Radiological Anatomy

Edited by

PAUL BUTLER
Royal Hospitals of St Bartholomew, The London and the London Chest

ADAM W·M·MITCHELL
Charing Cross Hospital, London

HAROLD ELLIS
King's College (Guy's Campus), London

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1

Surface anatomy

H. ELLIS

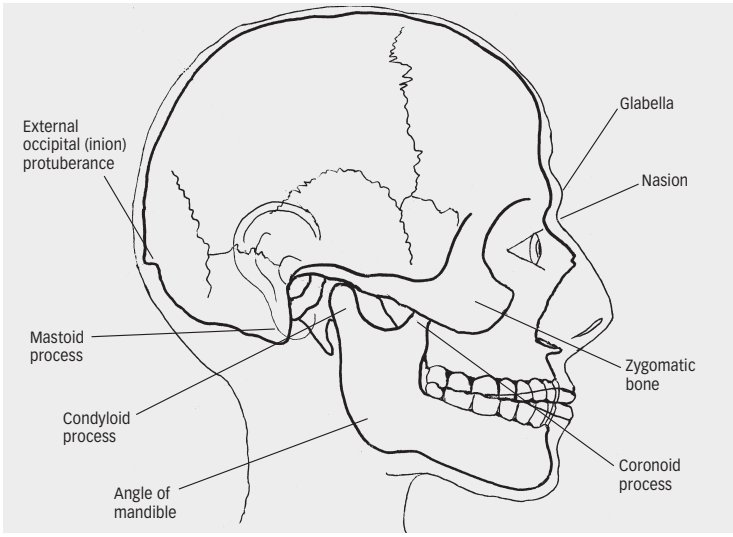
Introduction

Surface anatomy, to the radiologist, is principally concerned with bony landmarks, anatomical levels and vascular access. Bony landmarks allow for accurate positioning of the patient and provide convenient points of reference for adjacent soft tissue structures. Anatomical levels facilitate structure localization; for example, the coeliac axis origin from the aorta lies at the level of the twelfth thoracic vertebra. The anatomy of vascular access, in this modern era of invasive radiology, is of obvious practical importance. It is these three topics that will therefore be highlighted in this chapter.

The head and neck

Because the skull and mandible are covered, for the most part, only by skin, cutaneous tissues and a thin layer of muscle, their bony landmarks can be easily palpated and many of them in a thin subject, are actually visible (Fig. 1).

Fig. 1.
Surface anatomy features of the skull.



Anteriorly, the depression at the root of the nose is termed the nasion, which overlies the suture between the frontal and nasal bones. Above the nasion is felt the elevation on the frontal bone termed the glabella which, traced laterally, continues as the superciliary arch, which lies above and parallel with the supraorbital margin. The whole of the orbital border is readily felt by a finger run round the deeper aspect of its edge. Usually the supraorbital notch can be felt along the upper margin about 2.5 cm from the midline. This transmits the supraorbital branch of the ophthalmic division of the trigeminal nerve. Not infrequently, however, the notch is replaced by a foramen. Laterally, the suture between the frontal and zygomatic bones can be felt as a slight but distinct depression (the frontozygomatic suture).

The posterior border of the zygomatic process of the frontal bone can be traced upwards from the level of the frontozygomatic suture into the temporal line, which curves upwards and backwards on the parietal bone. The parietal eminence lies above the posterior part of the temporal line. A line joining the parietal eminence on each side forms the greatest transverse diameter of the skull.

The prominence of the cheek is formed by the zygomatic bone, whose lateral surface can be readily palpated. It can be traced upwards into the frontal process, backwards into the zygomatic arch and forwards and downwards into the maxilla.

Posteriorly, the external occipital protuberance can be felt and often seen at the upper end of the median nuchal furrow, which is plainly visible at the back of the neck and overlies the ligamentum nuchae. The inion is the term given to the point situated on the tip of the protuberance in the midline and is used in skull

measurements. Above the protuberance, the skull presents a backward convexity and the point of greatest curvature is named the maximum occipital point. Above, and in front of this, can be felt an irregular depression in the midline, the lambda. This corresponds to the posterior fontanelle in the newborn, at the junction of the sagittal and lambdoid sutures. Extending laterally from the external occipital protuberance the superior nuchal line can be felt.

The mastoid process is hidden by the lobule and lower part of the concha of the external ear. Its lateral aspect and anterior border are readily palpated but its tip and posterior border are obscured by the attachments of the sternocleidomastoid and splenius capitis muscles.

Almost the whole of the outer aspect of the mandible is readily palpable, including its body, angle and ramus. The condyloid process lies in front of the tragus of the external ear and can be felt to move forwards and downwards if the mouth is opened. It can also be felt to move with a finger placed within the external auditory meatus. The coronoid process can be identified by a finger placed in the angle between the zygomatic arch and the masseter muscle with the mouth opened. Its anterior border can also be palpated within the mouth. The overlying masseter muscle is readily appreciated with the teeth clenched, and the parotid duct can be rolled across its anterior border just below the zygomatic bone. The orifice of this duct can be seen within the mouth at the level of the second upper molar tooth. Here, it can be intubated to perform a parotid sialogram.

The mental foramen can be represented by a point midway between the upper and lower borders of the body of the mandible at the level of the interval between the two premolar teeth. It marks the point of egress of the mental branch of the inferior alveolar nerve.

The neck

The prominent landmark on the lateral side of the neck is the sternocleidomastoid (Fig. 2). This passes from the mastoid process and lateral half of the superior nuchal line of the occipital bone obliquely downwards and forward to a medial (or sternal) head, which is tendinous, and attached to the upper part of the anterior surface of the manubrium and a lateral (or clavicular) head, of fleshy fibres, which attaches to the superior border and anterior surface of the medial one-third of the clavicle. The depression between these two heads is easily felt and is an important landmark to the internal jugular vein (see below). The sternocleidomastoid on one side is tensed by pressing the chin against the examiner's hand towards the opposite side. This is a useful test for the eleventh cranial nerve (accessory nerve) which supplies this muscle. The anterior edge of trapezius can be seen and felt as it inserts along the lateral one third of the clavicle.

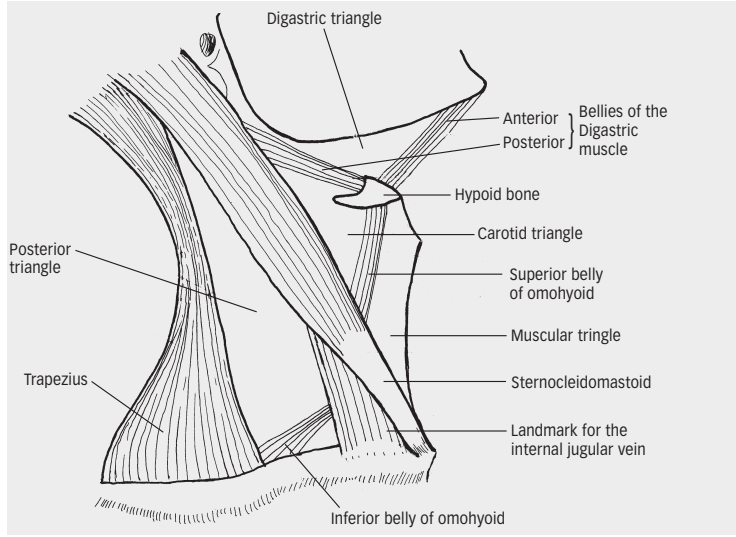


Fig. 2.
The triangles of the neck. The anterior triangle is further subdivided into digastric, carotid and muscular triangles.

The sternocleidomastoid divides the lateral aspect of the neck into the anterior and posterior triangles, which are useful for descriptive purposes. The posterior triangle lies between the posterior border of sternocleidomastoid, the anterior border of trapezius and the clavicle. The anterior triangle is formed by the midline anteriorly, the sternocleidomastoid behind and the base above is formed by the lower border of the body of the mandible and a line from its angle to the mastoid process.

In the midline of the neck, from above downwards, the following can be palpated (Fig. 3):

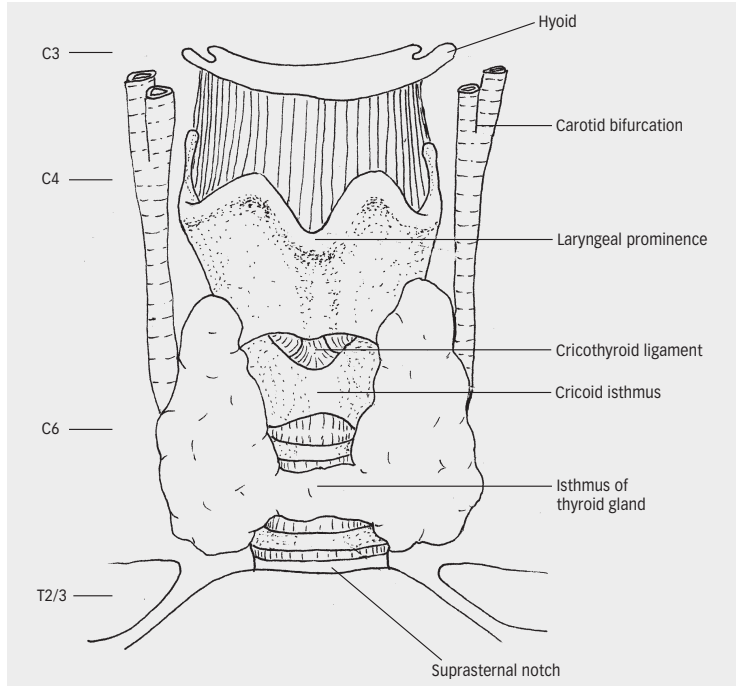


Fig. 3.
Palpable structures in the front of the neck and their vertebral levels.

