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Applied anatomy

Laparoscopic inguinal anatomy

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Summary: Irrespective of the merits of laparoscopic herniorrhaphy, the anatomy of this surgical approach is poorly understood by most surgeons. To describe and document the normal anatomy and its variations, the inguinal region was dissected from peritoneum outward by the open method in 70 cadaveric sides and by the closed laparoscopic method in 28 cadaveric sides. In our results we describe the various layers, fossae, spaces and their contents. The data presented include variations of nerves in the inguinal area and measurements of bony landmarks from important neurovascular elements. In 74%, the distance from anterior superior iliac spine (ASIS) to pubic tubercle (PT) was 11 cm (10.0-14.0); in 56% ASIS to external iliac vessels was 6 cm (4.5 - 7.5 cm); ASIS to femoral nerve in 64% was 5 cm (3.0 - 7.5). The lateral femoral cutaneous nerve was found 1 - 4.5 cm medial to ASIS in 15%, increasing the possibility of nerve injury. In 25.5% the ilioinguinal nerve ran through the iliac fossa, in some cases passing through the iliopubic tract. In 18% the lateral femoral cutaneous and ilioinguinal nerves were combined, and in 7.7% the ilioinguinal and genitofemoral nerves were combined. It is critical for laparoscopic surgeons to be aware of the normal inguinal anatomy and its variants to avoid unnecessary injury and pain. It is important to remember that in approximately 30% of cases, the laparoscopic anatomy of one side will not be a mirror image of the other side.

Key words: Laparoscopy — Herniorrhaphy — Inguinal anatomy — Iliopubic tract — Transversalis fascia

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"Of herniae: But it is most worthy of observation, and admiration, that Nature but a little helped by Art, healeth diseases that are thought incurable" Ambroise Paré, 1585, *Apology and Treatise*

The anatomy of the inguinal region as seen with the laparoscope, from the peritoneum to the posterior surface of the myopectineal orifice of Fruchaud, has been presented by a number of different authors in recent years. Among these reports are some works of beauty and others that lack anatomic precision. For all practical purposes, exploration of this area was spurred, and even dictated by necessity, by the entrance upon the surgical scene of the laparoscopic approach to herniorrhaphy. To most surgeons, this area was terra incognita. This study is based upon the dissection of 70 cadaveric sides by the open method and 28 cadaveric sides by the closed laparoscopic method. In our results we emphasize the various layers, fossae, spaces and their contents, plus other morphologic details in a way that we hope will help the reader understand the enigmatic and peculiar anatomy in this area. The data presented include variations of nerves in the inguinal area and measurements of bony landmarks from important neurovascular elements. Unintentional damage to nerves and vessels is rather unusual in the performance of inguinal hernia repairs using the "classic" anterior approach because this is the anatomy with which surgeons are generally familiar. Far fewer surgeons are familiar with the inguinal anatomy from the posterior or extraperitoneal (internal) approach. Several internal features effectively conceal the presence of regional nerves and vessels. These include the peritoneum, the internal fasciae of the transversus abdominis and the iliopsoas mm. and, significantly, varying quantities of adipose and membranous connective tissue. Table 1 and Figs. 1 – 5 will guide us in the step-by-step dissection of the layers, "walking" through the spaces, and studying the anatomic entities within.

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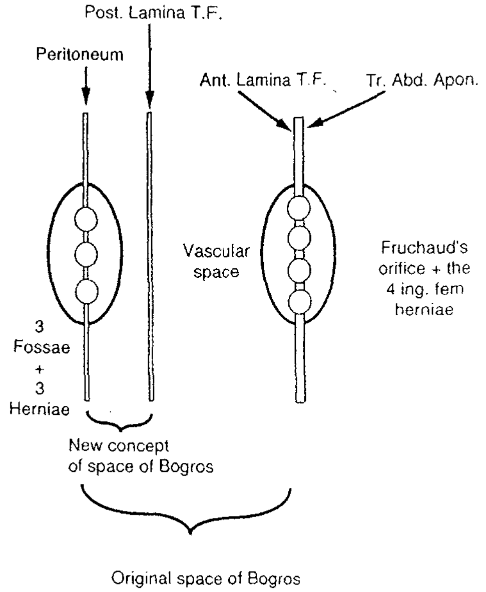

Fig. 1
Highly diagrammatic presentation of laparoscopic anatomy of the inguinal area demonstrating layers, fossae, spaces, and other anatomic entities between. (Used with permission from Problems in General Surgery 12:13, 1995)

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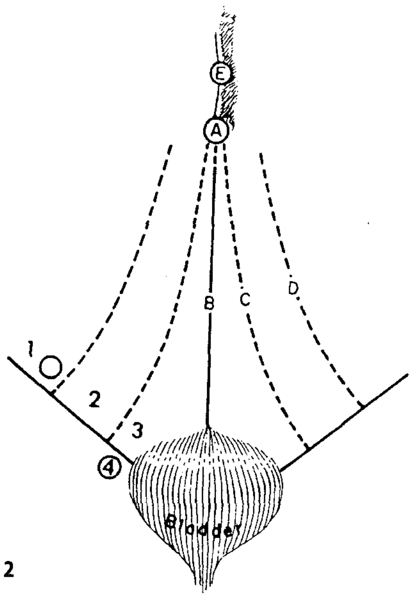

Fig. 2
Diagram of the fossae of the anterior abdominal wall and their relation to the sites of groin hernias: *A*, Umbilicus; *B*, median umbilical lig. (obliterated urachus); *C*, medial umbilical lig. (obliterated umbilical aa.); *D*, lateral umbilical lig. containing inferior (deep) epigastric aa.; and *E*, falciform lig. Sites of possible hernias: 1 = lateral fossa (indirect inguinal hernia); 2 = medial fossa (direct inguinal hernia); 3 = supravesical fossa (supravesical hernia); and 4 = femoral ring (femoral hernia). (From Rowe JS Jr, Skandalakis JE, Gray SW. Multiple bilateral inguinal hernias. Am Surg 39:269, 1973; with permission)

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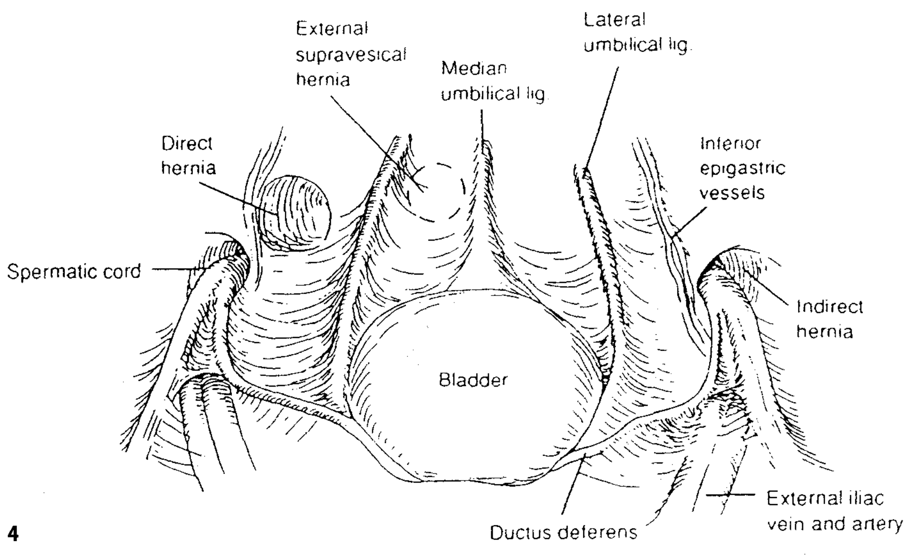

Fig. 4
Anatomic features of the inguinal region. Drawing from an open dissection of the left inguinal region and pelvic features. (Adapted from, and used with permission, Problems in General Surgery 12:13, 1995)

First layer: peritoneum and peritoneal fossae

Peritoneum

The peritoneum, this primitive lining of the early fetal celomic cavity, is the innermost layer of the internal abdominal wall. In the pelvis and, to be more specific, in the inguinal area, it has several characteristics related to the several anatomic entities with which it is associated. If one operates by the transperitoneal laparoscopic approach, that is, by beginning the herniorrhaphy from within the peritoneal cavity, knowledge of the characteristic features of the peritoneum lining the lower part of the anterior abdominal wall is of cardinal importance in initial orientation for subsequent operative procedures.

