Essential Anatomy of the Abdominal Wall

2

Vishy Mahadevan

The anatomy of the abdominal wall has been well documented in several standard anatomical reference texts. Detailed information is readily available from these sources. The line drawings in this chapter have been adapted from a small selection of publications in the anatomical and surgical literature, with particular emphasis being made in these illustrations, on applied surgical anatomy and surgically-significant anatomical variations and anomalies.

Certain pathological processes may, on occasion, distort the underlying anatomy, and the surgeon must be cognizant of, and take into account, these alterations. Only then will the surgeon be able to employ an appropriate and optimal surgical approach and thereby ensure successful outcome from hernia surgery. Optimally, the surgeon should tailor each operation to the specific anatomy encountered in the individual patient.

The impetus to revisit and redefine the anatomy of the anterior abdominal wall and in particular the anatomy of the inguinal region was driven chiefly by a desire to identify the reasons for the observed shortcomings of the traditional Bassini operation undertaken for the repair of inguinal hernias. This detailed re-examination of abdominal wall anatomy (both topographical and functional) has resulted in a significant enhancement in our understanding of the development of hernias and has also resulted in the generation of much practical advice for surgeons in the surgical management of hernias, in particular the management of variant forms of hernia that do not conform to standard descriptions.

Under normal circumstances the complex musculoaponeurotic elements within the abdominal wall are designed to retain the contents of the peritoneal cavity. There are, however, several specific and defined areas of natural weakness or relative deficiency within the musculoaponeurotic layers of the abdominal wall, and it is at these locations that there is a particular and predetermined tendency for hernias to present. Most notable among these areas of deficiency is the groin region in relation to the inguinal and femoral canals. Other sites of potential weakness include the umbilicus, epigastrium, lumbar triangle (of Petit), obturator canal, sciatic foramina, perineum, pelvic sidewall and the Spigelian line. The list is long, and it is most unlikely that a single clinician will encounter all types of abdominal wall hernias during a professional lifetime.

The work of Anson and McVay on the inguinal canal appeared in 1938 [1], and since then they and their associate Zimmerman have published extensively. Other notable contributors to the field of abdominal wall anatomy include Askar, Condon, Fruchaud, Lytle, Nyhus, Ruge, Skandalakis and Van Mameren.

External Anatomy: Surface Markings and Surface Features

Since the vast majority of abdominal wall hernias involve the *anterior* abdominal wall, it is the latter that will be the principal focus of this chapter. The geographical outline of the anterior abdominal wall is approximately hexagonal. It is bounded superiorly by the arched costal margin (with the xiphisternum at the summit of this arch) (Fig. 2.1). The lateral boundary on either side is defined, arbitrarily, as the midaxillary line (between the lateral part of the costal margin and the summit of the iliac crest). Inferiorly, on either side, the anterior abdominal wall is bounded, in continuity, by the anterior half of the iliac crest, inguinal ligament and pubic crest, with the two pubic crests meeting at the pubic symphysis. Situated vertically in the midline of the anterior abdominal wall is the linea alba. In the muscular or thin individual, the linea alba is manifest as a shallow furrow, being more evident above the level of the umbilicus. No such furrow is evident in the obese or rounded abdomen. The umbilicus lies, normally, at the junction of the upper three-fifths and lower two-fifths of the linea alba. In the healthy young adult, the rectus abdominis muscle is evident as a prominence on

V. Mahadevan
The Royal College of Surgeons of England, London, UK
e-mail: vmahadev@rcseng.ac.uk

© Springer International Publishing AG, part of Springer Nature 2018
K.A. LeBlanc et al. (eds.), *Management of Abdominal Hernias*, https://doi.org/10.1007/978-3-319-63251-3_2

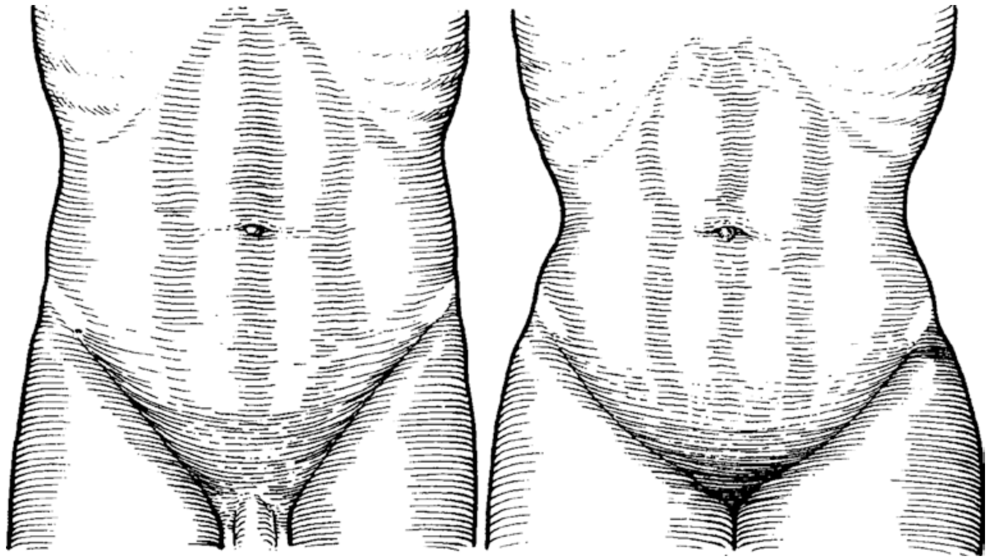

Fig. 2.1 Topographical anatomy of the abdomen—the distinctly different male and female characteristics are important in hernia surgery. The boundaries of the abdomen, the costal cartilages above and the crests of the iliac and pubic bones, and the inguinal ligament inferiorly are illustrated. The umbilicus, the rectus muscle, and the semilunar lines are important surface landmarks

either side of the vertical midline. The rectus muscle is particularly prominent inferolateral to the umbilicus: this rectus mound below the level of the umbilicus is of surgical importance. With ageing and obesity, the lower abdomen tends to sag. The rectus mound, however, does not shift and persists even into old age.

The linea semilunaris (semilunar line) is easily observed in the abdominal wall of a fit and muscular individual. By contrast, in the lax or obese abdominal wall, it is indistinct at best. The linea semilunaris indicates the outer margin of each rectus sheath and is a longitudinally disposed shallow groove with a gentle convexity facing laterally. It is most distinct in the upper abdomen where it commences at the tip of the ninth costal cartilage. At first it descends almost vertically, but inferior to the umbilicus it turns medially with a gentle curve to terminate at the pubic tubercle. It is along this line that the internal oblique aponeurosis splits into two laminae which run on either surface of the rectus abdominis to enclose the muscle in the upper two-thirds of the abdomen. The area corresponding to the inferior third of the semilunar line is also referred to as the Spigelian fascia and is one of the many documented sites of herniation (Chap. 18). In the lower abdomen, the relative configurations of the linea semilunaris and the rectus sheath differ between the sexes. This is chiefly due to the wider pelvis and greater pubic prominence which characterize the female form (Fig. 2.1).

The anterior superior iliac spine (ASIS) is the abrupt anterior extremity of the iliac crest. It is visible in the thin individual and readily palpable in all. The pubic tubercle can be felt as a bony nodule on the anterior aspect of the pubic crest, 2–3 cm lateral to the pubic symphysis. A line joining the ASIS to the pubic tubercle denotes on the surface, the location of the inguinal ligament. The base of the triangular superficial inguinal ring is superomedial to the pubic tubercle. Inferolateral to the pubic tubercle is the femoral ring (the proximal, open end of the femoral canal and through which a femoral hernia enters the femoral canal).

The deep inguinal ring (internal inguinal ring) may be represented on the surface by a point marked 2 cm vertically above the midpoint of the inguinal ligament (the latter point is halfway between the ASIS and pubic tubercle).

The inguinal canal may be indicated on the surface as an oblique band, 1.5–2 cm wide, running above and parallel to the medial half of the inguinal ligament.

The anterior abdominal wall is a many-layered structure (Fig. 2.22), a feature which is readily discernible in a transverse section through the abdomen of a cadaver as well as in an axially viewed CT or MR image of the abdominal wall (Figs. 2.45 and 2.46). A detailed and critical appreciation of these multiple layers, their relationship to each other, their individual textures and consistencies and variations in consistency of a given layer in different parts of the anterior abdominal wall is all crucial not only to a proper understanding of the development of abdominal wall hernias but also to the rational and optimal surgical management of the condition.

From the surface inwards, the multiple layers which make up the anterior abdominal wall are, successively:

- Skin
- Superficial fascia comprising two layers, an outer fatty layer known as Camper's fascia and an inner fibrous (fibroelastic) layer known as the membranous layer of superficial fascia or eponymously as Scarpa's fascia.
- Musculoaponeurotic plane (which is structurally complex and made up of several layers)
- Transversalis fascia (part of the endoabdominal fascia)
- Layer of extraperitoneal fat (or properitoneal fat)
- Parietal peritoneum

Skin

The skin over the anterior abdominal wall is thin compared with that of the back. It is relatively mobile over the underlying layers except in the vicinity of the umbilicus where it is tethered to subjacent layers and consequently relatively immobile.

The surgeon must be aware of the elastic and connective tissue lines in the skin if optimal postoperative cutaneous healing is to be achieved. Natural elastic traction lines in the skin of the anterior abdominal wall (known as relaxed skin tension lines or Kraissl's lines) are disposed transversely. Above the level of the umbilicus, these tension lines run almost horizontally, while below this level they run with a slight inferomedial obliquity (Fig. 2.2). Incisions made along, or parallel to, these lines tend to heal without much scarring, whereas incisions made at right angles to these lines gape and tend to splay out and eventually result in somewhat prominent scars. The longitudinal contraction of the healing wound, particularly when the wound crosses a skin delve or body crease, can result in unsightly scarring and wound contracture, and for these reasons vertical incisions over the groin should, whenever possible, be avoided.

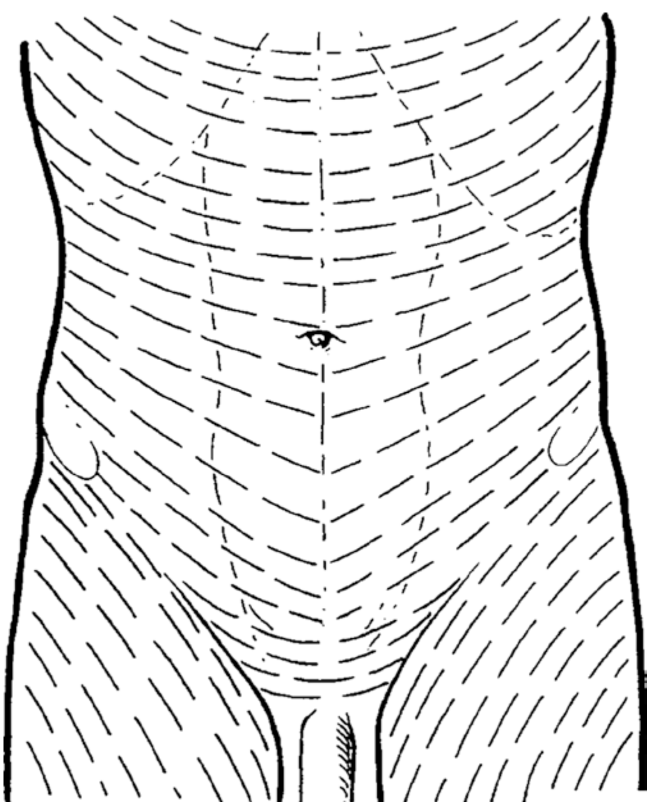

Fig. 2.2 Tension lines of the skin. Incisions at right angles to these lines tend to splay and lead to unsightly scars. This adverse phenomenon is enhanced if the incision also crosses a joint crease. Vertical incisions in the groin for hernia repair are particularly unsightly

However, rapid and unrestricted surgical access to the abdominal cavity often requires a generous vertical incision, and these continue to remain useful and popular in everyday general surgical and gynaecological practice, particularly in emergency surgery (Fig. 2.2).

The Subcutaneous Layer

Deep to the skin lie the subcutaneous areolar tissue and fascia. Superiorly over the lower chest and epigastrium, this layer is generally thin and less organized than in the lower abdomen where it becomes bilaminar—a superficial fatty stratum (Camper's fascia) and a deeper, stronger and fibroelastic layer termed membranous layer of superficial fascia (or Scarpa's fascia). Scarpa's fascia is well developed in infancy, forming a distinct layer which must be separately incised when the superficial inguinal ring is approached in childhood herniotomy.

It is to be noted that traced laterally around the abdominal wall, Scarpa's fascia can be made out distinctly only as far as the midaxillary line. Posterior to that line, Scarpa's fascia thins out gradually, and no Scarpa's fascia is evident in the posterior abdominal wall. Traced superiorly, Scarpa's fascia is seen to cross over onto the anterior chest wall, superficial to the costal margin, as a very thin layer, known as the retromammary fascia. This retromammary extension which can be traced as far superiorly as the second intercostal space is easier to demonstrate in the premenopausal adult female. Deep to the retromammary fascia is the retromammary space which separates the retromammary fascia from the underlying pectoral fascia and pectoralis major muscle.

Even in the adult, Scarpa's fascia is more prominent, of firmer consistency and more readily demonstrable in the lower abdomen than in the upper abdomen. It is generally more membranous, contains a small amount of elastic tissue and is almost devoid of fat. Traced inferiorly, the abdominal subcutaneous fat merges imperceptibly with the subcutaneous fat of the thigh. Scarpa's fascia, by contrast, crosses into the thigh anterior to the inguinal ligament and fuses with the deep fascia of the thigh (fascia lata) at the groin crease (flexure skin crease of the hip joint) below the level of the inguinal ligament, as far medially as the pubic tubercle and laterally as far as an area just inferior to the anterior superior iliac spine. Medially, Scarpa's fascia is prolonged into the anterior part of the perineum (urogenital region of the perineum) as the superficial perineal fascia (Colles' fascia) (Fig. 2.3). In the male, this extension is prolonged into the scrotum and also around the penile shaft. The fascia lata in the upper medial aspect of the thigh has certain anatomic features which are of importance to the hernia surgeon. It is traversed, from superficial to deep, by the great saphenous vein and other struc-

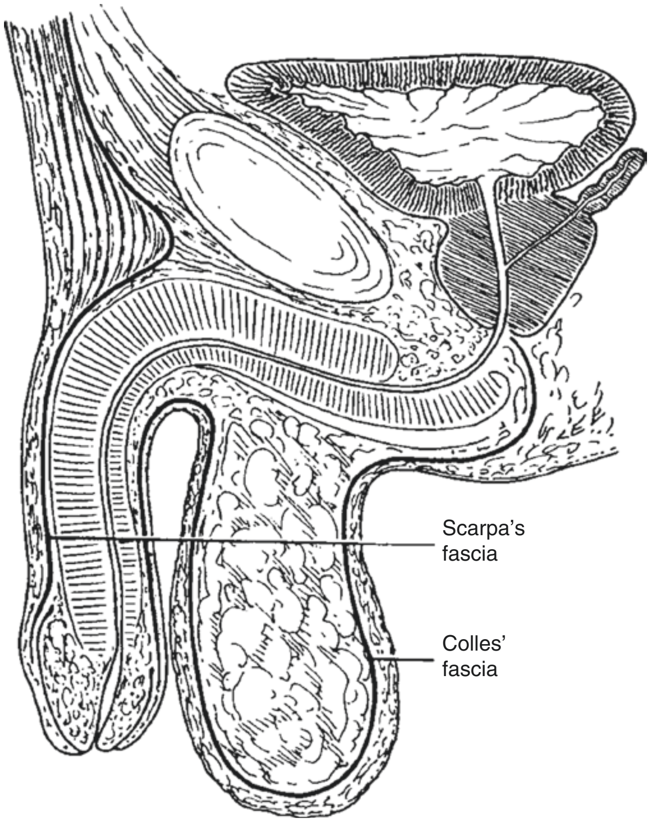

Fig. 2.3 The membranous layer of superficial fascia (Scarpa's fascia) is stronger over the lower abdomen where it forms a distinct layer that requires division in groin hernia operations

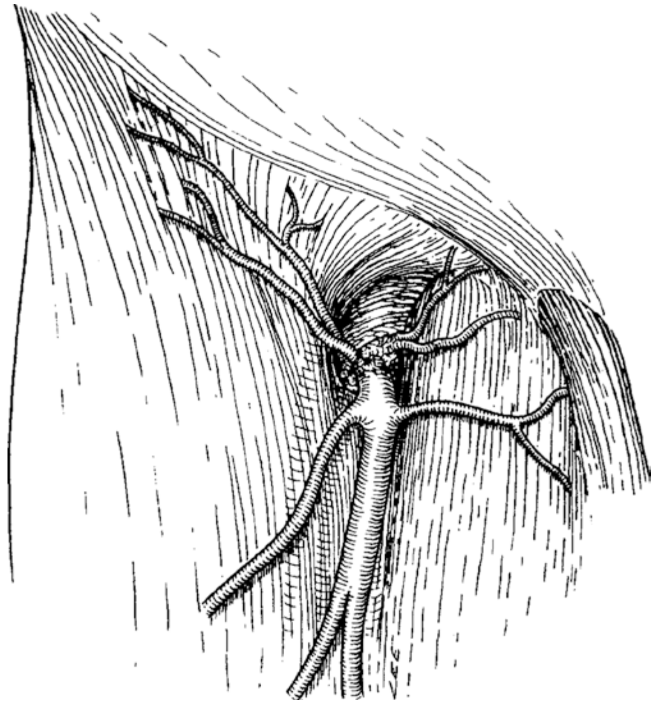

Fig. 2.4 In the upper thigh the long saphenous vein goes from superficial to deep to join the femoral vein which is contained in the femoral sheath, an extension of the extraperitoneal fascia

tures, at the saphenous opening or fossa ovalis. The attenuated connective tissue, the cribriform fascia, packs and 'closes' the saphenous opening. Although the cribriform fascia lies in the same plane as the deep fascia, it has many of the structural characteristics of superficial fascia. Thus, it is loose and fatty in texture and is easily distorted by the dilatation of any of the structures in its vicinity, e.g. a varicose saphenous vein, enlarged lymph nodes and lymphatics and a femoral hernia. The cribriform fascia contributes to the anterior boundary of the femoral canal at this site (Fig. 2.4).

The arterial supply to the anterior abdominal wall is derived from a number of vessels, large and small, which conform to a reasonably constant pattern. Superficially these vessels anastomose to make a network in the subcutaneous tissue. The seventh to tenth intercostal arteries and musculophrenic arteries bilaterally and the right and left superior epigastric arteries (terminal branches of the right and left internal thoracic arteries, respectively) supply the abdominal wall cephalad to the umbilicus. Caudal to the umbilicus, the 11th intercostal and subcostal arteries bilaterally make a modest contribution, while the superior epigastric vessels anastomose with the inferior epigastric vessels inside the rectus sheath either within the substance of the rectus abdominis muscle or deep to the muscle and together supply most of the infraumbilical part of the anterior abdominal wall. The inferior epigastric artery arises from the external iliac artery just proximal to the inguinal ligament. The inferior epigastric artery and accompanying veins form the lateral margin of Hesselbach's triangle [2]. The deep inguinal ring and thus the neck of an *indirect* inguinal hernial sac lie lateral to these vessels, while the neck of a direct inguinal hernia sac is medial to these vessels.