The hyoid bone can be felt immediately below the mandible and can be moved between the thumb and finger from side to side.

The laryngeal prominence of the thyroid cartilage is the midline point of fusion of the upper borders of the thyroid lamina. In the post-pubertal male, the laryngeal prominence, or 'Adam's apple' is usually visible because of the considerable enlargement that takes place in the male larynx at puberty. In the female and pre-pubescent male the prominence is easily palpable but not visible.

The thyroid cartilage isthmus can be felt in the midline running downwards from the laryngeal prominence.

The cricothyroid ligament is represented by a gap between the inferior border of the thyroid cartilage and the cricoid cartilage. This ligament is the site of puncture for emergency access to the trachea.

Below the cricoid can be felt the trachea with its characteristic rings. This extends down to the suprasternal notch of the manubrium.

Often the isthmus of the thyroid gland can be felt to cross, usually, the second to fourth tracheal rings.

Vertebral levels

The following vertebral levels are readily identified in the cervical region:

- The atlas and the dens of the axis: lie in the horizontal plane of the open mouth. (It is through the open mouth that a satisfactory radiograph of these structures can be obtained in the AP position.)
- The third cervical vertebra: lies at the level of the hyoid bone.
- The fourth cervical vertebra: lies at the level of the upper border of the thyroid lamina.
- The sixth cervical vertebra: lies at the level of the lower border of the cricoid cartilage.

The lower border of the cricoid cartilage, the level of the sixth cervical vertebra, is an important landmark since this demarcates:

(a) the junction of the larynx with the trachea.
(b) the junction of the pharynx with the oesophagus.
(c) the level at which the vertebral artery usually passes into the foramen transversarium of the cervical vertebra.

Blood vessels

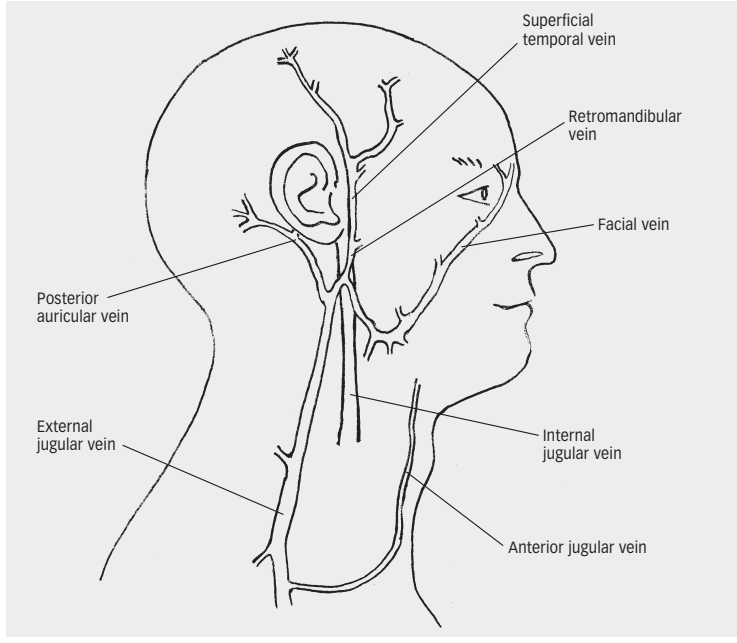
The course of the carotid artery can be marked out by a line connecting the sternoclavicular joint to the hollow between the mastoid process and the angle of the mandible. At the level of the upper border of thyroid cartilage (fourth cervical vertebra) the common carotid artery divides into its external and internal branches. The carotid pulse can be felt throughout its course but is most readily felt lateral to the thyroid cartilage. Inferiorly, the artery can be compressed by a direct backward pressure as it passes in front of the transverse process of the sixth cervical vertebra. This is sometimes performed during carotid arteriography when the contralateral carotid artery is injected with contrast medium in order to assess 'cross flow' through the circle of Willis (see Chapter 2).

The external jugular vein lies in the superficial fascia covered by the platysma muscle. Its surface marking is a line which joins the angle of the jaw to the midpoint of the clavicle (Fig. 4).

The vein can be made visible by performing the Valsava manoeuvre (forcibly blowing with the mouth closed and nose gripped between the fingers). It passes obliquely across the sternocleidomastoid muscle and then the posterior triangle, pierces the deep fascia immediately above the clavicle and drains into the subclavian vein. Not infrequently, it is double.

The surface marking for the internal jugular vein is just lateral and parallel to the line described for the carotid artery (see above). The vein can be cannulated using either a high or low approach. The patient is tilted head downwards (in order to distend the vein) with the neck extended and the head turned to the opposite side. Catheterization of the right side is preferred as the internal jugular vein, right brachiocephalic vein and superior vena cava are nearly in a straight line. In the anaesthetized patient under complete muscular relaxation, the internal jugular vein can be palpated

Fig. 4.
The veins of the head and neck.



deep to the sternocleidomastoid muscle about midway along a line joining the mastoid process and the sternoclavicular joint immediately lateral to the carotid pulse. The vein is punctured deep to the muscle and the needle advanced at an angle of 30 to 40 degrees to the skin surface. The low approach is used in the conscious patient or in an emergency situation where muscular relaxation is not obtained. The patient is positioned in a similar manner. The triangular gap between the sternal and clavicular heads of the sternocleidomastoid is identified immediately above the clavicle. The needle is inserted near the apex of this triangle at an angle of 30 to 40 degrees to the skin and is advanced caudally towards the inner border of the anterior end of the first rib behind the clavicle. A reflux of blood confirms successful venepuncture. The use of ultrasound to locate the internal jugular vein is now standard practice.

Thorax

Bony landmarks and levels

In the midline of the thorax, the sternum can be felt throughout its length (Fig. 5). Superiorly, the suprasternal (jugular) notch is obvious and lies between the sternoclavicular joint on each side. Immediately above the notch can be felt the cartilages of the trachea. A finger running down in the midline from the suprasternal notch then identifies the sternal angle of Louis, which marks the junction of the manubrium with the body of the sternum. This angle marks the medial end of the second costal cartilage on each side, which can be identified by placing the index and middle fingers, respectively, in the intercostal space above and below the cartilage at the manubriosternal junction. From this landmark, successive ribs can be palpated and enumerated from above downwards.

Continuing to palpate along the sternum in the midline, the finger reaches, at its lower end, the xiphisternal joint and the xiphoid process. From the lower end of the sternum, the costal margin can be palpated from the seventh costal cartilage downwards. The lowermost extremity of the costal margin is formed by the tenth costal cartilage and rib. Posteriorly, the free end of the eleventh costal cartilage is usually palpable, as may be the twelfth. However, frequently the twelfth rib is very short and may not be felt.

Vertebral levels

(a) The suprasternal notch corresponds to the level between the second and third thoracic vertebrae (Fig. 5).
(b) The angle of Louis is at the level of the junction between the fourth and fifth thoracic vertebrae.
(c) The manubrium therefore, lies in front of the bodies of the third and fourth thoracic vertebrae.
(d) The junction of the body of the sternum and the xiphoid process lies at the level of the eighth thoracic vertebra.
(e) The body of the sternum therefore lies in front of the fifth to eighth thoracic vertebral bodies.
(f) The tip of the xiphoid process usually lies at the level of the ninth thoracic vertebra.
(g) A line drawn across the inferior costal margin on each side transects the third lumbar vertebra.

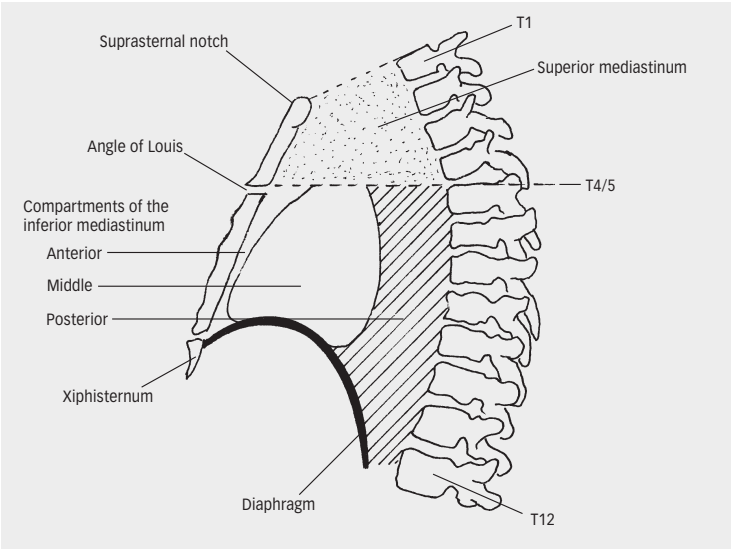
Note that the manubriosternal junction (angle of Louis), as well as marking the level of the second costal cartilage and also the junction of the fourth and fifth thoracic vertebral bodies, also marks the junction between the superior and inferior mediastina, the origin and termination of the aortic arch, the level at which the azygos vein enters the superior vena cava and the point at which the right and left pleura come into contact with each other (see below).

