The anatomical basis for femoral nerve palsy following iliacus hematoma

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With increased use of anticoagulant agents, femoral neuropathy subsequent to hemorrhage within the iliacus muscle has become a frequent clinical problem. The mechanism for this type of femoral nerve palsy was studied in dissections of the iliac region and by injections of latex into fascial planes in that area. In most dissections, up to four fascial layers, parallel to the iliacus sheath, could be identified. Variable states of fusion of these layers often produced up to three pouches, separated by loose connective tissue or fat. These fasciae (called "lamina peritonealis," "lamina transversalis," "lamina preiliaca," and "lamina iliaca") appear to be variable adult remnants of distinct fascial layers present in the posterior abdominal wall during embryological development, and serve to strengthen the intrinsic fascia of the iliacus muscle. Latex injected into the iliacus sheath spread from the midlumbar region to the femoral triangle, surrounding, compressing, and stretching the femoral nerve in different parts of its course. These observations suggest an anatomical basis for femoral nerve palsy during iliacus hematoma.

KEY WORDS  •  fascia  •  femoral nerve  •  iliacus hematoma  •  iliacus muscle  •  nerve compression syndrome

Femoral nerve palsy has long been known as a complication in hemophilia and other blood dyscrasias.14,7,8 Femoral nerve palsy is an occasional consequence of traumatic hematoma resulting from sport activities,6,10,14 from vehicular accidents,9 and, rarely, from rupture of an abdominal aortic aneurysm into the iliopsoas muscle.12

The recent increase in incidence of femoral neuropathies parallels the widespread use of anticoagulant agents to prevent coronary thrombosis, thromboflebitis, and embolism, and as antithrombotic prophylaxis in many surgical procedures.6,13,15,18,19 The location of the pelvic portion of the femoral nerve between the iliacus and psoas muscles makes the nerve particularly vulnerable in hemorrhage within the iliacus. The iliacus hematoma syndrome consists of a compression neuropathy of the femoral nerve subsequent to hemorrhage within the iliacus.

Patients with iliacus hematoma syndrome characteristically exhibit a large, painful, tender, globular swelling due to hemorrhage in the iliac fossa. Goodfellow, et al.,7 reported three cases where an additional fusiform mass developed in the psoas fascial compartment, with a palpable groove between the distended psoas and iliacus muscles. There may sometimes be swelling in the groin.1 Severe pain and sensory loss along the distribution of the femoral nerve, and weakness or paralysis of the quadriceps muscle are frequently encountered. Sometimes the pain radiates into the lumbar area, occasionally producing a secondary scoliosis. A puzzling phenomenon, however, is the position of the hip, which is characteristically flexed, abducted, and externally rotated. This peculiar hip position affords maximum relief from severe pain by reducing tension on the femoral nerve, which is stretched over the bulging hematoma.6

More than 70 papers have reported femoral nerve palsy due to hemorrhage, but we could find only two previous attempts1,7 to explain the mechanism of this type of femoral neuropathy by dissection or infusion experiments. Brower and Wilde1 demonstrated that the distal spread of fluid injected directly into the iliacus fascia in an unembalmed cadaver was blocked at the inguinal ligament. This demonstrated that
pressure produced by bleeding into the fascial funnel of the iliacus could compress the femoral nerve. However, it failed to account for the swelling in the femoral triangle, or the hip flexion so often associated with iliacus hematoma syndrome. In a second infusion experiment on a fresh cadaver, they succeeded in producing hip flexion and swelling in the femoral triangle by direct infusion of fluid into the area of the iliopsoas insertion after passing a long needle below the inguinal ligament.\textsuperscript{1} Goodfellow, \textit{et al.,}\textsuperscript{1} in their infusion experiments, succeeded in overcoming the blockage of fluid passage below the inguinal ligament, and obtained a swelling in the femoral triangle by forcing larger amounts of fluid into the substance of the iliacus muscle in the iliac fossa. They concluded that the compartments of the iliacus and psoas muscles are separate except for a communication in the thigh, because the psoas compartment could be filled in a retrograde manner from an injection into the iliacus compartment via a communication below the inguinal ligament. Their paper included a photograph clearly depicting a triangular sheet of thick iliacus fascia bridging the sulcus between the iliacus and psoas muscles and penetrated by the femoral nerve. Both papers stressed the known rigidity of this distal part of the fascial funnel which allowed compression of the femoral nerve in this area, but did not elaborate further about anatomical details.

