral radiculopathy without weakness or sphincter dysfunction. This situation is not a surgical emergency.


The traditional method to approach various pathologies of the spine is fusion of one or more segments depending on the individual situation. This technique of immobilizing motion segments was adopted from other areas of orthopaedic surgery, such as that of the hip and knee, where the painful joint was immobilized if the problem could not otherwise be solved. Increased understanding and improved technology allowed the joint to be replaced in spite of fusing it. This type of surgery has developed into a standard procedure for most joints in the body.

Fusion is still the most frequently used technique in the spine. The complexity of the anatomy and proximity to neural structures makes it more difficult to replace parts of the spine and preserve motion. These techniques do exist today, but widespread conclusive clinical data and results are
not yet available. Fusion of the spine can be performed in various ways. However, the principle always remains the same: to achieve solid bony union between the fused vertebrae. The fusion mass to enhance bony union is generally the autologous bone of the patient, specially prepared allogenic bone or bone substitutes. To enhance solid union, metallic implants are generally used anteriorly, posteriorly or combined.

**Figure 17.** Posterior Monosegmental Fixation.

**Figure 18.** Circumferential Monosegmental Fixation.
7. Conclusions

This purpose of this review paper was to give a detailed and in-depth review of the lumbar spine in the context of its gross anatomy, variants, radiographic, pathophysiology and management. This review reported that the lumbar spines is remarkably a strong vertebræ with highly flexible tendon, large muscles, sensitive nerves and perfect curves (Lordosis) designed to carry the massive weight of the body and protect the spinal root. It reported that the major common pathology and anomalies associated with the lumbar spines are Herniated nucleus pulposus (HNP), Radiculopathy, Spondylolisthesis and lumbosacral transitional vertebra (LSTV). Finally, the paper emphasised that although several modern techniques exist in the management of various lumbar spine pathologies, but the most reliable and safe procedure is fusion of the spine.

In addition, this paper opined that high-impact mechanical pressure, cardiovascular risk factors and healthy lifestyle-related factors (such as excess weight, smoking, and physical inactivity) may potentially lead to changes in motion and load create adaptive tissue during life such as loss of tissue elasticity, growth of osteophytes and calcification of ligaments. Consequentially, this may cause the structures around the spinal canal to increase in volume, thereby narrowing space for the nerve roots in the canal or the outlets for the roots leading to degeneration and anomalies in the lumbar spines. Hence, this review recommends that preventive strategies such healthy dietary lifestyles, reducing physical workload at workplace and public health surveillance may help to reduce the incidence of lumbar spine pathology and promote healthy functions of this vital tissue.

Conflict of Interest

The authors declare that there is no conflict of interests regarding the publication of this review article.

References