Dedication

To everyone whomsupport me

To my family and friends

Acknowledgment

I would like to express my great thanks and tribute to everyone who support me in mywork; especially who helped me in Alamal National Hospital.Fullregardless for my supervisor Dr. Ahmed Abukonnawho gave a perfect advice and ideas, in such way that he motivated me to complete the work in success.

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List of abbreviation

Abbreviation	Mean
ALL	Anterior longitudinal ligament
CT	ComputerizeTomography
MRI	MagneticResonanceImaging
PLL	posterior longitudinal ligament

Abstract

This was an analytical studyconducted to measure normal lumbar spinal canal in Sudanese population using computed tomography.CT KUB images were taken for 50 adult patientstheir age ranged from 20 to 50 yearsexamined at Alamal National Hospital. The measurement of lumbar canal was taken from L1 to L5 in axial cut from CT images.

The results of the study showed that the mean value of midsagittal measurement in the axial cut at L1 was 15.36±1.777mm; L2 was 14.45±1.721mm,forL3 was13.68±1.765 mm,for L4 was 13.21±1.784mm and for L5 was 15.11±2.927mm. The meanvalues of transverse measurement in the axial cut were21.01±2.662mm, 22.36±2.775 mm, 24.36±3.641 mm, 26.48±4.175 mm, and 28.54±4.552 mm from L1 to L5 respectively. The variations in midsaggitaldiameter do not exhibit significant differences between genders as observed in other population groups, except for L1 and L5.

The dimensions of transverse and mid sagittal diameter of lumbar spinal canal in male population were higher than female population.In this study the relationship between the patient height and weight measurement in the axial cut was found to be indirect relationship.

المستخلص

أجريت هذه الدراسة لقياس القناة العمودية القطنية الطبيعي في السكان السودانيين باستخدام الاشعة المقطعية.

اجريت هذه الدراسة داخل الخرطوم(مستشفى الامل الوطني)ل50 مريض تتراوح اعمارهم من20 الى 50عام .تم اخذ القياس لجميع الفقرات القطنية .

وأظهرت نتائج الدراسة أن قيمة القياس الطولي للفقرات القطنية من الفقرة الاولى للفقرة الخامسة على التوالي15.36±1.777مم,14.45±1.721مم,13.68±1.756مم,13.21±1.784مم,15.11± 2.927مم .وكانت القيم للقياس العرضي 21.01±2.662مم، 22.36±2.775مم، 24.36±3.641مم، 26.48±4.175مم، 28.54±4.52 مم من الفقرة القطنية الاولى إلى الفقرة القطنية الخامسة على التوالي.

في هذه الدراسة لا تظهر الاختلافات في القياس الطولي اختلافات كبيرة بين الجنسين كما لوحظ في مجموعات السكان الأخرى، باستثناءالفقرة الاولى والفقرة الخامسة.وتم العثور على ان العلاقة بين طول المريض ووزنه والقياسات الطولية والعرضية للقناة الشوكية علاقة غير مباشرة.

Chapter One

Introduction

1.1Introduction

The spinal canal is formed by the vertebral body anteriorly, the pedicles laterally, the laminaeposterolaterally, and the base of the spinous process posteriorly. This arrangement forms a protective ring for the neural tube. At the inferolateral aspect of each vertebra, a bony tunnel, the neural foramen, is appreciated bilaterally. The walls of the foramina are formed by the vertebral pedicle superiorly, the pedicle of the next vertebral body inferiorly, the facets posteriorly, and the diskovertebral junction anteriorly. Back pain results from many causes, including degenerative and congenital spinal stenosis, neoplasm, infection, trauma, and inflammatory or arthritic processes(Wu et al., 2014).

CT scans provides a noninvasive, non-operator dependent method of direct imaging of the spinal canal without injection of intra thecal contrast and is better than MRI for bone detail as in osteophytes.

CT and myelography are important in patients who, for technical reasons, cannot enter the MRI scanner (e.g., those with pacemakers or claustrophobia) or in patients whose MRI findings do not correlate with clinical symptoms(Dragani et al., 2000).

Though there is a wide variation in the capacity of spinal canal in patients who are clinically and radiologically normal. It is said that those with smaller canals are more likely to have symptoms from nerve root compression(Shahidi et al., 2017b).

By determining normal ranges of spinal canal diameter we can make early diagnosis in persons who have lower diameters of spinal canal.

These persons are predisposed to spinal canal stenosis, which is a major cause of spinal radiculopathies (Shahidi et al., 2017b).

Lumber canal stenosis is the most common spinal disorder in the elderly, consist of clinical signs and symptoms which result from narrowing of spinal canal its related modification that occur over time .this modification can be related to degeneration congenital traumatic,post-surgical or metabolic abnormalities(Shahidi et al., 2017a).

1.2 Problem of Study:

Low backache is a common clinical problem .The etiology in many of these patients is narrowing of the lumbar canal. The size of lumber canal differ among several factor, Therefore the measurement of canal diameters is considered as important issue in order to classify the normal and abnormal measurement.

1.3Objectives:

1.3.1 General objective

The general objective of this study tomeasurement of normal lumbar spinal canalin Sudanese using computed tomography.

.1.3.2 Specific Objectives

- To identify the transverse diameter of the lumbar vertebral canal among adult Sudanese.
- To identify the midsagittal diameter of the lumbar vertebral canal among adult Sudanese.
- To determine whether there is any difference related to gender, height and weight.

1.4Overview of the study

The study will fall into five chapters, Chapter one consists of introduction, objectives and the overview of the study. Chapter two includes the literature review, Chapter three detailed the material and methods, Chapter four includes the presentation of the results, and finally chapter five include the discussions, conclusionand recommendations.

Chapter Two

Literature Review

2-1 Anatomy:

The vertebral column has 33 vertebrae - 7 cervical, 12 thoracic, 5 lumbar, 5 sacral (fused) and 4 coccygeal (fused) vertebrae (figure2.1).

The spine of the fetus is flexed in a smooth C shape. This is referred to as the 'primary curvature' and is retained in the adult in the thoracic and sacrococcygeal areas. Secondary extension results in lordosis - known as the secondary curvature of the cervical and lumbar spine(Moro et al., 2005).