We have pursued the anatomical basis for femoral nerve palsy subsequent to iliacus hematoma in a series of dissections of fresh and embalmed cadavers. The results of our work show that the persistence of several fascial layers in the lower abdomen provides an unusually varied but rigid communication network between the iliacus and psoas muscles, distention of which can surround and compress the femoral nerve in iliacus hematoma.

\textbf{Materials and Methods}

Our observations are based on dissections of the iliac fossa, posterior abdominal wall, and subinguinal region in 44 embalmed cadavers, and on studies of the distribution of colored gelatin and latex injected into the sheaths surrounding the psoas and iliacus muscles in two embalmed and two unembalmed cadavers. The dissections were performed in the Departments of Anatomy at the University of Massachusetts Medical School and Yale Medical School, the Anatomisches Institut of the University of Zurich, and the Pathology Department of the Franklin County Hospital, Greenfield, Massachusetts.

Determination of the distensibility and extent of fascial layers demonstrated in dissections was attempted by injection of fluid into the psoas and iliacus sheaths in four additional specimens. Care was taken to keep these areas undisturbed before injection by entering the abdomen anteriorly, retracting the intestines, and entering the sheaths with a No. 20 needle directed parallel to the long axis of each muscle. Our
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attempts to use water to distend these spaces were not successful because it was difficult to control leakage. Next, we tried colored gelatin and contained leakage by injecting into a cool body. This also proved unsatisfactory because we were unable to inject large volumes without forming a gel. Our best results were obtained using colored latex in three bodies where leakage and working time could be controlled by addition of acetic acid to the mixture before and during injection.

Results

Anatomical relationships in the right iliac fossa and subinguinal region and some of our observations are illustrated in Fig. 1. Notice the course of the femoral nerve (15) between the iliacus and psoas muscles in the abdomen, between the psoas and inguinal ligament, and medial to the iliopsoas below the inguinal ligament.

In our first dissection we demonstrated a triangular sheet of thickened fascia in the lower iliac region similar to that shown in Fig. 1. This sheet had been described by Goodfellow, et al. Lacking prior designations, we named it “lamina preiliaca.” The lamina preiliaca forms an inverted triangle. Its base may be straight or slightly concave (Fig. 1). It lies ventral either to the continuous fascia iliaca, or to a reinforced distal portion of the fascia iliaca which we have named the “lamina iliaca.” The lamina preiliaca is attached medially to the psoas fascia, laterally and caudally to the fascia transversalis, and occasionally may also be attached cranially to the fascia iliaca, in which case an oblique lid is formed over the space between the two structures. The lamina iliaca was variably present and could be distinguished from the fascia iliaca upon close inspection by clearly prominent cross striations of dense, coarse connective tissue fibers giving the lamina increased thickness and strength. From the distal border, attached to the posterior aspect of the inguinal ligament, to its thin proximal base, the height of the lamina iliaca in several specimens varied from 4 to 10 cm.

Subsequent dissections confirmed the variable presence of these laminae iliaca and preiliaca, and also revealed two additional laminae, which, for lack of any previous nomenclature, we named, proceeding from posterior to anterior, “lamina transversalis,” and “lamina peritonealis.” These fasciae and laminae and the potential spaces that may be formed between them are located on the posterior abdominal wall (Fig. 2). Ventral to the lamina preiliaca is a triangular fascial sheet lying in the plane of the fascia transversalis, the lamina transversalis. The fascia transversalis covers the transversalis muscle, and continues proximally and distally as a continuous sheet to line the anterolateral and part of the posterior wall of the abdominal cavity. The reflected transversalis fascia turns medially on the posterior abdominal wall and lies posterior to the peritoneal lining. The lamina transversalis appears to be identical with the thickened distal part of the reflected fascia transversalis described by Gray.

Situated anterior to the lamina transversalis is the lamina peritonealis. This consists of the distal portion of the peritoneum, which is reinforced at this level by a dense fibrous sheet of connective tissue.

