Spinal cord (anatomy and internal composition), back, vertebrae

Vertebral Column (Moore pp 432, Netter Plate 142)
The vertebral column can be divided into individual parts namely: cervical (7), thoracic (12), lumbar (5), sacral (5), and coccygeal (4). Note that in adults, the sacral vertebrae fuse to become the sacrum. The total number of vertebrae is 33. The vertebral column plays important roles, namely:

- Protects the spinal cord and spinal nerves
- Supports the weight of body, transmit some weight onto lower limbs
- Plays in important role in posture and movement
- Allows bending of body, and pivoting of head

Curvatures of spine (Moore pp 434, Netter Plate 142)
The vertebral column has curvatures which act as shock absorbers. (i.e.: think of a spring against the wall). This allows for some flexibility during stresses. The vertebral column exhibits a: thoracic and sacral curvature → Primary curvatures because they develop during the foetal period. These are concave anteriorly. This is because the vertebrae are taller posteriorly. The secondary curvatures are: cervical and lumbar. These are obvious only during infancy and result because the IV discs are taller anteriorly.

Abnormal curvatures of the vertebral column can occur (Moore pp 435). An abnormally excessive curvature at the thoracic area results in: kyphoscoliosis. An abnormally excessive curvature at the lumbar area results in: lordoscoliosis. Scoliosis is a “non-straight” back when viewed from posteriorly. This is due to an abnormal lateral curvature.

“Typical” vertebrae (Moore pp 435, Netter Plate 143)
The vertebrae consist of many processes and facets for articulation. Between each vertebra is a resilient IV disc that allows for some shock absorption and flexibility. The parts are identified below:

- Vertebral body
- Vertebral arch: formed by pedicles and lamina
    - Spinous process: long process travelling inferiorly
    - Transverse process: travels transversely just below the pedicle
    - Lamina: meet the pedicles
    - Superior & inferior articular processes: former → above pedicle, latter → extends from spinous process.

Note that the vertebral arch posteriorly, and vertebral body anteriorly form the vertebral canal, in which the spinal cord safely resides. Also note, when viewed laterally, intervertebral foramen between pedicles (adjacent vertebrae).

Cervical vertebrae C3-C7 (Moore pp 437)
The three main differences in cervical vertebrae C3-C7 is that: they have smaller vertebral bodies (largely due to smaller weight bearing necessity), larger vertebral foramen (due to larger spinal cord → innervation of upper limbs), have small foramen in their transverse processes. The transverse process extends laterally, and terminate as anterior and posterior tubercles. The spinous process of C2-C6 cleft into two parts (Netter Plate 142), whereas that of C7 is very long and prominent → called **vertebra prominens** (flex neck, and run finger inferiorly along the back to feel for it).

Cervical vertebrae C1 (atlas) and C2 (axis) (Moore pp 439, Fig: 4.6)
Cervical vertebrae C1 (atlas) is characterised by three things: no vertebral body, anterior and posterior arches with respective tubercles, superior and inferior articular facets (former → for occipital condyles transmitting head weight, latter → articulation with axis).

Cervical vertebrae C2 (axis) has a vertebral body, and a very prominent dens extending superiorly to articulate with the dens facet of the atlas.

Joints of vertebral column (Moore pp 450 Netter Plate 146)
The vertebral bodies are joined together by the intervertebral disc. This is fibrocartilaginous joint (symphysis). It is designed for weight bearing and shock absorption. The IV disc contains a central nucleus pulposus, and peripheral anulus fibrosis. The zygapophyseal joints occur between the vertebral arches (i.e.: articulation between superior & inferior articular processes/facets of adjacent vertebrae). These are plain synovial joints. Movements allowed include: flexion/extension, lateral flexion, rotation (thorax only). The joints are innervated by dorsal primary rami of spinal nerves.

There are two craniovertebral joints (i.e.: head and vertebral column). The former is the atlantooccipital joint (Fig 4.18 A of Moore). This occurs as the articulation between the superior articular facets of atlas and the occipital condyles of the occipital bone. These joints are synovial (no IV disc) to allow for extensive movement of the head. They allow for flexion, extension of head ('yes' movement), & abduction. The latter is the: atlantoaxial joint. This joint is made up three articulations: articulations between the inferior articular facet of atlas and superior articular facet of axis (two lateral articulations) & 1 median articulation between the dens of the axis and facet for dens of the atlas. This allows for lateral rotation of head/neck.