The parietal peritoneum lining the anterior abdominal wall is eleva-

Table 1. Laparoscopic peripatos of the inguinal area

I. 3 Layers
A. Peritoneum and fossae — supravesical, medial, and lateral fossae
B. Cooper's posterior lamina of the transversalis fascia
C. Transversus abdominis m., aponeurosis, and anterior lamina of the transversalis fascia

II. 2 Spaces

A. Space of Bogros
B. Vascular space

III. Myopectineal orifice of Fruchaud

IV. Dangerous eye
A. Arch (above)
B. Iliopubic tract (below)

V. Potential triangles and circle
A. Triangle of doom
B. Triangle of pain
C. Circle of death

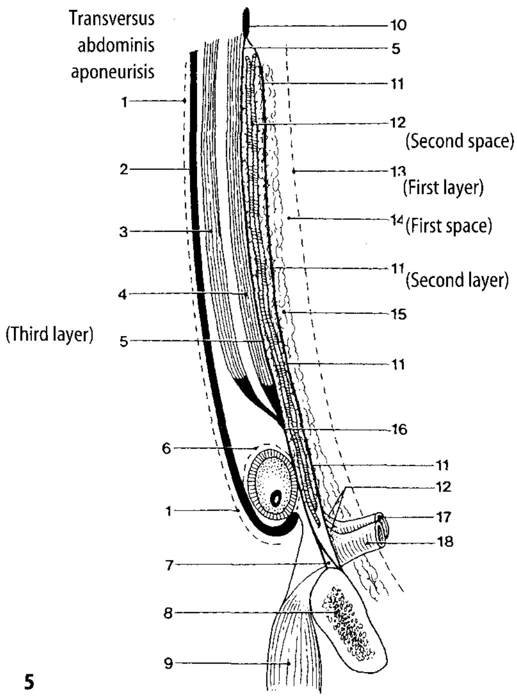

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Fig. 5
Highly diagrammatic representation of the layers of the inguinal area. 1 = external oblique fascia (of Gallaudet); 2 = external oblique aponeurosis; 3 = internal oblique m.; 4 = transversus abdominis m. and its aponeurosis; 5 = transversalis fascia anterior; 6 = internal spermatic fascia; 7 = Cooper's lig.; 8 = pubic bone; 9 = pectineus m.; 10 = transversalis fascia; 11 = transversalis fascia posterior lamina; 12 = vessels; 13 = peritoneum; 14 = home (space) of the prosthesis, space of Bogros; 15 = preperitoneal fat; 16 = transversus abdominis aponeurosis and anterior lamina of transversalis fascia; 17 = external iliac a.; 18 = external iliac v. (Modification by Skandalakis JE and Read RC from Lampe EW. Special Comment: Transversalis Fascia. In Nyhus LM, Harkins HN (eds). Hernia. Philadelphia: JB Lippincott, 1964, Fig. 2-20)

ted by underlying structures passing to the wall, thereby forming folds, or ligaments. Between these folds of the peritoneum (Figs. 2, 3) three fossae are formed bilaterally. The midline fold of peritoneum is caused by the urachus (whether obliterated or not) passing from the apex of the urinary bladder to the abdominal wall, en route to the umbilicus. This fold is called the median, or middle, umbilical lig. More laterally, a fold is formed by peritoneum over the umbilical a.; this fold is named the medial umbilical lig. Further laterally, a very slightly (if at all) elevated fold of peritoneum may be raised by the underlying inferior epigastric a. and v.; this is the lateral umbilical fold or ligament.

Peritoneal fossae

The fossae from the midline to the periphery are (a) the supravesical fossa, between the median umbilical lig. or fold and the medial umbilical lig. or fold (the obliterated segment of the umbilical a.); this is the home of the external supravesical hernia (Fig. 4); (b) the medial fossa, between the medial umbilical lig. or fold and the lateral umbilical lig. or fold (inferior or deep epigastric a. and v.); this is the area in which the direct hernia develops; and (c) the lateral fossa, lateral to the lateral umbilical lig.; within this fossa is the deep inguinal ring, through which the indirect hernia develops [Colborn 1995]. In many cases, with the peritoneum in place, the laparoscopist will also observe two underlying anatomic entities in the male: the gonadal vessels (bluish cordlike structures) and the ductus deferens (like a silver cord) (Fig. 6). In the female the round lig. will be seen.

After reflection of the peritoneum and extraperitoneal connective tissue, the cord elements can be clearly seen, passing through the deep (internal) inguinal ring, just lateral to the inferior epigastric vessels (Figs. 3, 7). Indirect inguinal hernias exit the abdomen by way of the deep inguinal ring; direct inguinal hernias are forced through a weakened area of the posterior wall of the inguinal canal, medial to the inferior epigastric vessels (Figs. 8 – 9).

Extraperitoneal connective tissue: some controversies

The extraperitoneal (preperitoneal, properitoneal) connective tissue between the parietal peritoneum and the transversalis fascia — in modern terms, the posterior lamina of the transversalis fascia — is separable, in some individuals, into a predominately adipose layer adjacent to the peritoneum and a fibrous or membranous layer in contact with the transversalis fascia, the inner fascial lining of the transversus abdominis m. In other cases, there appear to be multiple, more or less distinct laminae of

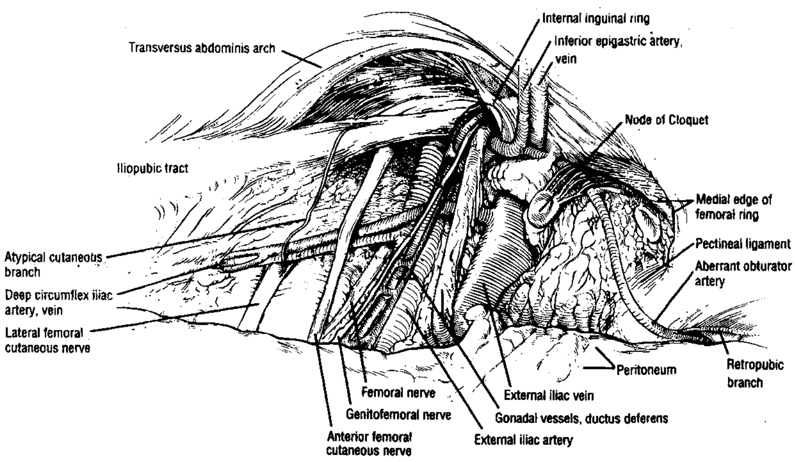


Fig. 7
Laparoscopic topographic anatomy of the inguinal region (of the male) – semischematic. The spermatic vessels join the vas deferens to form the spermatic cord. The presence of a fascial defect lateral or medial to the inferior epigastric vessels defines an indirect or a direct hernia, respectively. (Used with permission, Problems in General Surgery 12:20, 1995)

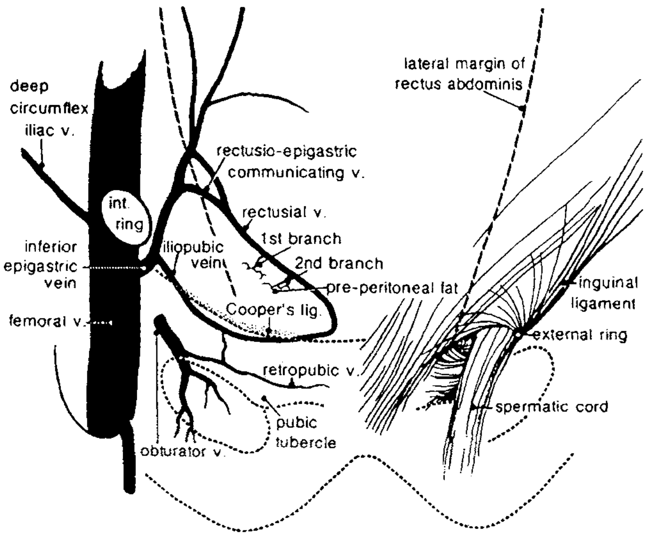


Fig. 11
The deep inguinal vasculature within the space of Bogros. Variations in the venous drainage. (From Bendavid R. The space of Bogros and the deep inguinal venous circulation. Surg Gynecol Obstet 174:356, 357 1992; with permission)

membranous tissue or tough fibrous tissue, between which variably thick loculations of adipose tissue are interposed. [It may be noted here that we have elected to use the term "extraperitoneal" to refer to the connective tissue just external to the parietal peritoneum. This word hopefully seems best to us for it can be used preferentially in place of either "preperitoneal" or "retroperitoneal" and seems more readily understandable than the other alternatives.]