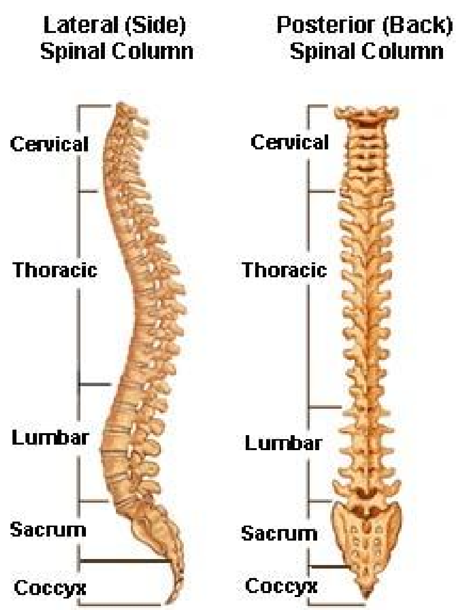

Figure2.1the vertebral column lateral and posterior view

All vertebrae share a basic common structure. They each consist of a **vertebral body**, situated anteriorly, and a posterior **vertebral arch** (figure 2.1)(Moro et al., 2005)**.**

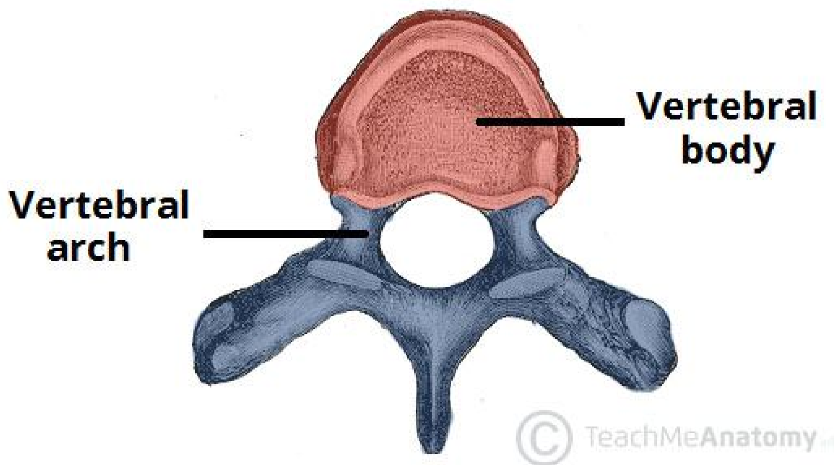

Figure 2.2basicstructures of vertebrae

2.1.1Bony Structures

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(Chalian et al., 2012).

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). (figure 2.3), joined together by facet joints and ligaments.

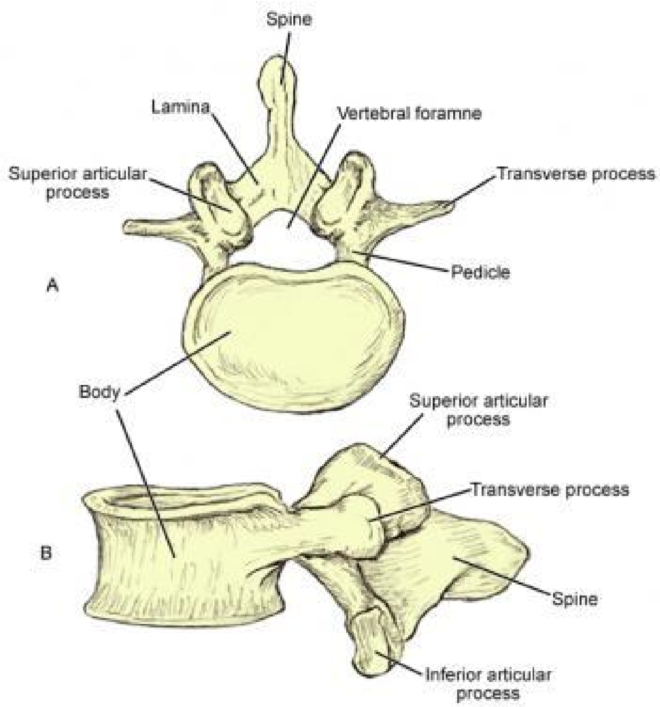

Figure 2.3 Bony Structures

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(Boszczyk et al., 2001).

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(Boszczyk et al., 2001).

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 (Hansen et al., 2006).

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. 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(Hansen et al., 2006).

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 (mammillary 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(Hansen et al., 2006).

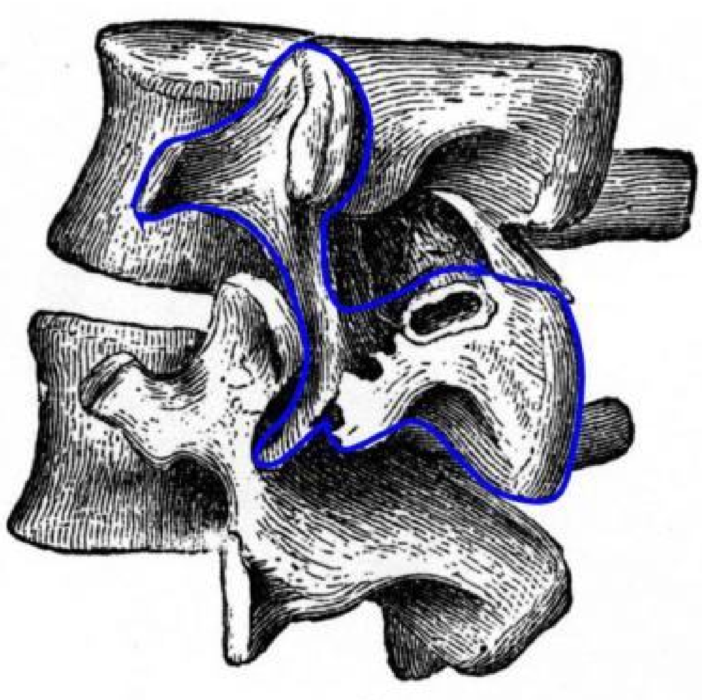

Figure2.4 Lumbar vertebral joints

The mobility of the vertebral column is provided by the symphyseal joints between the vertebral bodies, formed by a layer of hyaline cartilage on each vertebral body and an intervertebral disc between the layers.