Intervertebral disc (Moore pp 451 Netter Plate 144)
The intervertebral disc is made of fibrocartilaginous tissue. The periphery is made up of concentric lamellae of fibrocartilaginous tissue, called anulus fibrosis. Only the outer 1/3 is innervated. The anulus fibrosis is thinner posteriorly, therefore predisposition to posterior rupture of IV disc. The central ball is made up of mainly cartilaginous tissue, called nucleus pulposus. It is not innervated and is avascular. It acts as a compression ball, and is highly flexible.

Vertebral arch joints: zygapophyseal (Moore pp 455, Fig 4.16)
Refer above to: "Joints of vertebral column (Moore pp 450 Netter Plate 146)"

Ligaments of vertebral bodies (Moore pp 451, Netter Plate 146)
There are two main ligaments associated with the vertebral column, namely: anterior and posterior longitudinal ligaments. The anterior longitudinal ligament extends from the anterior surface of the sacrum, up till the anterior tubercle of C1 and a bit of the occipital bone. It covers the anterolateral aspects of the IV disc and vertebral bodies. It prevents hyperextension of the vertebral column, and also keeps the discs and vertebral bodies from being displaced anteriorly (posterior knock). The posterior longitudinal ligament extends on the posterior aspect of the vertebral bodies within the vertebral canal. It is narrower than its "anterior" counterpart, and prevents hyperflexion and keeps the discs from displacing posteriorly (anterior knock).

Ligaments of vertebral arches (Moore pp 457 Netter Plate 146)
The ligamenta flava are elastic fibrous tissue that connect adjacent lamina together. They bind adjacent lamina together, forming part of the posterior wall of the vertebral canal. They prevent abrupt flexion (which could separate adjacent lamina away) of vertebral column. Adjacent spinous processes are joined together by weak fibrous tissue named: interspinous ligament. The supraspinous ligament runs over the interspinous ligament, and connects adjacent spinous process apices. The supraspinous ligament ends superiorly at the level of C7, and merges here with the nuchal ligament. This is a broad sheet of ligament attaching the spinous process of cervical vertebrae to the external occipital protuberance. All of these ligaments have some function in limiting flexion.

Atlantooccipital joint (Moore pp 457, Fig 4.18A)
Refer to "Joints of vertebral column (Moore pp 450 Netter Plate 146)"

Atlantoaxial joint (Moore pp 460 Fig 4.180

Refer to “Joints of vertebral column (Moore pp 450 Netter Plate 146)”

Ligaments of atlantooccipital and atlantoaxial joints (Moore pp 459 Fig 4.19)
The skull and C1 and connected by the anterior + posterior atlantooccipital membranes. These extend from the anterior + posterior arches of the atlas to the anterior + posterior margins of the foramen magnum. The cruciate ligament is made up of three components namely: transverse ligament of atlas, superior and inferior longitudinal bands. The former extends between the medial aspects of the lateral masses of the atlas, and is thick. The latter (two) connect the occipital bone and C2 body to transverse ligament superiorly inferiorly, respectively. The tectorial membrane is the superior continuation of the posterior longitudinal ligament and the alar ligaments – extends from the sides of the dens to the lateral margins of the foramen magnum.

Muscles that move the spine (Moore pp 467)
The movements allowed by the spine include: flexion/extension, abduction/adduction, rotation. The muscles act against gravity to maintain an upright posture.

Extensors of spine (Moore pp 467, Netter Plate 160-162)
All the extensors of the spine are innervated by the dorsal rami of spinal nerves. There are two main groups: erector spinae, and transversospinalis muscle groups. In the neck there are two further groups: splenius & suboccipital – which are short little muscles. The function of all these muscles is to extend the spine from a flexed position, and control rate of flexion.

Extensors of spine: erector spinae (Moore pp 467 Netter Plate 161)
The erector spinae is a huge muscle, extending the whole length of the spine. It is divided into three columns, each named as a subset muscle. The erector spinae muscle exists bilaterally. The lateral column: iliocostalis, intermediate: longissimus, medial: spinalis. Each of these muscles is divided into three segments according to their position along the spine. Not all the muscles exist in all the divisions of the spine. Iliocostalis: lumborum, thoracis, cervicis, Longissimus: thoracic, cervicis, capitis, Spinalis: thoracis, cervicis.