Davies [1935] likened the arrangement of peritoneum and extraperitoneal connective tissue to the disposition of the skin and superficial fascial layers of the body wall in reverse order. We would agree in principle with this interesting line of thought, wherein, beneath the skin, Camper's fatty layer is succeeded by Scarpa's membranous fascia; this, in turn, by the outer muscular fascia of the body wall - to which it may cling delicately by a little connective tissue or more firmly by tough, septae-like interconnections. Similarly, after one divides the peritoneum, one may first encounter a fatty layer (thin or thick) of extraperitoneal connective tissue, then a more membranous layer of tissue (the posterior lamina of the transversalis fascia), followed by the inner lining of the transversus abdominis, the anterior lamina of transversalis fascia (Fig. 1). As shown in Fig. 10, the extraperitoneal layer adjacent to the peritoneum can be a very distinct, transparent, and fairly tough membrane.

Just as multiple, tough laminations of the superficial fascia are often present on the lower part of the anterior abdominal wall, predictable condensations of extraperitoneal connective tissue are present in the body cavity, such as the perirenal fasciae of Gerota, the supporting "pillars" of the rectum and the urogenital organs of the pelvis [Uhlenhuth 1948]. In the inguinal region we have observed the frequently significant contribution of the extraperitoneal connective tissues in the formation of the iliopubic tract and the vesicoumbilical fascia, to be described later. In the vicinity of the deep inguinal ring, several condensations of extraperitoneal connective tissue meet in complex fashion: (1) Laminae of tissues lateral to the deep inguinal ring; (2) endopelvic extraperitoneal connective tissue associated with the ductus deferens or round lig. and the umbilical aa.; (3) condensations of connective tissue borne along with the external iliac vessels; (4) variably heavy contributions of connective tissue associated with the iliac fossae. It is in part due to the complexity of blending and separation of these tissues

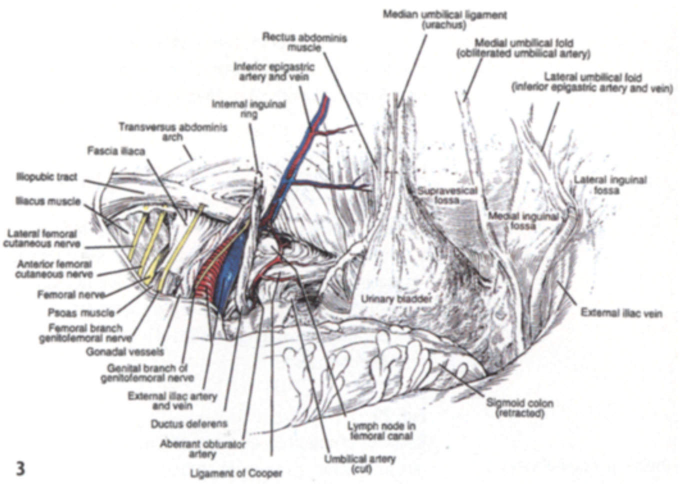


Fig. 3
Drawing from laparoscopic dissection photograph. Laparoscopic view of the umbilical lig. and the associated peritoneal fossae. The nerves, vessels and other important anatomic elements of the left inguinofemoral region are also seen here. (Adapted from, and used with permission, Problems in General Surgery 12:13, 1995)

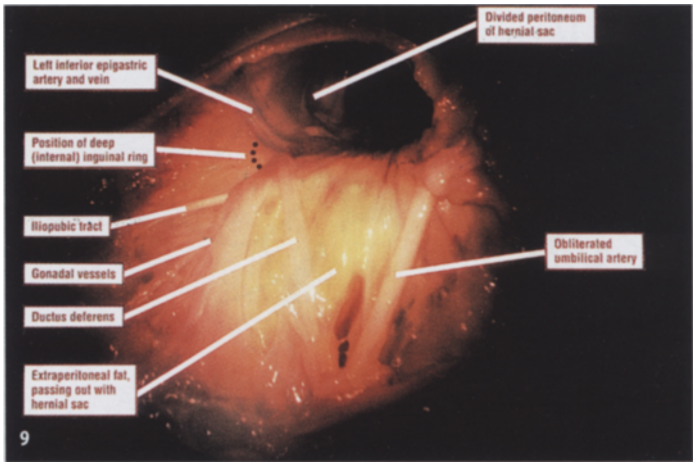


Fig. 9
Laparoscopic appearance of a left-sided direct inguinal hernia and its relations following removal of peritoneum and extraperitoneal connective tissues. (Used, with permission, from Surgical Rounds, June, 1995, p. 236)

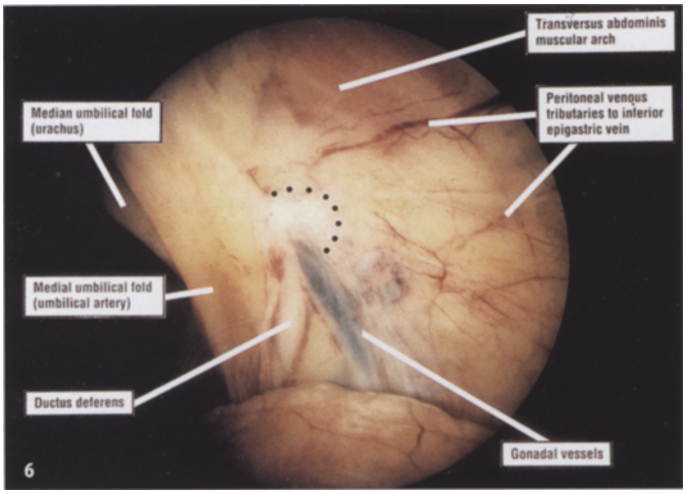


Fig. 6
The ductus deferens and gonadal vessels of the right side as seen with the laparoscope in the transperitoneal herniorrhaphy. (Used with permission from Surgical Rounds, May, 1995, p. 195)

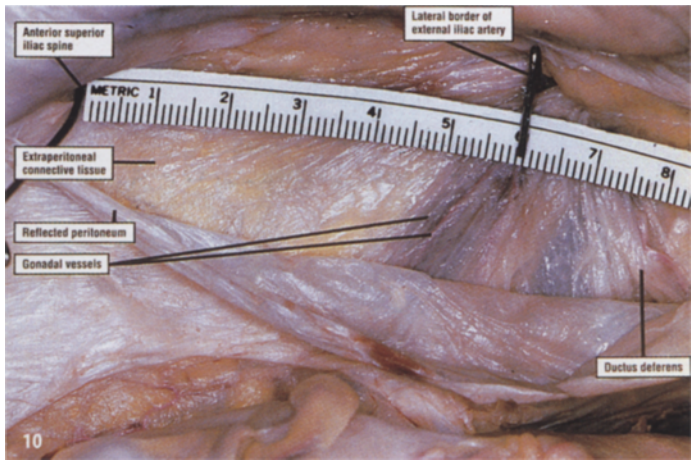


Fig. 10
Extraperitoneal covering of spermatic cord elements of the left side. The peritoneum has been reflected, revealing transparent extraperitoneal connective tissue covering the gonadal vessels and ductus deferens. A pin has been placed just lateral to the external iliac a., after determination of its distance from the anterior superior iliac spine. (Modified and used with permission from Surgical Rounds, May, 1995, p. 191)