In addition to the serially arranged vessels described above, there are three small superficial branches of the femoral artery in the upper thigh. These branches are the superficial circumflex iliac artery passing laterally and upwards superficial to the inguinal canal, the superficial epigastric artery coursing upwards and medially towards the umbilicus and the superficial external pudendal artery making its way medially to supply the skin of the penis and scrotum. All these arteries are frequently encountered in inguinal and femoral hernioplasty, and all anastomose adequately with their neighbours and with their counterparts across the midline. In most instances they can be divided with impunity, but very occasionally they are an auxiliary source of blood supply to the testicle (Fig. 2.5). The corresponding and accompanying veins drain to the great saphenous vein.

The veins draining the lower abdomen enter the femoral vein via the great saphenous vein through the saphenous opening or directly into the external iliac vein. From the upper abdomen venous blood eventually drains into the subclavian veins either via tributaries of the internal thoracic veins or via tributaries of the axillary veins.

The finer details of the vascular supply of the anterior abdominal wall are beyond the scope of this chapter but are

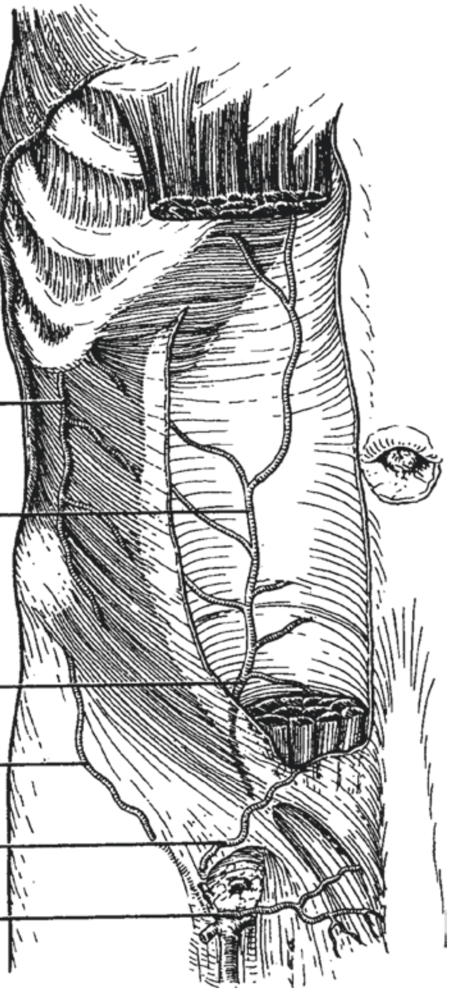

Fig. 2.5 The vasculature of the abdomen and groin is of particular interest to the surgeon. Fortunately the vessels all anastomose freely, so surgery does not need to be locked into vascular anatomy, except for the anastomosis of the pudendal with the cord vessels over the pubis. Care should be taken not to dissect the superficial tissues medial to the pubic tubercle to avoid threat to the pudendal anastomosis and the testicle

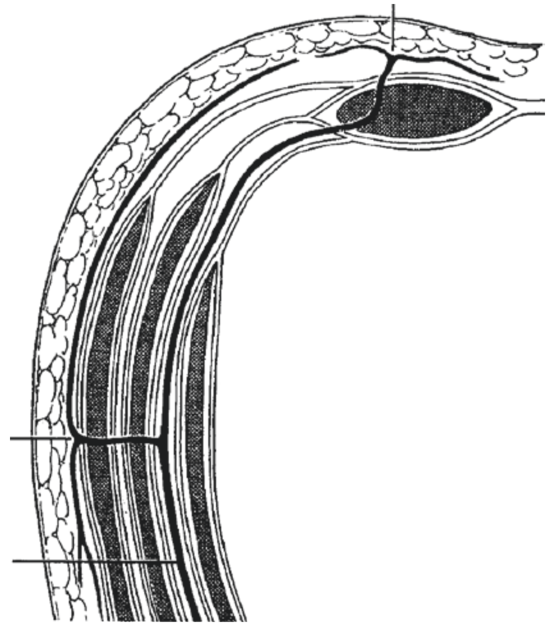

Fig. 2.6 The lower abdomen is segmentally supplied by the intercostal nerves. Each nerve has a lateral cutaneous branch which gives anterior and posterior divisions in the subcutaneous tissue. When a local anesthetic is administered, it is important to block the anterior division of the lateral cutaneous branch of these nerves

of paramount importance in the context of tissue transfer in plastic and reconstructive surgery. (The interested reader may consult [3].)

Superficial Nerves

The cutaneous nerves to the anterior abdominal wall are arranged and distributed segmentally, as in the anterior chest wall. The lower five intercostal nerves and the subcostal nerve (12th thoracic nerve) having run in their respective intercostal spaces cross the costal margin obliquely to enter the neurovascular plane of the anterior abdominal wall (i.e. the plane between the internal oblique and transversus abdominis) to supply the abdominal parietes. While still in the intercostal space, each gives off a lateral cutaneous branch which enters the overlying digitation of the external oblique muscle; this branch divides into a small posterior nerve which extends back to supply the skin overlying the latissimus dorsi and a larger anterior nerve which supplies the external oblique muscle and the overlying subcutaneous tissue and skin. The main stem of the intercostal nerve continues forwards in the neurovascular plane and enters the rectus sheath from behind by piercing the posterior lamella of the internal oblique aponeurosis. It gains the surface by passing through the rectus abdominis muscle which it supplies before emerging through the anterior rectus sheath a centimetre or so from the midline (Fig. 2.6).

The most caudal of the abdominal wall nerves are derived from the ventral ramus of the first lumbar spinal nerve; they are the iliohypogastric and ilioinguinal nerves. The ilioinguinal nerve is generally the smaller of the two—although occasionally, it may be the larger of the two. Rarely the ilioinguinal nerve is very small and may even be absent. The anterior cutaneous branch of the iliohypogastric nerve emerges through the aponeurosis of the external oblique, 1 or 2 cm above the superficial inguinal ring, and innervates the skin in the suprapubic region. The ilioinguinal nerve enters the inguinal canal at its lateral extremity (and not through the deep inguinal ring), and running through the canal usually inferolateral to the spermatic cord (or uterine round ligament), it becomes superficial by emerging through the superficial inguinal ring to supply the anterior one-third of the scrotal skin (vulval skin in the female) and a small area of the medial upper thigh and suprapubic skin (Fig. 2.7).

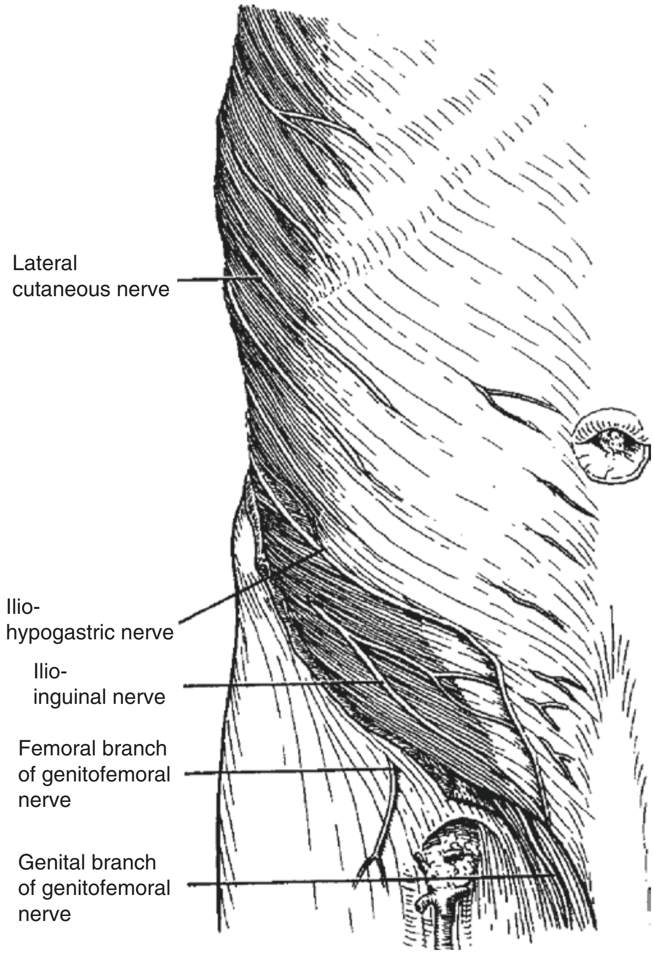

Fig. 2.7 The groin area is innervated principally by branches of the first lumbar nerve—the iliohypogastric and ilioinguinal nerves. These nerves innervate the skin area over the iliacc crest (the lateral branch of the iliohypogastric nerve), the suprapubic region (the anterior branch of iliohypogastric nerve), and the front and side of the scrotum and upper medial thigh (the ilioinguinal nerve after it emerges from the inguinal canal)

The genitofemoral nerve is derived from the ventral rami of the first and second lumbar spinal nerves and completes the innervation of the anterior abdominal wall and groin areas. At first it passes obliquely forwards and downwards through the substance of the psoas major. It emerges from the muscle and crosses its anterior surface behind the posterior parietal peritoneum, running posterior to the ureter. It divides at a variable distance from the deep inguinal ring into a genital and a femoral branch.

The genital branch, a mixed motor and sensory nerve, enters the inguinal canal at or just medial to the deep inguinal ring. The nerve penetrates the fascia transversalis of the posterior wall of the inguinal canal either through the deep ring or separately medial to the deep ring. The nerve traverses the inguinal canal lying between the spermatic cord above and the inguinal ligament inferiorly; the nerve is vulnerable to surgical trauma as it progresses along the floor of the canal (the gutter produced by the inturned lower edge of the inguinal ligament). The genital branch supplies motor innervation to the cremaster muscle and sensory innervation to the fascial coverings of the spermatic cord (or coverings of the uterine round ligament in the female). It may supply the skin of the scrotum.

The femoral branch enters the femoral sheath overlying the femoral artery and supplies a small area of skin over the upper part of the femoral triangle (Fig. 2.8).

The posterior two-thirds of the scrotum is supplied by S2 and S3 through the perineal and posterior femoral cutaneous nerves. The anterior scrotal cutaneous supply is frequently disrupted in open repair of inguinal hernias (Fig. 2.9) no doubt due to injury to the ilioinguinal nerve (caused inadvertently or otherwise).

The sensory nerve supply of the upper anterior and anterolateral thigh is derived from the lateral cutaneous nerve of the thigh, the femoral branch of the genitofemoral nerve, the ilioinguinal nerve and the genital branch of the genitofemoral nerve (Fig. 2.10). There is overlap between the territories of these nerves, and their pathways also show considerable variation.

The lateral cutaneous nerve of the thigh arises from the ventral rami of the second and third lumbar nerves. It emerges from the lateral border of the psoas major and crosses the

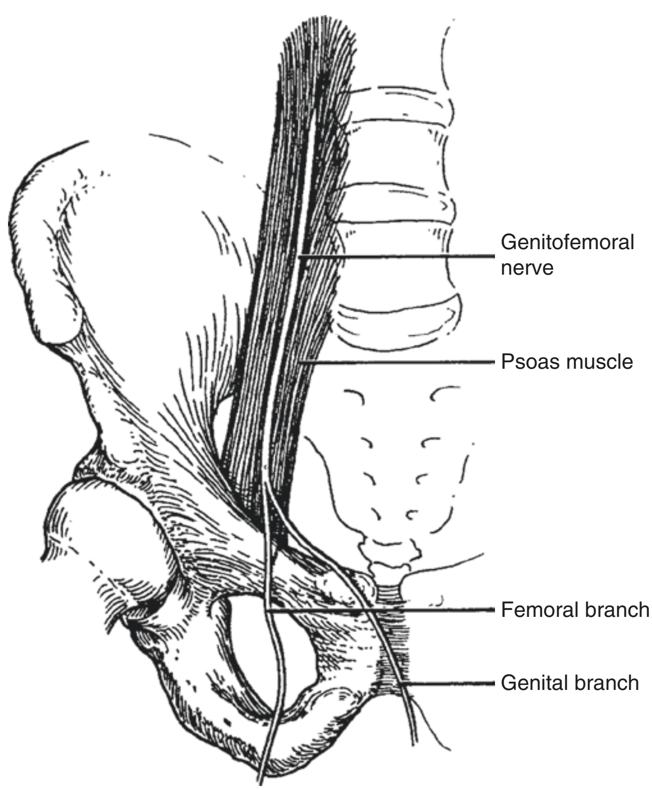

Fig. 2.8 The genitofemoral nerve, from L1 and L2, innervates the femoral sheath and the skin over it. It should be blocked prior to surgery for a femoral hernia under local anesthetic

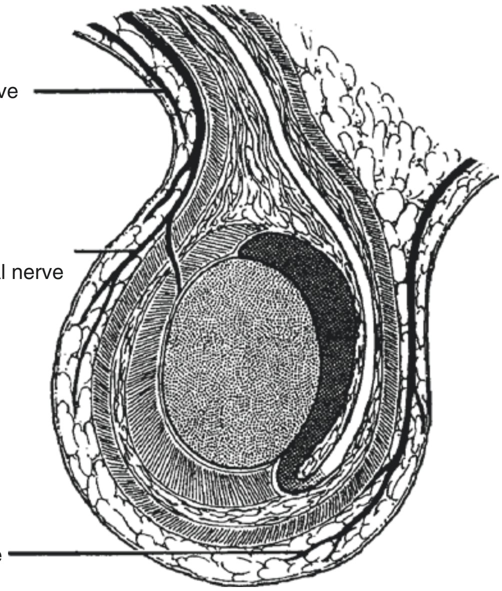

Fig. 2.9 The skin of the anterior scrotum is supplied by the ilioinguinal nerve, L1, and the genital branch of the genitofemoral nerve, L1. These nerves are often disrupted in hernioplasty

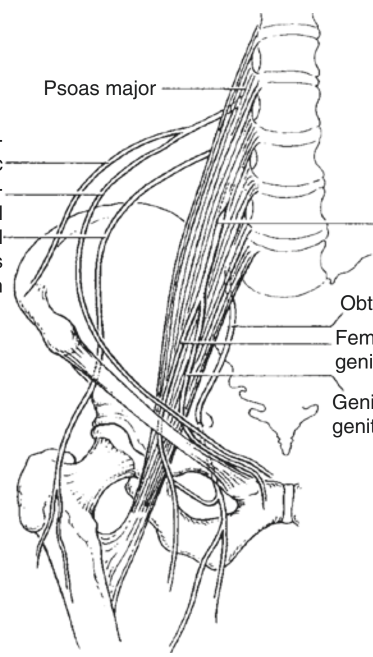

Fig. 2.10 The nerves of the lower abdomen, the groin and upper thigh. The lateral cutaneous nerve of the thigh and the femoral branch of the genitofemoral nerve are at special risk in extraperitoneal operations on groin hernia

ventral aspect of iliacus obliquely, running towards the anterior superior spine. It lies in the adipose tissue between the iliopsoas fascia and the peritoneum.

Usually the lateral cutaneous nerve of the thigh forms one single trunk, but it may divide into two branches at a variable distance proximal to the inguinal ligament (Figs. 2.10 and 2.11) [4]. The nerve then crosses into the

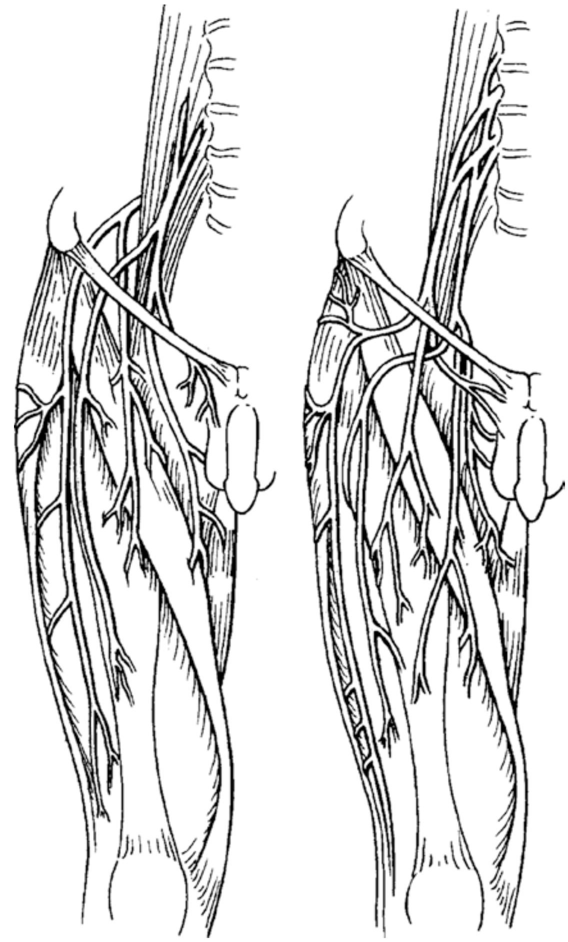

Fig. 2.11 The variable anatomy of the lateral cutaneous nerve of thigh and the femoral branch of the genitofemoral nerve. Both these nerves are in close proximity to the inguinal ligament as they progress to the thigh [4]

anterior thigh by passing deep to the lateral portion of the inguinal ligament. It may then lie superficial to the sartorius muscle or may pass through the sartorius before becoming superficial to supply the skin of the lateral side of the thigh. The variability of the course of the nerve in the abdomen is considerable, and the distance between nerve and the deep inguinal ring also variable [5]. The nerve may traverse the anterior abdominal wall cranial to the inguinal ligament or through the attachment of the ligament to the anterior superior iliac spine (Fig. 2.11).

The scrotal nerve supply is complex [6]. The autonomic supply of the testis is from T10 to T12, via nerves which accompany the spermatic vessels. These autonomic nerves are motor to the vasculature and to the smooth muscle of the tunica albuginea. However, they also have free, sensory endings in the interstitial spaces of the testis and convey noxious stimuli which may present as referred pain in the lower abdomen (T10–T12 segments). The autonomic supply of the vas and epididymis is distinct from those of the testis; pain from these structures is felt in the L1 segment, lower than testicular pain, in the distributions of the genitofemoral nerve.

The somatic nerve supply is the genitofemoral nerve, L1 and L2, and the sacral nerve, S2 and S3. The genital branch of the genitofemoral nerve supplies the cord, the cremaster, the tunica vaginalis and, along with the L1 component of the ilioinguinal nerve, the anterior third of the scrotal skin.

When viewed from behind, as during endoscopic hernia surgery, the area lateral to the cord vessels and above the inguinal ligament where the femoral branch of genitofemoral nerve and lateral cutaneous nerve of the thigh lie, has been dubbed the 'triangle of pain' by laparoscopic surgeons because of the hazard of nerve injury by entrapment with staples. In this area thick globular adipose tissue can surround and conceal the nerves. On a deeper plane, the femoral nerve crosses this triangle with the genitofemoral and lateral cutaneous nerve superficial to it (Fig. 2.12). This entire area is spoken of as the 'quadrangle of doom'. All of the nerves that can be injured during laparoscopic inguinal hernia repair are located in this anatomic region.