Extensors of spine: transversospinalis (Moore pp 471 Netter Plate 162)
Deep to the erector spinae group, are the transvesospinalis group. Generally, they arise from the transverse process of a vertebrae, and end on the spinous process of a superior vertebrae. Group of muscles includes: semispinalis (thoracic, cervicis). There is a semispinalis capitis which extends from the transverse process to occipital bone. These muscles span about 4-6 vertebrae. The multifidus muscles spans 2-4 vertebrae. The segmental muscles mainly: interspinous, intertransverse, rotatores span 1-2 vertebrae.

Extensors of spine: splenius and suboccipital muscles (Moore pp 475 Netter Plate 160-161)
Superficially lies the splenius muscle. This has two parts: splenius capitis, and splenius cervicis. The suboccipital triangle contains four small muscles namely: rectus capitis posterior minor + major, inferior + superior obliquus capitis. Suboccipital muscles are innervated by the suboccipital nerve (dorsal rami of C1).

Flexors of spine (Notes, Anatomy Notes 2002)
Neck: longus colli, scalenes, SCM
Lumbar: rectus abdominis, external and internal obliques
Psoas major: flexes thigh/trunk at hip joint
Lateral flexion offered by quadratus lumborum, psoas major

Vertebral canal
Ligaments of vertebral bodies (Moore pp 451, Netter Plate 146)
The vertebral canal houses the spinal cord from the foramen magnum to the sacral hiatus. The boundaries are: anterior → posterior longitudinal ligament, IV disc, vertebral body, posterior → lamina & ligamenta flava, lateral → pedicles. Plate 146 proves this well.

The vertebral canal also houses the associated structures of the spinal cord including: spinal nerve roots, meninges (subarachnoid space, epidural and subdural spaces), blood vessels (vertebral vessels). The spinal nerve roots exit the vertebral column via the intervertebral foramen (adjacent to vertebral body → between pedicles).

Spinal cord + spinal nerves (Notes)
Read lecture notes here, no additional notes. Just note that spinal nerve roots exit below the pedicle normally, except at cervical level where they exit above their respective pedicle.

Spinal nerves (Moore pp 477 Fig 4.28)
The general anatomy of the spinal cord was explained in another lecture but here goes again. There is a dorsal and ventral horn. The cell bodies of afferents entering the dorsal horn is located in the dorsal root ganglion. The dorsal root enters the dorsal horn. The ventral horn houses the cell bodies of efferent fibres. These efferents are generally somatic, although some visceral efferents may also be present. The dorsal and ventral roots form a spinal nerve just lateral to their entry/exit point, and almost immediately this splits into a small dorsal primary ramus, and a large ventral primary ramus. The dorsal primary ramus supplies skin, muscles of the back (i.e.: extensors of spine), whilst the larger anterior ramus supplies the anterior compartment of the body. The anterior rami forms a number of plexuses namely: C1-C4: cervical plexus, C5-T1: brachial plexus (upper limbs), T2-L1: intercostal nerves etc, L2-S3: lumbosacral plexus (lower limbs).

Dermatome
<u>Definition: The area of skin supplied by a spinal cord segment</u>

Myotomes (Table 10-1 of Nolte 5th Ed)
Myotomes are defined as muscle fibres supplied by the same spinal cord segment. This is very useful when doing the peripheral nerve examination, where you need to know which dermatomes you are testing for power. Memorise these myotomes so you know them very well.
<u>Lower Limb</u>
Hip Flexion: L2-L3 Extension: L5-S1
Knee Extension: L3-L4 Flexion: L5-S1
Ankle dorsiflexion/invert: L4-L5 plantar flexion/eversion: L5-S2
Toes Extension: L5-S1 Flexion: S1-S2

<u>Upper Limb</u>
Shoulder: C5-C7
Elbow Flexion: C5-C6 Extension: C7-C8
Wrist Flexion/Extend: C6-C7
Fingers Flex/Extend: C7-C8 Abduction/Adduction: C8-T1

Spinal cord segments vs Spinal processes of vertebrae
The spinal cord is much shorted than the vertebral column. The spinal cord ends at L1-L2 level at the level of the conus medullaris. From here the spinal nerve roots extend longer. The nerve roots inferior to the spinal cord is called the cauda equina region. There are two enlargements of the spinal cord, both at the level of nerve roots emerging to innervate the upper and lower limbs. The cervical enlargement arises at C5-T1 levels, lumbar enlargement at L2-S3 levels.