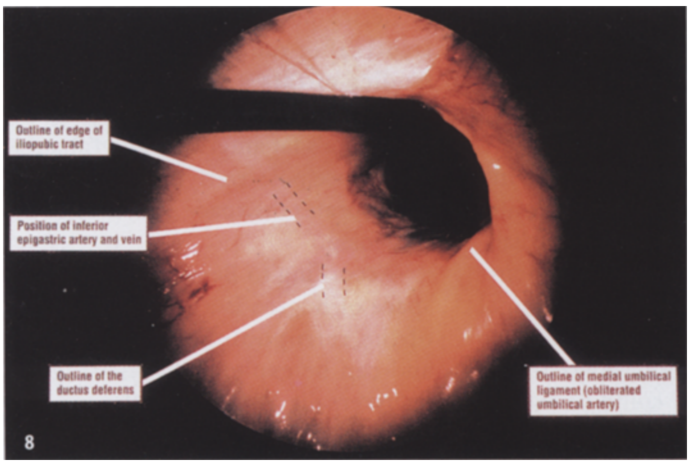


Fig. 8
Laparoscopic appearance of a left-sided direct inguinal hernia and its relations with the peritoneum intact. The dissection instrument has passed into the scrotum. (Used, with permission, from Surgical Rounds, June, 1995, p. 236)

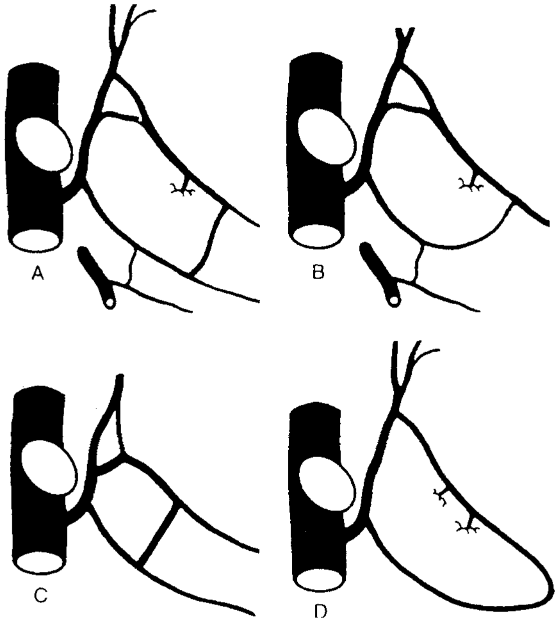


Fig. 12
Variations in the deep inguinal venous drainage within the space of Bogros. (From Bendavid R. The space of Bogros and the deep inguinal venous circulation. Surg Gynecol Obstet 174:356, 357 1992; with permission)

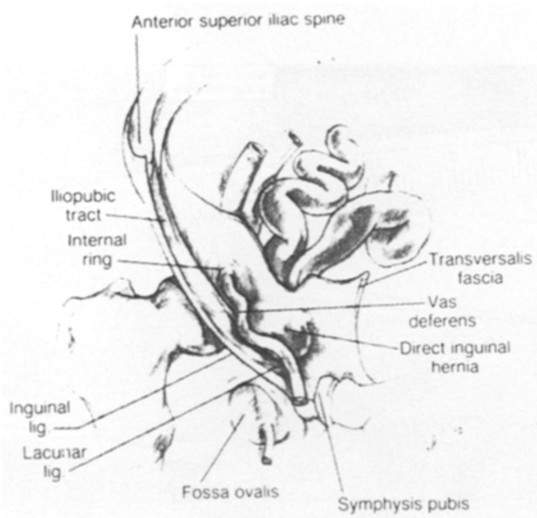


Fig. 14
Semi-schematic drawing of the inguinal region, depicting the relations of direct inguinal hernia to the posterior wall of the inguinal canal. (From Gray SW, Skandalakis JE: Atlas of Surgical Anatomy for General Surgeons. Baltimore; Williams and Wilkins, 1985, p. 307. With permission)

Fig. 13
The venous vessels of the medial inguinal region, including the "rectusial vv." of Bendavid. (Used, with permission, from Surgical Rounds, May, 1995, p. 197)

Fig. 16
Hesselbach's triangle of the left side of the body, indicating the borders provided by the lateral border of the rectus abdominis, inferior epigastric vessels and the iliopubic tract (unlabeled here), with an indication of its dimensions. The base of the triangle is formed by the iliopubic tract (previously defined as the inguinal lig.) in modern interpretation, separating the sites of inguinal hernias from femoral hernias

Fig. 20
Relations of important elements of the left inguinofemoral region, showing an aberrant obturator a. and aberrant v. crossing the femoral ring (unlabelled) and the pectineal lig. medial to the ductus deferens (unlabelled). (Used with permission from Surgical Rounds, May, 1995, p. 192)

Fig. 21
The "Triangle of Doom" of the left inguinal region, bounded by the gonadal vessels and the ductus deferens. Exposed by the reflection of peritoneum and removal of extraperitoneal connective tissue

Fig. 22
The "triangle of pain" of the left inguinal region, bounded by the gonadal vessels medially and the iliopubic tract inferolaterally. Staples or sutures placed into the iliopubic tract lateral to the deep inguinal ring can result in nerve injury, with pain or paralysis resulting postoperatively. (Modified from Surgical Rounds, p. 227, June, 1995, and used with permission)

Fig. 23
The "circle of death," formed by anastomosis of an aberrant obturator a. (or v.), arising from the external iliac or inferior epigastric, with a normal obturator vessel arising from the internal iliac

that the anatomy of the inguinal region yet defies total explication in a form agreeable to all.

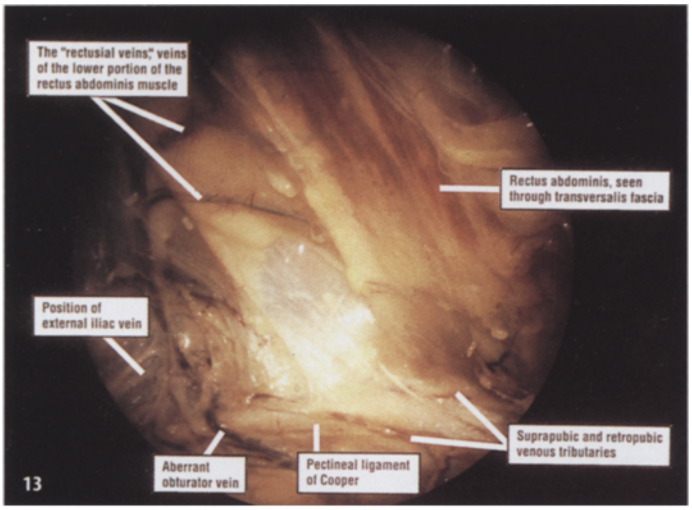
First space: space of Bogros

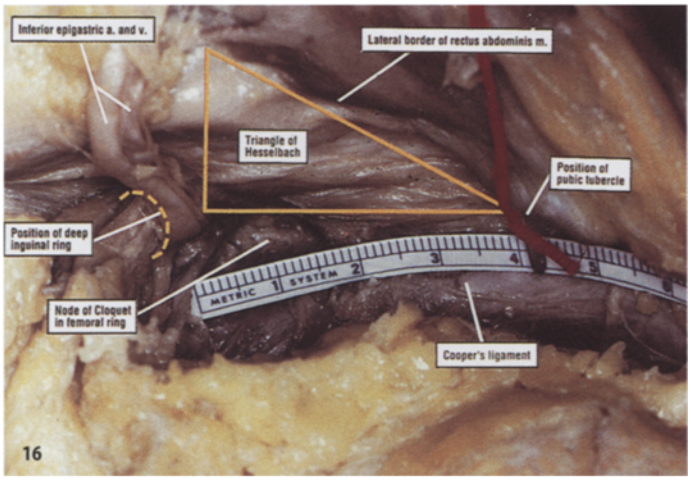
The layers of extraperitoneal fat and other connective tissues, either thick or thin, lie within a space between the peritoneum and the anterior lamina of the transversalis fascia (Fig. 1). This is the "space of Bogros." Fibrous bands are present here, and lipomata similar to those in the spermatic cord occasionally are found. The extraperitoneal space is exposed by the division and reflection of the parietal peritoneum toward the iliac fossa before it reaches the pubic bone [McVay 1984] or by direct entry into the space using methods such as those of Nyhus [1959, 1960], Stoppa [1989], and others.