The synovial joints between the superior and inferior articular processes on adjacent vertebrae are termed the facet joints (also known as zygapophysial joints or Z-joints). They permit simple gliding movements. The movement of the lumbar spine is largely confined to flexion and extension with a minor degree of rotation. The region between the superior articular process and the lamina is the pars interarticularis.

A spondylolysis occurs if ossification of the pars interarticularis fails to occur(Hansen et al., 2006).

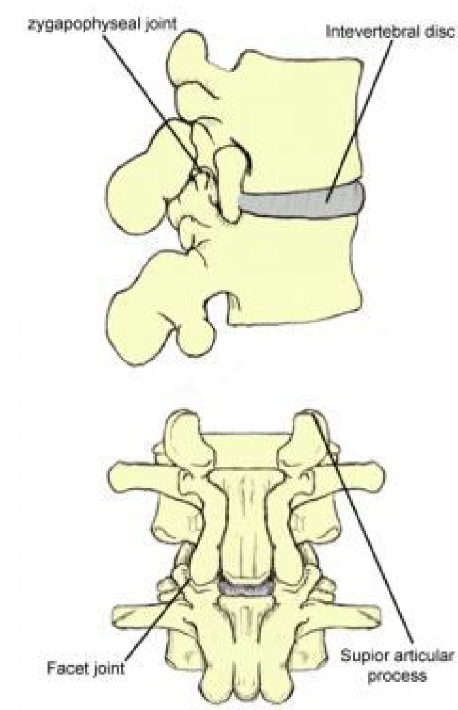

Figure 2.5the 3-joint complex is formed between 2 lumbar vertebrae. Joint 1: Disc between 2 vertebral bodies; Joint 2: Left facet (zygapophyseal) joint; Joint 3: Right facet (zygapophyseal) joint.

2.1.3Lumbar intervertebral discs:

Discs form the main connection between vertebrae. They bear loading during axial compression and allow movement between the vertebrae. Their size varies depending on the adjacent vertebrae size and comprises approximately one quarter the length of the vertebral column(Barrey et al., 2013).

Each disc consists of the nucleus pulposus; a central but slightly posterior mucoid substance embedded with reticular and collagenous fibers, surrounded by the annulus fibrosus, a fibrocartilaginous lamina. The annulus fibrosus can be divided into the outermost, middle, and innermost fibers. The anterior fibers are strengthened by the powerful anterior longitudinal ligament (ALL). The posterior longitudinal ligament (PLL) affords only weak midline reinforcement, especially at L4-5 and L5-S1, as it is a narrow structure attached to the annulus. The anterior and middle fibers of the annulus are most numerous anteriorly and laterally but deficient posteriorly, where most of the fibers are attached to the cartilage Plate (Barrey et al., 2013).The annular fibers are firmly attached to the vertebral bodies and are arranged in lamellae. This annular arrangement permits limiting vertebral movements, reinforced by investing ligaments (Barrey et al., 2013)

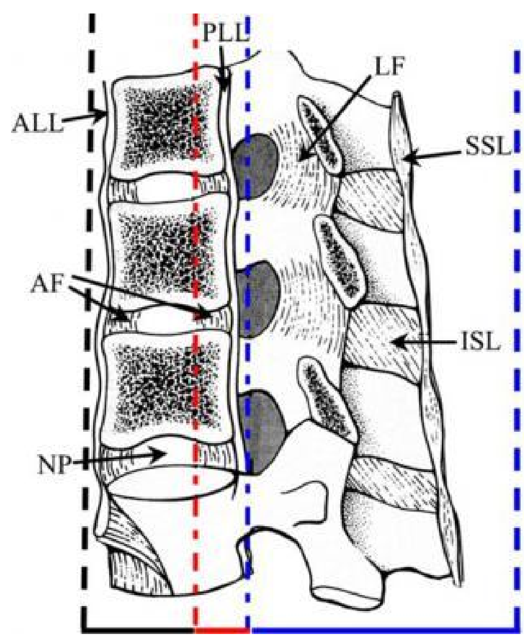

Figure 2.6Lateral drawing of the 3 spinal columns of the thoracolumbar junction. The anterior column (black dotted line) includes the anterior spinal ligament, the anterior annulus fibrosus (AF), the intervertebral disc, and the anterior two thirds of the vertebral bodies. The middle column (red dotted line) includes the posterior aspect of the vertebral bodies, the posterior annulus fibrosus, and the posterior longitudinal

ligament (PLL). The posterior column (thick blue dotted line) includes the entire spine posterior to the longitudinal ligament (thick blue dotted line). ALL = anterior longitudinal ligament; ISL = interspinous ligament; LF = ligamentumflavum; NP = nucleus pulposus; SSL = supraspinousligament(Barrey et al., 2013).

2.1.4Lumbar vertebral ligaments:

The ALL covers the ventral surfaces of lumbar vertebral bodies and discs. It is intimately attached to the anterior annular disc fibers and widens as it descends the vertebral column. The ALL maintains the stability of the joints and limits extension.

The PLL is located within the vertebral canal over the posterior surface of the vertebral bodies and discs. It functions to limit flexion of the vertebral column, except at the lower L-spine, where it is narrow and weak.

The supraspinous ligament joins the tips of the spinous processes of adjacent vertebrae from L1-L3. The interspinous ligament interconnects the spinous processes, from root to apex of adjacent processes. Sometimes described together as the interspinous/supraspinous ligament complex, they weakly resist spinal separation and flexion(Barrey et al., 2013).

The ligamentumflavum (LF) bridges the interlaminar interval, attaching to the interspinous ligament mediallyand the facet capsule laterally, forming the posterior wall of the vertebral canal. It has a broad attachment to the undersurface of the superior lamina and inserts onto the leading edge of the inferior lamina. Normally, the ligament is taut, stretching for flexion and contracting its elastin fibers in neutral or extension. It maintains constant disc tension (Barrey et al., 2013).