Musculoaponeurotic Plane

The musculoaponeurotic 'plane' is architecturally complex and composed of several layers.

A long and thick strap-like muscle, the rectus abdominis, lies on either side of the vertical midline. Lateral to the rectus abdominis on each side, the musculoaponeurotic plane comprises a three-ply arrangement of concentric muscular sheets. The largest and most superficial of the three is the external oblique muscle. The intermediate muscular sheet is the internal oblique muscle, while the deepest (innermost) sheet is the transversus abdominis. Of these three layers, the internal oblique and transversus abdominis curve posteriorly to attach to the lumbar fascia at the very lateral edge of the quadratus lumborum muscle on the posterior abdominal wall. The external and internal obliques and the transversus abdominis may be spoken of, collectively, as the anterolateral abdominal musculature.

Anteromedially, each of the abovementioned three muscular sheets becomes an aponeurosis (a flattened tendinous sheet). These aponeuroses envelop the ipsilateral rectus abdominis muscle in a highly specific and well-defined manner, and having done so, they interdigitate in the vertical midline with their counterpart aponeuroses from the contralateral side to form the linea alba. The aponeurotic envelope surrounding the rectus abdominis muscle is referred to as the rectus sheath.

A description of the rectus abdominis (and pyramidalis) muscles shall be followed by a detailed consideration of the three muscles which make up the anterolateral abdominal musculature.

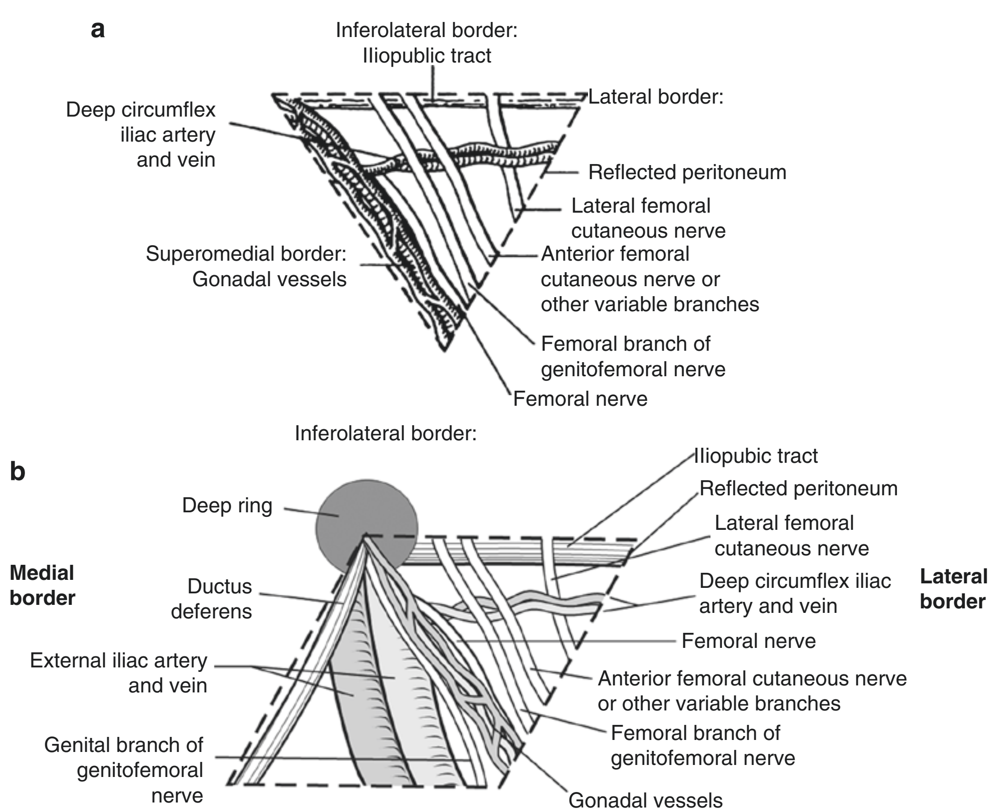

Fig. 2.12 (**a**) Laparoscopic view of the nerves immediately proximal to the inguinal ligament after reflection of the parietal peritoneum. These nerves lie in the adipose tissue just deep to the peritoneum and superficial to the iliopsoas muscle: the "triangle of pain." (**b**) Laparoscopic view of the deep inguinal ring and adjacent structures, the "triangle of doom" [29]

The Rectus Abdominis Muscle

The rectus muscle is flat and strap-like and extends from the level of the pubis to the thorax. The muscle is separated from its fellow of the opposite side by the linea alba. Each rectus abdominis muscle arises by two short tendons: the larger and lateral tendon from the pubic crest and the smaller and medial tendon from the upper and anterior surfaces of the pubic symphysis (some of the fibres from the medial tendon mingle with those of the medial tendon of the other side). The two tendons, lateral and medial, unite a short distance above the pubis to give rise to a single muscle belly which broadens as it runs upwards and crosses the costal margin to attach to the anterior surfaces and inferior margins of the seventh, sixth and fifth costal cartilages and, by a small slip, to the xiphisternum.

The upper part of the muscle belly usually shows three transverse tendinous intersections: one at the level of the xiphisternum, one at the level of the umbilicus and one halfway between the other two. Sometimes a further incomplete intersection is present below the umbilical level. The intersections extend into the thickness of the muscle for a variable distance but never penetrate the entire thickness of the muscle. They are always intimately adherent to the anterior lamina of the sheath of the muscle but have no attachment to the posterior sheath.

The pyramidalis muscle is triangular in shape, arising by its base from the ligaments on the anterior surface of the symphysis pubis and being inserted into the lower linea alba 2–3 cm above the pubic symphysis. The muscle is absent in 10% of subjects (Fig. 2.13) and in any case is not thought to be of any functional consequence.

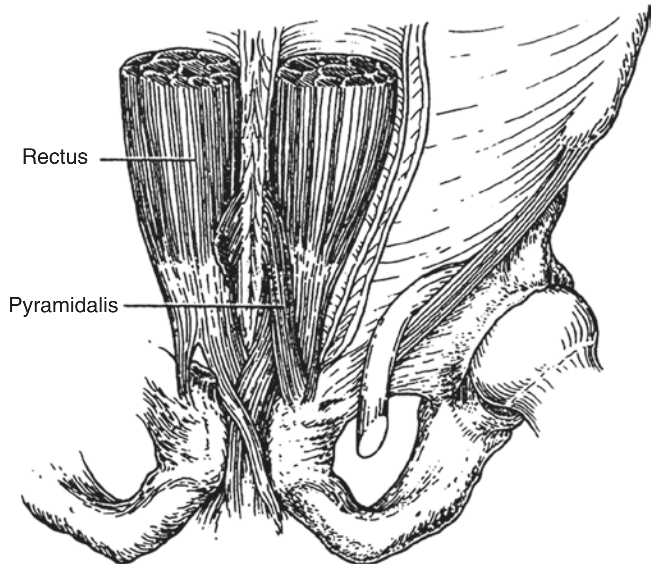

Fig. 2.13 The rectus muscle arises by two tendons—the larger and lateral from the crest of the pubis and the smaller and medial from the pubis of the opposite side and from the ligamentous fibers of the symphysis. The pyramidalis is variable; it arises from the ligamentous fibers of the symphysis and adjacent pubis and is inserted into the linea alba

The External Oblique Muscle

The external oblique muscle arises, typically, by eight slips: from the external surface and inferior border of each of the lower eight ribs. The upper four slips interdigitate with the slips of origin of the serratus anterior muscle. The lower four slips of the external oblique interdigitate with those of the latissimus dorsi muscle. The fibres pass downwards and forwards from their costal origins. The posterior fibres are nearly vertical and are inserted into the anterior half of the external lip of the iliac crest. The uppermost fibres run almost horizontally towards the ventral midline. The intervening fibres from above downwards display a progressively increasing obliquity as they run towards the ventral midline. All the superior and intermediate fibres end in the strong external oblique aponeurosis. The muscle may be said to have three borders: a posterior border which is muscular and upper and lower borders which are both aponeurotic.

The posterior border of the external oblique is free, so to speak, and forms the anterior boundary of the lumbar triangle (of Petit). The posterior boundary of the lumbar triangle is the anterolateral edge of the latissimus dorsi muscle, and the inferior boundary is the short length of iliac crest between the attachments of external oblique and latissimus dorsi. The 'floor' of this triangle is formed by the internal oblique and the underlying transversus abdominis. Both sheets are relatively thin at this level, and it is through this triangle that a lumbar hernia may present as a swelling in the flank.

Superiorly the external oblique aponeurosis is relatively thin and passes medially to be attached to the xiphoid process. Inferiorly the aponeurosis is very strong. The inferior margin of the aponeurosis forms the inguinal ligament. The latter is attached superolaterally to the anterior superior iliac spine and inferomedially to the pubic tubercle. Medially, the aponeurosis of the external oblique contributes to the anterior rectus sheath and thence interdigitates with its fellow of the opposite side at the linea alba. The external oblique aponeurosis is broadest inferiorly, narrowest at the umbilicus and broad again in the epigastrium.

The aponeurosis of the external oblique muscle fuses with the aponeurosis of the internal oblique in the anterior wall of the rectus sheath. This line of fusion which is considerably medial to the semilunar line has an oblique and somewhat curved trajectory, being more lateral above and more medial below. In fact, the external oblique aponeurosis contributes very little to the lower portion of the anterior rectus sheath. This latter point is of importance in inguinal hernioplasty (Fig. 2.14) [7].

There is a natural defect in the external oblique aponeurosis just above the pubis. This aperture known as the superfi-

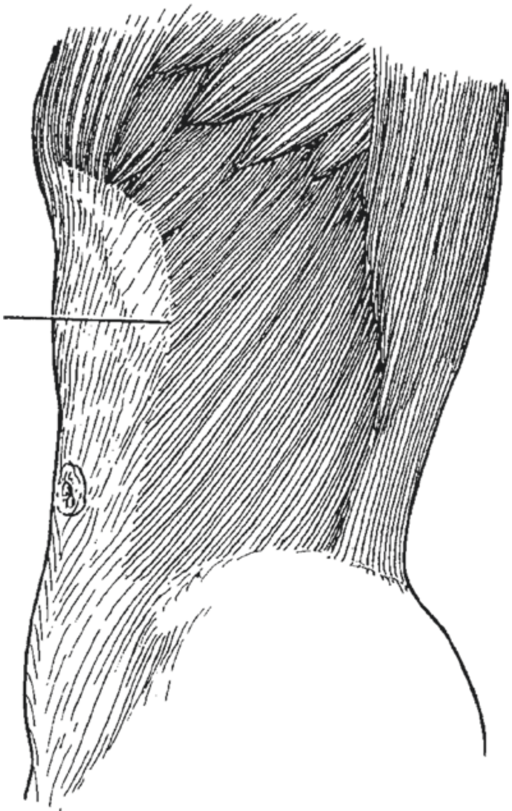

Fig. 2.14 The external oblique muscle and its aponeurosis invests the abdomen. The aponeurosis of this muscle forms the anterior wall of the rectus sheath by fusing with the underlying aponeurosis of the internal oblique. However, this line of fusion, in the lower abdomen especially, is considerably medial to the semilunar line. This is an anatomical point of importance in inguinal hernioplasty, as it allows a "slide operation" on the internal oblique without compromising the anterior rectus sheath

cial inguinal ring (external inguinal ring) is triangular in shape and in the male, transmits the spermatic cord from the abdomen to the scrotum. In the female the round ligament of the uterus emerges through this opening before blending with the subcutaneous tissue in the ipsilateral labium majus. The superficial inguinal ring is not a 'ring'; it is a triangular cleft with its long axis obliquely disposed in a superolateral direction from the pubic tubercle. It is approximately parallel to the inguinal ligament. The base of the triangle is formed by the crest of the pubis, and the apex is laterally directed towards the ASIS. The superficial inguinal ring represents the interval between that part of the external oblique aponeurosis which inserts into the pubic symphysis and pubic crest on the one hand and the inguinal ligament on the other hand, which inserts into the pubic tubercle. The aponeurotic margins of the ring are described as the superior and inferior crura. The spermatic cord, as it comes through the superficial inguinal ring, rests on the inferior crus which is a continuation of the floor of the inguinal canal (the enrolled inferomedial end of the inguinal ligament).

The dimensions of the superficial inguinal ring, or aponeurotic cleft, are of surgical importance and are far from being of standard size and predictable extent. It may sometimes fit snugly around the spermatic cord. At other times it may extend upwards and laterally beyond the anterior superior iliac spine. In 80% of cases, the cleft is confined to the lower half of the area between the midline and the anterior superior spine, but in the remaining 20%, it extends more laterally. In about 2% of individuals, one or more accessory clefts are seen. When present, they are usually superolateral to the main cleft. The accessory cleft may transmit the ilio-hypogastric nerve (Fig. 2.15) [8].

The relationship between the apex of the cleft and the inferior (deep) epigastric vessels (indicating the lateral margin of Hesselbach's triangle) is of crucial importance in closing the inguinal canal anteriorly and containing a potential direct inguinal hernia. Whereas the canal is usually described as closed anteriorly by the external oblique aponeurosis, in only 11% of cases does the apex of the cleft lie less than halfway along a line from the pubic tubercle to the inferior epigastric artery, in 52% the cleft extends to the level of the epigastric vessels and, most importantly, in 37% the apex of the cleft is lateral to the epigastric vessels (Fig. 2.16) [8].

The crura of the superficial ring are joined together by intercrural fibres derived from the outer investing fascia of the external oblique aponeurosis. The size and strength of these intercrural fibres vary. It has been estimated that in 27% of individuals these fibres do not cross from crus to crus and, therefore, do not reinforce the margins of the cleft [8].

The inferior border of the external oblique aponeurosis is rolled inwards to form a gutter. This enrolled edge is termed the inguinal ligament (Poupart's ligament). It is attached superolaterally to the anterior superior iliac spine and inferomedially to the pubic tubercle. Both bony landmarks are readily palpable. Reciprocal to the gutter-shaped, concave upper surface, the inguinal ligament presents a rounded inferior border towards the thigh. Attached to this rounded distal surface of the inguinal ligament is the deep fascia of the thigh, the fascia lata. The medial end of the inguinal ligament at the pubic tubercle gives rise to the lacunar ligament (Gimbernat's ligament) which extends upwards and backwards to reach the pectineal line on the superior ramus of the pubis. The crescentic, free, lateral edge of the lacunar ligament forms the medial boundary of the femoral ring. From its attachment on the pectineal line, the lacunar ligament sends a strong extension which runs superolaterally and has a firm attachment along the iliopectineal line. This extension is termed the pectineal ligament (of Astley Cooper). Finally, from the pubic tubercle, certain fibres of the inguinal ligament run superiorly and medially behind the spermatic cord to interdigitate at the linea alba with corresponding fibres from the contralateral side. This superomedial extension of the inguinal ligament is termed the reflected part of the inguinal ligament. The inguinal ligament shows a gentle curvature, with its concavity directed medially and upwards

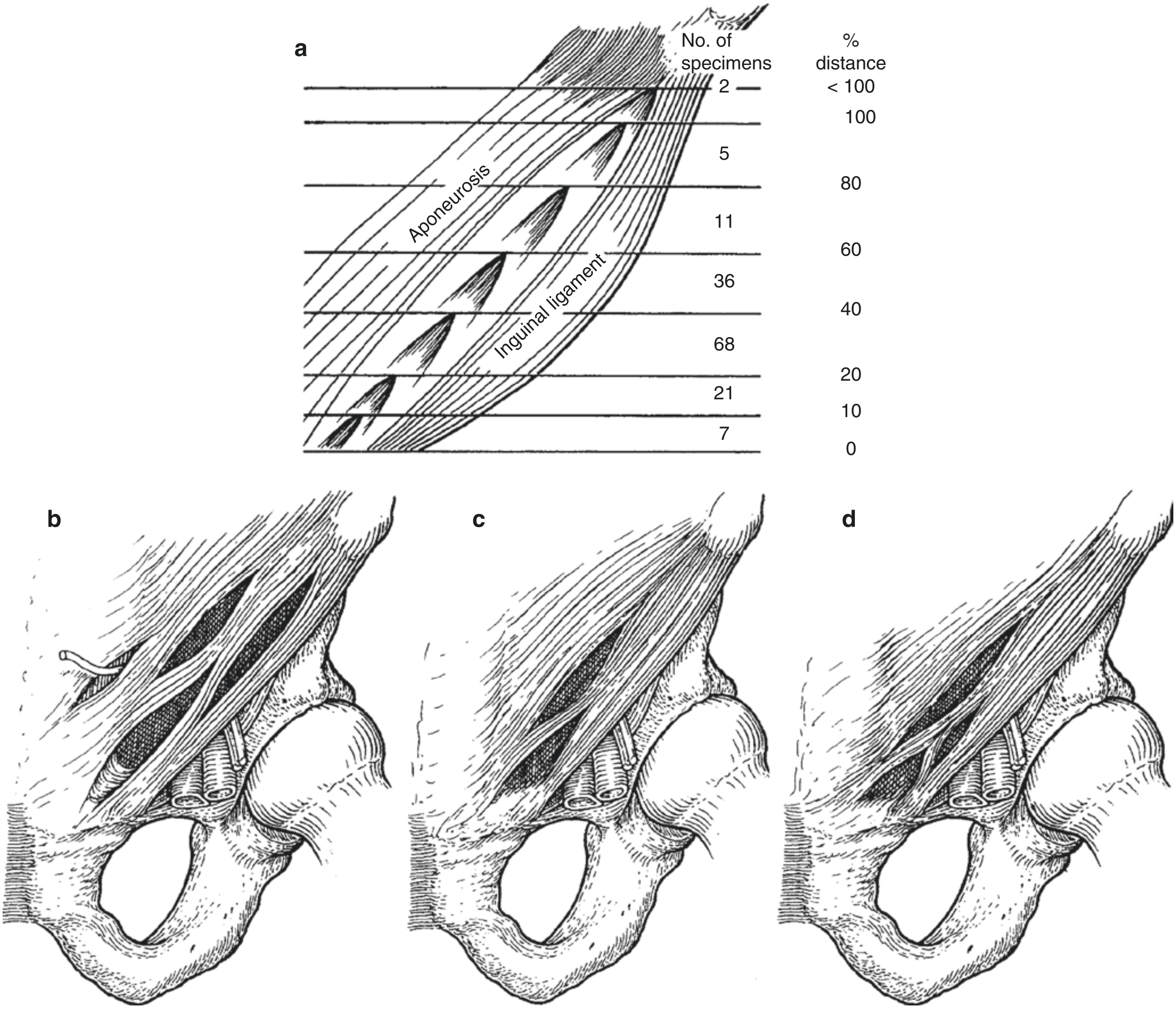

Fig. 2.15 The anatomy and dimensions of the superficial inguinal ring are very variable. The "ring" is a triangular cleft separating the insertions of the external oblique aponeurosis into the pubic crest and the pubic tubercle. Its base is medial and inferior and its apex superior and lateral. In 80% of subjects the apex lies in the medial half of the lower abdomen, but in the remaining 20% the apex approaches the anterior superior iliac spine (**a**). In 2% of subjects, there are accessory clefts superior to the main cleft (**b**–**d**). One of these clefts may transmit the iliohypogastric nerve (**b**) [8]

towards the (Fig. 2.17) abdomen and the reciprocal convexity directed inferolaterally towards the thigh.