In the preserved cadaver, the trachea bifurcates at this level, but in the living subject in the erect position the lower end of the trachea can be seen in oblique radiographs of the chest to extend to the level of the fifth or, in full inspiration, the sixth thoracic vertebra.

Posteriorly, the thoracic cage is covered by muscles and obscured by the scapula, but note that there are two useful landmarks to the rib levels (see Fig. 9):

The easily felt transversely running spine of the scapula lies at the level of the third thoracic vertebra and at the level of the third rib.

Fig. 5.
The mediastinal compartments and the angle of Louis.



The lower pole of the scapula overlies the seventh rib.

Although the thoracic viscera are completely enclosed within the bony cage of the chest, their positions are quite constant and can therefore be marked out with a fair degree of accuracy from the bony landmarks.

The lines of pleural reflection

The outline of the pleural margins can be marked out on the chest wall as follows (Fig. 6):

- The apex of the pleura extends about 3 cm above the medial third of the clavicle.
- The pleura then passes downwards and medially behind the sternoclavicular joint to meet the opposite pleura behind the sternum at the level of the sternal angle of Louis.
- At the fourth cartilage, the left pleural margin deflects to the lateral edge of the sternum. This corresponds to the cardiac notch of the underlying lung produced by the bulging to the left of the heart and pericardium. This deflection then descends to the sixth costal cartilage.
- On the right side, however, the pleural edge continues vertically downwards and projects somewhat below the right costo-xiphoid angle.

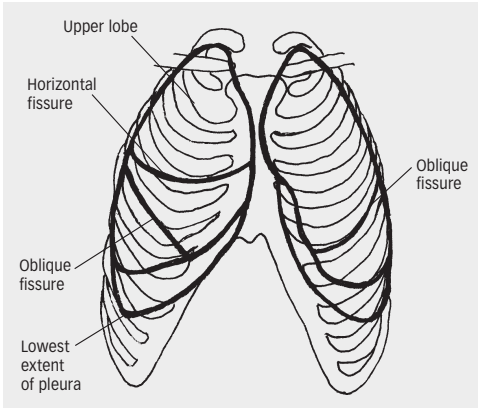


Fig. 6(*a*). **Surface markings of the lungs and pleura (anterior aspect).**

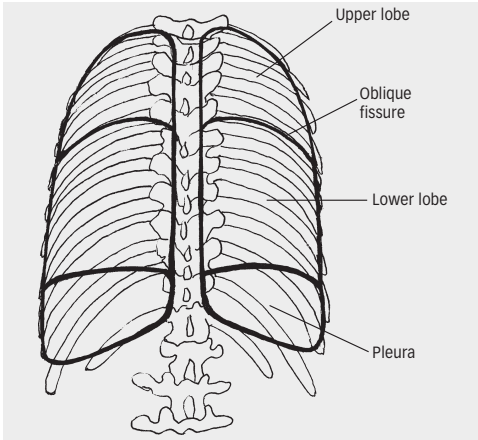


Fig. 6(*b*). **Surface markings of the lungs and pleura (posterior aspect).**

The pleural margin then descends on each side to lie at:

- the level of the eighth rib in the mid-clavicular line;
- the level of the tenth rib at the mid-axillary line;
- at the twelfth rib at the paravertebral level posteriorly.

Note that the pleural edge is at its lowest level in the mid-axillary line and also that posteriorly the margin extends slightly below the costal margin at the costo-vertebral angle.

From the practical point of view, the pleura is at risk of damage as it projects above the clavicle during operations on the neck, stab wounds in this region and, most especially, in attempts at subclavian venepuncture. Inferiorly, the pleura may be opened in resection of the twelfth rib during surgical access to the kidney or suprarenal gland.

The lungs

The surface projection of the lungs is somewhat less extensive than that of the parietal pleura (Fig. 6). Moreover, the lower border of the lung varies quite considerably with the phase of respiration.

The apex of the lung closely follows the line of the cervical pleura and the surface marking of the anterior border of the right lung corresponds to that of the right mediastinal pleura. However, on the left side the anterior border of the lung has a distinct notch, termed the cardiac notch, which passes behind the fifth and sixth costal cartilages.

The lower border of the lung has an excursion of between 5 to 8 cm in the extremes of respiration, but in the neutral position it lies along a line which may be marked out as crossing the sixth rib in the mid-clavicular line, the eighth rib in the mid-axillary line and which reaches the tenth rib adjacent to the vertebral column posteriorly. It will be noted that the lower border thus lies about two rib-breadths above the corresponding lower border of the parietal pleura.

The lung fissures

Each lung is divided by a deep oblique fissure and the right lung is further divided by a transverse fissure. Thus, the right lung is trilobed and the left bilobed.

The right oblique fissure can be marked out by a line which leaves the vertebral column posteriorly at the level of the fifth rib and then follows the rough direction of this rib, tending to lie slightly lower than this landmark, to end near the costo-chondral junction, either in the

fifth space or at the level of the sixth rib. The left oblique fissure has a more variable origin, anywhere from the third to the fifth rib level, but its subsequent course is similar to that of the right side. A useful and quite accurate surface marking is to ask the subject to hold the arm above the head; the vertebral (medial) border of the scapula corresponds to the line of the oblique fissure.

The transverse fissure can be marked out by a horizontal line which runs backwards from the fourth right costal cartilage to reach the oblique fissure in the mid-axillary line at the level of the fifth rib or interspace.

These fissures are far from constant and more often than not the transverse fissure is either incomplete (about the half the specimens) or absent, in about 10% of cases.

The heart

The outline of the heart can be represented on the chest wall by an irregular quadrangle bounded by the following four points (Fig. 7):

(a) The lower border of the second left costal cartilage a finger's breadth from the edge of the sternum.
(b) The upper border of the third right costal cartilage a finger's breadth from the sternal edge.
(c) The sixth right costal cartilage a finger's breadth from the sternum.
(d) The fifth left intercostal space 9 cm from the midline.

The left border of the heart, which is indicated by the curved line which joins points (a) and (d), is formed almost entirely by the left ventricle, apart from superiorly, where the apex of the auricular appendage of the left atrium peeps round the left border. The lower border (the horizontal line joining points (c) and (d), corresponds to the right ventricle and the apical part of the left ventricle, while the right border demarcated by the line (which joins points (b) and (c)), is formed entirely by the right atrium.

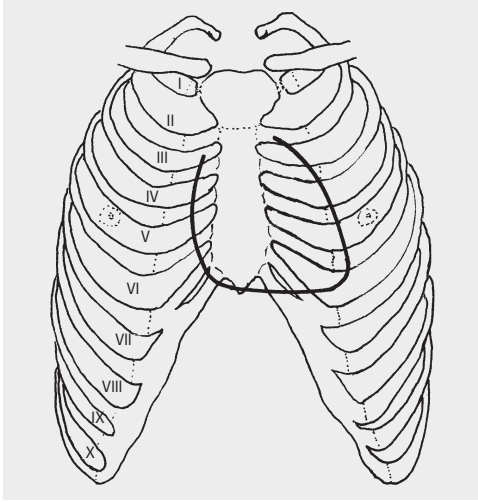


Fig. 7. **Surface markings of the heart.**

To outline the heart as described above is something of an academic exercise. In practice, it is sufficient to note that the boundaries of the heart are demarcated above and below by the body of the sternum, whereas the great vessels lie behind the manubrium. A useful approximation to the surface markings of the heart is for the subject to place his closed right fist, palmar surface against the chest, over the body of the sternum. The fist corresponds closely to what should be the normal heart outline of the subject. Note that the fist projects over to the left side along its inferior (ulnar) border to mimic the projection of the heart apex to the left.

The great vessels

The aortic arch can be marked out by a curved line which commences behind the manubrium at the level of the second right costal cartilage (the sternal angle of Louis) arches upwards to the midpoint of the manubrium sterni, then passes downwards to the level of the second left costal cartilage to become the descending aorta. The brachiocephalic artery on the right side and the common carotid artery on the left can be marked out by lines which arise behind the midpoint of the manubrium and ascend to the right and left sternoclavicular joints respectively.

The right brachiocephalic vein commences behind the medial end of the clavicle, just lateral to the right sternoclavicular joint, where it is formed by the junction of the right internal jugular and right subclavian veins, to pass vertically downwards behind the superior portion of the manubrium. The longer left brachiocephalic vein passes almost horizontally from behind the medial end of the left clavicle to join the right brachiocephalic vein behind the superior portion of the manubrium at the level of its junction with the first costal cartilage. Both join to form the superior vena cava at this point.

The superior vena cava then descends as a 2 cm wide band along the right sternal margin to enter the right atrium at the level of the third right costal cartilage. The azygos vein enters the superior vena cava at the level of the sternal angle of Louis.