The intertransverse ligament joins the transverse processes of adjacent vertebrae and resists lateral bending of the trunk.

The iliolumbar ligament arises from the tip of the L5 transverse process and connects to the posterior part of the inner lip of the iliac crest. It helps the lateral lumbosacral ligament and the ligaments mentioned above stabilize the lumbosacral joint (Barrey et al., 2013).

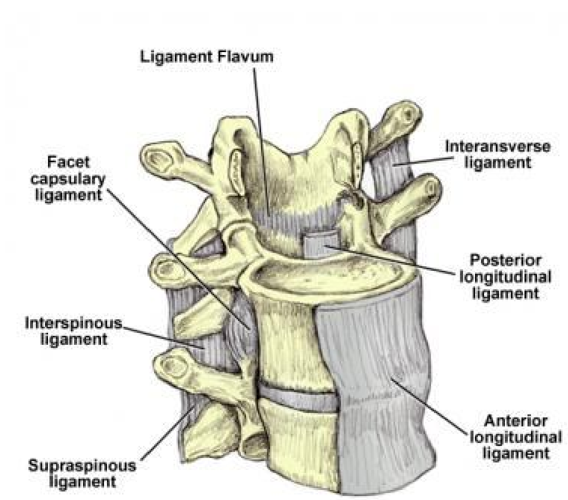

Figure 2.7Anterolateral view of the lumbar spine demonstrating the multiple ligaments of the lumbar spine. These ligaments include the following: ligamentumflavum (LF), anterior longitudinal ligament (ALL), posterior longitudinal ligament (PLL), intertransverse ligament, interspinous ligament, supraspinous ligament, and facet capsular ligament

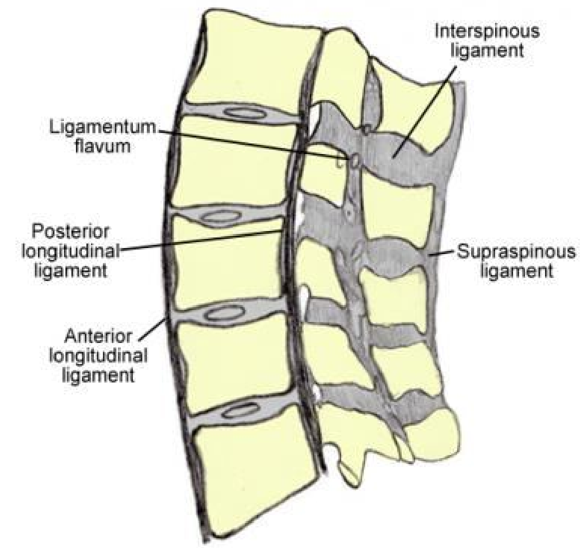

Figure 2.8 Lumbar spinal ligaments, lateral view.

2.1.5 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.

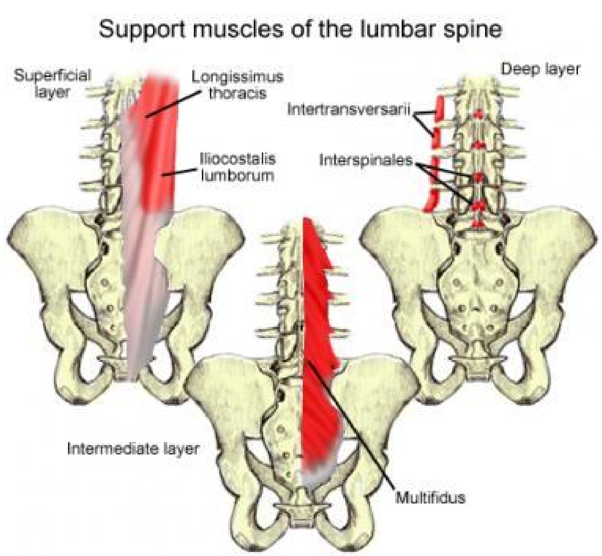

Figure 2.9 muscles of the lumbar spine

2.1.5.1 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 on to 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(Chalian et al., 2012).

A 3-layered fasciculated muscle, the transversospinal muscle group, lies deep to the erector spinae and originates on the mamillary 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(Chalian et al., 2012).

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 interspinalesandintertransversarii. 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(Chalian et al., 2012).

***2.1.5.2* 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 obliquus, 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(Chalian et al., 2012).

***2.1.5.3* 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(Hansen et al., 2006).

2.1.5.4 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(Hansen et al., 2006).

The transversospinal muscle group, innervated by the dorsal rami of spinal nerves, is deep to the erector spinae 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 semispinalis, 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(Hansen et al., 2006).

2.1.6 Lumbar spine vasculature

2.1.6.1 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(Hansen et al., 2006).

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(Dragani et al., 2000).

2.1.6.2 **Venous**

The venous drainage parallels the arterial supply. Venous plexuses 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 venous plexuses as they accompany the spinal nerves through the foramen to drain into the lumbar segmental veins(Willburger et al., 2005).

2.1.7 Vertebral canal

The tubular vertebral canal contains the spinal cord, its meninges, spinal nerve roots, and blood vessels supplying the cord, meninges, vertebrae, joints, muscles, and ligaments. Both potential and real spaces intervene between the spinal cord, meninges, and osseoligamentous canal walls. The canal is enclosed within its column and formed by the juxtaposition of the vertebral foramen, lined up with one another in series. The vertebral bodies and discs make up the anterior wall (with the PLL draped over it), whereas the laminae and ligamentumflavum border the canal posteriorly. Laterally, spinal nerves and vessels travel through the intervertebral foramen(Willburger et al., 2005).

2.1.8 Meninges and related spaces

The meninges consist of 3 layers: the pia, arachnoid, and dura mater. Together, they enhance the protection of the spinal cord and roots. The dura is the most superficial but resilient layer. The pia and arachnoid, together termed the leptomeninges, are frail. The spinal cord, roots, and nerve rootlets are closely invested by the pia. The dura and arachnoid together form a loose sheath (termed dural/thecal sac) around these structures, separated from the canal walls by the epidural space(Willburger et al., 2005).

