Core Surgical Sciences course for the Severn Deanery

Surgical Anatomy: Thorax and spine – detailed learning objectives/stations

The session will be taught in small groups, with examination of prosections, and three rotating stations: vertebral column; thoracic walls and lungs; heart and mediastinum.

Vertebral column

1. Bones, joints and muscles of the spine

You should be able to:

Describe the functions of the spine:
- to support the trunk
- to protect the spinal cord
- to provide muscle attachment
- haemopoiesis

Identify the following general features of vertebrae:
- Ventral body - principal weight-bearing element; small vascular foramina front and sides, large (sometimes double) foramen posteriorly for basivertebral veins
- Dorsal neural arch (protects spinal cord): pedicles, laminae, superior and inferior articular processes (articulate to form zygapophyseal joints)
- Spinous and transverse processes - act as levers for muscles
- Intervertebral foramen - transmits spinal nerve (C1 to C7 emerge above the corresponding vertebrae; C8 emerges below C7 vertebra; subsequent spinal nerves emerge inferior to corresponding numbered vertebra), small recurrent nerves, blood and lymphatic vessels

The vertebral body largely comprises trabecular/cancellous/spongy bone – containing red bone marrow - with outer shell of cortical bone perforated by vascular foramina; the pedicles, articular and transverse processes are mainly compact bone, whilst the spinous process has a cancellous interior.

Identify individual vertebrae and their features, and relate their structure to the movements in the various regions of the spine (describe the relative extents of flexion, extension, lateral flexion and axial rotation in different regions of the vertebral column, and the muscles performing these actions):

- Atlas (C1): anterior and posterior arches; lateral masses; no body
- Axis (C2): with odontoid process (dens)
- A typical cervical vertebra: large vertebral foramen compared with size of body; sloping facets; transverse foramen (transmits vertebral artery and vein, and sympathetic nerves); small, bifid spine
- A typical thoracic vertebra: heart-shaped body; zygapophyseal facets oriented in coronal plane; demifacets on body; long, sloping spinous process
- A typical lumbar vertebra: large body compared with size of vertebral canal; facets oriented in para-sagittal plane; large, square spinous process
- the sacrum – and its alae
- the coccyx

NB. The number of vertebrae varies from 32-35 and there may be blurring between sections eg: lumbarised thoracic. The spinal column is around 70cm long in males and 60cm long in females; intervertebral discs contribute 25% of this length.

Identify and describe the following joints and ligaments:

Atlanto-occipital and atlanto-axial joints:
- Flexion and lateral flexion occur at atlanto-occipital joint
- Rotation occurs at the atlanto-axial joint
- Transverse ligament of the atlas; ligaments attaching the axis to the occiput: tectorial membrane, cruciform ligament, apical ligament, alar ligaments

Intervertebral joints:
- The intervertebral disc: a secondary cartilaginous joint comprising annulus fibrosus and nucleus pulposus; resists compressive forces
- The zygapophyseal joints (synovial) between the articular processes; these joints bear more weight as the disc degenerates and may be a source of back pain

Ligaments of the spine:
- The anterior and posterior longitudinal ligaments
- ligamentum flavum, supraspinous and interspinous ligaments

Identify and describe the following muscles acting on the spine:

- Intrinsic muscles of the spine: multifidus and semispinalis; erector spinae (iliocostalis, longissimus, and spinalis) - these muscles are supplied segmentally by posterior primary rami of spinal nerves
- Extrinsic muscles (eg: muscles attaching to upper limb such as trapezius and latissimus dorsi) also act on the spine, and are generally supplied by anterior primary rami of spinal nerves

Describe and identify the normal curvatures of the spine:
- primary thoracic and pelvic curvatures – convex dorsally
- secondary cervical and lumbar curvatures begin to appear at 8 weeks, but are not obvious until 1 year after birth; probably caused by muscles acting on very flexible spine (from US studies)
- neonatal spine has no fixed curvatures – when dissected can be bent (flexed/extended) in perfect half-circle
- thoracic spine then develops fixed curvature; AP diameter of thorax much larger than abdomen
- lumbar curvature important in balancing c of g over legs when walking starts
- usually no lateral curvatures (though often v slight scoliosis in upper thoracic region)