The vessels of the thoracic wall

The surface markings of the vessels of the thoracic wall are of importance if these structures are to be avoided in the performance of aspiration of the chest.

The internal thoracic (internal mammary) vessels run vertically downwards behind the costal cartilages half an inch (1.5 cm), or approximately a finger's breadth, from the lateral border of the sternum. The intercostal vessels lie immediately below their corresponding ribs (the vein above the artery). It is therefore safe to pass a needle immediately above a rib while it is more dangerous to pass it immediately below.

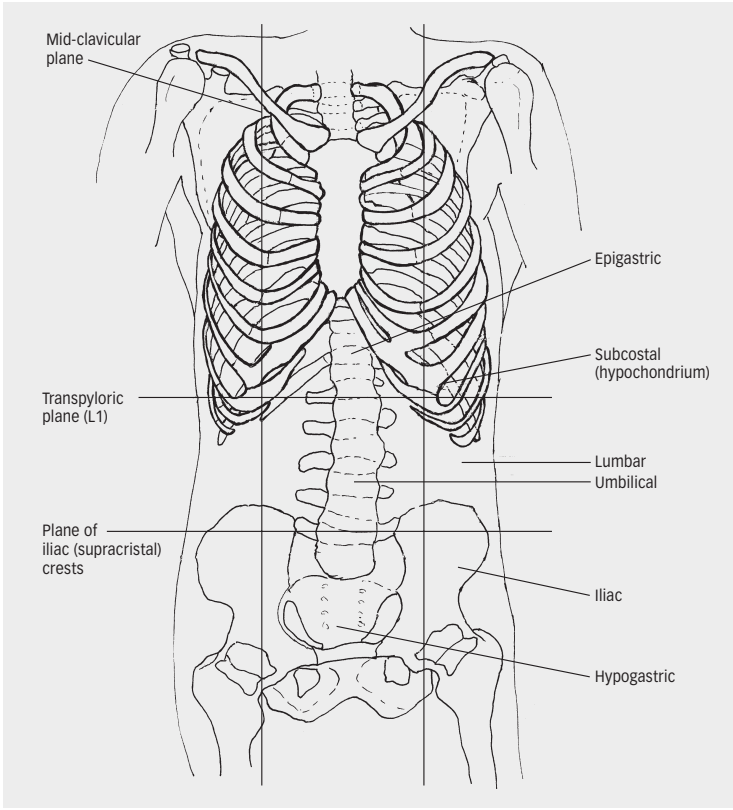
Abdomen

The bony margins of the abdomen (Fig. 8) are bounded above centrally by the xiphoid and flanked by the costal margin on either side. The tip of the lower border of the ninth costal cartilage can usually be defined as a distinct step along this border.

Inferiorly, the midline limit is marked by the upper border of the pubic symphysis. Laterally from this extends the pubic crest which ends at the pubic tubercle, about 2.5 cm from the midline. This tubercle can be identified by direct palpation in a thin subject but can be detected, even in the obese, by running the fingers along the tendon of adductor longus, which is tensed by flexion, abduction and external rotation of the thigh, to its origin immediately below the tubercle.

For the purpose of description, the abdomen can be divided by a number of imaginary horizontal and vertical lines. The horizontal planes are also used to define approximate vertebral levels and the position of some relatively fixed intra-abdominal viscera.

Fig. 8.
The abdominal zones.



Horizontal planes

(a) The xiphisternal plane passes through the xiphoid at the level of the ninth thoracic vertebra. This plane marks the level of the upper border of the liver, the central part of the diaphragm and the lower margin of the heart. Note, however, that the position of these structures varies with the position of the body, the phase of respiration and the body habitus.

(b) The transpyloric plane. This was defined by Addison as a point midway between the suprasternal notch of the manubrium and the upper border of the symphysis pubis. In clinical practice it corresponds to the hand's breadth of the subject below the xiphoid. This plane passes through the body of the first lumbar vertebra and laterally passes through the costal margin at the ninth costal cartilage (usually marked by a distinct step at the costal margin).

Structures demarcated by this plane include:

- the fundus of the gall bladder at the costal margin on the right side;
- the origin of the superior mesenteric artery from the aorta; the neck of the pancreas;
- the junction of the superior mesenteric and splenic veins to form the origin of the portal vein;
- the hila of both kidneys together with their vascular pedicle; posteriorly, the termination of the spinal cord.

In spite of its name, the plane does not typically correspond with the pylorus of the stomach. Indeed, the position of the pylorus, together with the rest of the stomach, depends on body type, extent of gastric filling and the position of the subject. In the erect position and with the stomach full and with a stomach of the J-shape the pylorus may descend to the level of the third lumbar vertebra or even below.

(c) The subcostal plane passes across the lower margins of the thoracic cage formed by the tenth costal cartilage on each side. It transects the third lumbar vertebral body. This indicates the level of origin of the inferior mesenteric artery from the aorta.

(d) The supracristal plane joins the highest point of the iliac crest on each side. It transects the body of the fourth lumbar vertebra and corresponds to the level of bifurcation

of the aorta. It is a useful landmark in the performance of a lumbar puncture. This procedure should be carried out below this level, when the spinal theca will be punctured at an intervertebral space safely below the termination of the spinal cord (see p. 9).

(e) The plane of the pubic crest passes through the termination of the sacrum.

Vertical planes

(a) The midline passes from the xiphoid to the pubic symphysis (Fig. 8). It passes through the umbilicus which is an obvious but somewhat inconstant landmark. In the normal recumbent adult, it lies at the level of the disc between the third and fourth lumbar vertebrae so that the aorta bifurcates 2 cm distal to it. However, in the erect position, in subjects with a pendulous abdomen and in the child, the umbilicus is at a lower level. The median groove of the linea alba can readily be seen in the thin subject when the abdominal muscles are tensed. It is wide and obvious above the umbilicus but almost linear and invisible below this level.

(b) The mid-clavicular line passes vertically downwards through the midpoint of the clavicle. It is sometimes termed the lateral, or the mammary, line. Inferiorly it passes through a point midway between the anterior superior iliac spine and the symphysis pubis.

The abdominal regions

The abdomen is divided into nine regions, which are used for descriptive localization. The regions are constructed of a combination of the two mid-clavicular lines with two transverse lines constructed by dividing the distance between the xiphoid and the symphysis pubis into thirds.

The nine regions thus formed are termed (Fig. 9):

(a) The epigastrium, or epigastric region.
(b) The right and left hypochondrium, or subcostal region.
(c) The umbilical or periumbilical region.
(d) The right and left lumbar region.
(e) The hypogastrium or suprapubic region.
(f) The right and left iliac region or fossa.

Palpable abdominal organs

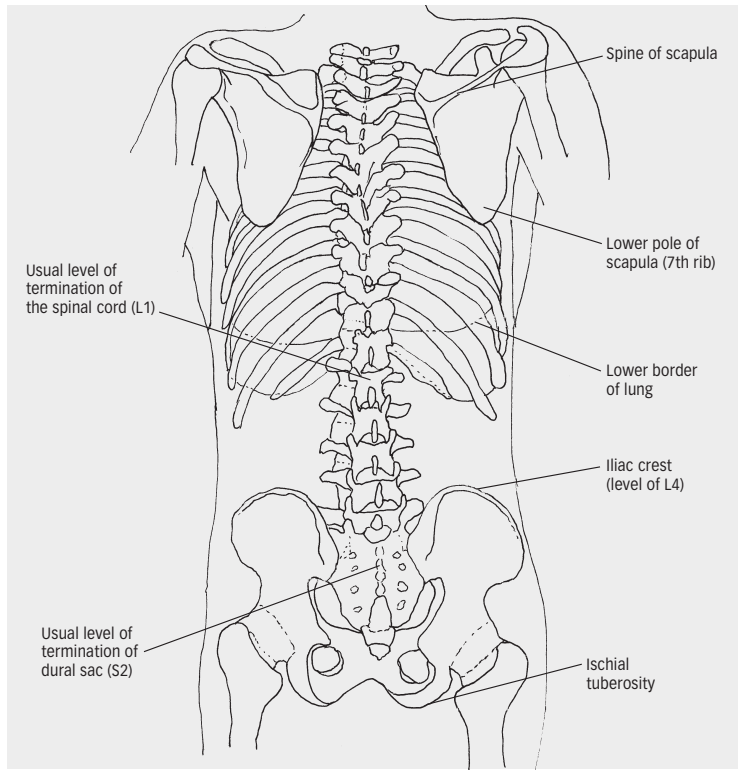
In normal subjects, the abdominal aorta can be felt by deep palpation. Its pulsations can be felt by pressing firmly in the midline downwards on to the vertebral column with the subject recumbent. It bifurcates at the level of the fourth lumbar vertebra in the supracristal plane just below the level of the umbilicus. The other abdominal organs or viscera are often totally impalpable. However, the lower border of the normal liver may be felt below the right costal margin, the lower pole of the normal right kidney may sometimes be felt by bimanual palpation of the right flank during deep inspiration, especially in a thin female subject. It is not rare to palpate a soft gurgling caecum in the right iliac fossa in thin females. The sigmoid colon may be felt as a sausage-shaped swelling in the left iliac fossa, particularly if the bowel is loaded with faeces.