2.1.8.1Spinal dura mater

The dura is composed of tough, longitudinal, collagen fiber bundles interwoven with circular elastic fibers. The external surface is rough and blends with loose connective tissue in the epidural space. The internal surface, facing into the subdural space, is smooth and covered by a layer of mesothelium. Inferiorly, the dural sac ends at the sacral canal, usually at S2-S3 (sometimes S1).

The dura continues caudally as a fibrous thread named the filumterminaleexternum or coccygeal ligament, which blends with the PLL over the coccyx. The dural sac sends sleevelike projections into the intervertebral foramen, where the dura blends with the epineurium of the spinal nerves. Connective tissue slips in the foramen anchor the dural sleeves so that they can protect the spinal nerve roots from being stretched during L-spine movements. In addition to these tetherings, the dura is attached in places to the PLL(Willburger et al., 2005).

***2.1.8.2* Epidural space**

The epidural (peridural/extradural) space terminates inferiorly at the sacral hiatus, where it is sealed by the posterior sacrococcygeal ligaments. The nerve roots transverse the space as they extend into the intervertebral foramen. The entire space is occupied by loose connective tissue with variable fat content, providing padding around the dural sac and spinal cord and acting as a form to hold the thin internal vertebral plexus of veins open. The vertebral venous plexus is embedded in the epidural loose connective tissue, sometimes transmitting large amounts of blood(Buckland et al., 2017).

***2.1.8.3* Leptomeninges**

The pia and arachnoid are delicate membranes composed of loose connective tissue and separated from one another by the subarachnoid space. A layer of mesothelium covers all leptomeningeal surfaces bathed by cerebrospinal fluid (CSF).

The arachnoid mater lines the entire dural sac and extends into the dural sleeves. It also sends trabeculae across the subarachnoid space to the pia, facilitating CSF mixing. Along the posterior midline, the trabeculae form a well-defined subarachnoid septum. Inferiorly, it lines the dural sac within the sacral canal and ends on termination of the sac at the S2 vertebral level.

The pia mater provides support for the vasculature and nerves in the subarachnoid space. It adheres intimately to the spinal cord. The pia forms a separate sheath for each nerve rootlet and root as far laterally as the foramen, blending with the epineurium. Caudally, the pia continues as the thin filumterminaleinternum. After reaching the lower end of the dural sac, the filum becomes enclosed within the filumterminaleexternum and continues to the coccyx(Buckland et al., 2017).

2.1.8.4 Subarachnoid space

The spinal subarachnoid space is spacious in the lumbar spine, and below the level of L2 it is termed the lumbar cistern. Its CSF content (20-35 mL) is only a fraction of the total CSF volume (120-150 mL). The lower third of the arachnoid sac contains only the filumterminaleinternum and the caudaequina, which contains lumbar, sacral, and coccygeal nerve roots that hang like a horse’s tail form the lower part of the spinal cord (conusmedullaris) as they leave the vertebral canal below the lower third of the arachnoid sac(Buckland et al., 2017).

2.1.9 Spinal cord

Other than the brain, the spinal cord is one of the 2 anatomic components of the central nervous system (CNS). It is the major reflex center and conduction pathway between the brain and the body. As noted earlier, the spinal cord normally terminates as the conusmedullaris within the lumbar spinal canal at the lower margin of the L2 vertebra, although variability of the most caudal extension exists.

All lumbar spinal nerve roots originate at the T10 to L1 vertebral level, where the spinal cord ends as the conusmedullaris. A dorsal or posterior (somatic sensory) root from the posterolateral aspect of the spinal cord and a ventral or anterior (somatic motor) root from the anterolateral aspect of the cord join in the spinal canal to form the spinal nerve root.

The roots then course down through the spinal canal, forming the caudaequina, until they exit at their respective neural (intervertebral) foramina as a single pair of spinal nerves. Thus, the lumbar nerve roots exit the spinal canal at a lower level than where they arise(Gopinathan, 2015).

2.1.9.1 Exit levels of spinal nerves

Lumbar spinal nerves exit the vertebral canal by passing inferior to the pedicles of the corresponding vertebrae since early in development. In the lumbar region, the first division of the spinal nerve takes place within the intervertebral foramen, resulting in the posterior and anterior (dorsal and ventral) rami. The posterior rami pass posteriorly, skirting the articular processes at that level, whereas the anterior rami proceed laterally to supply the body wall and the lower limbs(Gopinathan, 2015).

2.2Physiology

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.

2.3 Pathology

2.3.1 Lumbar spinal stenosis

Lumbar spinal stenosis is a narrowing of the spinal canal in the lower back, known as the lumbar area. This usually happens when bone or tissue or both grow in the openings in the spinal bones. This growth can squeeze and irritate nerves that branch out from the spinal cord (Gopinathan, 2015).

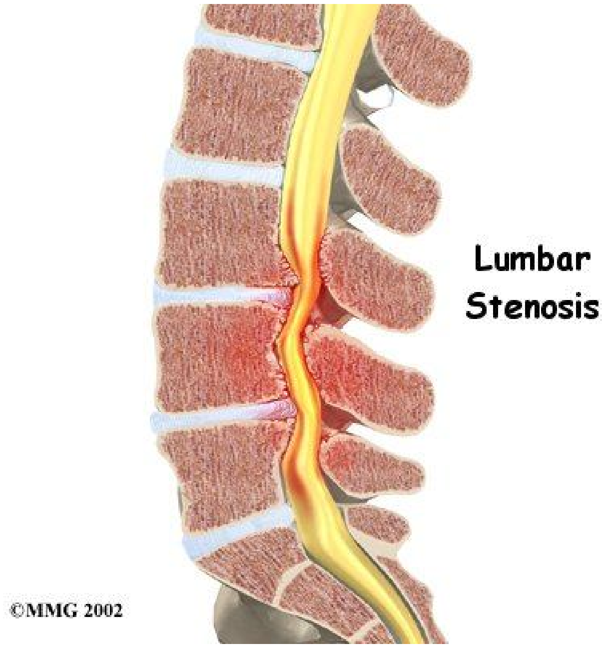

Figure 2.10 lumbar stenosis

Some patients are born with this narrowing, but most often spinal stenosis is seen in patients over the age of 50. In these patients, stenosis is the gradual result of aging and “wear and tear” on the spine during everyday activities. There most likely is a genetic predisposition to this since only a minority of individuals develops advanced symptomatic changes. As people age, the ligaments of the spine can thicken and harden (called calcification). Bones and joints may also enlarge, and bone spurs (called osteophytes) may form(Gopinathan, 2015).