The extensions from the medial end of the inguinal ligament as the lacunar (Gimbernat's) and the pectineal (Cooper's) ligament give a fan-like expansion of the inguinal ligament at its medial end. This expansion has important surgical implications.

The lacunar ligament is a triangular continuation of the medial end of the inguinal ligament. Its apex is at the pubic tubercle, its superior margin is continuous with the inguinal ligament and its posteromedial margin is attached to the iliopectineal line on the superior ramus of the pubis. Its lateral crescentic edge is free and is an important firm structure in the medial margin of the femoral ring (the proximal end of the femoral canal). The ligament lies in an oblique plane, with its upper (abdominal) surface facing superomedially and being crossed by the spermatic cord and its lower (femoral) surface looking inferolaterally. With the external oblique aponeurosis and the inguinal ligament, the superior surface forms a groove for the cord as it emerges from the inguinal canal (Fig. 2.18).

The reflected part of the inguinal ligament (Colles') is a broad band of rather thin fibres which arise from the crest of the pubis and the medial end of the iliopectineal line and pass anterosuperiorly behind the superior crus of the subcutaneous inguinal ring to the linea alba. The reflected part of the inguinal ligament is very variable in its extent, but it is an important structure closing the

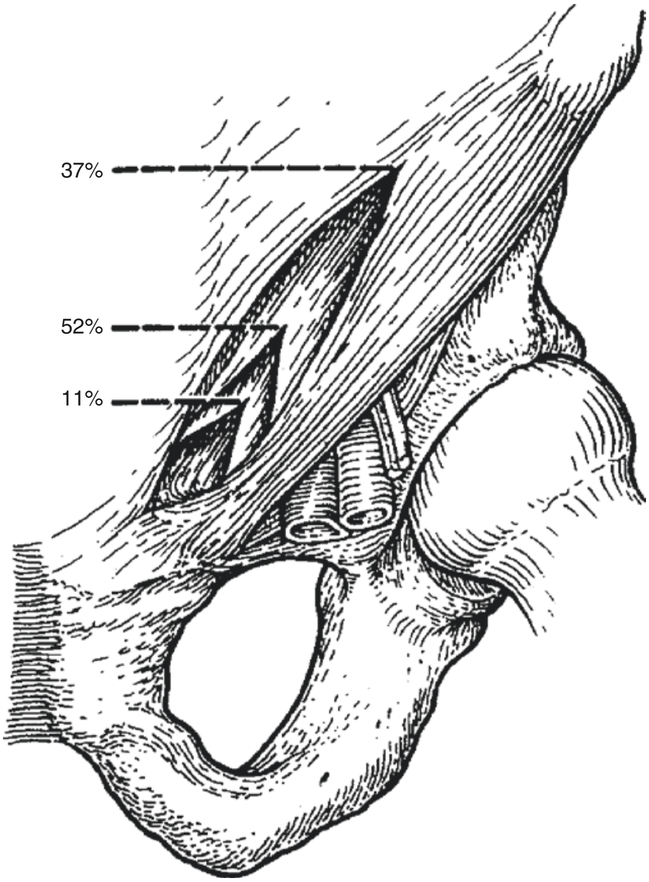

Fig. 2.16 The size of the superficial inguinal ring, the cleft in the external oblique, is crucial in closing the inguinal canal anteriorly. In 11% of subjects the cleft extends less than 50% of the length of the inguinal canal, in 52% it extends as far as the deep epigastric vessels, and in 37% the cleft extends lateral to the deep epigastric vessels [8]

potential space in the posterior wall of the inguinal canal between the iliopectineal line and the lateral margin of the rectus muscle (Fig. 2.19).

The Internal Oblique Muscle

The internal oblique muscle arises from the lateral two-thirds of the abdominal surface of the inguinal ligament, the intermediate line on the anterior two-thirds of the iliac crest and from the whole length of the lumbar fascia. The general direction of the fibres (above the level of the anterior superior iliac spine) is upwards and medial. The posterior fibres are inserted into the inferior borders of the cartilages of the lower four ribs. The intermediate fibres pass upwards and medially and end in a strong aponeurosis which extends from the inferior borders of the seventh and eighth costal cartilages and the xiphisternum to the linea alba along the entire length of the latter. The lowermost fibres arise from the inguinal ligament and arch downwards and medially. These fibres along with the lowest fibres of the transversus muscle pass in front of the rectus abdominis muscle, contribute to the anterior rectus sheath and insert onto the pubic crest and the iliopectineal line behind the lacunar ligament and reflected part of the inguinal ligament (Fig. 2.20).

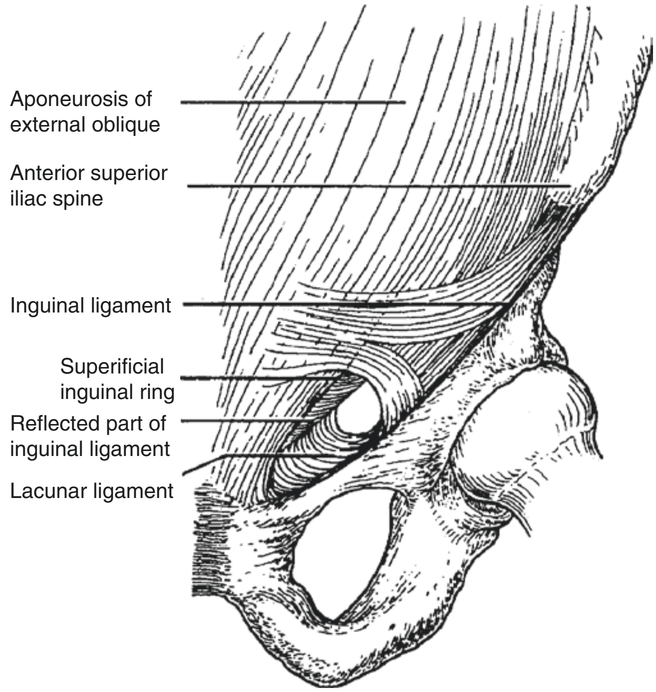

Fig. 2.17 The inguinal ligament is the lower margin of the external oblique muscle. Medially it is attached like a fan to the iliopectineal line (Cooper's ligament) and the tubercle of the pubis

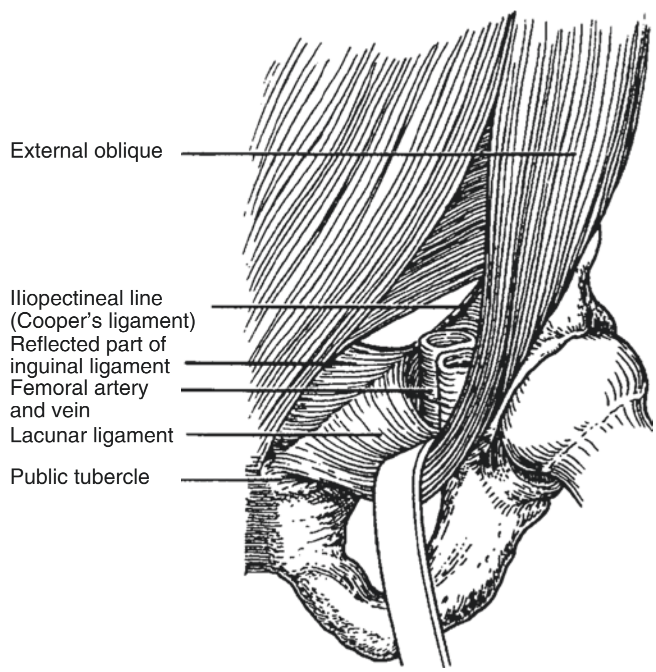

Fig. 2.18 The upper abdominal surface of the attachment of the inguinal ligament to the pubic tubercle is the floor of the inguinal canal which the cord rests on as it emerges from the canal

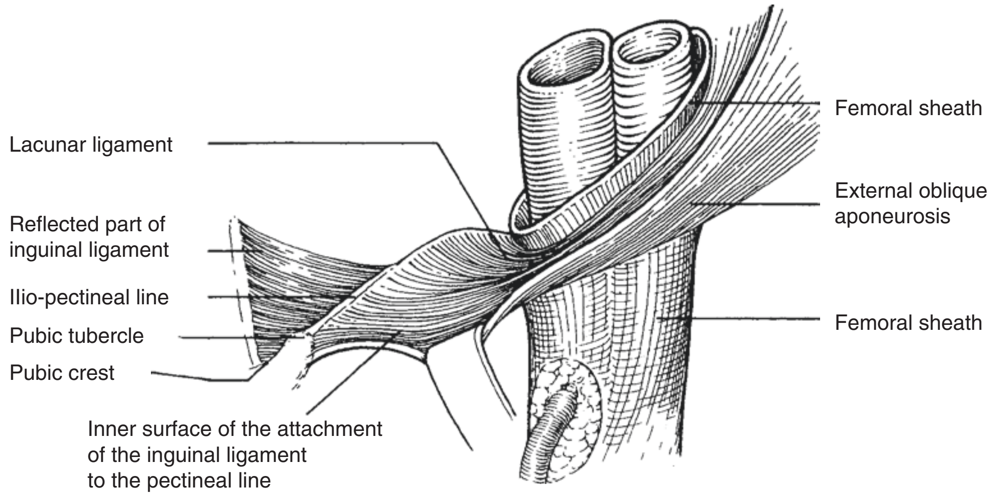

Fig. 2.19 Medially the posterior wall of the inguinal canal is reinforced by the reflected part of the inguinal ligament, a strong triangular fascia arising from the pubic crest anteriorly to the attachments of the internal oblique and transversus muscles and passing medially to the linea alba into which it is inserted

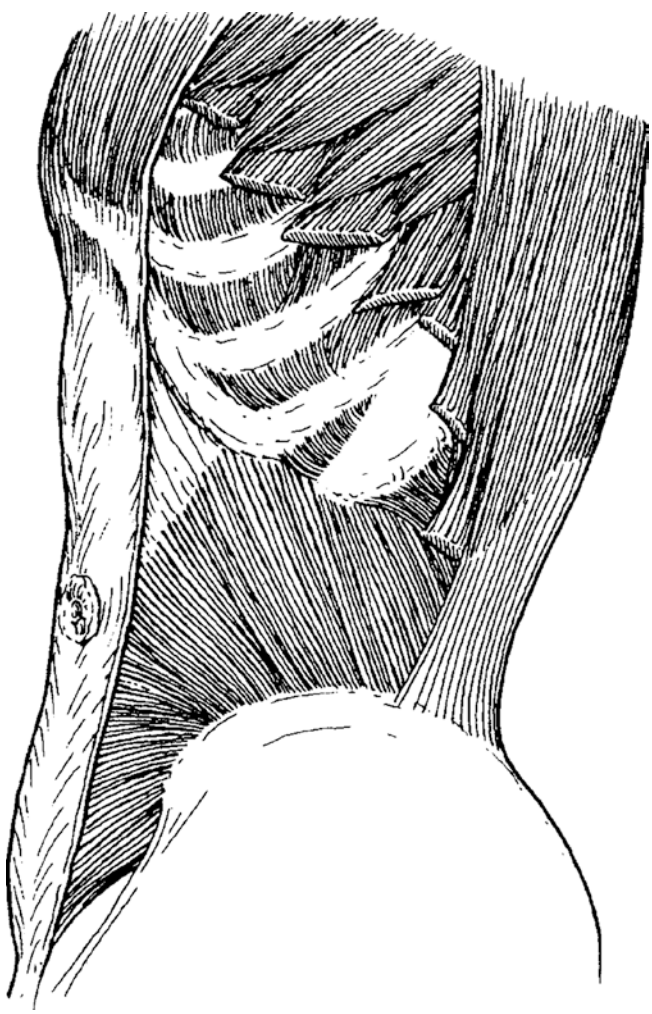

Fig. 2.20 The internal oblique muscle arising from the lateral half of the inguinal ligament and the iliac crest to be inserted into the lower costal cartilage and, via its aponeurosis, continuous with its fellow muscle contralaterally

A recent publication has questioned the traditional description of the lowest fibres of internal oblique (and transversus abdominis) arising from the upper surface of the inguinal ligament [9]. According to Acland, the lowest fibres of internal oblique and transversus abdominis arise not from the inguinal ligament but from a thickened ridge of iliopsoas fascia.

The internal oblique is not invariable in its anatomy in the inguinal region. Its origin may commence in front of the internal ring or at a variable distance lateral to the ring. The muscle may then insert either onto the pubic crest and tubercle or into the lateral margin of the rectus sheath a variable distance above the pubis. With regard to the behaviour of the internal oblique in the region of the groin, there are thus four possible combinations of origin and insertion. The contribution of the internal oblique to groin anatomy and in particular to the 'defences' of the inguinal canal is very variable. There are a number of well-recognized variations in the anatomy of the internal oblique in the groin (see p. 46) (Fig. 2.21).

The detailed anatomy of the semilunar line and rectus sheath, and that of the insertion of the lowermost fibres of the internal oblique into the pubic bone, is of surgical significance and warrants more detailed consideration.

At the lateral margin of the rectus muscle, the aponeurosis of the internal oblique splits into two lamellae—the superficial lamella passes anterior to the rectus, and the deep lamella goes posterior to the rectus. The superficial lamella fuses with the aponeurosis of the external oblique to form the anterior rectus sheath. The deep lamella fuses with the aponeurosis of the underlying transversus abdominis muscle. The detailed anatomy varies but has importance in the causation of umbilical and epigastric hernias. In the lower part of the abdomen, in an area inferior to a point about midway between the umbilicus and the pubis, the aponeurosis does not split into lamella but courses entirely in front of the rectus to fuse with the overlying aponeurosis of the external oblique (Fig. 2.22).

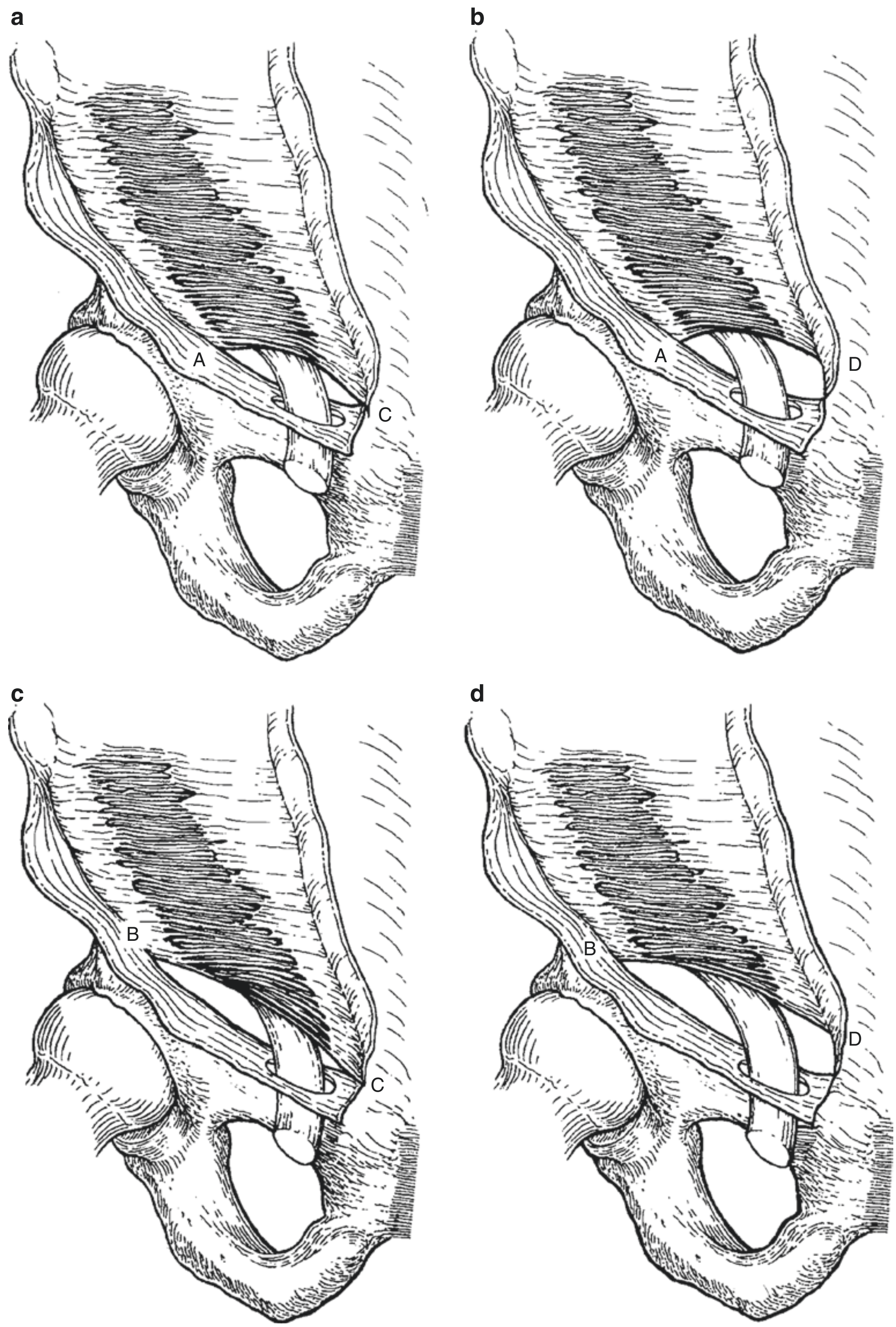

Fig. 2.21 The origin and insertions of the internal oblique muscle and aponeurosis in the inguinal region are variable. The origin of the red muscle fibers is from the lateral inguinal ligament; this origin may extend as far medially as the deep ring (**a**), or the muscle may arise more laterally (**b**). The insertion of the aponeurosis is also variable; it may be inserted into the pubic crest and pubic tubercle (**c**) or solely into the rectus sheath (**d**). This gives four variants of the lower margin of the internal oblique in the inguinal canal: A–C, A–D, B–C, and B–D

The internal oblique muscle in its lateral fleshy part is not uniform in structure; it is segmented or banded. The muscular bands terminate just lateral to the border of the rectus muscle and are most marked in the inguinal and lower abdominal region. The bands are generally arranged like 'the blades of a fan' with the interspaces increasing as the medial extremities are reached [10, 11]. The bands may be separable up to the point where they fuse with the aponeurosis lateral to the rectus muscle. In a fifth of cases, there are potential parietal deficits between these bands. Spigelian hernias occur through these defects in the region of the semilunar line, these defects being more pronounced in the lower abdomen.