The introduction of imaging of the abdominal viscera has shown that considerable variations occur in what was once believed to be 'normal' anatomy. Little emphasis is now placed on specific definition of the surface outlines of the intra-abdominal structures.

The back

In the midline a median furrow extends from the external occipital protuberance downwards to the natal cleft. In the cervical region, the tips of the spines of the cervical vertebrae are obscured by the overlying tough, fibrous ligamentum nuchae. This terminates inferiorly at the spine of the seventh cervical vertebra, which can be felt and may be visible as the highest projection in this region (the vertebra prominens). Immediately below this, the spine of the first thoracic vertebra can be felt and is usually more prominent than the seventh cervical spine. From here downwards the successive spines can be felt (Fig. 9).

Fig. 9.
Anatomical landmarks: posterior trunk.



At the sides of the lower part of the back, the iliac crest can be palpated through its whole length downwards and medially to the posterior superior iliac spine. This lies 5 cm from the midline. This corresponds to the position of the obviously visible sacral dimple. A line joining the dimple of each side passes through the second sacral spine and marks the level of the centre of the sacroiliac joint. This is also the level of the termination of the dural sac.

The spinal cord

The surface markings of the spinal cord and its membranes are of obvious clinical relevance.

Up to the third fetal month, the spinal cord extends the length of the vertebral column. As a result of more rapid differential growth of the vertebrae compared with the cord, at birth the spinal cord terminates at the lower border of the third lumbar vertebra. In the adult, the termination of the cord is usually found at the level of the disc between the first and second lumbar bodies. However, there is considerable variation in this level which ranges frequently from the body of the first to the body of the second lumbar vertebra. Rarely the range extends to the twelfth thoracic vertebra above down to the third lumbar vertebra.

The differential growth between the spinal cord and the vertebral column results in the lumbar and sacral nerve roots becoming considerably elongated in their passage to their corresponding intervertebral foramina. This results in the formation of the cauda equina. In contrast, the cervical roots pass almost laterally in their intraspinal course and the upper thoracic roots incline only slightly. As an approximate guide, there is one segment difference in the cervical cord between the cord segment and the vertebral body level, two in the upper thoracic region, three in the lower thoracic zone and four to five in the region of the lumbar and sacral cord.

The lower limit of the spinal cord (the conus medullaris) lies a little above the level of the elbow joint when the arm is by the side and is approximately demarcated anteriorly by the transpyloric plane.

The dural sac and its contained subarachnoid space usually extends to the level of the second segment of the sacrum. This corresponds to the line joining the sacral dimples.

The upper limb

Bony landmarks

Much of the skeletal anatomy of the upper limb can be defined by palpation (Fig. 10).

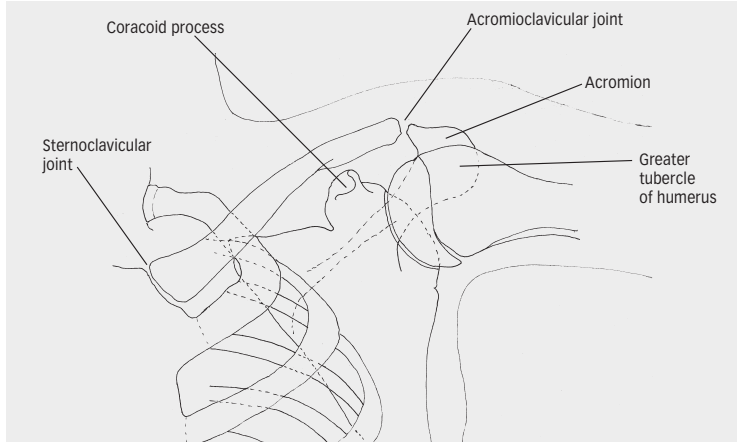


Fig. 10.
Bony landmarks: left shoulder.

The clavicle is visible and palpable throughout its course. Its outline can be traced from the expanded sternal end, at the lateral boundary of the suprasternal notch, to its flattened acromial extremity. Its medial two-thirds is convex forwards, while its lateral one-third is concave anteriorly. Medially, it forms the sternoclavicular joint, which is a ball and socket joint and which can be felt to move in a reciprocal direction from the movements of the shoulder joint.

Laterally, the line of the acromioclavicular joint can be felt as a distinct transversely placed step. The acromion process of the scapula can then be traced from this joint to its lateral extremity and then backwards until it meets the crest of the spine of the scapula which can be palpated across the scapula to reach the medial (vertebral) scapular border. The spine is easily visible in a thin subject. Below, the medial border of the scapula ends at the inferior angle, which overlies the seventh rib.

Inferior to the clavicle, at the junction of its medial convex and lateral concave portions can be seen a small depression which lies between the origins of pectoralis major and the deltoid. This is the infraclavicular fossa (or deltopectoral triangle). In this groove lies the cephalic vein as it passes up the lateral aspect of the upper arm on its way to drain into the subclavian vein. Just to the lateral side of this fossa, about 2.5 cm below the clavicle, and under cover of the fibres of the deltoid can be felt the coracoid process of the scapula and indeed this can be seen in a very thin subject. Confirm that this is part of the scapula and not the humerus because it will not move when the humerus is rotated. Palpation lateral to the coracoid process reveals another bony swelling; this is the lesser tubercle of the humerus and this, in contrast, will be felt to move as the humerus is rotated laterally or medially. The most lateral extremity of the shoulder is the greater tubercle of the

humerus. The head of the humerus is palpated on deep pressure in the apex of the axilla when the arm is raised and can be felt to rotate on movement of the upper limb.

The shaft of the humerus can be felt rather vaguely throughout its course since it is obscured by overlying muscles. At the elbow (Fig. 11) the medial, and less prominent, lateral epicondyle are easily felt and each can be traced upwards as the medial and lateral supracondylar ridge on either side. The ulnar nerve can be rolled posteriorly as it runs behind the medial epicondyle. Distal to the lateral epicondyle, and in the floor of a depression that can be seen posteriorly with the elbow extended can be felt the head of the radius. This can be felt to rotate as the forearm is pronated and supinated. Between the lateral epicondyle and the radial head can be felt a distinct transverse depression, which is the humeroradial section of the elbow joint.

The olecranon is obvious at the tip of the elbow. Its posterior surface is subcutaneous and forms a triangle apex downwards. From this apex, the posterior border of the ulna is subcutaneous and can be felt throughout its whole extent to the styloid process of the ulna inferiorly. This projects distally from the postero-medial aspect of the rounded head of the ulna, which forms the obvious elevation on the posterior aspect of the ulnar side of the pronated wrist.

In contrast, the shaft of the radius can only be felt indistinctly because of its covering of muscles. Its expanded lower end forms a slight elevation on the radial side of the wrist and can be traced downwards into the styloid process of the radius (Fig. 12). This is easily felt in the most proximal part of the obvious anatomical snuffbox. The expanded distal end of the posterior aspect of the radius is somewhat obscured by the overlying extensor tendons, but in spite of this can be both seen and felt.

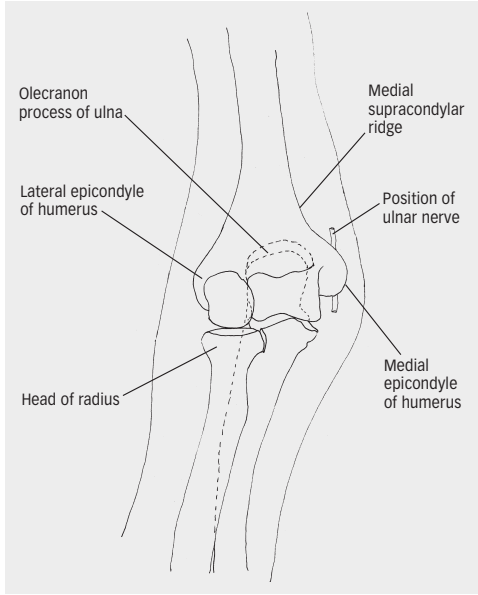


Fig. 11.
Bony landmarks: right elbow.

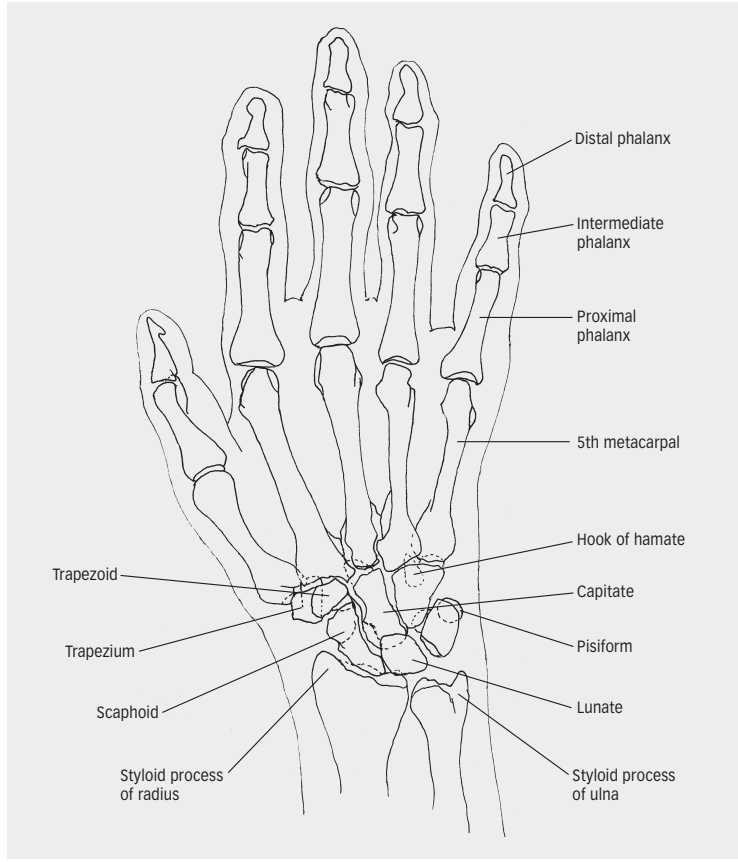


Fig. 12.
Palpable landmarks: wrist and hand.