Describe the anatomical basis of common pathological conditions affecting the spine:

- Low back pain is the commonest reason for physician visits; common causes include disc herniation, spinal stenosis, spondylolisthesis, osteoporotic crush fractures, degenerative facet disease.
- Annulus fibrosus degenerates with age; nucleus pulposus may herniated, which may compress or irritate spinal nerves; 'slipped disc' commonly occurs at L4/5, L5/S1 in lower back – may cause sciatica, and at C5/6, C6/7
- Scoliosis (abnormal lateral spinal curvature) may be congenital or acquired (eg: secondary to neurological or muscular disorders)
- Pathological kyphosis may develop due to wedge fractures in an osteoporotic spine.
- Spina bifida - neural arch fails to fuse; spina bifida occulta is a mild, usually asymptomatic, form of this condition, where the L5 or S1 bony neural arch is unfused in the midline; a dimple or hair tuft may mark the site. More serious forms of spina bifida involve the protrusion of meninges (meningocele), or part of the spinal cord (meningomyelocele) through the defect, and are accompanied by neurological deficits.
- The spine is a common site of metastases from primary cancer elsewhere.
- Vertebral fractures must be carefully assessed to determine the stability of the vertebral column (and the likelihood of damage to the spinal cord); collars may be employed to stabilise the cervical spine.
- Back/lumbar strain (muscular – often a lifting injury) and neck sprain (ligamentous – 'whiplash').

2. Contents of the vertebral canal

You should be able to:

Describe and identify the meninges covering the spinal cord: dura mater, arachnoid mater and pia mater; pia continues beyond conus medullaris as filum terminale.

Identify and describe the spinal cord:

- About 45cm long in adult
- Begins at the foramen magnum as a continuation of the brainstem;
- Ends level with the L1/2 intervertebral disc in the adult (L3 in the newborn);
- Contains grey matter (cell bodies; H-shaped with dorsal and ventral horns; lateral horns in thoracic cord contain cell bodies of preganglionic sympathetic nerves) and white matter (myelinated ascending and descending tracts, in dorsal, lateral and ventral tracts).

Identify and describe the spinal nerves:

- 31 pairs of spinal nerves (8 cervical, 12 thoracic, 5 lumbar, 5 sacral and 1 coccygeal)
- Motor and sensory nerve roots leave the ventral and dorsal spinal cord respectively, on each side, then unite to form a spinal nerve, which then exits via the intervertebral foramina – and almost immediately divides into dorsal and ventral primary rami; identify dorsal root ganglia (cell bodies of senory nerves)
- Lumbar and sacral nerve roots form the cauda equina
- A myotome is a group of muscles innervated by a single spinal nerve; a dermatome is an area of skin innervated by a single spinal nerve

Describe the arterial supply of vertebrae, spinal cord and spinal nerves:

- Dorsal branches of intersegmental arteries (eg: posterior intercostal and lumbar arteries) form main arterial supply to vertebrae, dura and epidural tissues; anastomoses in neck and sacral regions persist as longitudinal vessels (vertebral artery, lateral sacral artery)
- 3 main arteries supply spinal cord: one anterior and two posterior spinal arteries, from vertebral arteries and anastomosing at conus medullaris; intramedullary arteries spring from anterior and posterior spinal arteries to supply the cord – functional end-arteries
- Anterior and posterior radicular arteries branch from the intersegmental dorsal arteries; most anterior radicular arteries are small and end in the ventral nerve roots, but some are very large, forming *anterior medullary feeder arteries* – including the famous **artery of Adamkiewicz**; this may arise from lower intercostal, subcostal or upper lumbar arteries – usually on the left, and may be the main supply to the lower two thirds of the spinal cord.
- Internal and external vertebral venous plexuses: internal plexus lies in epidural space; receives tributaries from vertebrae and spinal cord; basivertebral veins emerge from posterior foramina and drain into both external and internal plexuses; plexuses are valveless, freely anastomosing - wide permit spread of sepsis and metastases; drain into caval and azygos systems via vessels accompanying arteries; communicate with dural venous sinuses, and deep veins of neck and pelvis
- Lymphatic drainage follows arterial supply: cervical spine drains to deep cervical nodes; thoracic spine to posterior intercostal nodes; lumbar spine to lateral and retro-aortic nodes; sacrum to lateral sacral and internal iliac nodes