At the lowermost part of the internal oblique muscle, adjacent to its origin from the inguinal ligament, the spermatic cord passes through or adjacent to the inferomedial margin of the muscle. Laterally the cord lies deep to the fleshy muscular fibres; then as it emerges alongside the muscle, it acquires a coat of cremaster muscle from the muscle.

The fascicles of the lower part of the internal oblique muscle follow a transverse or oblique direction. Medial to the cord, the muscle fibres are replaced with an aponeurosis which continues inferomedially to reach the pubis. There are variations both in the medial and the inferior extent of the muscle fibres of the internal oblique.

The fleshy muscle extends to the inferior margin in only 2% of cases; in 75% the extent is a centimetre or so above the margin, and in 20% there is a broad aponeurotic leaf superior to the spermatic cord. Likewise the fleshy muscle extends as far as the emergent cord in 20%, medial to the cord but not as far medially to the rectus margin in 75% and medial to the lateral margin of the rectus in 2%.

In clinical practice a direct inguinal hernia is never encountered when the lower margin of the internal oblique is fleshy *and* when the fleshy fibres extend medial to the superficial ring. Direct herniation is most frequently found at operation when the internal oblique muscle is replaced with flimsy aponeurosis in the roof of the inguinal canal (Fig. 2.23) [8].

In 52% of cases the lowermost arching fibres of the internal oblique are continuous above with the remainder of the internal oblique muscles, but in the remainder a variety of spaces between banding occur. In the medial and lower musculoaponeurotic part, defects superior to the spermatic cord may compromise the shutter mechanism of the canal and lead to direct inguinal herniation. Similarly, Spigelian hernia defects can develop between the muscle bands, enter the inguinal canal and present as direct inguinal hernia (Fig. 2.24) [12].

Rarely (0.15% of hernia cases), the spermatic cord is seen to come through the fleshy part of the lower muscle belly. In this rare situation, the muscle may be said to have an origin from the inguinal ligament medial to the emergent cord. In these cases there is prominent banding of the muscle in the lower abdomen; effectively, there is a band caudal to the cord (Fig. 2.25).

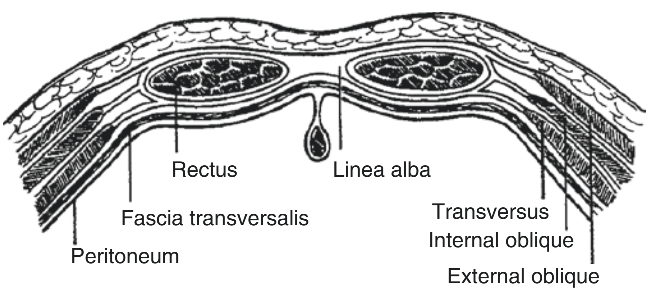

Fig. 2.22 Structure of the posterior rectus sheath in the upper abdomen. The internal oblique divides into two lamellae which enclose the rectus. The line of the fascia transversalis is deliberately emphasized

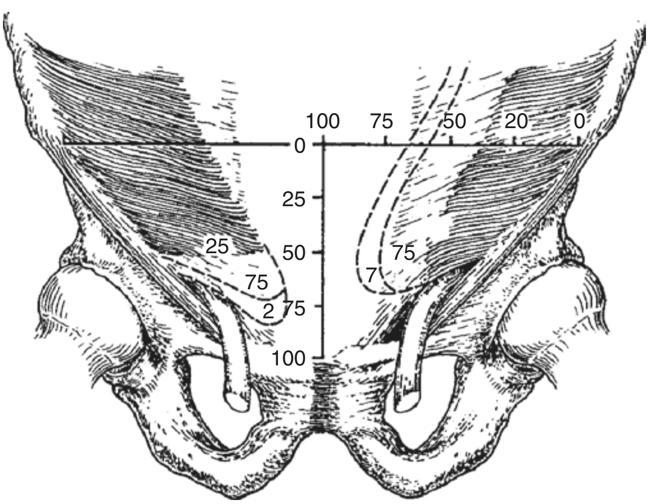

Fig. 2.23 Extent of the muscular fibers of the internal oblique. In only 2% of subjects the muscle extends inferiorly to the inguinal canal (*left* of diagram). Similarly the medial extent of the fleshy muscle fibers varies (*right* of diagram). The contribution of the internal oblique to the "defenses" of the inguinal canal is very variable [8] (from Anson et al.; with permission)

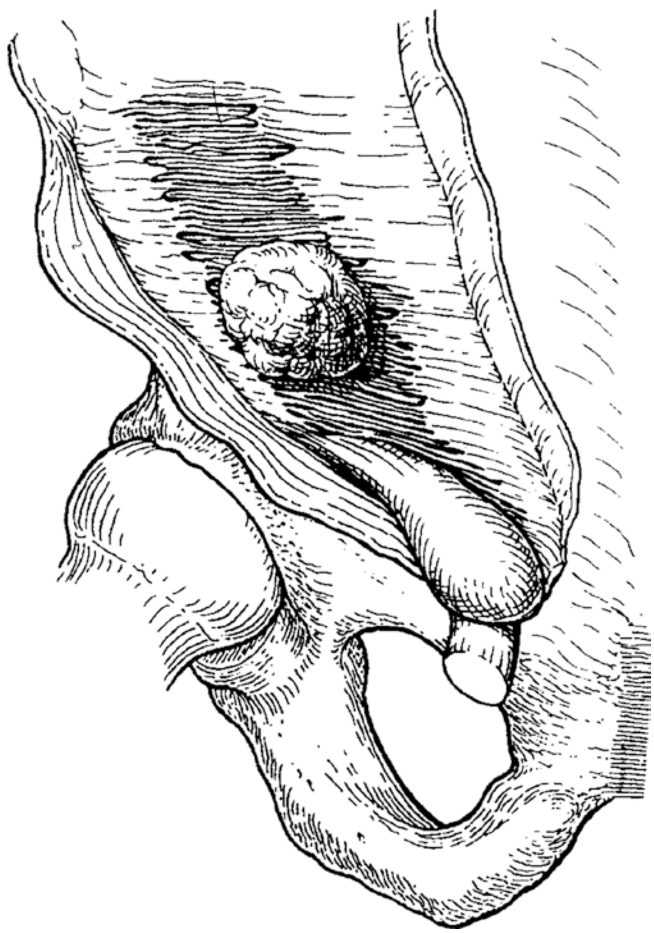

Fig. 2.24 A hernia can occur between bands of the internal oblique muscle. Although this hernia is in effect a variant Spigelian hernia, it presents as a direct hernia into the inguinal canal

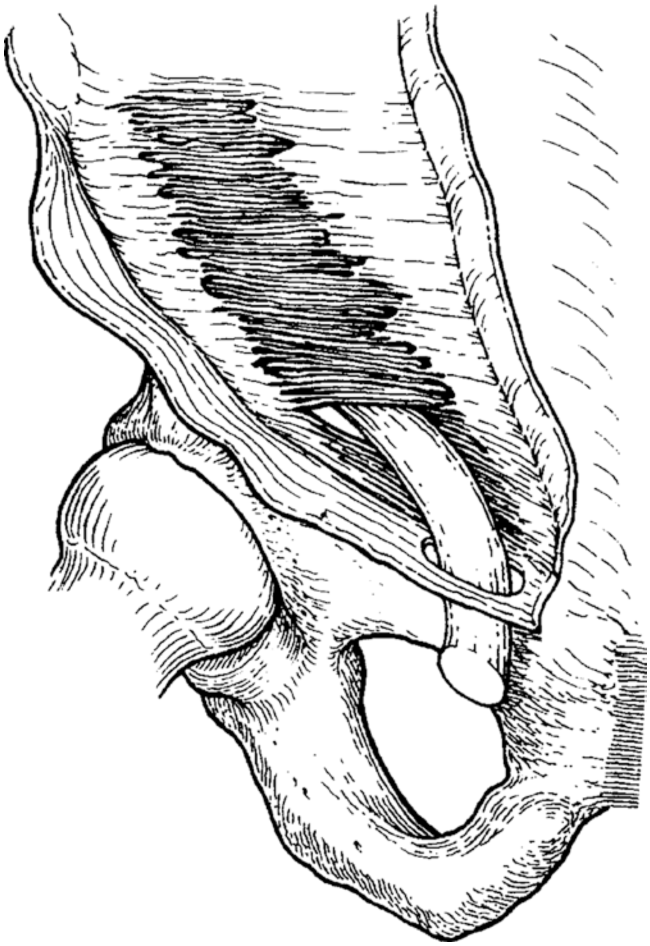

Fig. 2.25 Rarely fibers of the internal oblique muscle may extend medial to the deep ring, both above and below the ring, so that the cord is seen to pass between bands of the muscle

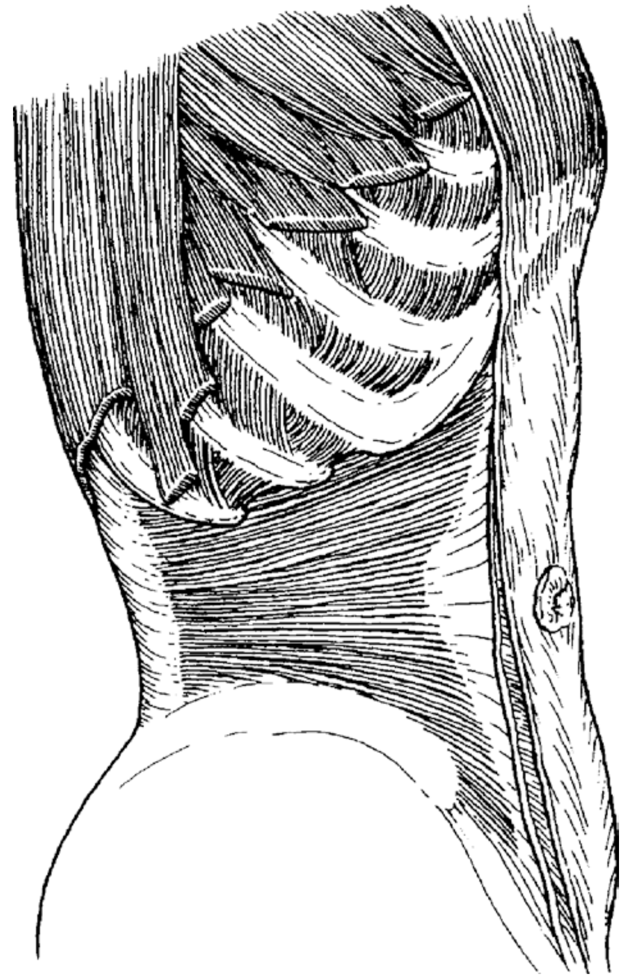

Fig. 2.26 The transversus muscle is the deepest of the anterolateral abdominal wall muscles; it arises from the iliopsoas fascia and inner lip of the iliac crest in its anterior two-thirds. The muscle extends to the inner surfaces of the lowest six costal cartilages, and its aponeurosis extends to the linea alba

The Transversus Abdominis Muscle

The transversus abdominis is the third and deepest of the three anterolateral abdominal muscle layers. The muscle arises in continuity from the inner surface of the costal margin, from the lumbar fascia, from the iliopsoas fascia along the internal lip of the anterior two-thirds of the iliac crest and from the lateral half or so of the superior surface of the inguinal ligament. The iliopsoas fascia is continuous posterosuperiorly with the anterior layer of the lumbar fascia, and the costal cartilages of the lower six ribs are interdigitating with the origin of the diaphragm (Fig. 2.26).

Traced anteromedially, the muscle fibres end in a strong aponeurosis which is inserted into the linea alba, the pubic crest and the iliopectineal line. For the most part, the muscle fibres run transversely, but the lowest of the muscle fibres take on a downward and medial curve so that the lower margin of the muscle forms an arch over the inguinal canal. The lower fibres of the muscle give way to the aponeurosis which gains insertion into the pubic crest and the iliopectineal line. The insertion of the transversus muscle is broader than that of the internal oblique, and consequently its aponeurosis extends further along the iliopectineal line (Fig. 2.27).

In the epigastrium and in the lower abdomen, down to a point midway between the umbilicus and the pubis, the transversus aponeurosis fuses with the posterior lamina of the aponeurosis of the internal oblique to form the posterior wall of the rectus sheath. In the lowermost abdomen, the aponeurosis passes in front of the rectus muscle and fuses with the deep surface of the aponeurosis of the internal oblique which in turn fuses with the deep aspect of the external oblique muscle to form the anterior wall of the rectus sheath (Fig. 2.28)

The transversus abdominis muscle is made up, proportionately, of more aponeurotic tissue and less muscle tissue than either the external or internal oblique muscles. In

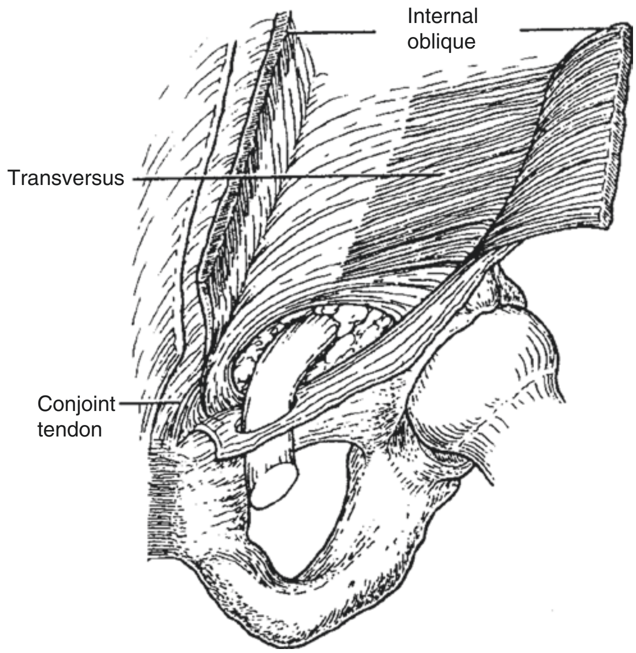

Fig. 2.27 The transversus muscle fibers run transversely, except in the lower abdomen where they form a strong aponeurosis (tendon) which is inserted to the pubic crest and the iliopectineal line. The insertion of the transversus tendon is broader than that of the internal oblique. The extent to which this tendon extends along the iliopectineal line determines its contribution to reinforcing the posterior wall of the inguinal canal. In surgical jargon the lowest fibers of the transversus aponeurosis cross over the cord to form the "roof" of the canal. These white aponeurotic fibers are referred to as the "arch" by some surgeons

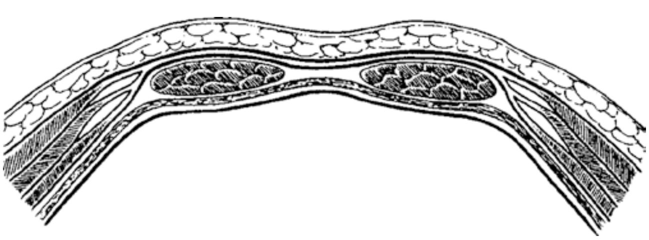

Fig. 2.28 Composition of the posterior rectus sheath in the lower abdomen. In the lower abdomen, inferior to the arcuate line of Douglas, the rectus sheath becomes deficient posteriorly. This is due to the fact that below the level of the arcuate line, all three aponeuroses (ext. oblique, int. oblique, and transversus abdominis) run in front of the rectus abdominis. The fascia transversalis, however, runs behind the rectus abdominis and in this location is denser and stronger than it is elsewhere

one study [8] it was observed that in 67% of cases fleshy muscle covered only the upper part of the inguinal region. In only 14% of cases were any fleshy fibres found in the lowermost fibres arching over the inguinal canal. Similarly, in 71% of subjects, the red fibres did not extend medial to the inferior epigastric vessels. The aponeurotic portion of the muscle shows its greatest anatomical variation in the inguinal region, where it is most important in hernia repair.

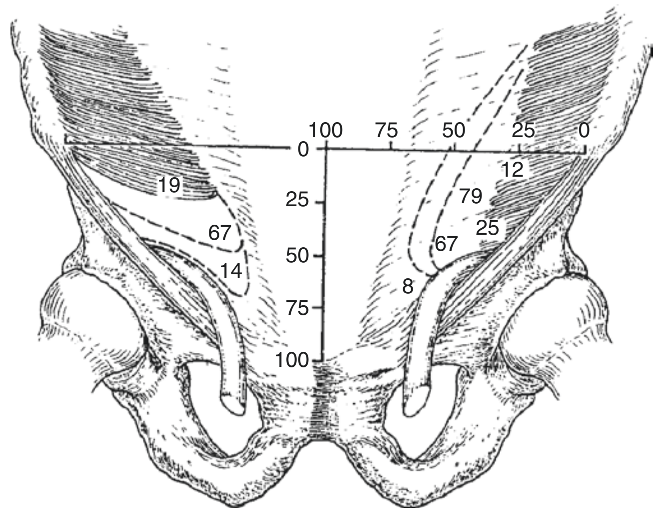

Fig. 2.29 The extent of fleshy red muscle in the transversus muscle is much less than in the internal oblique. Only in 14% of subjects is the lower margin of this muscle in the roof of the inguinal canal composed of red muscle (*left* of diagram). The medial extent of red fibers is similarly restricted; in 71% of subjects muscle fibers do not extend medially to the inferior epigastric vessels (*right* of diagram) [8] (from Anson et al.; with permission)

The lower border of the transversus abdominis aponeurosis is called the 'arch'. Above the arch the transversus aponeurosis forms a continuous strong sheet, with no spaces between its fibres. Below the arch the posterior wall of the inguinal canal is closed by transversalis fascia alone. This is a weak area through which direct herniation can occur. The aponeurotic arch is easily identifiable as a 'white line' of aponeurosis at operation (Figs. 2.27 and 2.29).

The Conjoint Tendon

The transverse fibres of the transversus muscle proceed horizontally to their insertion in the rectus sheath and the linea alba, while the lower fibres course downwards and medially—sometimes to fuse with the overlying fibres of the internal oblique as they insert onto the pubic crest and the iliopectineal line.

Only when the aponeuroses of the transversus and the internal oblique are fused some distance lateral to the rectus sheath is the term *conjoint tendon* appropriate and accurate. Thus the conjoint tendon represents the fused aponeuroses of the internal oblique and transversus muscles and which in turn is inserted onto the anteromedial 2 cm of the iliopectineal line. The transversus muscle contributes 80% of the substance of the conjoint tendon. The conjoint tendon is lateral to the rectus muscle and lies directly deep to the superficial inguinal ring. It passes down to its insertion on the pubis, deep to the inguinal and lacunar ligaments. The spermatic cord (or uterine round ligament) lies anterior to the conjoint tendon as it passes through the superficial inguinal ring.