True or potential pouch-like spaces may be formed between these four laminae (Fig. 3), and we have designated them as ventral, intermediate, and dorsal pouches (Fig. 2) when all three are present (Fig. 4). The ventral space lies between the lamina peritonealis and lamina transversalis (Figs. 2 and 5). An intermediate pouch is formed by the lamina transversalis and the lamina preiliaca (Figs. 2 and 4), and the dorsal pouch lies between the lamina preiliaca and the lamina iliaca (or the iliococcygeal fascia covering the iliacus muscle when a lamina iliaca is absent) (Figs. 2 and 4). A fourth potential pocket between the lamina iliaca and the iliococcygeal fascia (Fig. 2) is not designated because a definite lamina iliaca was observed in only a few of our specimens, and in each case was tightly adherent to the subjacent iliococcygeal fascia. The lateral border and
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FIG. 3. Dissection of right iliac fossa showing two pouches, one (13) between two laminae and another between the posterior lamina and the femoral nerve (12). The common iliac artery (3), genitofemoral nerve (7), and lateral femoral cutaneous nerve (10) are also labeled. This and the following figures are oriented so that proximal is at the top and distal at the bottom. Medial and lateral aspects will vary according to the side of body.

FIG. 4. Deep dissection of specimen shown in Fig. 3, with laminae peritonealis (1) and transversalis (2) reflected to show the lamina preiliaca (deep to paper arrow). The potential spaces between 1 and 2, 2 and the lamina preiliaca, and deep to lamina preiliaca (paper arrow) represent ventral, intermediate, and dorsal pouches, respectively.

bottom of all pouches were attached or anchored to the posterior aspect of the inguinal ligament. Some pouches were completely closed distally, while others communicated with the pectineal fossa in the thigh.

The laminae forming the walls at times contained additional layers of subperitoneal fat, the thickness of which varied with the obesity and body type of the individual. Because the sheet of subperitoneal fat was only loosely attached to the lamina, its complete detachment resulted in additional subdivisions of a pocket. In slender and emaciated subjects it was easy to demonstrate pouches filled only with loose strands of interwoven connective tissue fibers and trabeculae. In obese specimens the pouches were filled with variable amounts of areolar fat, and became evident only after separating the laminae by blunt dissection.

The presence and extent of laminae and pouches varied greatly. Each cadaver save one had at least one lamina and pouch. When present, they were usually not identical bilaterally. Thus, one cadaver could have one pouch on the left side and two (Fig. 3), or none at all, on the right. As shown in the drawing (Fig. 2), when there is no space between different laminae the latter may be fused to form leaflets in the anterior or posterior walls of one of the remaining pouches. Thus the anterior wall of a dorsal pouch might consist of a leaflet formed by fusion of the laminae preiliaca, transversalis, and peritonealis (Fig. 2 lower left); or the posterior wall of the ventral pouch might consist of the fused lamina transversalis, lamina preiliaca, and the lamina (or fascia) iliaca (Fig. 2 lower right). Except for the observation that most cadavers had at least one pouch and lamina, we found no prevailing patterns or combinations.

Proximally, these laminae became progressively thinner and were extremely difficult to dissect. We attempted to probe the projections and connections of these laminae by superficial injections of colored latex into six pouches overlying the iliacus muscle (Figs. 6 to 8) in three unembalmed cadavers. These injections confirmed the vulnerability of the femoral nerve in this area as it was surrounded, stretched (Fig. 8), and compressed (Figs. 6 and 7) by the injected latex. By changing the depth of the injection, it was possible to fill pouches with a superficial injection or bypass them with a deeper one (Fig. 9). Latex injected into pouches
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FIG. 5. Superficial dissection of left iliac fossa showing a ventral pouch between the lamina peritonealis (1) and lamina transversalis (2).

overlying the iliacus penetrated proximally between laminae in anterior and posterior layers to vertebral level L-2. These masses encircled the femoral nerve, and the posterior mass reached more cranial than the anterior one. In one instance, the proximal spread of the latex was stopped at the level of the iliac crest by the semilunar margin of fusion of two laminae, similar to that shown in Fig. 9. Distally, latex injected into the iliacus muscle proceeded deep to the inguinal ligament into the femoral triangle in a broad band posterior and lateral to the femoral nerve. Below the inguinal ligament there was retrograde filling of the adjacent part of the psoas sheath, and reflection of some latex onto the pectineus about 2 cm below the level of the lesser trochanter. Cross sections of the injected area showed that the latex injections penetrated to the tendinous insertion of the iliopsoas.