Describe the innervation of vertebrae, joints, and epidural tissue:

- Dorsal ramus of spinal nerve supplies facet joints, periosteum of neural arch, overlying muscles and skin;
- Recurrent meningeal (sinuvertebral) nerves arise from ventral ramus, re-enter intervertebral foramen, to supply walls of vertebral canal, dura and epidural tissue

Describe the anatomical basis of lumbar puncture, epidural and regional anaesthesia.

Thoracic walls and lungs

1. Thoracic Walls

You should be able to:

Describe and identify the components of the bony thorax:

- The thoracic inlet (T1 vertebra, first ribs and manubrium sterni) superiorly
- The ribs and intercostal muscles laterally
- The costal cartilages (may calcify with age) and sternum anteriorly (identify manubrium, body and xiphoid process of sternum)
- The ribs and thoracic vertebrae posteriorly
- The thoracic outlet (T12, the costal margin formed by the lower 6 ribs, and the xiphoid process inferiorly – closed by the diaphragm

Ribs may be vertebrosternal (1-7), vertebrochondral (8-10), or vertebral/'floating' (11,12).

Describe and identify typical ribs and atypical ribs.

Ribs may be fractured by direct blows or indirect crushing injuries; a segment detached by the fractures of several ribs produces paradoxical respiratory movement ('flail chest'); rib fracture may cause pneumo- or haemothorax.

Describe and identify the joints of the thoracic wall:

- Costovertebral (synovial)
- Costotransverse (synovial)
- Costochondral (primary cartilaginous)
- Interchondral (synovial)
- Intervertebral (synovial facet joints & secondary cartilaginous intervertebral discs)
- Manubriosternal (secondary cartilaginous)

Describe and identify the muscles of the thoracic wall and accessory muscles of respiration

- External, internal and innermost intercostal muscles
- Accessory muscles: sternocleidomastoid, scalenes, pectoral muscles, latissimus dorsi

Describe and identify the vessels and nerves of the thoracic wall:

- Anterior intercostal arteries (majority from internal thoracic arteries)
- Posterior intercostal arteries (majority from thoracic aorta)
- Anterior intercostal veins (majority drain to internal thoracic veins)
- Posterior intercostal veins (majority drain to azygos system)
- Ventral primary rami of thoracic spinal nerves form intercostal nerves; receive rami communicantes from the sympathetic trunk
- The intercostal vein, artery, nerve lie in that order, from superior to inferior, in the costal groove
- When draining fluid from the pleural cavity, the needle is inserted across the superior border of a rib to avoid the main neurovascular bundle, usually in the 5th intercostal space, midaxillary line (any lower and the diaphragm may be pierced)

Describe and identify the attachments of the diaphragm:

- Sternal part from posterior xiphisternum
- Costal part from the lower 6 ribs
- Right and left crura from lumbar vertebrae
- Medial and lateral arcuate ligaments – from fascia over psoas and quadratus lumborum

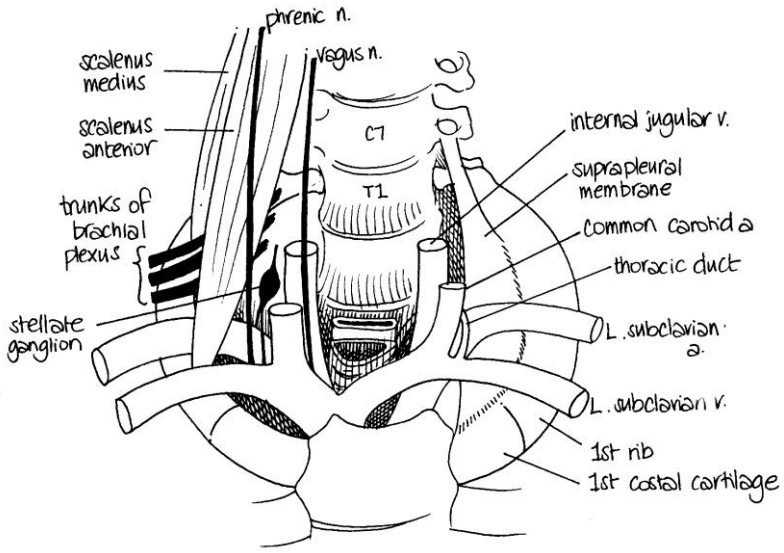
Identify structures passing through/behind the diaphragm (thoracic outlet):