The conjoint tendon has a very variable structure, and in 20% of subjects, it does not exist as a discrete anatomic structure. It may be totally absent or only partially developed, or it may be replaced by a lateral extension of the tendon of origin of the rectus muscle, or it may extend lateral to the deep inguinal ring so that no interval is present between the lower border of the transversus and the inguinal ligament. A shutter mechanism for the conjoint tendon can only be demonstrated when the lateral side of the tendon, that is, the transversus and internal oblique muscles, extends onto and is attached to the iliopectineal line [13]. The extent of this insertion is very variable. In 8% of cases, this attachment does not extend lateral to the rectus muscle, leaving the posterior wall of the inguinal canal (fascia transversalis) in such individuals unsupported. In 31% the attachment extends to the midpoint of the posterior wall between the pubic tubercle medially and the inferior epigastric vessels laterally; in 40% it extends as far laterally as the inferior epigastric vessels. In a minority of cases, bands of aponeurosis arise from the main aponeurotic arch and are inserted independently into the iliopectineal line. Sometimes, therefore, the lateral margin of the rectus sheath is formed only from the lowermost fibres of the transversus aponeurosis which curve inferiorly to become attached to the pubis—this is called the falx inguinalis.

A few fibres of the lowermost lateral margin of the rectus tendon may be fused with the fascia transversalis in their attachment to the iliopubic ligament—this has been called Henle's ligament (Fig. 2.30).

To understand the importance of the attachment of the internal oblique and transversus aponeuroses to the iliopectineal line, the posterior aspect of the inguinal canal must be visualized from inside the abdomen. If there is full attachment of the conjoint tendon to the iliopectineal line, the posterior wall of the inguinal canal may be said to be completely reinforced by aponeurosis. Absence of this attachment therefore renders the posterior wall devoid of reinforcement. In this situation there is clearly the potential for a direct hernia or a large indirect hernia to develop.

Of all the anatomic layers, the external oblique is the least variable; in the inguinal region, it is invariably aponeurotic. The internal oblique and transversus layers are very variable; they may be fleshy almost to the midline, aponeurotic or banded fan-like with the space between the musculoaponeurotic bands occupied only by the flimsiest fascia. If these local weaknesses in the internal oblique and transversus are superimposed, herniation is facilitated.

Zimmerman and colleagues have drawn attention to the frequency with which defects occur in the internal oblique and transversus muscles in this area. In 45% of their dissections, there was a defect in one or other of these two layers, and in 6% the defects were present in both layers and superimposed in the region of the lower linea semilunaris. These defects predispose to spontaneous ventral hernias either of preperitoneal fat or more extensive hernias with peritoneal sacs [13].

The Linea Alba and the Rectus Sheath

The linea alba is a longitudinally disposed, midline interdigitation (decussation) of the aponeuroses of the three-ply muscles of one side (external oblique, internal oblique and transversus abdominis) with those of the other. It is a pale band of dense fibrous tissue which extends from the xiphoid process above to the pubic symphysis, below. The linea alba is wide, thick and tough above the level of the umbilicus. It is broadest at the umbilicus, and below the umbilicus it becomes progressively narrower until it is little more than a narrow strip between the two rectus muscles at the suprapubic level. The linea alba is pierced by several small blood vessels and by the umbilical vessels in the foetus.

The anterior wall of the rectus sheath forms the most important portion of the abdominal wall aponeuroses. When the anterior wall of the sheath is gently dissected, during a paramedian incision, for example, it is seen to be made up of three laminae. The most superficial fibres of the anterior wall of the sheath are directed downwards and laterally; these are derived from the contralateral external oblique. The next layer is derived from the ipsilateral external oblique and has fibres which are oriented at right angles to those of the first layer, that is, they run downwards and medially. Finally, the third lamina of the anterior wall of the rectus sheath is formed from the anterior lamina of the ipsilateral internal oblique muscle, whose fibres generally run in the same direction as, and parallel to, the fibres of the external oblique of the opposite side. This gives the anterior rectus sheath a triple crisscross pattern similar to plywood [14, 15]. In the lower abdomen, the fusion of the external oblique aponeurosis to the internal oblique aponeurosis is very medial, an important anatomical arrangement that allows a tendon slide to be used to release the tension of the internal oblique in direct inguinal hernia repair without compromising the integrity of the anterior rectus sheath [14].

The most important feature from a surgical perspective is that the fibres of the rectus sheath run from side to side. Vertical incisions divide fibres, while horizontal incisions down closure with sutures encircling fibres rather than between fibres.

The posterior rectus sheath has a similar trilaminar crisscross pattern above the umbilicus, where it is composed of the posterior lamina of the internal oblique and the aponeurosis of the transversus abdominis muscle from either side.

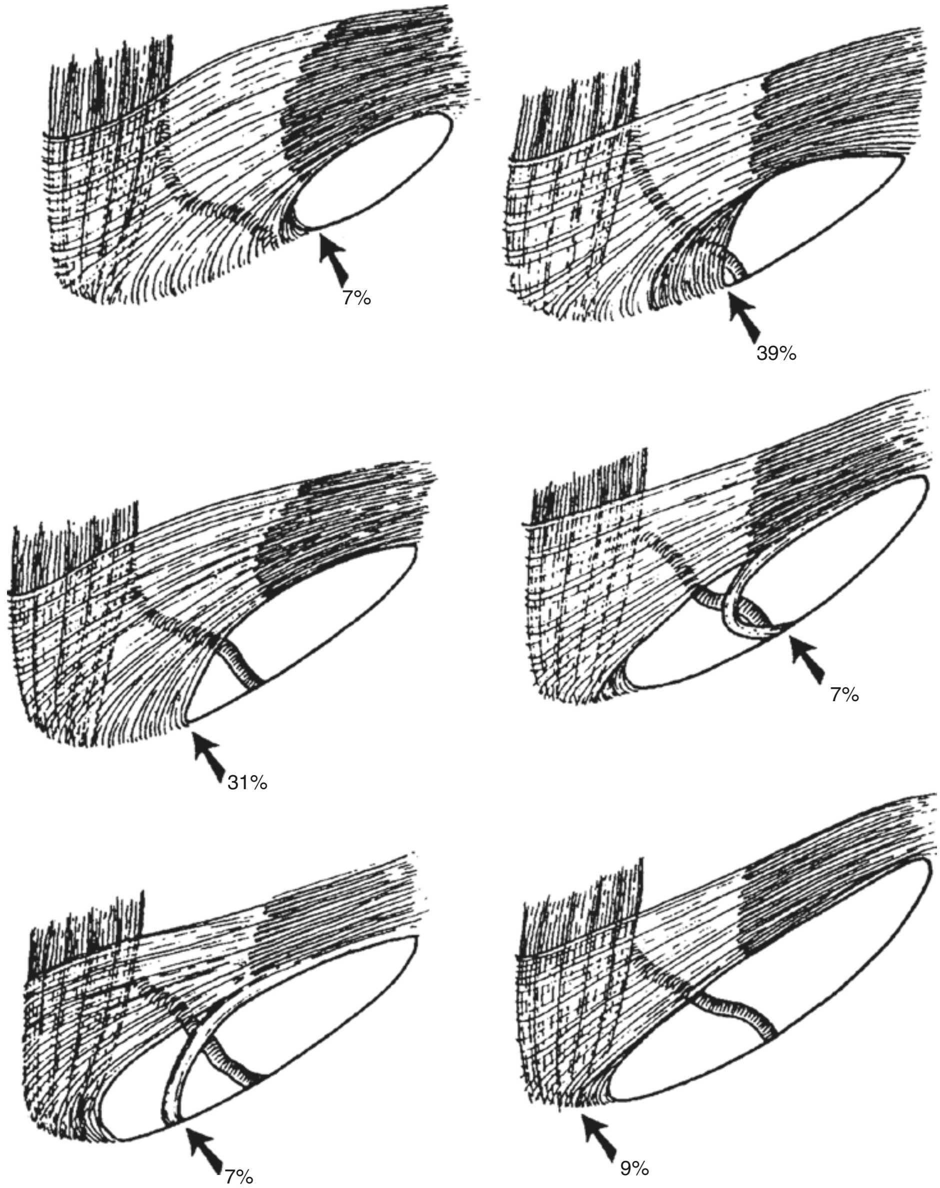

Fig. 2.30 The extent to which the tendon of transversus abdominis contributes to the posterior wall of the inguinal canal. In each illustration the *arrow* indicates the lateral most extension of the tendon and the corresponding percentage of subjects [8]

Within the rectus sheath are the rectus muscles, the pyramidalis muscle, the terminal portions of the lower six thoracic nerves and the superior and inferior epigastric vessels (Fig. 2.33).

Function of the Anterior Abdominal Wall

Although the anterior abdominal wall is composed of symmetrical halves, right and left, these halves function together in a coordinated and synergistic manner. The individual muscles cannot work separately and independently. The upper part of the anterior abdominal wall is the actively mobile respiratory zone, where the rectus sheath—the (anterolateral) flank muscles and the rectus muscle through its tendinous attachments to the rectus sheath—functions collectively as an accessory respiratory muscle. The lower part has no tendinous intersections and is a relatively fixed lower belly support zone. This anatomical and physiological configuration has been demonstrated using a transillumination silhouette technique by Askar [14].

The Fascia Transversalis: The Space of Bogros

The fascia transversalis lies immediately deep to the transversus abdominis muscle and, for the most part, is intimately adherent to the deep surface of the muscle. It is continuous from side to side and extends from the rib cage above to the pelvis inferiorly (Fig. 2.31).

In the upper abdominal wall, the fascia transversalis is thin, but in the lower abdomen and especially in the inguinofemoral region, the fascia is thicker and has specialized bands and folds within it. In the groin region, where the fascia transversalis is an important constituent of the posterior wall of the inguinal canal and where it forms the femoral sheath distal to the inguinal ligament, the anatomy and function of the fascia transversalis is of particular importance to the surgeon, as originally stated in his exquisite and detailed account of the fascia transversalis in the groin [16]. Sir Astley Cooper described the fascia transversalis as consisting of two layers. The anterior strong layer covers the deep aspect of the transversus abdominis muscle where it is intimately blended with the tendon of the transversus muscle. It then extends across the posterior wall of the inguinal canal medial to the deep ring and is attached to the inner margin of the medial end of the inguinal ligament. The posterior (deep) layer of fascia transversalis is a filmy, membranous layer and lies between the anterior substantial layer of fascia transversalis and the peritoneum. The extraperitoneal fat lies behind this filmy layer: between it and the peritoneum (Fig. 2.32). The (deep) inferior epigastric vessels run between the two layers of fascia transversalis.

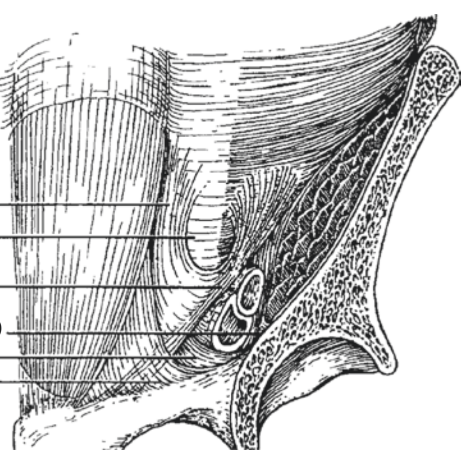

Fig. 2.31 The fascia transversalis, part of the endoabdominal fascia, lies on the deep surface of the transversus muscle. In the upper abdomen this fascia is thin and featureless; however, in the lower abdomen and pelvis the fascia transversalis has an important role. It is thickened and includes specialized bands and folds. It forms the posterior wall of the inguinal canal, and at the deep ring it has a condensation medial to the cord. This condensation is part of a U-shaped sling through which the cord passes. This sling hitches the cord up laterally when the transversus muscle contracts. Just above the inguinal ligament, the fascia transversalis is thickened as the iliopubic tract or Thomson's band [30]

These two distinct layers of fascia transversalis are readily identified laparoscopically and must be opened separately to allow access to the avascular preperitoneal space (of Bogros) when undertaking an extraperitoneal repair of a groin hernia either endoscopically or by open surgery. The deeper layer extends down behind the inguinal canal and fuses with the pectineal ligament (of Cooper) before continuing downwards into the pelvis. The deeper layer fuses with the spermatic cord at the deep ring and continues along the cord as part of the internal spermatic fascia [16–18]. The existence of the bilaminar structure of the fascia transversalis at the deep ring was confirmed by Lytle [19] and by Cleland et al. [20], but its nature was disputed by Anson et al. [8], and its relevance and importance were questioned by experienced surgeons [22].

The dissection of both layers of fascia transversalis from the cord structures at the deep inguinal ring is an important component of hernioplasty; it allows dissection of an indirect peritoneal sac and allows the divided peritoneal stump to retract at the deep ring in a classic Bassini and Shouldice operation for indirect hernias.

In the lower abdomen, it is attached laterally to the internal lip of the iliac crest, along which line it becomes continuous with the fascia over the iliacus and psoas muscles. From these lateral attachments, the fascia extends medially as a continuous curtain, which is interrupted only by the transit of the spermatic cord at the deep inguinal ring. The fascia transversalis invests the cord structures as they pass through it with a thin layer of fascia, the internal spermatic fascia. On the medial margin of the deep ring, the fascia transversalis is condensed into a U-shaped sling, with the cord supported in the concavity of the ring and the two limbs extending superiorly and laterally to be suspended from the posterior aspect of the transversus muscle. The curve of the 'U' lies at or just below the 'arched' lower border of the aponeurosis of the transversus muscle.

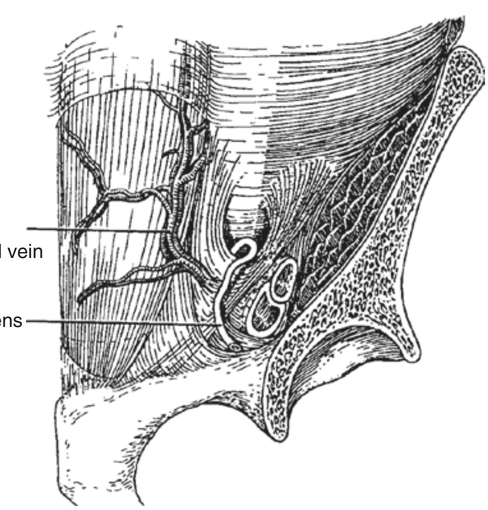

Fig. 2.32 Seen from behind, the view from within the abdomen, the inferior epigastric vessels are deep, on the abdominal side, of this curtain of fascia transversalis. The vas deferens and cord structures ascend to and hook over the sling of fascia transversalis at the deep ring

This U-shaped fold, the fascia transversalis sling, is the functional basis of the inguinal 'shutter' mechanism; as the transversus muscle contracts during coughing or straining, the column/pillars of the ring are pulled together and the entire sling drawn upwards and laterally. This motion increases the obliquity of exit of the spermatic cord structures through the ring and provides protection from forces tending to cause an indirect hernia (Figs. 2.33 and 2.34) [19, 30]. The reconstruction of this sling medially with preservation of the function of the ring laterally is the rationale of anterior inguinal hernioplasty. In front of the ring lies the lower border of the transversus muscle and the internal oblique muscle. Each of these structures supports the internal ring, and together they provide a very effective valve when the intra-abdominal pressure rises.

The 'shutter' action of the internal ring, the fascia transversalis sling, can be demonstrated readily at operation under local anaesthetic. If the patient is asked to cough, the ring is suddenly pulled upwards and laterally behind the lower margin of the transversus muscle. In the adult with an obliterated processus vaginalis, a flat lid of peritoneum covers the ring internally for the spermatic vessels, and the vas deferens lies extraperitoneally. The spermatic vessels pass down almost vertically retroperitoneally on the psoas muscle. As they enter the narrow gutter of the groin, they are joined by the vas deferens: the spermatic cord thus formed turns obligingly upwards and then hooks around the fascia transversalis sling to enter the deep ring, acquiring an investment of internal spermatic fascia as it traverses the ring (Fig. 2.35).

The inferior border of the internal ring abuts on a condensation of the fascia transversalis, the iliopubic tract or bandelette iliopubienne of Thomson. This narrow fascial band extends from the anterior superior iliac spine laterally to the pubis medially. The band is a condensation (and integral part) of the fascia transversalis; it lies on a plane somewhat deeper than the inguinal ligament which can be readily demonstrated as distinct from it, at operation. The iliopubic tract bridges the femoral canal medially and then curves inferiorly and posteriorly to spread out fanwise to its attachment to a broad area of the superior ramus of the pubis along the iliopectineal line just behind Cooper's ligament. The iliopubic tract thus forms the inferior margin of the defect in the fascia transversalis both in an indirect inguinal hernia and in a direct hernia [29, 31]. However, it is superior to the neck of the peritoneal sac of a femoral hernia (Figs. 2.31 and 2.36).