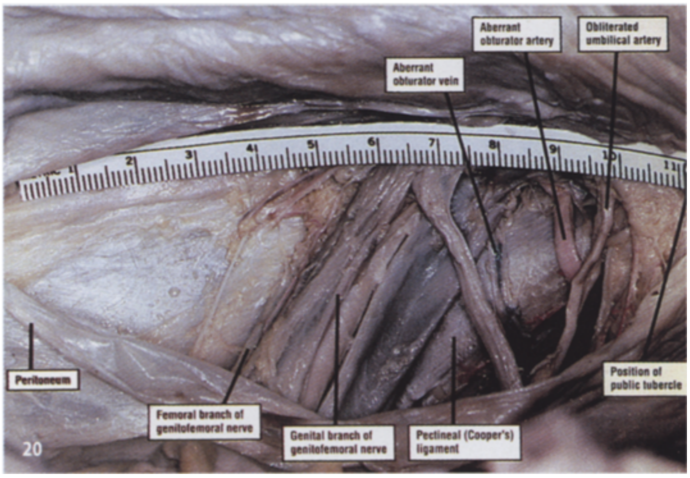
According to Stoppa [personal communication, 1992], Bogros was a French anatomist and surgeon who wrote a thesis in 1823 about the surgical anatomy of the iliac region. He described a triangular space with the following boundaries: lateral -- iliac fascia; anterior -- transversalis fascia; and medial -- parietal peritoneum. Bogros demonstrated that an incision in the inguinal region could allow access to a space within which the inferior epigastric or external iliac vessels could be ligated without dividing the peritoneum.

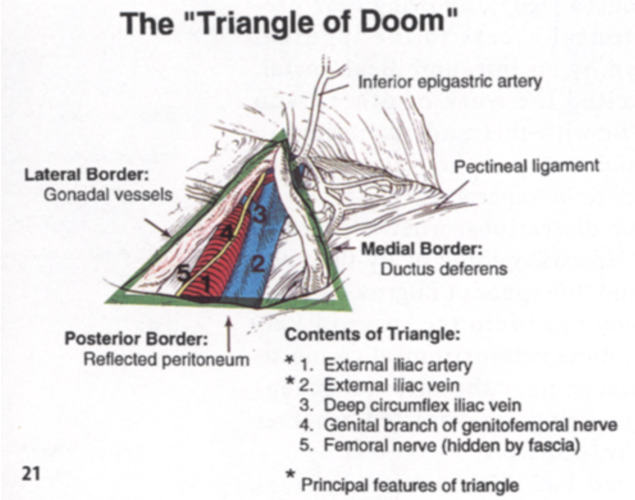
Stoppa [personal communication, 1992] stated that this cleavable interparietoperitoneal space is considered to be the lower prolongation of the great posterior paraurinary space. Hureau [1991], after radiologic and anatomic studies of this area, considered the posterior paraurinary area as follows: (1) Gerota's fat anteriorly and (2) a cellular space posteriorly that most likely incorporates the space of Bogros of the iliac fossa.

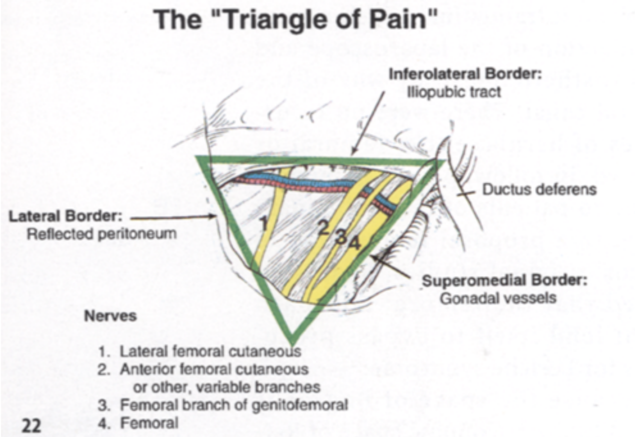
According to Bendavid [1992], the space of Bogros is a lateral extension of the retropubic space of Retzius and can be explored by incising the transversalis fascia from the internal ring to the pubic crest. He also repor-

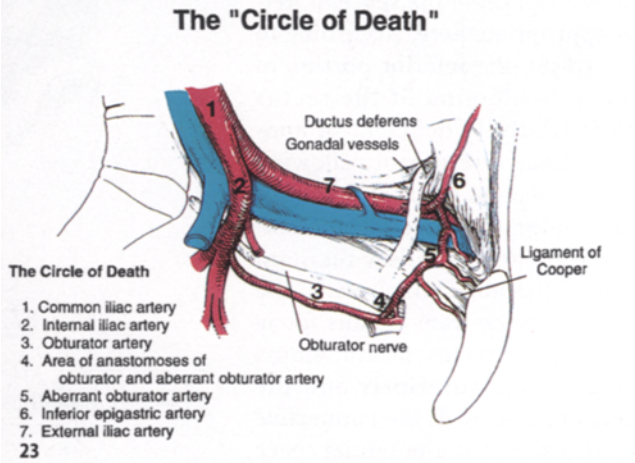












ted that a venous network is located at the lower anterior part of the space of Bogros with fixation of the network to the anterior wall. The Bendavid "venous circle" of veins, located at the subinguinal space of Bogros, is a venous network composed of the deep inferior epigastric v., the suprapubic v., the rectusial v., the retropubic v., and the communicating rectusioepigastric v., which form a venous circular network that, again according to Bendavid, is variable (Figs. 11–13). He advises familiarity with this venous circle, particularly by those surgeons using prosthetic material. In our dissections we have found the suprapubic and retropubic venous tributaries highly variable in size; in one case a suprapubic v. was approximately 1 cm in diameter and received tributaries from the urinary bladder.

Read has noted that the space of Retzius is continuous with the space of Bogros [1997], allowing easy preperitoneal access to the inguinal region by an infraumbilical portal, and cited the work of others who concur with this understanding, in addition to those who believe the two spaces to be separate. In the majority of our dissections, whether performed laparoscopically or by the open method, the space of Bogros does not directly open into the space of Retzius unless extraperitoneal connective tissues near the internal (deep) inguinal ring are dissected, whether bluntly or sharply.

Read has demonstrated [1997] that the space of Bogros can be entered by an infrainguinal incision, with introduction of the laparoscope and the prosthetic mesh by way of the femoral canal. There were no recurrences of hernia, either femoral or inguinal, in followup after 18 months on the 10 patients of the preliminary study. In a proposal reminiscent of Bogros' original studies, Read suggested that the femoral approach might lend itself to bypass procedures for Leriche syndrome.