- T8 – IVC and right phrenic nerve (left phrenic nerve pierces diaphragm independently)
- T10 – Oesophagus, left gastric vessels, vagus nerve
- T12 – Descending aorta, azygos vein, thoracic duct

Describe the movements (and joints and muscles involved) in normal, vigorous and forced respiration:

- Diaphragm contracting – main muscle of respiration
- Movements of chest wall in vigorous respiration: 'bucket-handle' and 'pump-handle'
- Extrinsic muscles attaching to chest wall (accessory muscles of respiration) enlisted in forced respiration

Identify and describe the thoracic inlet and the structures passing through it: apex of lung, trachea, oesophagus, subclavian artery and vein, T1 spinal nerve root, phrenic and vagus nerves, common carotid arteries, internal jugular vein



2. Trachea, bronchi, lungs and pleural cavity

You should be able to:

Identify and describe the trachea:

- 15-20 c-shaped cartilage rings
- Fibrous tissue & trachealis muscle posteriorly
- Lined with ciliated columnar mucous (respiratory) epithelium
- Bifurcation (carina) at level of sternal angle (T4/T5) – may be widened by enlarged tracheobronchial lymph nodes

Identify and describe the anatomy of the lungs:

Structures at the pulmonary hilum:

- Main bronchus (lies posteriorly): hyaline cartilage & smooth muscle wall; lined with pseudostratified ciliated columnar epithelium; right main bronchus is shorter (~2.5cm), wider and more vertical than left, and gives off upper lobe bronchus at hilum; left is ~5cm long (inhaled foreign bodies more likely to lodge in right bronchus than in left)
- Pulmonary arteries - lying above the pulmonary veins at the hilum

Both lungs are conical, with:

- an apex
- costal, mediastinal, diaphragmatic (base) surfaces
- thin anterior and inferior borders; rounded posterior border
- right lung has 3 lobes, left has 2.

Bronchopulmonary segments

- the anatomical, functional and surgical units of the lungs; each has a segmental bronchus and artery, lymph vessels and autonomic nerves; intersegmental veins lie in the adjoining connective tissue
- Each lung has 10 bronchopulmonary segments

Blood supply, lymphatic drainage and innervation of the lungs:

- The lungs and visceral pleura are supplied by bronchial arteries (branches of the descending aorta)
- Corresponding bronchial veins drain into the azygos and hemiazygos veins
- Lymph from lungs drains to bronchopulmonary nodes at the hilum, to tracheobronchial nodes in the mediastinum, to tracheal nodes; lung cancer spreads via these pathways, to lymph nodes at the hilum, mediastinum and root of the neck
- The lungs and visceral pleura are supplied with autonomic innervation from the sympathetic trunks and vagus nerves, via the pulmonary plexuses; parasympathetic stimulation constricts the bronchioles; sympathetic dilates the bronchioles

Identify and describe the visceral and parietal pleura.

- Pleura are mesothelial membranes that enclose the pleural space, containing thin film of pleural fluid; this creates a seal, linking movements of the chest wall to expansion of the lungs and lubricates lung movement during breathing.
- The parietal pleura has costal, diaphragmatic and mediastinal parts (which have somatic innervation supplied by the intercostal and phrenic nerves)
- The visceral pleura is adherent to the surface of the lung, and descends into fissures, and is supplied by autonomic nerves
- The pleura is reflected around the hilum; the pulmonary ligament allows distension of the pulmonary vein at the hilum

Describe the surface anatomy of the lungs and pleura:

- The apex of the lung (and cervical pleura) extends 2cm above the clavicle
- The edge of the pleural sacs reaches the midline behind the sternum, at the sternal angle
- On the left, the pleura curves out laterally at the 4th costal cartilage, around the heart; the margin of the right pleura descends to the 6th rib then passes laterally
- Both pleural sacs extend down to the 8th rib in the midclavicular line, the 10th in the midaxillary line, and the 12th at the angle of the ribs.
- The lower margin of the lungs lies 2 ribs above the pleural limit: 6th rib in the midclavicular line, 8th in the midaxillary line, and 10th at the angle of the ribs.
- The oblique fissures runs from the spine of T4 to the 6th rib in the midclavicular line
- The horizontal fissure runs from the 5th rib in the midaxillary line to the 4th costal cartilage at the sternum

Describe the cause and treatment (decompression) of a tension pneumothorax:

- An injury to the chest wall acts like a valve - air is drawn in with each inspiration, but fails to escape on expiration
- The mediastinum is pushed to the opposite side and the venae cavae become compressed – this will be fatal if not treated promptly
- A large needle is inserted through the 2nd intercostal space in the midclavicular line – and a hiss should be heard as air is released; a plan should be made for insertion of a chest drain

Describe chest drain insertion:

- Approach is through the 5th intercostal space in the mid-axillary line, above the inferior rib (to avoid the neurovascular bundle)
- The cleaned, anaesthetized area is incised with a scalpel above the rib; a gloved finger is used to bluntly dissect through the fascia and intercostal muscles, and then to perforate the parietal pleura
- The chest drain is inserted through the tunnel and into the pleural cavity and secured with a purse-string suture; the drain is connected to a drainage device – an underwater seal is required in pneumothorax.

Chest drains are used to drain air or fluid in the pleural space, eg:

- Pneumothorax – air in the pleural space (e.g. rib fracture or penetrating injury)
- Haemothorax – blood in the pleural space (usually from a bleeding chest wound)
- Chylothorax – lymph in the pleural space (after rupture of the thoracic duct)
- Empyema – pus in the pleural space (infection)

Mediastinum, heart and great vessels

1. Mediastinum

You should be able to:

Identify the boundaries of the mediastinum

- The mediastinum is the area lying between the two pleural cavities, and contains all the thoracic viscera except the lungs
- Bounded by the thoracic inlet above, the diaphragm below, the thoracic vertebrae posteriorly, the sternum and costal cartilages anteriorly, the pleural sacs laterally.

The mediastinum is divided into a superior and inferior portion by a transverse plane; anatomical structures lying on this plane include:

- Manubriosternal joint
- L4/5 intervertebral disc
- Arch of aorta
- Ligamentum arteriosum
- Azygos vein draining into SVC
- Thoracic duct
- Bifurcation of the trachea
- Left recurrent laryngeal nerve looping under the aortic arch and ligamentum arteriosum

Describe and identify the contents of the divisions of the mediastinum:

Superior mediastinum contains:

- Lower trachea
- Oesophagus
- Thoracic duct
- Aortic arch
- Brachiocephalic trunk
- Commencement of carotid and subclavian arteries
- Brachiocephalic veins
- Superior vena cava
- Phrenic and vagus nerves
- Left recurrent laryngeal nerve
- Cardiac nerves
- Lymph nodes
- Thymus remnant

The inferior mediastinum is subdivided into a middle region (containing the heart within the pericardium), an anterior region and a posterior region.

Anterior mediastinum contains:

- Thymus gland in children
- Lymph nodes

Middle mediastinum contains:
- Heart
- Origin of great vessels
- Phrenic nerves
- Pericardiocophrenic vessels

Posterior mediastinum contains:
- Descending thoracic aorta
- Oesophagus
- Vagus and splanchnic nerves
- Azygos and hemiazygos veins
- Thoracic duct
- Lymph nodes

2. The pericardium and heart

Identify and describe the pericardium:

Structure:
- Outer fibrous layer, inner serous layers
- The fibrous pericardium is anchored to the central tendon of the diaphragm below and blends with the adventitia of the great vessels above
- Serous pericardium possesses visceral and parietal layers: the parietal layer is closely adherent to the fibrous pericardium whilst the visceral layer is closely adherent to the myocardium; the potential space between the two is the pericardial cavity, containing a thin film of pericardial fluid
- Pericardial reflections: forming transverse sinus between the aorta above and pulmonary veins and SVC below; and oblique sinus behind left atrium, below pulmonary veins and to the left of the IVC

Functions:
- Restricts excessive movements of the heart as a whole
- Provides a lubricated container inside which different parts of heart can contract

Innervation:
- Phrenic nerves travel in the fibrous pericardium to the diaphragm – and supply sensation to the fibrous and parietal layer of serous pericardium
- Pain from the pericardium (e.g. pericarditis) may be referred to the shoulder tip because of the common innervation (C4)

Clinical Aspects
- Pericarditis may be caused by infection, systemic disease or MI; the central chest pain may be relieved by sitting forward (unlike the pain of MI); constrictive pericarditis may compress the heart and require surgical decompression
- Excess fluid in the pericardial space can cause cardiac tamponade

Describe the orientation of the heart in life, and its surfaces:

- Anterior (sternocostal) surface: anterior surface: 2/3 right ventricle, 1/3 left ventricle; auricle of left atrium
- Inferior (diaphragmatic) surface: entrance of IVC into right atrium; 1/3 right ventricle, 2/3 left ventricle
- Pulmonary (posterior) surface (base): left atrium (only the left auricle is visible anteriorly). Left ventricle

Describe and identify the heart borders as seen on a chest radiograph, describing the parts of the heart that contribute to each border:

- Right: right atrium, IVC and SVC
- Inferior: right ventricle; apex of left ventricle
- Left: left ventricle, left auricle

On a PA chest radiograph the cardiothoracic ratio should be less than or equal to 1:2. Chest radiographs taken anteroposteriorly magnify heart size, and are only taken in emergencies.

Describe and identify the following features within each chamber:

Features of the right atrium

- Crista terminalis (and sulcus externally) between IVC and SVC, separating smooth posterior wall (from embryonic sinus venosus) and rough-walled parts with pectinate muscle (from embryonic common atrium)
- Right auricle
- Fossa ovalis in interatrial septum (from embryonic foramen ovale)
- Openings of coronary sinus, SVC and IVC

Features of the right ventricle

- Trabeculae carneae
- Septomarginal trabecula ('moderator band') – carrying conducting fibres
- Papillary muscles with chordae tendineae attaching to tricuspid valve – 3 cusps: septal, anterior, posterior
- Interventricular septum (muscular and membranous parts)
- Smooth conus arteriosus (outflow tract)
- Pulmonary valve – 3 semilunar cusps

Features of the left atrium

- Smooth walled – except rough-walled auricle
- 4 pulmonary veins
- Floor of fossa ovalis (valve of foramen ovale) in interatrial septum

Features of the left ventricle

- Walls 2-3 times thicker than right ventricle; longer than right
- Finer trabeculae carneae than right ventricle
- Papillary muscles with chordae tendineae attaching to mitral valve – 2 cusps: anterior and posterior
- Aortic valve – 3 semilunar cusps

Describe the anatomical basis of congenital septal defects:

- Septal defects occur due to anomalies in the embryological septation of the heart
- Septal defects may involve the interatrial or interventricular septa – or both
- Atrial and ventricular septal defects both allow blood to flow from left to right side, resulting in right ventricle hypertrophy and pulmonary hypertension

Describe the components of the conducting system of the heart:

- Sinuatrial node (SAN) - at superior end of crista terminalis
- Atriventricular node (AVN) – above coronary sinus opening
- Atrioventricular bundle (of His); Right and left bundle branches
- Subendocardial (Purkinje) fibres

The atria are electrically insulated from the ventricles by the fibrous skeleton of the heart: fibrous rings support each of the heart valves. Coronary heart disease (CHD) may affect the conducting system of the heart, resulting in dysrhythmias.