The fascia transversalis superior to the iliopubic tract extends over the posterior wall of the inguinal canal up to and posterior to the arch of the transversus muscle. Medially the fascia transversalis runs behind the aponeurosis of the transversus abdominis muscle and thereby blends with the posterior wall of the rectus sheath above the level of the arcuate line. Below the level of the arcuate line, it is directly related to the posterior surface of the rectus abdominis. Inferolaterally, it is directly posterior to the lowermost arch-

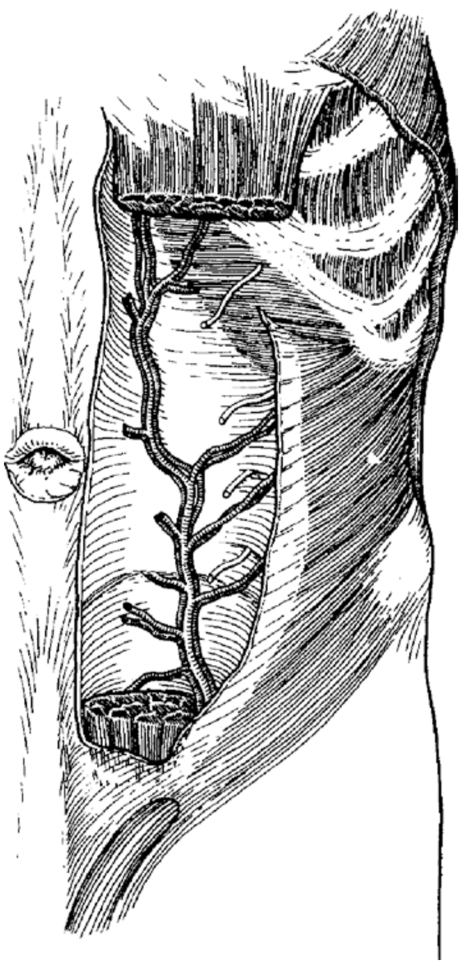

Fig. 2.33 Rectus sheath and linea alba. The contents of the rectus sheath are the rectus and pyramidalis muscles, the superior and inferior epigastric vessels, and the terminal branches of the lower six thoracic nerves

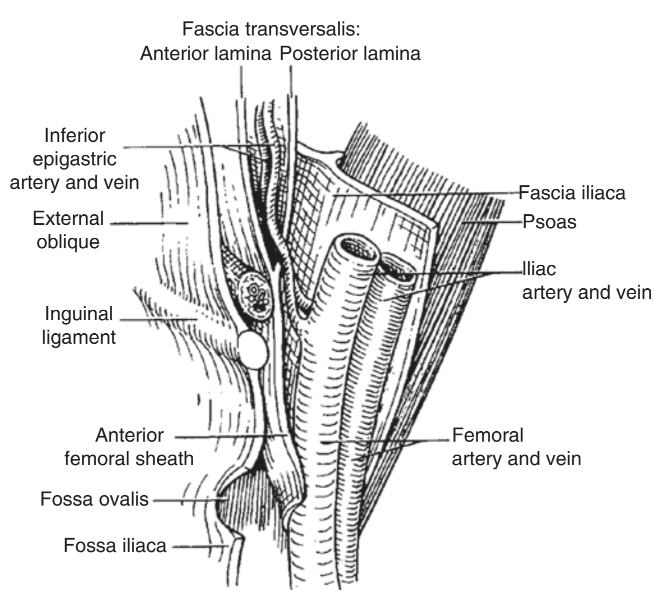

Fig. 2.34 The bilaminar fascia transversalis in the groin [18, 29]

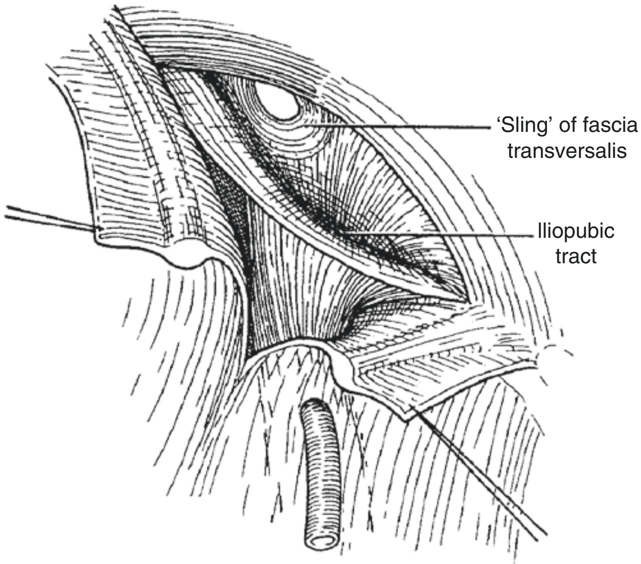

Fig. 2.35 Dissected further anteriorly, if the inguinal ligament is divided, the fascia transversalis can be seen to be continuous with the femoral sheath. The thickening at the junction of fascia transversalis with the femoral sheath is the iliopubic tract. The internal oblique muscle, which arises from the lateral inguinal ligament, acts as a shutter or "lid" on the deep inguinal ring

ing fibres of transversus abdominis muscle and conjoint tendon. The fascia transversalis in the posterior wall of the inguinal canal is supported to a variable extent by the aponeurosis of the transversus muscle as it arches down to its attachment to the pubis and iliopectineal line. Medial to the deep inguinal ring and deep to the fascia transversalis, lying in the extraperitoneal fat between the peritoneum and the fascia, the deep epigastric vessels follow an oblique course upwards and medially to the deep aspect of the rectus muscle. This triangular area, bounded by the deep epigastric vessels laterally, the lateral margin of the rectus muscle medially and the inguinal ligament below, is known to surgeons as Hesselbach's triangle; this is the area through which a direct inguinal hernia protrudes.

More exactly, a direct hernia explodes through the fascia transversalis in the area bounded by the iliopubic tract inferiorly, the medial limb of the fascia transversalis sling laterally and the lower margin of the arch of the transversus aponeurosis superiorly.

Condon [21, 22] has investigated the anatomy of the fascia transversalis using a technique of transillumination of fresh tissue. He clearly shows these anatomic details and defines the margins of the aponeurotic deficiency in the pos-

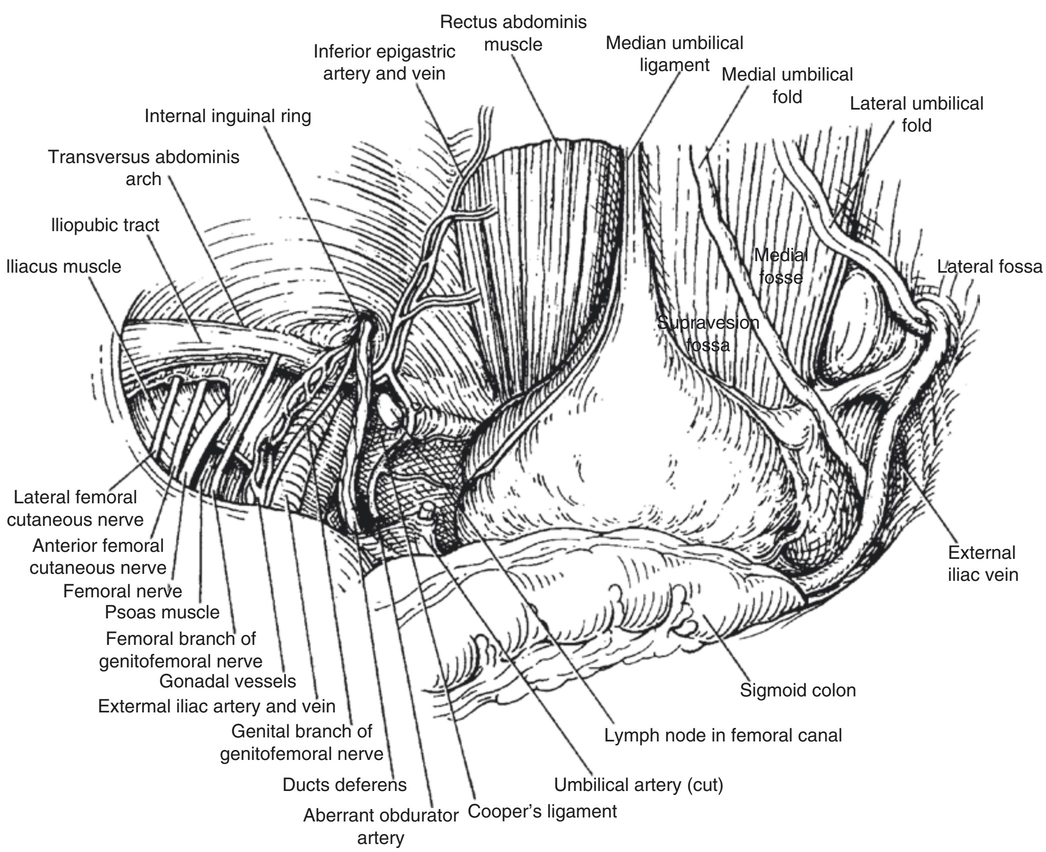

Fig. 2.36 The posterior view of the lower abdomen. The peritoneum is intact on the right side, illustrating the fossae demarcated by the umbilical ligaments. On the contralateral side the peritoneum has been removed to allow visualization of the extraperitoneal structures, the vessels and nerves [5, 31]

terior inguinal canal wall through which direct hernia protrudes. This area of fascia transversalis is buttressed anteriorly to a greater or lesser degree by the aponeurosis of the transversus muscle as it inserts to the iliopectineal line. At operation these features—the iliopubic tract, the deep ring and the 'line' of the arch of the transversus aponeurosis—are easily identifiable if the fascia transversalis is adequately dissected. Indeed, the identification of all these features is an essential prerequisite to adequate inguinal hernioplasty (Fig. 2.36) [22].

The fascia transversalis in the groin is but a part of the fascial continuum which surgical anatomists refer to as the endoabdominal fascia. This fascia is distinct in the lower abdomen but is fused into the fascia on the deep surface of the transversus abdominis muscle superiorly. This composite layer, the transversus muscle and its fascia (the fascia transversalis), is the most important of the abdominal wall strata in solving the problem of inguinofemoral hernia, as the integrity of this layer prevents herniation. Defects in it, congenital or acquired, are the aetiology of all groin hernias.

The fascia transversalis descends behind the inguinal ligament into the thigh as the sheath of the femoral vessels—this is a funnel-like sheath. Inferior to the inguinal ligament, the fascia transversalis attaches to the iliopectineal line medially and posteriorly to the femoral vessels. This funnel of fascia transversalis extends into the thigh as far as the fossa ovalis in the deep fascia. This anatomic arrangement allows for a small 'space' medial to the femoral vein through which some lymphatics pass. When a femoral hernia develops, this 'space' is expanded (Figs. 2.37 and 2.38).

What, then, is the anatomy of the peritoneum in relation to the layers of the abdominal wall we have considered previously? In the lower abdomen, the peritoneum is thrown up into five folds which converge as they pass upwards to the umbilicus. The median umbilical fold extends from the apex of the bladder to the umbilicus and contains the remnant of the urachus. To either lateral side, the medial umbilical fold contains the obliterated umbilical artery, and more laterally the inferior epigastric vessels raise the lateral umbilical fold. These folds create depressions or fossae in the anterior abdominal peritoneum: the supravesical fossae right and left and the medial and the lateral inguinal fossae right and left. A further depression on either side is below and medial to the lateral inguinal fossa and separated from it by the inguinal ligament. This overlies the femoral ring and is called the femoral fossa.

Hernias egress through these fossae—the femoral through the femoral fossa, the indirect inguinal through the lateral inguinal fossa and the direct through the medial fossa. Internal supravesical hernias can occur in the supravesical fossa (Fig. 2.36).

The landmarks are the peritoneal folds, particularly the medial umbilical ligament (containing the obliterated umbilical artery), and the lateral umbilical fold (containing the

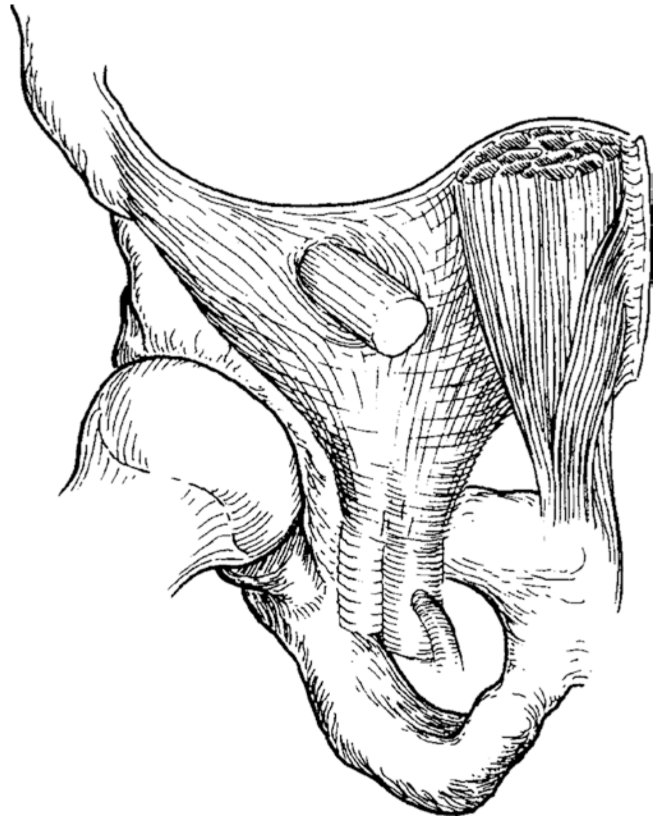

Fig. 2.37 From the front, as the surgeon visualizes the subject, the fascia transversalis in the groin resembles a funnel with a valved side vent. The femoral vessels come out of the funnel below and the cord structures out of the "side vent" which is "valved" by the sling of the fascia transversalis at the deep ring

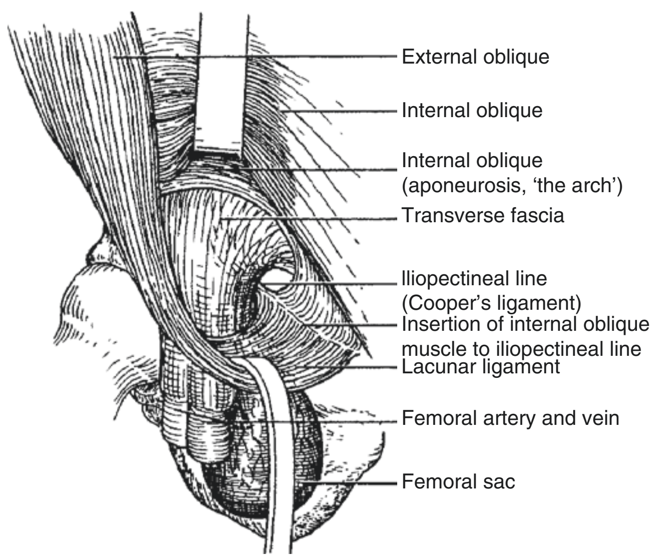

Fig. 2.38 A dissection to demonstrate the anatomy of a femoral hernia. The femoral cone of fascia transversalis is stretched on its medial aspect; the hernial sac extends within this cone of fascia transversalis medial to the femoral vein and lateral to the lacunar ligament

inferior epigastric vessels). The peritoneum overlying the deep inguinal ring is identified with the testicular vessels and vas deferens in the male, and the round ligament of the uterus in the female, all clearly visible beneath the peritoneum. The peritoneum is separated from the underlying fascia transversalis by adipose tissue except medial to the deep ring where the peritoneum is more firmly fixed to the overlying fascia transversalis. Below, posterior to, the inguinal ligament the genital branch of the genitofemoral nerve is seen joining the cord structures at the deep ring.

The lateral cutaneous nerve of the thigh and the femoral branch of the genitofemoral nerve lie rather deeper in the fatty tissue overlying the iliopsoas muscle. Blood vessels are also found in the adipose tissue beneath the peritoneum, in the extraperitoneal plane branches of the deep circumflex iliac vessels laterally and of the obturator vessels inferiorly and medially. There is an extensive venous circulation (anastomosis) in the extraperitoneal tissues between the inferior epigastric vein and obturator veins. This venous anastomosis lies between the two lamina of the fascia transversalis in the space of Bogros [17]. This space is continuous from side to side and with the pelvic space, the cave of Retzius. The space of Bogros is important for extraperitoneal repair of hernia and is the repository of bleeding in pelvic trauma.

The Peritoneum: The View from Within

Hernia sacs are composed of peritoneum, and they may contain intra-abdominal viscera. From within they consist of the peritoneum, then a loose layer of extraperitoneal fat, then the deep membranous lamina of fascia transversalis, then the vessels such as the epigastric vessels in the space of Bogros, then the stout anterior lamina of fascia transversalis and then the muscles and aponeuroses of the abdominal wall [23]. The preperitoneal space lies in the abdominal cavity between the peritoneum internally and transversalis fascia externally. Within this space lies a variable quantity of adipose tissue, loose connective tissue and membranous tissue and other anatomical entities such as arteries, veins, nerves and various organs such as the kidneys and ureters. The clinically significant parts of the preperitoneal space include the space associated with the structural elements related to the myopectineal orifice of Fruchaud, the prevesical space of Retzius, the space of Bogros and retroperitoneal periurinary space [24]. The myopectineal orifice of Fruchaud represents the potentially weak area in the abdominal wall, which permits inguinal and femoral hernias. The preperitoneal space that lies deep to the supravesical fossa and the medial inguinal fossa is the prevesical space of Retzius. The space of Retzius contains loose connective tissue and fat but more importantly vascular elements such as an abnormal obturator artery and vein. Bogros' space, which is a triangular area between the abdominal wall and peritoneum, can be entered by means of an incision through the roof and floor of the inguinal canal through which the posterior preperitoneal approach for hernia repair can be achieved. In the groin these muscles and aponeuroses are variously absent over the inguinal and crural canals. The myopectineal orifice of Fruchaud [25, 26] (Fig. 2.39) denotes a well-defined area through which all groin hernias present. Such a unifying concept of a single groin aperture is relevant for mesh repairs, whether repair is achieved by anterior open operation or by posterior endoscopic operation. The boundaries of the myopectineal orifice of Fruchaud are as follows: superiorly the 'arch' of the transversus muscle, laterally the iliopsoas muscle, medially, the lateral border of rectus abdominis muscle and inferiorly, the superior ramus of the pubis [27]. The space is utilized in both the transabdominal preperitoneal and the totally extraperitoneal laparoscopic approaches to the repair of inguinal and femoral repairs. A thorough understanding of the limits of this myopectineal orifice is necessary to accomplish an effective repair of the inguinal floor using laparoscopic methods.

Between the peritoneum and the fascia transversalis, there is a loose layer of extraperitoneal fat, used as an important landmark in many surgical operations. Hernial protrusions progress from within outwards through deficiencies in the musculoaponeurotic lamina of the abdominal wall; they carry this extraperitoneal fat with them along the track of the hernia sac. Abundance of this fat at the fundus of an indirect

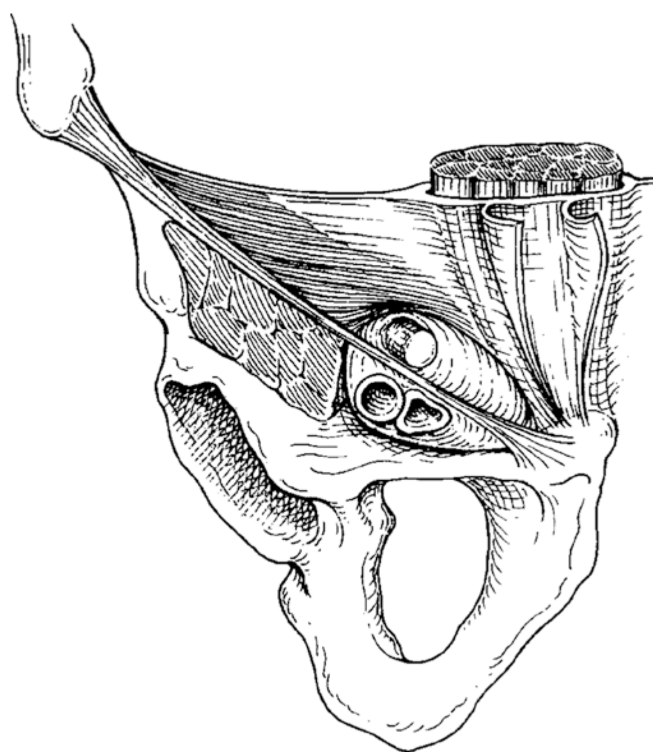

Fig. 2.39 The "myopectineal orifice of Fruchaud": the area of the groin limited above by the arching fibers of internal oblique and transversus abdominis, and below by the superior ramus of the pubis. It is crossed obliquely by the rigid inguinal ligament above which is the inguinal canal and below which lies the femoral canal [26]

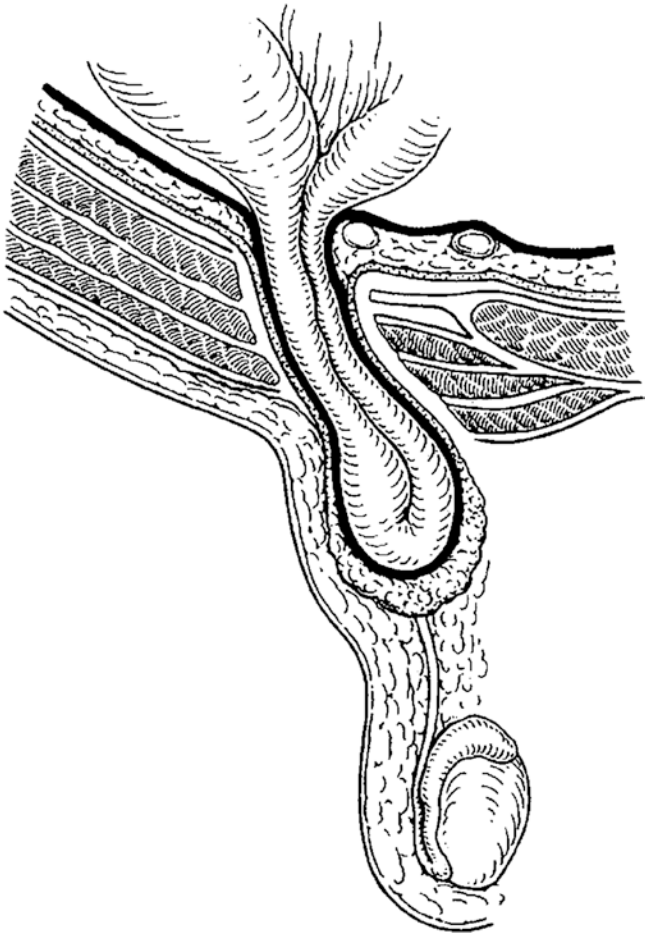

Fig. 2.40 As the peritoneum forms an indirect inguinal hernia it carries with it a covering of extraperitoneal fat. This extraperitoneal fat is referred to by many surgeons as "lipoma of the cord"

inguinal hernia gives rise to the surgical misnomer a 'lipoma of the cord'—in reality this is no more than extraperitoneal fat around the fundus of a peritoneal hernia sac (Fig. 2.40).