Bulging or herniated discs are also common. Spondylolisthesis (the slipping of one vertebra onto another) also occurs and leads to compression. When these conditions occur in the spinal area, they can cause the spinal canal to narrow, creating pressure on the spinal nerve(Buckland et al., 2017).

2.3.2 Classification of lumbar canal

Spinal canal stenosis can be classified in various ways. Below, a brief one is presented.

A. Congenital-developmental stenosis of the spinal canal

- Achondroplastic stenosis
- Normal patient with narrowed spinal canal

B. Acquired stenosis of the spinal canal

- Stenosis due to degenerative changes
- Stenosis due to degenerative spondylolisthesis
- Iatrogenic—postfusion stenosis
- Post-traumatic
- Miscellaneous skeletal diseases such as Paget's disease,

C. Combined A and B

2.4 CT

A CT scan makes use of computer-processed combinations of many X-ray images taken from different angles to produce cross-sectional (tomographic) images (virtual "slices") of specific areas of a scanned object, allowing the user to see inside the object without cutting. Other terms include computed axial tomography (CAT scan) and computer aided tomography.

Digital geometry processing is used to generate a three-dimensional image of the inside of the object from a large series of two-dimensional radiographic images taken around a single axis of rotation.Medical imaging is the most common application of X-ray CT. Its cross-sectional images are used for diagnostic and therapeutic purposes in various medical disciplines(Dragani et al., 2000). The term "computed tomography" (Papageorghiou et al.) is often used to refer to X-ray CT, because it is the most commonly known form. But, many other types of CT exist, such as positron emission tomography (PET) and single-photon emission computed tomography (SPECT). X-ray tomography is one form of radiography, along with many other forms of tomographic and non-tomographic radiography.

CT produces a volume of data that can be manipulated in order to demonstrate various bodily structures based on their ability to block the X-ray beam. Although, historically, the images generated were in the axial or transverse plane, perpendicular to the long axis of the body, modern scanners allow this volume of data to be reformatted in various planes or even as volumetric (3D) representations of structures. Although most common in medicine, CT is also used in other fields, such as nondestructive materials testing. Another example is archaeological uses such as imaging the contents of sarcophagi. Individuals responsible for performing CT exams are called radiographers or radiologic technologists.

Use of CT has increased dramatically over the last two decades in many countries.An estimated 72 million scans were performed in the United States in 2007. One study estimated that as many as 0.4% of current cancers in the United States are due to CTs performed in the past and that this may increase to as high as 1.5 to 2% with 2007 rates of CT use;however, this estimate is disputed, as there is not a consensus about the existence of damage from low levels of radiation. Side effects from intravenous contrast used in some types of studies include kidney problems(Dragani et al., 2000).

2.5 Previous Studies

BholaShrestha et al,(2013)The study aims to measure the transverse and sagittal diameter of the lumbar vertebral canal in people from Western region of Nepal and compare with the published results. Methods: In this study, Fifty young patients (24 males and 26 females) complaining of LBP were done X-ray of lumbar spine in Antero-Posterior (AP)/ Lateral in supine views. From the images, midsagittal (AP) dimensions, transverse (interpedicular) distances and width of vertebral body were measured at each level with the help of electronic calipers. The study revealed that the mean transverse diameter of lumbar canal ranged from 24.8 mm at L1 to 33.25 mm at L5. This gradual increase in the transverse diameter from L1 to L5 was statistically significant. Measurement of lumbar vertebral width ranged from 41.37 mm at L1 and 52.96 mm at L5. There was gradual increase in the size from L1 to L5. But the measurement of AP distance showed a gradual decrease in diameter from L1to L5 The decrease in the AP diameter from L1to L2 and Canal body ratio was not constant at all levels(Shrestha and Dhungana, 2013).

Another study by MehrnazMashoufi et al(2010), The aim of this study is to evaluate lumbar spinalcanaldiameters and relationship with gender, age, stature, weight and job. "Patients and Methods: One-hundred men and 100 women in the age range of 25 to 40 years from East Azarbayjan who were referred to Sheikholrais MRI Center were selected. The diameters of the spinalcanal were measured on the midsagittal and axial section on T2 weighted images by 0.3 T MRI Unite. The results of measurements were analyzed by SPSS software. Results: The results showed that the least anteroposteriordiameter was at the third lumbar vertebra but the narrowest transverse diameter was at the first lumbar vertebra. The mean anteroposteriordiameter of the lumbar spinalcanaldecreased from the first to the third lumbar vertebra, followed by an increase from the third to the fifth. From the first to the fifth lumbar vertebra, there was an increase in the mean transverse diameters. The mean transverse diameter in the middle part of the vertebra is longer than the lower part. A frank relation was seen between the genders of physical workers with lumbar spinalcanal stenosis, although there was no relation between age, stature, and weight with lumbar spinalcanal stenosis. Conclusion: Considering the high incidence of lumbar canal stenosis and the relationship with heavy manual work.(Mehrnazet.al,2010).

(MukeshMallik et al, 2014) The study was conducted with the objectives to establish the measurements of spinalcanal and lumbar vertebra at L3 to L5 region in Nepalese population. Methodology: It is a cross-sectional study among 36 patients (17 males and 19 females having age variation from 20-60years whose abdomen was scanned by GE bright speed 16 slice CT scanner with slice thickness 10mm and then reconstructed at 1.2mm for images in different body plains for the measurement of spinalcanal. Results: Almost all the parameters increase from L3 to L4 to L5 but the difference is more between L4 and L5 than between L3 and L4 except in vertebral body width (VBW where it increases smoothly, however canal body ratio (CBR remained constant at 0.6. All the parameters were larger in males than in females except antero-posterior dimension of canal in transverse section (APT which is larger in females. It also shows that none of the parameters vary significantly depending upon sex except vertebral body width (VBW at L3 which is 39.041 Â± 4.1334 in males and 36.474 Â± 2.8509 in females (p=0.036) Conclusion: Antero- posterior dimension in trans-verse and sagittal is almost identical but the chances of measurement error is higher in transverse due to trigonal shape of canal so AP diameter should be done in sagittal section as this is consistent and measures 14mm at L3, 14mm at L4 and 15 mm at L5 hence defining average antero-posterior canal dimension in sagittal section to be 14 mm but CBR constant at 0.6 (Mukeshet al, 2014).