Describe the autonomic innervation of the heart:

- Sympathetic innervation from cervical and upper thoracic ganglia of the sympathetic chain, parasympathetic from vagus nerves, via deep and superficial cardiac plexuses
- Autonomic efferents control heart rate (fibres ending on SAN and AVN) and contractility (fibres ending on myocardium)
- Visceral afferent nerves from the heart pass via thoracic splanchnic nerves to T1-4 levels of the spinal cord – pain (eg: from angina) is referred to the upper thorax and arm.

Describe and identify the coronary arteries and their main branches:

Right coronary artery

- Arises from anterior aortic sinus to lie in atrioventricular groove
- Main branches: marginal branch and posterior interventricular or posterior descending artery (PDA)
- Supplies right atrium and ventricle
- Supplies both sinuatrial node (SAN) and atrioventricular node (AVN) in most people

Left coronary artery

- Arises from left posterior aortic sinus, runs behind pulmonary trunk to lie in atrioventricular groove
- Main branches: anterior interventricular or left anterior descending artery (LAD), circumflex artery (continues in AV groove)
- Supplies left atrium and ventricle

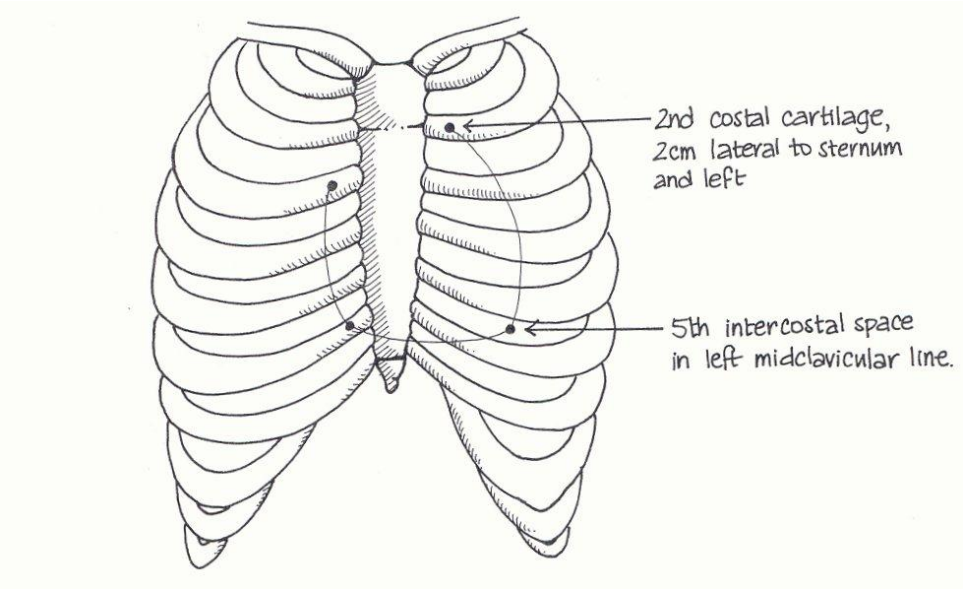
Variations:

- posterior interventricular artery may arise from left coronary artery ('left dominance', in ~10%)
- Co-dominance occurs in ~10%
- SAN supplied by right coronary artery in 60%; by circumflex artery in 40%
- AVN supplied by right coronary artery in 90%; by circumflex artery in 10%

Describe the venous drainage of the heart:

- Minute venae cordis minimae drain heart muscle
- Small anterior cardiac veins drain into right atrium
- Coronary sinus forms main venous drainage; tributaries:
    - Great cardiac vein (runs with anterior interventricular artery)
    - Middle cardiac vein (runs with posterior interventricular artery)
    - Small cardiac vein (runs with marginal artery)
    - Oblique or posterior cardiac veins

Describe the surface projections of the heart:



Describe the optimal sites for auscultation of the heart valves:

- Mitral valve – apex beat – 5th intercostal space, left midclavicular line
- Tricuspid valve – 5th intercostal space, left sternal edge
- Pulmonary valve – 2nd intercostal space, left sternal edge
- Aortic valve – 2nd intercostal space, right sternal edge

Mitral and tricuspid valves snap shut at the start of ventricular systole; aortic and pulmonary valves at the end of ventricular systole/beginning of diastole.