Intervertebral Disc Herniation (Moore pp 479 – Blue Box Netter Plate 144)
Note from earlier in the lecture we noted that the IV disc is composed of a fibrous outer layer: annulus fibrosis, and a cartilaginous inner circular layer: nucleus pulposus. In the lumbar and cervical enlargements, we find there are a number of nerve roots emerging to supply the lower and upper limbs. Thus any herniation of the nucleus pulposus will compress the nerve roots in these regions. Pain caused will be distributed along their dermatomes.

Lumbar back pain (Moore pp 474)
Lumbar back pain is a very common complaint, especially from those that participate in sport. It is caused by extreme movements of the vertebral column resulting in stretching or microscopic tearing of back muscles or ligaments (i.e.: hyperextension, hyperrotation etc). In response to these inflammatory conditions, the muscles involuntarily contract producing reflex spasms. Note that the IV disc supports much of the weight of the body, so if any IV disc degeneration occurs – this would imply more stresses implanted onto the zygapophyseal joints causing pain. Lumbar back pain can also be caused by arthritis of the zygapophyseal joints or occasionally due to more serious conditions such as: cancer, AAA, infection etc.

Meninges of spinal cord (Moore 477)
Like the brain, the spinal cord is embedded in sheaths of connective tissue for protection. The outer most layer is the dura mater. It is continuous with the dura of the cranial cavity. The arachnoid mater is a delicate layer of connective tissue in close association of the inner aspect of the dura. It is NOT attached to the dura but simply held against it due to the CSF pressure. The arachnoid sends delicate strands of connective tissue, connecting it to the pia mater. These strands are called the arachnoid trabeculae. These trabeculae traverse the subarachnoid space, which contains the CSF. The innermost layer is the pia mater, directly forming a membrane over the spinal cord. This also covers the spinal nerve roots. All these layers blend with the epineurium of the spinal nerve roots at the IV foramina.

Spaces associated with meninges of spinal cord (Moore 477-482)
Between the dura and the vertebral column is the epidural space. This is filled with fat and venous plexuses. The subdural space is a potential space between the dura and arachnoid. It does not exist normally, but bleeding into this will cause a subdural haematoma. The subarachnoid space is between the pia and arachnoid mater and is filled with CSF. Caudal to the conus medullaris, the subarachnoid space enlarges to form the lumbar cistern. Note in the brain the epidural space is a POTENTIAL space.

Limits of meninges and spaces (Moore 477-482)
The dura mater extends with the spinal nerve roots along the dorsal and ventral rami distal to the spinal ganglia to form the dural root sleeves (Fig 4.29). The dural sac (formed by the dura) within the vertebral column adheres to the margins of the foramen magnum all the way to the sacrum. It is anchored inferiorly to the coccyx by the terminal filum. The denticulate ligaments are saw toothed enlargements of the pia mater between the dorsal and ventral roots, attaching to the inner dural sac.

Lumbar puncture (Moore pp 483)
A lumbar puncture is done to assess a sample of CSF. Assessment may provide critical information about a person's CNS. Meningitis will cause the CSF to be cloudy in colour, other CNS conditions may produce blood in CSF or change the chemical constituents of the CSF. The spinal cord ends at L1-L2, but CSF continues in the lumbar cistern between this. Thus you can access the lumbar cistern (subarachnoid space) between L3-L4, L4-L5 spinous processes to avoid causing damage to the spinal cord. Examination of the fundus through ophthalmoscopy should be done to determine raised intracranial pressure, if position – then do not perform lumbar puncture. Drugs or radiological contract can be delivered this way.

Anatomy of the spinal cord (Nolte 5th Ed pp 223 Netter Plate 151)
The spinal cord is the beginning of the CNS, even though it is not considered as such. It is symmetrical in shape, with an anterior median fissure separating the ventral side, and a posterior medial sulcus separating the dorsal side. The spinal cord is segmented. By this, I mean – along the spinal cord you see dorsal roots entering it, and ventral roots exiting it. The small central canal contains the CSF and like all CSF containing structures – it is lined by ependymal cells. A cross section of a spinal cord reveals distinct appearances. There is a darker and lighter area. The darker area → gray matter, lighter area → white matter. Gray matter consists of neuron cell

bodies, glial cells (of CNS), dendrites & axon terminals. White matter consists of myelinated axons, glial cells (of CNS). The "whiteness" comes from the myelination.