Yasir Ahmed Mohamed Elhassan et al,(2014). This study aims to determine the normal Anteroposterior diameter of the spinal canal in lumbosacral region among the adult Sudanese population using the MRI and to determine whether there are any differences related to age, sex and race regarding this diameter. **Material and Method:** The study was descriptive cross-sectional analytical study. MRI measurements were performed in Ribat Teaching Hospital for 142 normal Sudanese subjects to study the lumbosacral region. The data was collected through check list, analyzed by SPSS. **Results:** The majority of the participants were male (57%), young between 20and 28 years of age with mean height 168cm and mean weight 66 kilogram. The results showed that the longest mean AP diameter was at L1 (17.5±2.0mm) in male while (18.1±2.7) in female. The shortest mean AP diameter was at S1 (15.9±3.2mm) in male and (15.4±3.2) in female. The AP diameter gradually decreased from L1 to S1.there is no significant difference between both sexes. There is significant difference between people live in different zones. There is association between age, height and weight and the AP canal diameter.

Chapter Three

Materials and methods

This study was conducted with the objectives to establish the measurements of lumbar spinal canal related togender,height and weight of patients. In Khartoum state Adult population using CT scan.

3.1Materials

3.1.1 The subjects:

50 adult patients their age ranged from 20 to 50 years(28 males and 22females). Subjects selected were patients referred to perform CT scan of abdomen and KUB having no low back pain or other abnormalities attributable to lumbar spine.

Study being based on hazardous electromagnetic radiation, no scan was carried out for the purpose of study alone. Patients below the age of 20years and above the age of 50years were excluded because former may be at growing stage and later may have age related degenerative or other problems. Patients having sciatic pain with or without pain in the back, having previous history of back surgery and patients having osteophytes or other abnormalities in lumbar vertebrae were also not included. Patients having developmental anomalies, any trauma or vertebral fracture and known case of lordosis, scoliosis or kyphosis were also avoided in this study.

3-1-2 The machine

Material used in this study was**CT** machine**(**TOSHIBA aquilion 64 slices).

3.2Methods

3.2.1 ScanningTechnique:

Patients under this study were scanned for abdomen. The patient lies supine on the examination couch,Arms are usually positioned above the head to eliminate artifact and instruct patient not to move during scanning. Patient is positioned into the gantry with the help of laser light accurately. Height and position of table is fixed and cleared to make table position zero, Routine abdomen CT is performed in axial axis. Slices are started from the top level of dome of diaphragm to the iliac crest. Slice thickness varies but routine study slices are of 8-10 mm thick, Field of view is adjusted according to the size of the body.

3.2.2Measurements

Mid-sagittal diameter of the spinal canal: Was done in the cross-sectional images of each of the lumbosacral vertebra by measuring the distance between the middle of the posterior edge of the vertebral body and the lamina posteriorly at the midline. Using the cursor of the mouse**.** Transverse diameter of the lumbar spinal canal was measured as the maximum distance between the medial surfaces of the pedicles of a given vertebra**.**

3.2.3 Data analysis

The data were analyzed using mean value and the standard deviation, as well as the *p*-value to detect the degree of significance using SPSS (Social program for statistical analyses)**.**

Chapter Four

Results

This study includes 50KUB and abdomen CT that were used to collect the data by measuring 2 variables in axialKUB and abdomen CT(1-diameter ofmidsagittal lumbar canal 2-diameter of transverse e lumbar canal).The results included the mean and standard deviation of the variables.

Table(4-1) gender distribution.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	male	28	56.0	56.0	56.0
	female	22	44.0	44.0	100.0
	Total	50	100.0	100.0	

Table (4-2) Showed statistical values of transverse diameter measurement of lumbar canal from L1 TO L5 lumbar vertebra.

	N	Minimum	Maximum	Mean	Std. Deviation
L1 transverse diameter	50	16	27	21.01	2.662
L2 transverse diameter	50	18	29	22.36	2.775
L3 transverse diameter	50	16	32	24.36	3.641
L4 transverse diameter	50	17	37	26.48	4.175
L5 transverse diameter	50	16	37	28.54	4.522

Table (4-3) Showed statistical values ofMid Sagittaldiameter measurement of lumbar canal from L1 TO L5 lumbar vertebra.

	N	Minimum	Maximum	Mean	Std. Deviation
L1 Midsagittal diameter	50	11	20	15.36	1.777
L2 Midsagittal diameter	50	11	18	14.45	1.721
L3 Midsagittal diameter	50	11	17	13.68	1.756
L4 Midsagittal diameter	50	10	16	13.21	1.784
L5 Midsagittal diameter	50	10	30	15.11	2.927
Valid N (listwise)	50				

Table (4-4)transverse diameter of lumbar canal among gender

	gender	N	Mean	Std. Deviation	Std. Error Mean
L1 transverse diameter	Male	28	20.94	2.296	.434
	Female	22	21.11	3.121	.665
L2 transverse diameter	male	28	22.75	2.647	.500
	female	22	21.86	2.916	.622
L3 transverse diameter	male	28	25.32	3.320	.627
	female	22	23.13	3.734	.796
L4 transverse diameter	male	28	27.22	3.949	.746
	female	22	25.53	4.352	.928
L5 transverse diameter	male	28	29.29	4.654	.879
	female	22	27.58	4.261	.909

Table (4-5)Midsagittal diameter of lumbar canal among gender

	gender	N	Mean	Std. Deviation	Std. Error Mean
L1 Midsagittal diameter	male	28	15.83	1.164	.220
	female	22	14.78	2.233	.476
L2 Midsagittal diameter	male	28	14.85	1.223	.231
	female	22	13.93	2.120	.452
L3 Midsagittal diameter	male	28	14.08	1.293	.244
	female	22	13.17	2.135	.455
L4 Midsagittal diameter	male	28	13.52	1.611	.304
	female	22	12.83	1.953	.416
L5 Midsagittal diameter	male	28	16.14	3.162	.598
	female	22	13.80	1.981	.422