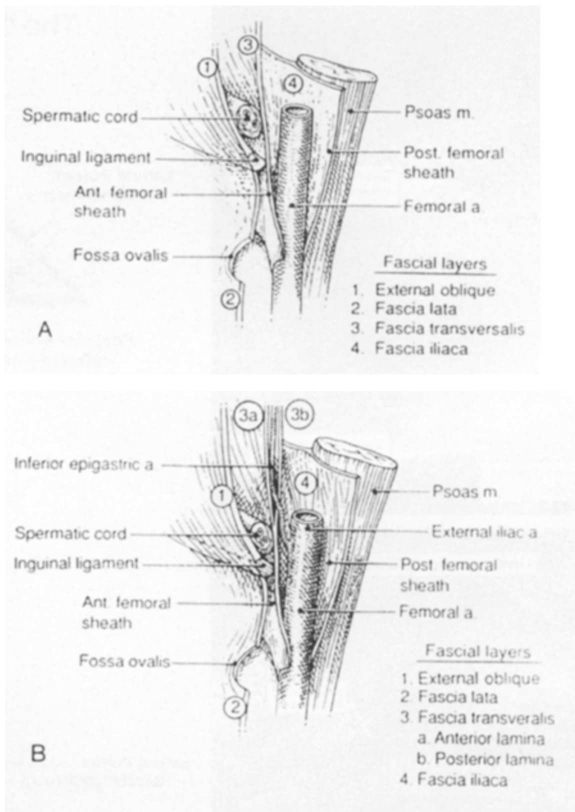


Fig. 15
A, Highly diagrammatic drawing of the transversalis fascia and femoral sheath (old concept); *B*, Highly diagrammatic drawing of the transversalis fascia and femoral sheath (new concept), emphasizing the bilaminar nature of the transversalis fascia in the inguinal area. (From Surgical Clinics of North America 73:817, 1993. With permission)

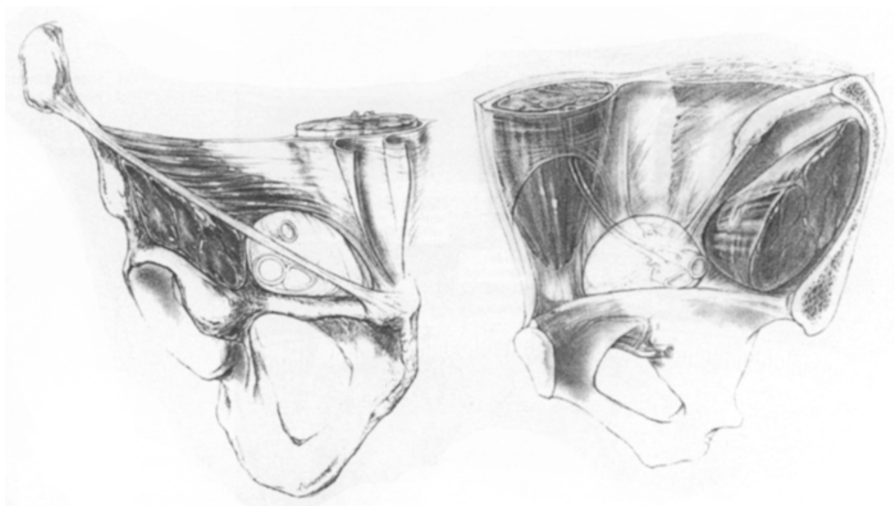


Fig. 17
Myopectineal orifice of Fruchaud. *A*, anterior view; *B*, posterior view

Because the space of Bogros is related to the retropubic space of Retzius, a description of the space of Retzius is appropriate here. According to Retzius [1858], the inferior portion of the posterior lamina of the rectus sheath is relatively deficient of aponeurotic tissue, presumably allowing the urinary bladder to expand upward into the abdomen in an extraperitoneal position against a less resistant portion of the abdominal wall. The space between the transversalis fascia of the posterior rectus sheath lamina and pubic bone anteriorly and the bladder, together with the connective tissue enclosing it is a potential space to which has been given the name, the "space of Retzius." This space extends from the umbilicus above to the muscle fascia and pubovesical ligg. of the pelvic floor below.

As the urachus and the umbilical aa. ascend toward the umbilicus from the level of the bladder apex they are incorporated into a thick mat of extraperitoneal connective tissue which is continuous from the bladder to the umbilicus, although this lamina of fatty tissue becomes thinner as the umbilicus is approached. This layer of tissue is called the vesicoumbilical fascia. The more or less triangular mat of fatty tissue is bordered laterally by the medial umbilical ligg. as they pass to, and attain, the anterior abdominal wall. It should be remembered that the lateral edge of the bladder can lie just medial to the medial umbilical lig., near which point the patent part of the umbilical a. provides origin for the superior vesical branches to the bladder. If the medial umbilical lig. appears more lateral than usual, one should guard against an unexpected encounter with, and injury to, the urinary bladder. Exces-

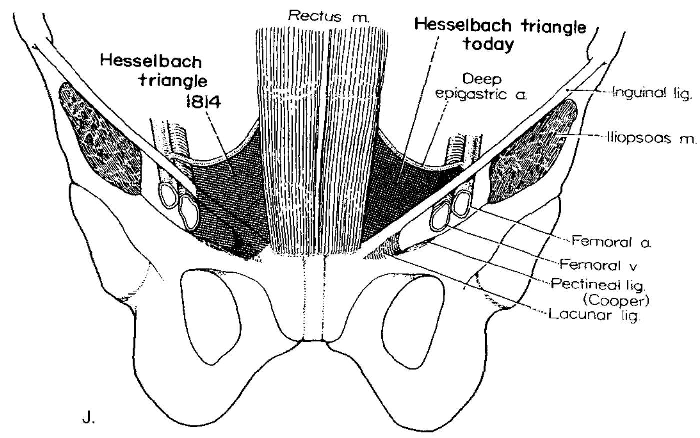


Fig. 18
The changing parameters of the triangle of Hesselbach. From a laparoscopic point of view, the iliopubic tract forms the base of the modern triangle of Hesselbach, because the inguinal lig. cannot be seen from within the body unless the iliopubic tract has been dissected away. (From Gray SW, Skandalakis JE: Supravesical hernia, in Hernia, 3rd edition. Nyhus LM, Condon RE (eds). Lippincott, Phila. 1989, p. 389. Used with permission)

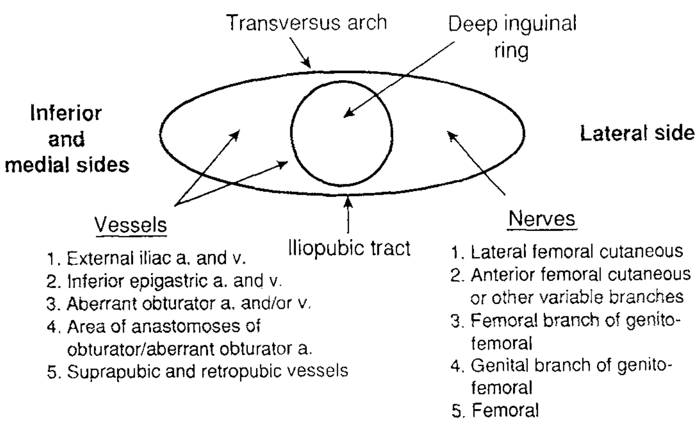


Fig. 19
Highly diagrammatic representation of the "Dangerous Eye" and its relationships to vessels and nerves

sive amounts of adipose tissue can further disguise the proximity of the bladder to the deep inguinal ring.

The space of Retzius is sealed more tightly by extraperitoneal connective tissue (or, the posterior lamina of the transversalis fascia?) which seems to divide just lateral to the inferior epigastric vessels. One lamina of this tissue is often distinctly visible as it passes to the posterior lamina of the rectus sheath. The other lamina passes toward the lateral aspect of the bladder, incorporates the umbilical a. and then, becoming increasingly thickened by fatty tissue, reaches the bladder. The internal aspect of the vesicoumbilical fascia is covered with peritoneum. Over the abdominal surface of the bladder, the vesicoumbilical fascia is very thin; so thin, in fact, that the peritoneum cannot be reflected bluntly from the bladder, thus preventing complete extraperitoneal mobilization of the bladder unless sharp dissection is performed.

It can be said, then, that the space of Retzius is a triangular potential space bordered posterolaterally in the pelvis by the lateral pillar of the bladder. Above this, it is closed by the umbilical and inferior epigastric vessels with their investments of fibroareolar tissue. Studies based upon computerized axial tomography by Korobkin, et al. [1992] have demonstrated that the prevesical space of Retzius is continuous with the retroperitoneal spaces surrounding the kidney.