Functions of the spinal cord (Nolte 5th Ed pp 230)
The spinal cord is involved in three main functions: processing of sensory information, producing motor output, and reflexes. Primary afferent fibres come through the dorsal root, conveying information to the spinal cord. From here, it can synapse with neurons in the gray matter, it can not synapse and ascend directly to more rostral structures (i.e.: medulla). The cell bodies of these primary afferent fibres are located in the dorsal root ganglion.

The spinal cord is also involved in motor output. The motor neurons innervating the skeletal muscles, and preganglionic sympathetics/parasympathetics innervating the visceral structures are located in the ventral horn/intermediate horn respectively. So the spinal cord is responsible for voluntary movement, involuntary visceral actions, innervates cardiac, smooth muscle and glands.

Lastly, the spinal cord is itself (without higher centre involvement) involved in reflex processing. This unconscious/in voluntary movement involves input via dorsal roots, and output via ventral roots with integration by the interneurons (polysynaptic reflexes).

Gray matter: anterior (ventral) horn (Nolte 5th Ed pp 232)
The ventral horn of the spinal cord houses the cell bodies of motor neurons. These are called lower motor neurons or alpha motor neurons, and their axons leave the spinal cord via the ventral root to innervate ipsilateral skeletal muscles. Thus any interruption to this outflow will produce paralysis of those muscles, called flaccid paralysis – therefore the muscle atrophies (lack of trophic factors to muscles via axons). Reflexes will not longer be activated – areflexia. These alpha motor neurons are arranged in clusters, so one cluster will innervate one muscle. Interspersed within these alpha motor neurons are gamma motor neurons that innervate the intrafusal fibres of muscle spindles. The ventral horn is enlarged laterally at cervical and lumbar enlargements of the spinal cord. This is to accommodate for LMNs for muscles of the upper and lower limbs.

Gray matter: intermediate gray and lateral horn (Nolte 5th Ed pp 233)
The gray matter between the ventral and dorsal horns, is the lateral horn. It contains preganglionics that innervate the visceral structures + glands. Axons of cell bodies located in the lateral horn leave via the ventral root. The lateral horn only exists between T1-L2, and S2-S4. T1-L2 consists of preganglionic sympathetic fibres innervating the visceral structures, whilst S2-S4 consists of preganglionic parasympathetics to hindgut and pelvic structures.

Clarke's nucleus is an important structure located on the medial aspect of the base of the dorsal horn. It is an important relay nucleus for the transmission of information via the posterior spinocerebellar tract.

Gray matter: dorsal (posterior) horn (Nolte 5th Ed pp 230)
The dorsal horn is the entrance point of the sensory information. It contains all the interneurons whose processes remain within the spinal cord. This area of gray matter consists of two important structures: substantia gelatinosa, and the body. The substantia gelatinosa is involved in conveyance of pain + temperature information via the spinothalamic tract. The dorsal horn also contains projection neurons, whose axons have aligned to form ascending tracts to more rostral structures.

Gray Matter: lamina of Rexed (Nolte 5th Ed pp 233)
The gray matter of the spinal cord was subdivided into lamina by Rexed. Each lamina consists of a particular structure. i.e.: Lamina II → substantia gelatinosa and Lamina VII: IML etc.

White Matter (Notes)

The white matter is subdivided into three main columns, ipsilaterally. The posterior, anterior and lateral column. These columns (funiculi) consist of tracts that are conveyed to and from the brain. Ascending tracts go to the thalamus, cerebral cortex, cerebellum. Descending tracts come from cerebral cortex to brain stem. Tracts that travel between the spinal cord segments. are called fasciculus proprius.

White Matter: Posterior Columns (Somatosensory sytem lecture, Netter Plate 151)
The posterior columns contain tracts of primary sensory neurons. For example: fasciculus gracilis (below T6) and fasciculus cuneatus (above T6). The dorsal column medial lemniscal pathway uses the posterior columns to convey proprioception, 2 point discrimination, tactile and vibration sensation to higher centres. It utilises the posterior column to do so.