Note that the styloid process of the ulna projects less distally than that of the radius. This allows a greater degree of adduction than of abduction of the wrist joint.

The anterior line of the wrist joint is demarcated by the proximal of the two transverse skin creases at the wrist. The more distal crease, in fact, lies superficial to the proximal carpal bones. Four of the bones of the carpus can be palpated and positively identified. The tubercle of the scaphoid lies at the base of the thenar eminence; it can often be seen as a small elevation. Immediately distal to it, the crest of the trapezium can be identified on deep pressure. Both these bones can also be palpated in the anatomical snuffbox immediately distal to the radius and the wrist joint. The pisiform can be felt, and usually seen, at the proximal extremity of the hypothenar eminence. On flexing the wrist the tendon of flexor carpi ulnaris can be felt, and often seen, to insert into it. The hook of the hamate lies 2.5 cm distal to the pisiform and can be felt on deep pressure. This is uncomfortable because the superficial division of the ulnar nerve lies over the bone at this point.

Pulses

The arterial tree in the upper limb can be traced from above downwards by successive palpation of the pulses. The third part of the subclavian artery can be felt by pressing downwards onto the first rib behind the midpoint of the clavicle with the head deviated to the same side in order to relax the neck muscles. This palpation is uncomfortable because of pressure against the adjacent trunks of the brachial plexus.

The axillary artery can be felt by pressing against the upper shaft of the humerus in front of the posterior axillary fold. It will usually be accompanied by paraesthesiae along the radial side of the palm of the hand due to pressure on the subjacent median nerve.

The brachial artery pulse can be felt in the furrow along the medial side of the biceps muscle and can be felt more distally adjacent to, and on the medial side of, the biceps tendon immediately above the elbow where the artery lies directly in front of the lower end of the shaft of the humerus.

The radial artery is readily felt at the wrist in the interval between the tendon of flexor carpi radialis and the lower part of the anterior border of the distal radius on the lateral side. Its pulsation can be picked up again in the anatomical snuffbox.

The ulnar artery can be felt less easily at the wrist immediately to the radial side of the tendon of flexor carpi ulnaris. Here it lies on the radial side of the adjacent ulnar nerve.

The superficial veins

The irregular plexus of the dorsal venous arch is visible on the back of the hand and its arrangement is highly variable. The cephalic vein arises from the radial extremity of the arch and can be both seen and felt, if a venous tourniquet is applied, as it lies immediately posterior to the styloid process of the radius at the wrist. This is a common site for intravenous cannulation. The cephalic vein then ascends along the radial border of the forearm to the lateral side of the antecubital fossa and then lies in a groove along the lateral border of the biceps. In a well-developed subject it may be visible throughout its course before it dives beneath the deep fascia at the distal border of pectoralis major. The vein then lies in a groove between this muscle and the deltoid, then finally pierces the clavipectoral fascia to enter the axillary vein. The groove between pectoralis major and deltoid is a conveniently identifiable site for a cutdown if no other superficial vein can be found. A catheter inserted into the cephalic vein, however, frequently fails to enter the axillary vein because of the sharp curve as it passes through the clavipectoral fascia and because a valve commonly guards this junction.

The basilic vein originates from the ulnar side of the dorsal venous arch and ascends along the ulnar side of the forearm. Its position in the forearm is quite variable and there are usually other minor superficial veins ascending along the anterior aspect of the forearm. The basilic vein then ascends along the medial border of the biceps before piercing the deep fascia at the middle of the upper arm. Near the lower border of the axilla, it is joined by the venae comitantes of the brachial vein to form the axillary vein.

The median cubital vein (which may also be termed the median basilic or median cephalic vein) usually arises from the cephalic vein about 2.5 cm distal to the lateral epicondyle of the humerus. It then runs upwards and medially to join the basilic vein about 2.5 cm above the transverse crease of the elbow to give a rather drunken H-shaped arrangement. The median cubital vein receives a number of tributaries from the veins running along the front of the forearm, as well as giving off a deep median vein, which pierces the deep fascia roofing the antecubital fossa to join the venae comitantes of the brachial vein. A frequent variation is for a median forearm vein to bifurcate just distal to the antecubital fossa. One limb then passes to the cephalic and the other to the basilic vein, to give an M-shaped pattern.

In a plump upper limb, the median cubital vein may be the only superficial vein which can be made obvious. It is quite safe to use this for venepuncture but there is a danger in employing this vein for an intravenous injection. This is because the brachial artery lies immediately deep to the vein and may be inadvertently punctured. Fortunately a sheet of deep fascia, termed the bicipital aponeurosis, which arises from the medial border of the lower end of the biceps muscle and its tendon, is placed between the two. This was much appreciated by the Barber–Surgeons of old who used the antecubital vein for blood-letting; they named it the ‘grâce à Dieu’ (praise be to God) fascia.

The surface markings for cannulation of the subclavian vein are important. It may be approached either from below or above the clavicle. The patient is tipped head downwards and the head turned to the opposite side. For infraclavicular puncture, the needle is inserted below the midpoint of the clavicle and is directed medially and upwards behind the clavicle towards the tip of the index finger

of the operator placed deeply into the suprasternal notch. Supraclavicular puncture is achieved by inserting the needle through a point which joins the medial one-third and lateral two-thirds of the clavicle about 2 cm above the clavicle. This corresponds to the lateral border of the clavicular head of the sternocleidomastoid muscle. The needle is then inserted medially and upwards towards the subclavian vein, which lies about 2.5 cm behind the sternoclavicular joint.

The lower limb

The upper bony landmarks of the lower limb, the iliac crest, its anterior termination at the anterior superior iliac spine and its posterior termination, at the posterior superior iliac spine, have already been described (p. 9). The ischial tuberosity is readily palpated in the inferior portion of the buttock. In the standing position, the tuberosity is covered by the fleshy fibres of gluteus maximus, but when the hip is flexed, this muscle slips above the tuberosity so that, when we sit, the tuberosity adopts a subcutaneous position, separated from the skin only by fat and a bursa.

The greater trochanter of the femur lies a hand's breadth below the midpoint of the iliac crest. It can be felt and usually seen as the prominence in front of a hollow on the side of the hip. It is the only part of the proximal femur which can be palpated distinctly and it can be felt to move as the hip is rotated. The shaft of the femur can only be vaguely felt on deep palpation through the muscles of the thigh. Distally, the medial aspect of the medial condyle and the lateral aspect of the lateral condyle of the femur can be palpated, and part of the femoral articular surface can be felt on either side of the lower part of the patella (Fig. 13).

The patella is subcutaneous and readily palpated. When the knee is fully extended, the patella can be moved from side to side over the lower articular surface of the femur because the quadriceps femoris is relaxed. The lower limit of the patella terminates in the ligamentum patellae, which can be felt to descend and insert into the tibial tuberosity.

It is important to note that the knee joint extends a handsbreadth above the upper border of the patella as the suprapatellar pouch. This becomes obviously distended when there is a significant effusion of fluid into the knee joint. The tibial condyles are visible and palpable on either side of the ligamentum patellae. When the knee is in the flexed position, their anterior margins can be felt in the depression on either side of this ligament. Above them,

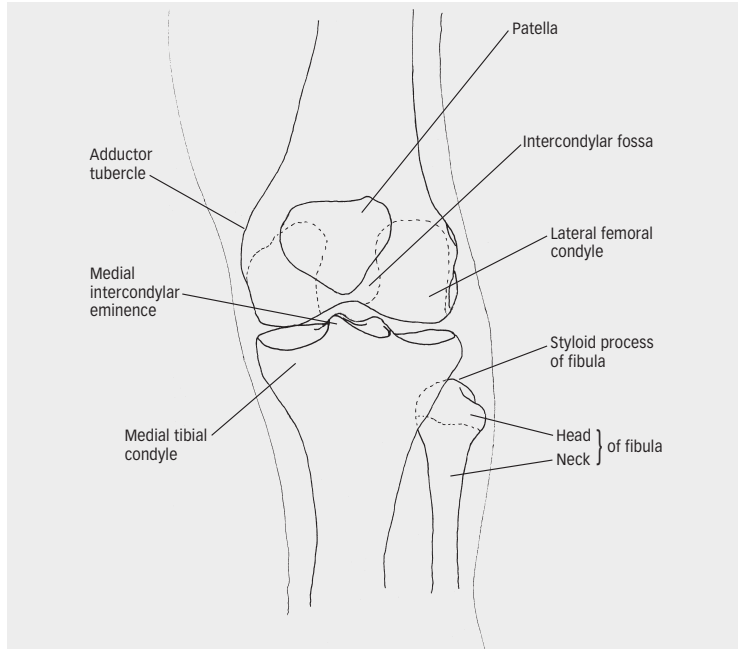


Fig. 13.
Bony landmarks: knee.

a distinct groove can be felt, which demarcates the line of the knee joint.