Table (4-6):Correlation between Midsagittal diameter, height and weight

		height	weight	L1 Midsagittaldiameter	L2 Midsagittaldiameter	L3 Midsagittaldiameter	L4 Midsagittal diameter	L5 Midsagittal diameter
height	Pearson Correlation	1	.537**	.020	.127	.079	.034	.156
	Sig. (2-tailed)		.000	.891	.380	.586	.814	.278
	N	50	50	50	50	50	50	50
weight	Pearson Correlation	537.**	1	.092	.268	.028	.109	.260
	Sig. (2-tailed)	.000		.525	.060	.847	.452	.068
	N	50	50	50	50	50	50	50

**. Correlation is significant at the 0.01 level (2-tailed).

Chapter Five

Discussion, Conclusion and Recommendations

5.1 Discussion

This study was conducted toassess the transverse and mid sagittal diameter normal lumber canal in Sudanese population by CT,and data were collected fromAlamal National Hospital from50patients(56% male and 44% female).

The measurements of variables were done by DICOM measurement tools and was measured in (mm) to find out the transverse and mid-sagittal diameter normal lumber canal in Sudanese population by CT and we noted thatalmost all the transverse diameter increasefrom L1to L5 with the mean ±standarddeviation21.01±2.662 at L1and at L5 the 28.54±4.522(Table 4-2,for mid-sagittal diameter decrease from L1to L4 the mean ±standard deviation15.36±1.777 for L1 ,13.21±1.784for L4 while the mean ±standarddeviation15.11±2.927 at L5(Table 4-3)this result was in line with study done byBholaShresin people from Western region of Nepal.

The transverse diameter of lumbar canal among gender were higher in male than female the mean ±standard deviation in male was20.94±2.296 at L1 29.29 ±4.654at L5while in female21.11±3.121 at L1, 27.58±4.261 at L5mean differences are significant at L3 (Table 4-4)and the mid-sagittal diameter also higher in male than female the mean ±standard deviation in male15.83±1.164 at L1 16.14±3.162 at L5 for female14.78±2.233 at L1,13.80±1.981 at L5 mean differences are significant at L1 and L5(Table 4-5). In this study there isno relationshipwithHeight,weight of person and parameters of lumbar canal.

Of the several factors responsible for lumbar spinal stenosis, one of the factors is transverse diameter of the vertebral canal. In the present study transverse diameter of lumbar canal suggests sexual geographic differences at L1 and L5 vertebral level. The variations in diameter do not exhibit significant differences between gendersthus emphasizing the need for obtaining the data which will help in radiological diagnosis of lumbar spinal stenosis.

5.2 Conclusion

This study aimed to measure the transverse and mid-agittal diameter of the lumbar vertebral canal among adult Sudanese population using CT scan to determine whether there are any difference related togender, height and weight of person.

The measurement of lumbar canal were taken at L1 to L5 in axial cut from CT KUB and abdomen .The mean transverse diameter of lumbar canal ranged from 21.01 at L1, 22.36 at L2, 24.36 at L3, 26.48 at L4, T0 28.54at L5.This gradual increase in the transverse diameter from L1 to L5 was statistically significant.

The mean of mid-sagittal diameter showed a gradual decrease in diameter from L2 14.45 to L4 13.21 and there was gradual increase in the size at L1 15.36 and at L5 15.11.

The dimensions of transverse and mid-sagittal diameter of lumbar spinal canal in male population were higher than female population.

In this study no significant correlation between height and weight with measurement.

5.3Recommendations

-Use more sample from different state.

-Further similar study using sagittal cut is recommended.

-Use other variables like job, body mass index ofpatients to accurate measure lumbar canal.

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Appendix

Data sheet

Patient number:

Gender:

Weight:

Height:

lumbar Vertebral level	Transverse diameter of lumbar canal	Midsagittal diameter of lumbar canal
L1		
L2		
L3		
L4		
L5		

Figure 5.1: show diam ٹ ڈ ڃ ڄ ڄ ڇ ڇ ڇ ڳ ڱ ڲ ڱ ڲ
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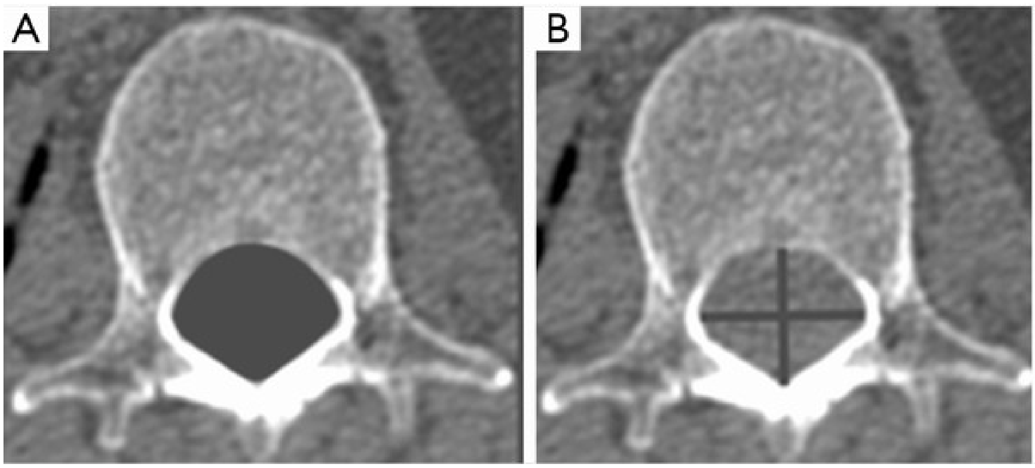
المؤمنون: ١٢ - ١٤ چeter range of lumbar spinal canal in axial cut:



Reformatted axial CT image at mid pedicular level showing measurement of (A) spinal canal cross sectional area, (B) spinal canal diameter