White matter: lateral columns (Somatosensory system lecture, Netter Plate 151)
The lateral columns contain both ascending and descending tracts. The ascending tracts conveying sensory information to higher centres include: anterior + posterior spinocerebellar tracts, and part of the spinothalamic tract (anterolateral system). The former conveys non-conscious proprioception, the latter transmitted pain + temperature + some tactile sensation. The spinothalamic tract contains 2nd sensory neurons from the contralateral side (substantia gelatinosa). The descending tracts include: lateral corticospinal tracts and rubrospinal tracts. The former controls the skeletal muscles of the contralateral side, whilst the latter arises in the red nucleus, crossing over in the mid brain and descending down, providing an alternate route for voluntary movement. Both tracts contain upper motor neurons that control LMN.

White matter: anterior columns (Somatosensory system Lecture, Netter Plate 151)
The anterior columns consist of both ascending and descending tracts. The ascending tracts are: part of the spinothalamic tract (anterolateral system), part of the anterior spinocerebellar tract. The descending pathways include: anterior corticospinal tract, and tectospinal tract. These are involved in voluntary movement of skeletal muscle. The tectospinal tract is thought to be involved in reflex movement of head.

Appearance of spinal cord (Refer to lecture notes)
Most of this already mentioned above.

Muscle stretch reflex (Nolte 5th Ed pp 234)
Stretching a muscle will produce a muscle stretch reflex. This is the simplest reflex arc, called a monosynaptic reflex. The muscle spindle is stretched, exciting the terminal ends of the Ia afferent. This conveys the sensory information to the alpha motor neuron situated in the ventral horn. This fires off to produce a reflex contraction of the muscle involved. Clinically, the muscle stretch reflex tells us a lot about the following things: receptor is working, peripheral nerve is functional (sensory aspect), sensory neuron is intact (1a afferent), spinal cord segment is not damaged, motor neuron is intact, peripheral nerve is functional (motor aspect), NMJ is functional, and muscle is toned. Commonly tested reflexes include: Patellar – L3-L4 (Extension of knee), Cacaneal (achilles) tendon: S1-S2, Biceps brachii: C5-C6 (elbow flexion), Triceps brachii: C7-C8 (elbow extension). Refer to myotomes.

Reflexes: withdrawal reflex (Nolte 5th Ed pp 235)
The withdrawal reflex (or flexor reflex) is involved when we encounter a painful stimulus such that we flex the offended part of our body to rid ourselves of the painful stimulus. The flexor reflex pathways are inhibited by higher centres normally, such that only noxious stimuli cause its activation. Withdrawal reflexes involved several neurons, including a primary sensory neurons which detects the noxious stimuli and many interneurons. These interneurons may span several spinal cord segments. This is because, we are talking about flexing the whole limb affected (per say). The withdrawal reflex involves excitatory components, affecting the agonist muscles and inhibitory components, affecting the antagonist muscle. For example: stepping on a pin will cause flexors to activate and extensors (of hip) to deactivate. Note that these reflexes are polysynaptic usually, involved many interneurons etc.

Arteries of the vertebral column (Moore pp 486 Netter Plate 157)
The spinal cord is supplied mainly by three longitudinal arteries namely: anterior spinal artery, two parallel posterior spinal arteries. These arteries travel the length of the spinal cord. They are formed from vertebral, posterior intercostal, lumbar, and lateral sacral arteries. The anterior spinal artery travels in the anterior medial fissure, and gives off central (sulcal) arteries that enter the spinal cord via this fissure. These arteries supply about 2/3 of the gray matter. The posterior artery travels on the posterior aspect of the spinal cord parallelling each other, forming anastomosing branches in the pia mater. It supplies the posterior and lateral columns (funiculi).

Vertebral venous plexus (Moore pp 486 Netter Plate 159)
There are two vertebral venous plexuses. These are the internal and external vertebral venous plexus. The internal plexus is in the epidural space, while the external is just outside the vertebral column. There are three anterior + posterior spinal veins, that freely communicate with each other. These veins receive blood from the medullary and radicular veins. The internal vertebral plexus travels superiorly to communicate with the dural venous sinuses. Eventually drains into the IVC via lumbar, internal iliac, jugular, deep cervical veins, and SVC via azygous veins.