The head of the fibula can be felt as a projection on the upper part of the postero-lateral aspects of the leg. Below the head can be felt the neck of the fibula, around which passes the common peroneal nerve, which can be felt indistinctly at this point. The shaft of the fibula can only be felt indistinctly through its overlying muscles but inferiorly the lateral malleolus of the fibula forms a conspicuous projection on the lateral side of the ankle. This lateral aspect of the lateral malleolus continues superiorly with an elongated triangular area of the lower shaft of the fibula which is also subcutaneous. The subcutaneous medial surface of the tibia can be felt throughout its course from the medial condyle of the tibia above to the visible prominence of the medial malleolus below. It is crossed only by the great saphenous vein and the accompanying saphenous nerve immediately in front of the medial malleolus and here the vein is easily visible when the leg is dependent. The medial malleolus descends less than the lateral malleolus and is placed on a more anterior plane. It is the more extensive projection of the lateral malleolus that accounts for the fact that eversion of the angle is more limited than inversion.
Much of the bony anatomy of the foot is palpable (Fig. 14). The conspicuous tendo calcaneus (Achilles tendon) is obvious on the posterior aspect of the lower leg and can be followed downwards into its insertion into the posterior aspect of the calcaneus. On the dorsum of the foot, the upper anterior part of the calcaneus can be palpated in front of the lateral

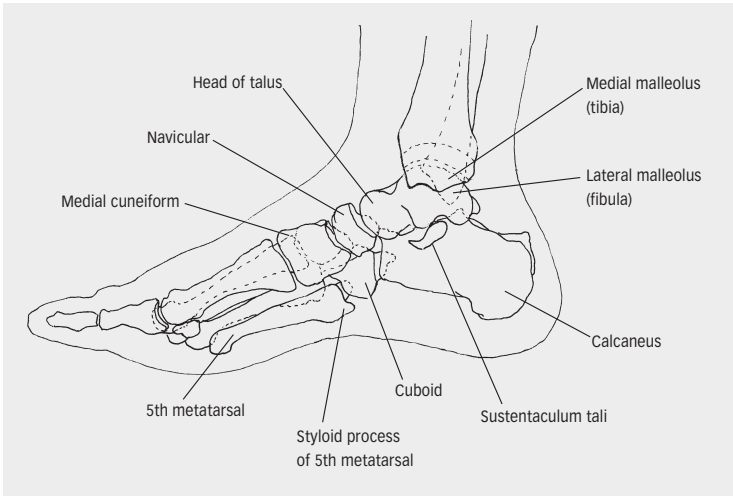


Fig. 14.
Bony landmarks: right foot.

malleolus. The lateral surface of the calcaneus can be felt on the lateral aspect of the heel and usually its peroneal tubercle can be felt 2 cm below the tip of the lateral malleolus. Medially, the sustentaculum tali of the calcaneus can be felt 2 cm below the medial malleolus. With the foot inverted, the upper part of the head of the talus can be felt and usually seen about 3 cm anterior to the distal end of the tibia. The tuberosity of the navicular can be felt and is often visible 2.5 cm in front of the sustentaculum tali. Anterior to this, the medial cuneiform can be identified by tracing the tendon of tibialis anterior into it when the foot is inverted and extended. The styloid process at the base of the fifth metatarsal is palpable on the lateral side of the foot and marks the insertion of peroneus brevis.

In the standing position, the foot rests on the posterior part of the inferior surface of the calcaneus, on the heads of the metatarsal bones and, to a lesser extent, on the lateral border of the foot, which forms the lateral longitudinal arch of the foot. The instep, which corresponds to the medial longitudinal arch, is elevated from the ground.

The sciatic nerve

Because of the risk of damage to the sciatic nerve from intramuscular injections, its exact surface markings are of considerable importance. The course of the nerve (Fig. 15) can be represented by a line which commences at a point midway between the posterior superior iliac spine (shown by the lumbar dimple) and the ischial tuberosity and which then curves outwards and downwards through a point midway between the greater trochanter of the femur and the ischial tuberosity. Continue the line vertically downwards in the midline of the posterior aspect of the thigh to the upper angle of the popliteal fossa.

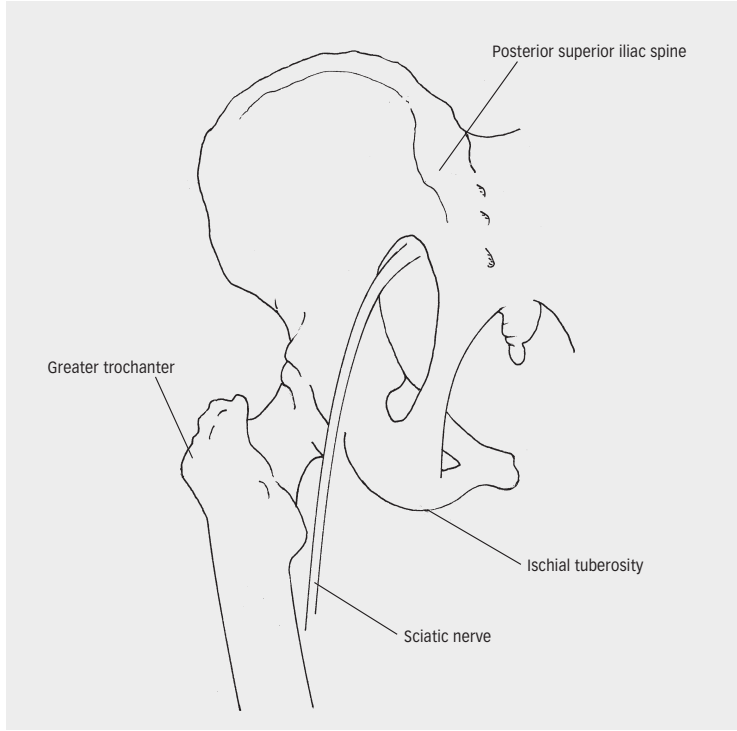


Fig. 15.
The surface markings of the sciatic nerve. The midpoint between the ischial tuberosity and the posterior superior iliac spine is joined to the midpoint between the ischial tuberosity and the greater trochanter by a curved line which is continued vertically down the back of the leg. This line represents the course of the sciatic nerve.

Arteries

The femoral artery (Fig. 16) enters the thigh at a point midway between the anterior superior iliac spine and the midline pubic symphysis. Its course down the leg can be represented by the upper two-thirds of the line which joints that point to the adductor tubercle when the thigh is flexed, abducted and laterally rotated. The adductor tubercle itself is felt by sliding the hand down the medial side of the thigh until it hits the first bony prominence immediately above the medial condyle of the femur.

At its origin, the pulsations of the femoral artery can be felt as this vessel emerges from under the inguinal ligament to lie in front of the tendon of psoas major as this crosses the superior ramus of the pubis. The pulse is a useful landmark to the position of the head of the femur. A finger's breadth lateral to the femoral pulse marks the position of the femoral nerve and immediately medial to the pulse is the surface marking of both the femoral vein and great saphenous vein (see below). The popliteal artery can be represented by a line which begins at the junction of the middle and lower one-third of the thigh along the line drawn from the femoral pulse at the groin to the adductor tubercle. The artery then runs downwards and laterally in the popliteal fossa to reach the midline at the level of the knee joint. It then descends to the level of the tibial tubercle, where it bifurcates into the anterior and posterior tibial arteries. The popliteal pulse is often difficult to feel.

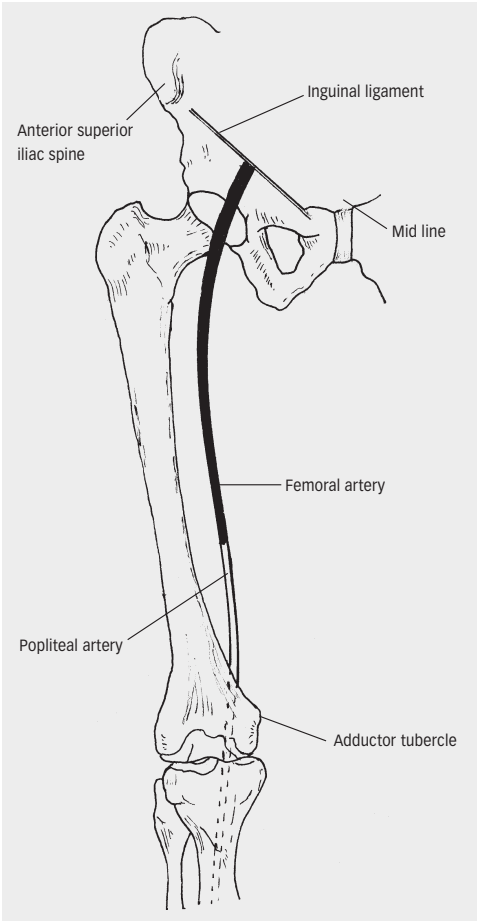


Fig. 16.
The surface markings of the femoral artery; the upper two-thirds of a line joining the mid-inguinal point (halfway between the anterior superior iliac spine and the symphysis pubis), to the adductor tubercle.