Second layer: Cooper's posterior lamina of transversalis fascia

Transversalis fascia in the inguinal area

The inguinal canal is similar to a cleft between two major musculoaponeurotic layers. The anterior layer is formed by the external oblique aponeurosis and the innominate (Gallaudet's) fascia. The posterior layer is formed by the transversus abdominis aponeurosis, the internal oblique aponeurosis, and the transversalis fascia (Figs. 5, 14–15). This latter layer is of primary importance to the surgeon repairing the floor of the inguinal canal.

Sir Astley Cooper [1804] described the transversalis fascia as follows: "When the lower portions of the internal oblique and transversalis mm. are raised from their subjacent attachments, a layer of fascia is found to be interposed between them and the peritoneum, through which the spermatic vessels emerge from the abdomen. This fascia, which I have ventured to name fascia transversalis, varies in density, being strong and unyielding towards the ilium, but weak and more cellular towards the pubes".

The term "transversalis fascia" was once applied only to the deep fascia covering the internal surface of the transversus abdominis m., but it can now be employed in a very general way to the entire connective tissue sheet lining the musculature of the abdominal cavity. Alternatively, in some areas this fascial layer is named specifically for the muscle covered by it, such as "iliacus", "psoas", or "transversalis fascia" where it covers those specific muscles. The transversalis fascia varies in nature. It is thin and closely adherent in the portion covering the transversus abdominis aponeurosis, but in other areas it is thick and discrete [Cooper 1804]. By itself, however, the transversalis fascia is a weak layer that is useless for hernia repair. Yet, when fused with the transversus abdominis aponeurosis, it forms "good stuff" for repair.

In spite of our familiarity with the publications of Cooper [1804, 1807], we never thought about the possibly bilaminar formation of the transversalis fascia at the inguinal area until the work of Read [1992]. According to him [Read 1992], the transversalis fascia bifurcates, producing two laminae: the posterior lamina which is the second layer and the anterior lamina which is the third layer (Figs. 5, 15 A, B). In our innumerable dissections, fresh and old, as well as in the operating room, we found a thin membrane that covered the preperitoneal fat. We paid little attention to this because the presence of more adipose preperitoneal fat led us to think this was simply a tissue-paper-like membrane covering the fat. We never thought of this as the posterior Cooperian lamina of the transversalis fascia. We observed "the transversalis fascia", now described by Read as the anterior lamina, but we thought this nothing more than the transversalis fascia. As to the covering of the preperitoneal fat, we never investigated the beginning and end of this preperitoneal covering. We noticed the presence of the inferior epigastric vessels under a "transversalis" fascial layer, but again we did not pay any attention to their fixation anteriorly or to their deeper occurrence in relation to the preperitoneal fat. Occasionally the posterior lamina is very thin and unrecognizable. In this event, it is said that the space of Bogros extends to the anterior lamina.

It cannot yet be said that this mild debate is over, as to whether the transversalis fascia is bilaminar or whether the "posterior lamina" is simply a significant regional condensation of extraperitoneal connective tissue. Perhaps it is not a matter which should really concern us in practical terms. Nonetheless, the disagreement is reminiscent of that which surrounds the issue of the nature of the perirenal fascia of Gerota. Thorek, for example, has long maintained that the perirenal fascial envelope of the kidney is derived from transversalis fascia [1962, 1997]. Fowler [1975], Anson and McVay [1984], and others have stated that this fascia is derived from extraperitoneal connective tissue.

Second space: vascular

Accepting the concept of a bilaminar transversalis fascia, it is to be noted that a second potential space (vascular) is located between the two anterior and posterior laminae of the transversalis fascia which envelop the inferior epigastric vessels, their branches and tributaries. Therefore, the "anterior lamina" of the transversalis fascia is the third layer (Figs. 5, 15).

Third layer: the transversus abdominis m., aponeurosis, and the anterior lamina of the transversalis fascia

(Figs. 5, 15)

The transversus abdominis m., its aponeurosis, and the anterior lamina of the transversalis fascia form the third layer of the anterior abdominal wall in the inguinal area. These elements become attenuated at the deep (internal) inguinal ring, the site of passage for the gonadal vessels and ductus deferens or the round lig. to enter the inguinal canal. The anterior lamina of the transversalis fascia is fused with the aponeurosis of the transversus abdominis m. Both of these anatomic entities belong to the "good stuff" to be used for hernioplasty. In 3/4 of individuals the posterior wall of the inguinal canal is composed of transversalis fascia, reinforced by a substantial representation of the transversus abdominis aponeurosis. In 1/4 the transversus abdominis aponeurosis is not present, or is quite diminished in its contribution to the wall. Perhaps this is one of the chief factors in the etiology of inguinal hernias.

That part of the transversus above the position of the deep ring is usually mostly muscular; that below it is composed of aponeurosis and transversalis fascia. The lower part of the transversus abdominis takes origin laterally from the fascia of the iliopsoas m., usually referred to as the fascia iliaca. Passing from origin to insertion, the transversus arches over the external iliac vessels to insert upon the pectineal lig. Those fibers which form the arching, muscular lower border of the transversus abdominis arise especially from a thickened portion of the fascia iliaca, the iliopectineal arch, which inserts medial to the iliopsoas m. upon the iliopectineal eminence, deep to the external iliac a. and v. The muscular lower border of the transversus abdominis arches over the position of the deep inguinal ring, its aponeurosis inserting medially upon the pectineal lig. of Cooper and the fascia of the pectineus m., where it is joined by the most inferior segment of the aponeurosis of the transversus abdominis, the iliopubic tract (Figs. 3, 9). Between the "touchdown" of the transversus adominis upon the pectineal lig. and the external iliac v. is the ovoid opening of the femoral canal, wherein areolar tissue, fat and the lymph node of Cloquet (or Rosenmuller) are usually clearly visible with the laparoscope, with minimal dissection (Figs. 3, 6, 16). As the iliopubic tract crosses the external iliac vessels, it contributes to the formation of the femoral sheath, being joined externally at the lower border of the inguinal lig. by the investing fascia of the external oblique aponeurosis. From our observations, we believe that that the iliopubic tract in most individuals consists of more than aponeurotic fibers of the transversus abdominis and transversalis fascia. In our dissections extraperitoneal connective tissue also contributes to the formation of the iliopubic tract, increasing the brightness of reflection of the light from the laparoscope. A rather dense, falciform band of fascia seems often to span laterally from the psoas m., contributing also to the density of the iliopubic tract. The deep circumflex iliac a. and v. and several nerves, including the femoral n., pass deep to the iliopubic tract and are concealed by it; other nerves pass through the tract [Brick 1995, Colborn 1995]. Any of these elements can be in jeopardy from staples or sutures applied to the iliopubic tract, resulting variably in postoperative pain, muscle weakness or paralysis, or hematomata.

The myopectineal orifice of Fruchaud (Fig. 17 a, b)

As described in the fascinating paper by Stoppa and Wantz [1995], Fruchaud attributed the occurrence of inguinofemoral hernias to the weak area in the groin which he called the "myopectineal orifice," the site both of inguinal (indirect, direct, and external supravesical) and femoral hernias. This funnel-shaped outlet region is bounded below by the pubic bone, medially by the lateral border of the rectus abdominis m., laterally by the iliopsoas m., and superiorly by the arching lower borders of the internal oblique and, chiefly, the transversus abdominis. The area of weakness is bridged by the inguinal lig. which, in effect, separates the inguinal ring and canal above from the outlet for the femoral sheath and femoral canal below.