Discussion

We have demonstrated that in the iliac fossa as many as three distinct laminae, demonstrable by blunt dissection, reinforce the distal portion of the iliac fascia. Their attenuated proximal extensions reached midlumbar levels in some specimens. These laminae were either fused or separated to produce up to three pouches of various sizes. Latex injected into some of these spaces spread from midlumbar levels to below the lesser trochanter, encircling, compressing, and stretching the femoral nerve in its abdominal and subinguinal course. These laminae could reinforce the iliac fascia, preventing the escape of extravasated blood. Our observations complement earlier studies and provide an anatomical basis for femoral nerve palsy, which accompanies the iliacus hematoma syndrome.1,7,14,18

Classification and nomenclature of the variable number of laminae and the diversity of pouches posed problems. As is often the case, previous embryological studies provided an explanation. The early work of Gerota,4 complemented by that of Daseler and Anson8

FIG. 6. Left iliac fossa and subinguinal region after removal of anterior abdominal wall, inguinal ligament, and intestines in an unembalmed specimen with latex injection. The locations of the femoral (1) and lateral femoral cutaneous (2) nerves are indicated by arrows. Latex injected in the iliacus sheath (*) can be distinguished from that injected into the psoas (**).
and Tobin\textsuperscript{16} has supplied evidence for stratification of the posterior abdominal fascia into three layers. The first layer is the transversalis fascia immediately adjacent to the inner surface of the transversalis muscle and aponeurosis, and its intrinsic fascia, and ventral to, but separate from, the intrinsic fascia of the quadratus lumborum and psoas muscles. The second layer is retroperitoneal tissue of fatty and collagenous-elastic fibers interposed between the fascia transversalis and peritoneum. (In our dissections the fatty content of the ventral pouch appeared to be a distal part of the areolar sheet of retroperitoneal fascia descending from the kidney region). The third stratum is the renal fascia arising, according to Tobin,\textsuperscript{16} not from the split transversalis fascia but from the retroperitoneal tissue, to form the capsule enveloping the kidney, peritoneal fat, and adrenal glands. In certain stages of embryonic development, it can be shown that each of the three strata forms a continuous layer from the kidney to the inguinal region.\textsuperscript{16} It seems reasonable to infer that the laminae and pouches we have described are varying distal remnants of these embryonic strata. Thus, all the puzzling variations of fascial morphology which we found in the distal iliacus region seem to parallel Tobin’s observations in the kidney region and elsewhere in the abdomen,\textsuperscript{16} and therefore can be understood in the context of the development of the abdominal fasciae as a whole.

The pouches we have described may have multifaceted clinical, diagnostic, and surgical significance, aside from their anatomical interest. The fascial walls and laminae of the pouches tend to reinforce the rigidity of the fibrous arch over the femoral nerve in the intermuscular groove; and, when the pouches are filled with blood, would further increase pressure on the subjacent nerve. Openings, often found in the
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function of unusual local hemodynamics might well be explored by microangiographic techniques. 

From the study of anatomical descriptions and pictures alone, one can easily obtain the impression of a compact muscular envelope in limbs and abdominal walls. This illusion is further enhanced by cross sections picturing the muscles tightly surrounded by thin fascial lines without interspaces. However, pathological hemorrhages, effusions or pus collections, and experimental insufflation with air or fluid prove this concept to be erroneous. The abdominal walls and the upper thigh often contain large potential intercommunicating fascial compartments extending the entire length of the abdomen and thigh, respectively, crossed only by fine adipose strands and bridges. The importance of fascial spaces in anatomy and surgery, as well as the divergent and confusing state of our present knowledge, suggest the potential usefulness of similar studies of other regions of the body.

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References


various pouches, could allow hemorrhage from the iliac fossa or from the pouch walls themselves to enter the femoral triangle. Some of our dissections showed a proximal lid covering and closing the funnel-like compartment of the dorsal pouch, attached ventrally to the rim of the pouch wall and dorsally to the fascia iliaca. A probe into this dorsal pouch revealed that it opened proximally into the iliacus compartment and distally beneath the inguinal ligament into the psoas sheath in the thigh, thus offering an unobstructed path from the iliacus compartment into the femoral triangle. Bleeding into the deep substance of the iliacus muscle itself could also enter the femoral triangle by gravitational flow, following the muscle beneath the constricting inguinal ligament into the thigh.

The predisposition of the iliacus muscle to intramuscular hemorrhage remains unexplained and deserves investigation. The extent to which this is a


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