It is usually palpated with the patient lying on his back and with the knee bent to a right angle, the foot resting on the bed. This relaxes the tense popliteal fascia, which roofs the fossa. The pulse is felt by deep pressure over the midline of the fossa against the popliteal surface of the femur. An alternative method is to lie the subject face downwards with the knee bent to a right angle and supported by the examiner so that the muscles are relaxed.

The pulse of dorsalis pedis, the termination of the anterior tibial artery, is felt immediately lateral to the tendon of extensor hallucis longus against the underlying tarsal bones. That of the posterior tibial artery is sought by palpation behind the medial malleolus as the artery runs between the tendons of flexor hallucis longus and flexor digitorum longus.

The superficial veins

The dorsal venous arch, together with its tributaries, forms a conspicuous feature of the dorsum of the foot and curves, convex forwards, across the metatarsal bones. From its medial end, the great saphenous vein arises and runs upwards and backwards immediately in front of the medial malleolus to cross the subcutaneous surface of the tibia. It is accompanied by the saphenous nerve (which arises from the femoral nerve at the groin and which runs down to supply the medial side of the leg to the base of the great toe), and which usually lies in front of the vein. This nerve is a occasionally damaged in varicose vein surgery. The small saphenous vein arises from the lateral extremity of the dorsal venous arch. It then passes posterior to the lateral malleolus and drains into the popliteal vein in the popliteal fossa.

The surface marking of the great saphenous vein can be indicated by a line passing from the obviously visible vein in front of the medial malleolus to a point a hand's breadth behind the patella at the level of the knee joint and then upwards to a point a finger's breadth medial to the femoral pulse, where the vein drains into the femoral vein at the groin.

The anatomy of surgical access in upper respiratory obstruction

In an acute emergency, with the patient dying of laryngeal obstruction, intubation of the trachea can be carried out via the cricothyroid ligament or through the trachea itself.

Cricothyroid puncture (laryngotomy)

To perform a tracheostomy does require a modicum of surgical skill and is not a particularly easy operation. In an acute emergency, a cricothyroid puncture may be a life-saving temporary procedure, which has the merit of requiring little prowess on behalf of the operator. The head of the patient is firmly held in the midline position with the neck fully extended. The operator grasps the larynx between the thumb and little finger of the left hand and palpates the groove between the cricoid and the thyroid cartilages with the left index finger. Any available cutting instrument is used to make a 2.5 cm transverse incision over this groove through skin, deep fascia and the avascular cricothyroid ligament to open into the larynx (Fig. 17). The knife handle then levers open a space through which any suitable tube is passed downwards into the trachea. Even if nothing at all is to hand, direct mouth-to-larynx artificial respiration can be applied through the opening.

The procedure is made even easier if a special trocar and cannula in a sterile pack specially designed for cricothyroid puncture is available in the department.

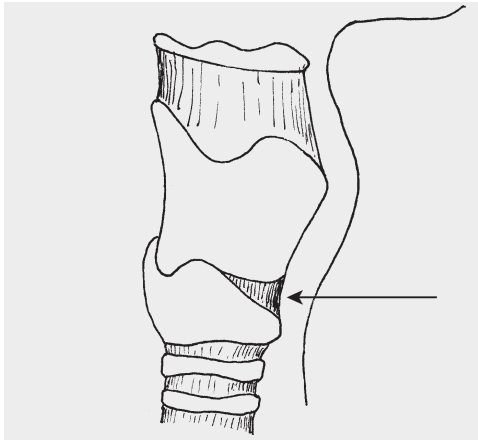


Fig. 17.
Site for cricothyroid puncture (arrowed). **The soft area between the cricoid and thyroid cartilages is easily palpated in the midline and is relatively avascular.** (Redrawn from Ellis & Feldman, 1996)

Tracheostomy

Anterior relations of the cervical portion of the trachea are naturally of importance in performing a tracheostomy. The head is kept fully extended with a sand bag or firm pillow placed between the patient's shoulders. The head must be maintained absolutely straight with the chin and the sternal notch in a straight line. From the cosmetic point of view, it is better to use a short transverse incision placed mid-way between the cricoid cartilage (which is easily felt), and the suprasternal notch. The tyro may find in an emergency that it is safer to use a vertical incision which passes from the lower border of the thyroid cartilage to just above the suprasternal notch.

The great anatomical and surgical secret of the operation is to keep exactly in the midline. In doing so, the major vessels of the neck are out of danger. The skin incision is deepened to the investing layer of deep fascia, which is split and held apart by retractors. The first ring of the trachea now comes into view and the position of the trachea is carefully checked by

palpation of its rings. It is usually possible to push the isthmus of the thyroid gland downwards to expose the upper rings of the trachea. Occasionally, the isthmus is enlarged and, under these circumstances, it must be lifted up by blunt dissection and divided vertically between artery forceps. The trachea is opened by a small transverse incision between the second and third rings. This alone will suffice to insert a tube, but it is advisable to make a small window by removing portions of the second and third, or third and fourth rings, using a fine scalpel or scissors. (Fig. 18). A tracheostomy tube of the largest size that will fit the tracheostome comfortably is inserted. The trachea is aspirated through it, and the wound loosely closed with two or three skin sutures.

The introduction of the mini-tracheostomy tube had made construction of a small tracheostomy possible as a temporary emergency procedure with a minimum of dissection.

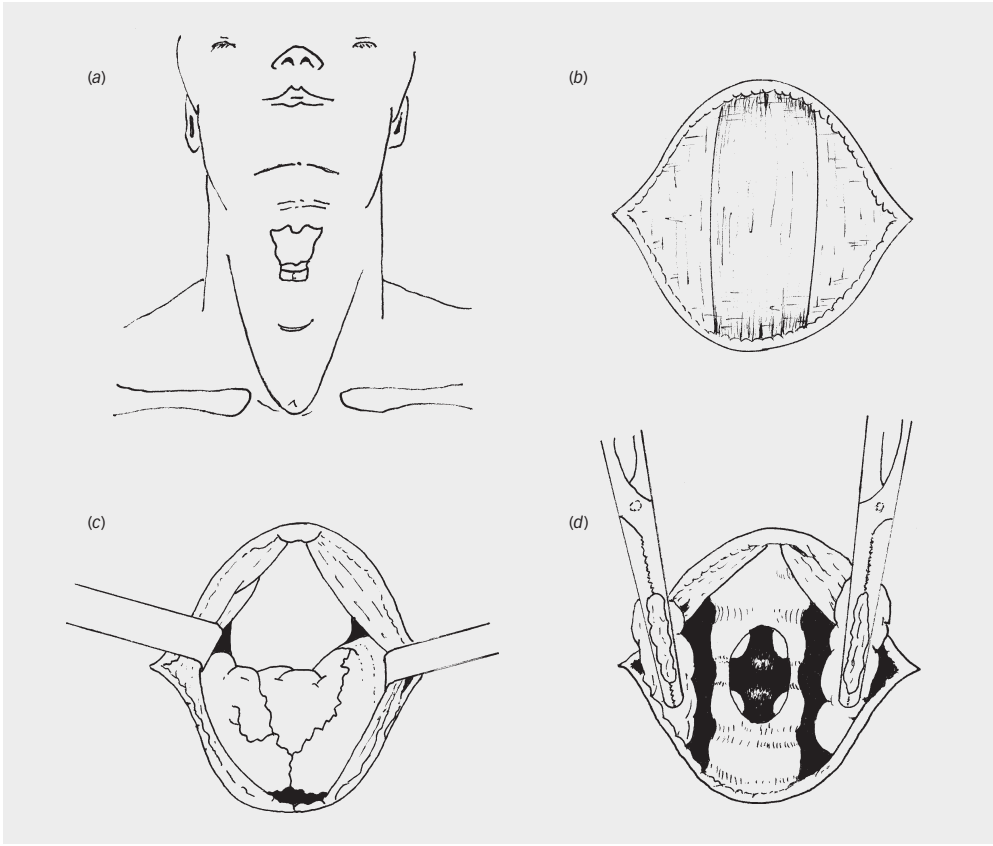


Fig. 18(*a*). **Tracheostomy. The incision is placed midway between the cricoid cartilage and the suprasternal notch**

Fig. 18(*b*). **The investing layer of fascia covering the pretracheal muscles is exposed.**

Fig. 18(*c*). **The isthmus of the thyroid is cleared. This must either be divided between artery forceps or displaced downwards.**

Fig. 18(*d*). **A tracheal window is fashioned by resecting a circular area through the second and third, or third and fourth cartilaginous rings. A vertical incision alone is inadequate.**

Reference
Ellis, H. & Feldman, S. (1996). *Anatomy for Anaesthetists*, 7th edn. Oxford: Blackwell Scientific.