The triangle of Hesselbach

The inguinal lig., as noted above, divides the myopectineal orifice into a superior portion and an inferior portion. The inferior epigastric vessels provide a topographical division of the myopectineal orifice into the lateral inguinal fossa, characterized by the presence of the deep inguinal ring and the medial inguinal fossa, the region embodying the triangle of Hesselbach (Figs. 16, 18). The deep inguinal ring is the site of occurrence of indirect inguinal hernias. It is within the triangle of Hesselbach that direct inguinal hernias and femoral hernias take origin. The triangle of Hesselbach, then, is bounded laterally by the inferior epigastric a. and v. The lateral border of the rectus abdominis provides a medial border. The superior ramus of the pubic bone, surmounted by the pectineal lig., forms a base for the triangle, as originally defined.

At the present time, the majority of textual sources state that the inguinal lig., rather than the superior pubic ramus, forms the base of the triangle of Hesselbach. From the point of view of the laparoscopic surgeon this cannot be the case, if one is defining visible boundaries, for the inguinal lig. cannot be seen from within the abdominal cavity unless the transveralis fascia and the transversus abdominis aponeurosis have been dissected away. What one does see is the iliopubic tract. Again, from a strictly practical point of view, one may see the validity of defining the base of the triangle as the iliopubic tract. From the laparoscopic point of view, the iliopubic tract divides this extraperitoneal area into the inguinal region above and the femoral area below, as observed earlier by Page [1996].

The dangerous eye

The "dangerous eye" is nothing more than the area formed by the transversus arch and the iliopubic tract, and which surrounds the deep inguinal ring (Fig. 19). Characteristically, the nerves in this area are located lateral to the deep inguinal ring; the vessels are located below and medial to the ring.

The most lateral nerve is the lateral femoral cutaneous nerve, in most cases leaving the iliac fossa just medial to the anterior superior iliac spine. Superficial to the external iliac a. is the genital branch of the genitofemoral nerve. Lateral to the external iliac a. is the femoral branch of the genitofemoral nerve; and further, but not far enough away to avoid injury, is the femoral nerve, which lies in the trough between the psoas and iliacus mm. (Fig. 7).

Several important vessels are medial to the ring: the venous circle, inferior epigastric a. and v., internal and external iliac a. and v., rectus vessels, suprapubic and retropubic vessels, and aberrant obturator a. and/or v. (present in 30%-40% of cases).

Neurovascular topography and nerve variations

To provide a baseline of potentially useful data for the laparoscopic surgeon, we measured various parameters in the inguinal region, relating several visible or palpable features to vessels and nerves of the region (Figs. 7, 16, 20). In 41 of 74 measurable cases, or 74%, the distance from the anterior superior iliac spine to the pubic tubercle was 11 cm (+/- 0.5 cm) (Fig. 20). The range was from 10.0 cm (10 cases) to 14 cm (2 cases).

In our studies we found that the distance from the anterior superior iliac spine (ASIS) to the external iliac a. was about 6 cm (+/- 0.5 cm) in 18 of 32 instances, or 56% (Fig. 10). The range was from 4.5 cm (1 case) to 7.5 cm (9 cases).

Nerves destined for distribution to the thigh usually pass deep to the deep circumflex iliac vessels and the iliopubic tract. Nerves passing to the abdominal wall and urogenital region pass superficial to the deep circumflex vessels and through the iliopubic tract; there they are in jeopardy when staples or sutures are placed lateral to the internal inguinal ring [Colborn 1995].

The distance from the ASIS to the femoral nerve was usually about 5 cm (36 of 56 cases - 64%). The range was from 3.0 (1 case) to 7.5 cm (2 cases). The femoral nerve lies deep to the edge of the iliopsoas m. to a point about 6 cm above the iliopubic tract, at which point it is covered only by a dense band of fascia which leaves the psoas m. and passes laterally deep to the iliopubic tract.

In most cases (44 of 56 cases, or 82%) the lateral femoral cutaneous nerve exits the pelvis 0 - 1 cm medial to the ASIS. The nerve was found 1 - 4.5 cm medial to the ASIS in 12 specimens (15%), thus increasing the possibility of injury or entrapment from staples or sutures.

In 20 of 78 specimens (25.5%) the ilioinguinal nerve ran through the iliac fossa in the terminal course of the nerve to reach the inguinal canal. In its typical course, the ilioinguinal nerve passes above the iliac crest, well out of harm's way. In variations, the ilioinguinal nerve passed through the iliopubic tract 1 - 4.5 cm medial to the ASIS. This path can obviously render the nerve more vulnerable to iatrogenic injury.

The ilioinguinal and lateral femoral cutaneous nerves were combined (sometimes only part of the ilioinguinal), or ran closely parallel in the iliac fossa (14 cases, or 18%). In 6 cases (7.7%) the ilioinguinal and genitofemoral nerves were combined.

In 8 cases (10%) an anterior femoral cutaneous or accessory femoral nerve was present and visible anterior to, or slightly lateral to, the femoral nerve.

Potential anatomic entities involved in laparoscopic herniorrhaphy

The triangle of doom

The so-called triangle of doom of the inguinal region (Fig. 21) is bounded medially by the ductus deferens, laterally by the gonadal vessels and inferiorly (in a transperitoneal laparoscopic procedure) by the fold of peritoneum reflected downward from the region wherein the prosthesis is to be placed. The external iliac a. and v. pass through this triangle and are the reason for the name of the area. The genital branch of the genitofemoral nerve also passes distally upon the external iliac a., leaving it to traverse the deep inguinal ring. In one of our cases, wherein the genital branch appeared to be more than 2 mm in diameter, it proved to be a combination of the ilioinguinal and genital nerves, which entered the inguinal canal medial and deep to the spermatic cord.

The triangle of pain

The identity, courses, and distribution of nerves in the inguinal region are highly unpredictable. Annibali, et al. coined the name "The triangle of pain" to describe the area bounded by the gonadal vessels inferomedially and the iliopubic tract superolaterally [1993] (Figs. 3, 7, 22). According to these authors, staples placed in this "triangle" can injure the femoral branch of the genitofemoral nerve, the lateral femoral cutaneous nerve, and even the femoral nerve. In every case we have thus far dissected, we have found one or more additional nerves of varying size superficial to, or between the fascial laminae over the iliacus m., between the femoral branch of the genitofemoral nerve and the usual position of the lateral femoral cutaneous nerve. The multilaminar nature of the fascia iliaca [Nobel, 1980] offers excellent concealment for the various nerves that cross the iliac fossa to pass deep to, or through, the iliopubic tract. It is clear that anatomical and surgical atlases and texts overly simplify the anatomy of the nerves in the inguinal region, and do not provide the surgeon adequate guidance in recognizing the potential hazards in the "triangle of pain."

The circle of death

The mnemonic term, the "circle of death," refers to the hazards presented by an aberrant obturator a. (Figs. 20, 23). The frequency of appearance of this artery may approximate 40%, or even more in some populations (e.g., 69% [Missankov, 1996]). Gilroy [1997] found aberrant obturator aa. or vv. in 83% - 90% of whole pelves. This vessel arises from the inferior epigastric or external iliac aa. and crosses the pectineal lig. in the vicinity of the femoral ring, there passing medial to the ring, lateral to the ring, or directly across the ring. In some cases the aberrant a. anastomoses in the pelvis at the obturator foramen with a normal obturator a., which takes origin from the internal iliac a., thereby forming an arterial "circle" between the external iliac aa., obturator aa., and internal iliac a. If such an anastomosis is present, injury to the aberrant vessel will result in brisk bleeding from both sides of the site of injury, with combined contributions from both internal iliac and external iliac aa.

Lymphatic elements of the femoral canal are often continuous with retropubic aggregates of lymph nodes and vessels medial to the external iliac v.; these often totally obscure an aberrant obturator a., aberrant obturator v., or both, even when they are of relatively large diameter.

It should be realized that the frequency of appearance of an aberrant obturator v. is far greater than that of the aberrant a., and that such vessels can be quite large in diameter. The danger presented by a torn aberrant v. can be more subtle than that of an arterial injury. Bleeding from the cut or torn veins may not be evident until the pressure of insufflation is released; in other words, postoperative bleeding may occur. The laparoscopist should, therefore, be very gentle and very observant.

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