The Umbilicus

Between the sixth and tenth week of gestation the abdominal viscera enlarge rapidly and to such an extent that they can no longer be contained within the proportionately smaller coelomic cavity. Consequently, developing viscera (derived exclusively from the mid-gut) are temporarily extruded through the broad umbilical deficit into the exocoelom which occupies the base of the umbilical cord. At about the tenth week the abdominal cavity has enlarged sufficiently to reaccommodate the extruded viscera, and by the time of birth all the intestines are contained within the abdominal cavity proper. At birth the abdominal wall is complete except for the space occupied by the umbilical cord. Running in the cord are the urachus (from the apex of the urinary bladder), the umbilical arteries coursing up from the pelvis, and the

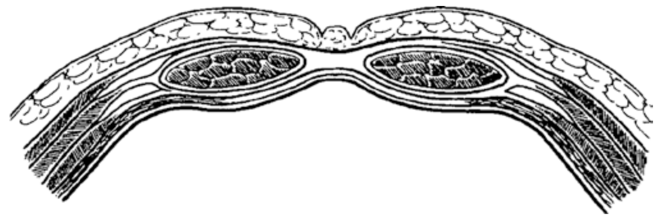

Fig. 2.41 Cross section through the umbilicus and adjacent anterior abdominal wall. The aponeuroses of the anterolateral abdominal muscles of the two sides are fused with each other in the umbilical cicatrix

umbilical vein directed to the liver. After the cord is ligated the stump sloughs off and the resultant granulating surface cicatrizes and epithelializes from its periphery.

In the normal umbilicus there is a single layer of fused fibrous tissue consisting of the superficial fascia, the medial edge of the rectus sheath and linea alba, and the fascia transversalis. The peritoneum is adherent to the deep aspect of this (Fig. 2.41).

The Spermatic Cord

The spermatic cord is composed of (a) arteries (the testicular artery, the artery to the vas deferens and the cremasteric artery), (b) veins (the testicular veins which arise from the pampiniform venous plexus within the spermatic cord), (c) lymphatics, (d) nerves (the genital branch of the genitofemoral nerve and autonomic nerves), (e) vas deferens and (f) the processus vaginalis.

The spermatic cord, as it emerges through the abdominal wall from the deep inguinal ring, receives investments of fascia. The fascia transversalis forms a thin, funicular coat called the internal spermatic fascia: the internal oblique invests it with a tracing of muscle fibres, the cremaster muscle, and most superficially it is coated with external spermatic fascia derived from the external oblique aponeurosis at the margins of the superficial inguinal ring. Each of these fascial layers requires opening to identify the processus vaginalis or sac of an indirect hernia. Until birth the processus vaginalis, although minute and narrow, is nevertheless an uninterrupted diverticulum from the abdominal peritoneum through the length of the cord to the testis, where it opens out to become the tunica vaginalis of the testis. Normally, the processus vaginalis becomes obliterated in most males soon after birth, except for the portion of the processus that surrounds the testis. This unobliterated part is known as the tunica vaginalis testis. More recently, the persistence of the processus vaginalis into adult life has been confirmed when hydrocele or hernia has complicated peritoneal dialysis in renal failure patients. The theories and mechanism of testicular descent and the development of the processus vaginalis (Fig. 2.42) are described in detail in Chap. 9.

An indirect inguinal hernia sac is a similar peritoneal diverticulum which extends into the spermatic cord and occupies the same position as the primitive processus vaginalis. Often indirect hernias also have extraperitoneal fat at their fundus.

Comparative Anatomy

A cool environment for spermatogenesis is a necessity in warm-blooded birds and mammals. Birds, which have high blood temperatures and are invariably cryptorchid, keep their testes cool by an air stream around the abdomen. In some sea-living mammals—whales and sea cows—the testes remain intra-abdominal, but presumably the constant contact with cold water is effective in keeping them cool.

The necessity to have the testes reside in a cooler temperature as prevails in the scrotum leads to problems, not only in humans but also in domestic and farm animals; the topic of hernia and undescended testicles appears in veterinary textbooks where it has a practical and economic importance of its own. Inguinal hernias are fairly common in pigs and horses but less common in bovine species. The economic consequence of an inguinal hernia in a stallion is considerable; the hernia may become incarcerated during mating, and this may hinder full consummation. A similar problem is documented in stud bulls. Hernias are relatively common in dogs but are rather rare in cats. Dogs, both male and female, may develop inguinal hernias, but the males are more likely to have intestine caught within the hernia sac. When a female dog develops a hernia, the usual content is one of the uterine horns and the broad ligament; this can present the danger of strangulation if the animal becomes pregnant (the content of a congenital hernia in a girl is most likely an ovary and/or fallopian tube). In the dog, most veterinary surgeons treat the hernia by orchidectomy (a proposition which is sometimes put forwards for dealing with the same situation in the elderly human).

Bats have testicles which are normally intra-abdominal and descend into the scrotum only at the time of mating. In these animals there is a low incidence of hernia and of a patent processus vaginalis. The testicles in bats descend to the scrotum and ascend to the abdomen, although there is no patent processus vaginalis. In small boys with retractile testicles which disappear up to the external inguinal ring, a hernia is rarely present.

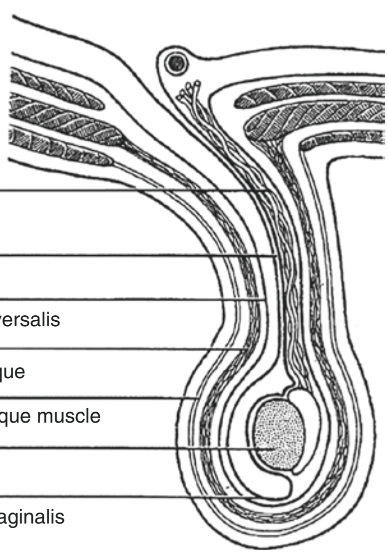

Fig. 2.42 Section through the spermatic cord and testis. The importance of the layers is demonstrated. The external spermatic fascia is derived from the fascia over the external oblique muscle at the superficial ring, the cremaster arises from the internal oblique muscle, and the internal spermatic fascia is the continuation of the fascia transversalis over the cord structures. Each of these layers needs division in inguinal hernia repair

Radiological Anatomy

Precise knowledge of the radiological anatomy is the key to success in the diagnosis and evaluation of groin masses which defy clinical diagnosis. Several diagnostic modalities are available including conventional radiography, ultrasound, CT and MRI scanning [28]. Herniography can be used in the diagnosis of hernia for patients with equivocal findings or those presenting with groin pain (see Chap. 11). The technique involves intraperitoneal administration of 50 ml of non-ionic contrast medium; a standard series of views of both groins is obtained during straining with the patient prone and in a slightly elevated position, as follows: posteroanterior, posteroanterior with caudocranial angulation of the tube (15°), two oblique views and a lateral view. A normal herniogram shows the median medial and lateral umbilical folds and the supravesical, medial inguinal and lateral inguinal fossae (Fig. 2.43). A disadvantage of her-

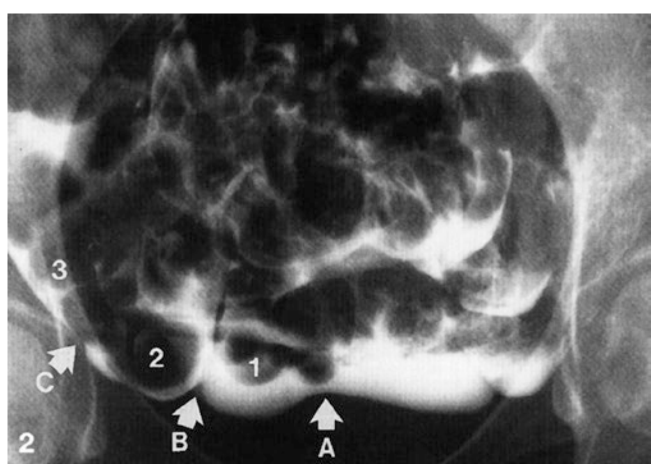

Fig. 2.43 Normal herniography. *A*, median umbilical fold; *B*, medial umbilical fold; *C*, lateral umbilical fold; *1*, supravesical fossa; *2*, medial inguinal fossa; *3*, lateral inguinal fossa

Fig. 2.44 Extended field-of-view ultrasound image demonstrating part of the anterior abdominal wall. *A*, external oblique muscle; *B*, internal oblique muscle; *C*, transversus muscle; *D*, rectus abdominis muscle

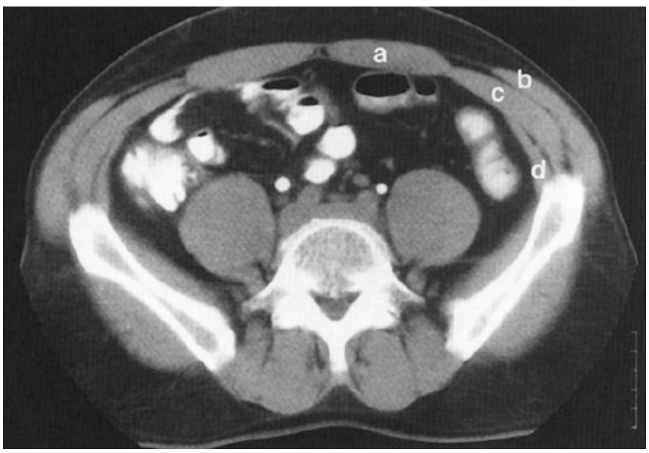

Fig. 2.45 A CT scan demonstrating normal anatomy of the muscles of the abdominal wall. *a*, Rectus abdominis muscle; *b*, external oblique muscle; *c*, internal oblique muscle; *d*, transversus muscle

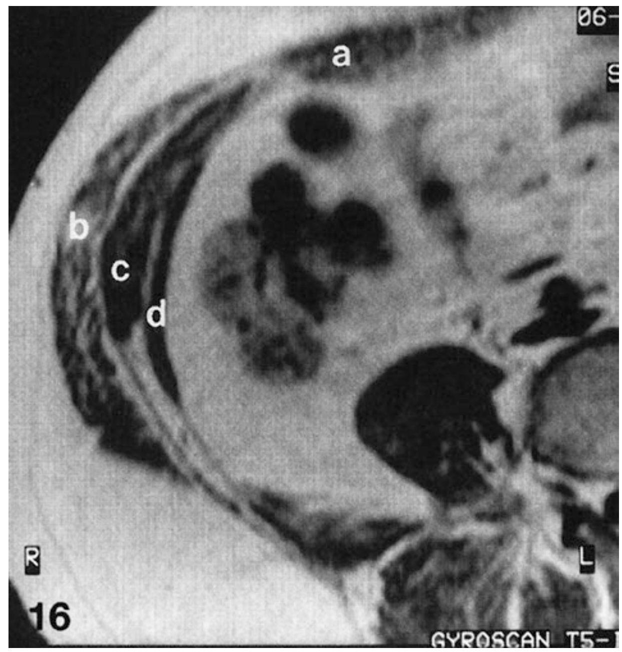

Fig. 2.46 Transverse T2-weighted MR image depicting the muscles of the anterior abdominal wall; *a*, rectus abdominis muscle; *b*, external oblique muscle; *c*, internal oblique muscle; *d*, transversus muscle; *R*, lateral; *L*, medial

niography is its invasiveness and its inability to depict pathological conditions other than hernias.

Ultrasonography with a high-frequency (7.5–10 MHz), short-focus transducer can depict the muscle and fascial layers of the abdominal wall and groin region. In these patients 5- or even 3.5-MHz transducers may be used which however result in low-resolution images. The entire anterior abdominal wall including the oblique muscles, transversus muscle, rectus abdominis and peritoneum can be visualized separately and clearly (Fig. 2.44). A major advantage is the ability to perform the examination in supine and upright positions as well as at rest and during straining, the so-called dynamic scanning technique. Yet another advantage is that ultrasound examination is noninvasive and allows comparison between the symptomatic and the asymptomatic side. The disadvantage however is its operator dependency and the considerable variation in imaging quality associated with the body habitus of the subject.

Computed tomography (CT) is usually performed in the inguinal region during breath-hold without straining. The anatomy of the anterior abdominal wall can be delineated clearly (Fig. 2.45). Because the inferior epigastric vessels forming the lateral umbilical folds can be clearly identified, CT is very reliable in helping differentiate between direct and indirect inguinal hernias.

Magnetic resonance imaging (MRI) has the advantage of being able to obtain images in any plane either by direct scanning in different planes or by making multiplanar reconstructions on a work station. MRI can also be performed during straining to gain dynamic images. The layers of the anterior abdominal wall (including transversalis fascia, extraperitoneal fat and peritoneum) can be delineated with precision using MRI (Fig. 2.46). CT scanning and MRI imaging have approximately the same order of sensitivity and specificity in diagnosing groin hernias.

References

1. Anson BJ, McVay CB. The anatomy of the inguinal region. Surg Gynecol Obstet. 1938;66:186–94.
2. Hesselbach FK. Neueste Anatomisch-Pathologische Untersuchungen uberden Ursprung und das Fortschreiten der Leisten und Schenkelbruche. Warzburg: Baumgartner; 1814.
3. Rozen WM, Ashton MW, Taylor GI. Reviewing the vascular supply of the anterior abdominal wall: redefining anatomy for increasingly refined surgery. Clin Anat. 2008;21:89–98.
4. Ruge, 1908 Cited in Rauber's Lehrbuch der Anatomie des Menschen, Kopsch FR Abt Nervansystem: 388, 1920.
5. Van Mameren H, Go PMNYH. Anatomy and variations of the internal inguinal region. In: Schumpelick V, Wantz GE, editors. Inguinal hernia repair. Basel: Karger; 1994.
6. Yeates WK. Pain in the scrotum. Br J Hosp Med. 1985;133:101–4.
7. McVay CB. The anatomy of the relaxing incision in inguinal hernioplasty. Q Bull N West Univ Med Sch. 1962;36:245–52.
8. Anson BJ, Morgan EH, CB MV. Surgical anatomy of the inguinal region based upon a study of 500 body halves. Surg Gynecol Obstet. 1960;111:707–25.
9. Acland RD. The inguinal ligament and its lateral attachments: correcting an anatomical error. Clin Anat. 2008;21:55–61.
10. Spangen L. Spigelian hernia. Acta Chir Scand Suppl. 1976;462:1–47.
11. Zimmerman LM, Anson BJ. Anatomy and surgery of hernia. 2nd ed. Baltimore: Williams and Wilkins; 1967. p. 216–27.
12. Ulbak S, Ornsholt J. Para-inguinal hernia: an atypical spigelian variant. Acta Chir Scand. 1983;149:335–6.
13. Zimmerman LM, Anson BJ, Morgan EH, CB MV. Ventral hernia due to normal banding of the abdominal muscles. Surg Gynecol Obstet. 1944;78:535–40.
14. Askar O. Surgical anatomy of the aponeurotic expansions of the anterior abdominal wall. Ann R Coll Surg Engl. 1977;59:313–21.
15. Rizk NN. A new description of the anterior abdominal wall in man and mammals. J Anat. 1980;131:373–85.
16. Cooper A. The anatomy and surgical treatment of inguinal and congenital hernia I. London: T Cox; 1804.
17. Bendavid R. The space of Bogros and the deep inguinal circulation. Surg Gynecol Obstet. 1992;174:355–8.
18. Read RC. Cooper's posterior lamina of transversalis fascia. Surg Gynecol Obstet. 1992;174:426–34.
19. Lytle WJ. The deep inguinal ring, development, function and repair. Br J Surg. 1970;57:531–6.
20. Cleland J, MacKay JY, Young RB. The relation of the aponeurosis of the transversalis and internal oblique muscles to the deep epigastric artery and the inguinal canal. Mem Memor Anat. 1889;1:142.
21. Condon RE. The anatomy of the inguinal region and its relation to groin hernia. In: Nyhus LM, Condon RE, editors. Hernia. 4th ed. Philadelphia: Lippincott; 1995.
22. Condon RE. Surgical anatomy of the transversus abdominis and transversalis fascia. In: Annals of surgery. New York: Raven Press; 1991.
23. Condon RE. Reassessment of groin anatomy during the evolution of preperitoneal hernia repair. Am J Surg. 1996;172:5–8.
24. Kingsnorth AN, Skandalakis PN, Colborn GL, Weidman TA, Skandalakis LJ, Skandalakis JE. Embryology, anatomy and surgical applications of the preperitoneal space. Surg Clin N Am. 2000;80:1–24.
25. Fruchaud H. Anatomie chirurgicale des hernies de l'aine. Paris: G Dion; 1956.
26. Wantz GE. Atlas of hernia surgery. New York: Raven Press; 1991.
27. Arregui ME. The laparoscopic perspective of the anatomy of the peritoneum, preperitoneal fascia, transversalis fascia and structures in the space of Bogros. Postgrad Gen Surg. 1995;6:30–6.
28. van den Berg JC, de Valois JC, Go PMNYH, Rosenbusch G. Radiological anatomy of the groin region. Eur Radiol. 2000;10:661–70.
29. Skandalakis LJ, Gadacz TR, Mansberger AR, Mitchell WE, Colborn GL, Skandalakis IE. Modern hernia repair. New York: Parthenon Publishing; 1996.
30. Lytle WJ. Internal inguinal ring. Br J Surg. 1945;32:441–6.
31. van Mameren H, Go PMNYH. Surgical anatomy of the interior of inguinal region: consequences for laparoscopic hernia repair. Surg Endosc. 1994;8(10):1212–5.