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Compartment-Like Organization of Adipose Tissue Deep to the Transversalis Fascia Around the Deep Inguinal Ring

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Abstract

Purpose

The tissue deep to the posterior wall of the inguinal canal, between the transversalis fascia and peritoneum, remains insufficiently understood. We aimed to develop a compartment-like three-dimensional morphological model of this tissue by clarifying its structure-associated organization, continuity, and spatial relationships around the deep inguinal ring.

Methods

Five inguinal regions from three formalin-fixed adult male cadavers were examined: one by anterior dissection, three by peritoneal dissection, and one by serial block-face imaging using the CoMBI system. Three-dimensional reconstruction was performed from the serial block-face images.

Results

The tissue between the transversalis fascia and peritoneum was not arranged as a uniform layer of preperitoneal fat. Three structure-associated fibroadipose units related to the inferior epigastric vessels, ductus deferens, and testicular vessels were delineated, together with the vesicoumbilical fibroadipose territory (VFT) and median-paramedian adipose region (MPAR). The ductus deferens- and testicular vessel-associated units extended directly toward the deep inguinal ring, whereas the inferior epigastric vessel-associated unit, VFT, and MPAR occupied adjacent territories.

Conclusion

The findings support a compartment-like three-dimensional morphological model in which the fibroadipose units and territories remain open and continuous, rather than a set of histologically closed, independent anatomical compartments. Distinguishing ring-directed fibroadipose units from adjacent territories may help clarify how established fascia-, space-, and ring-based concepts relate to the internal fibroadipose arrangement.

INTRODUCTION

Groin hernia repair is one of the most frequently performed surgical procedures worldwide, and a precise understanding of posterior inguinal anatomy is essential for safe and effective repair [1, 2]. In posterior and laparo-endoscopic approaches, including transabdominal preperitoneal repair (TAPP), totally extraperitoneal repair (TEP), and robotic TAPP, surgeons approach the inguinal region from the peritoneal or preperitoneal side rather than from the anterior body-wall side [3–5]. In these approaches, the operative field directly involves the posterior wall of the inguinal canal, the deep inguinal ring, and the

tissue plane between the transversalis fascia and peritoneum. Accordingly, understanding the three-dimensional organization of this region is important both for anatomical description and for interpreting the surgical field encountered during posterior groin hernia repair [6, 7].

The posterior wall of the inguinal canal has classically been described as being formed mainly by the transversalis fascia, and the configuration of the inguinal canal and deep inguinal ring has long been a central issue in inguinal anatomy [8]. Lying deep to this posterior wall, the inguinal region has been interpreted using several related anatomical concepts, including the preperitoneal fascia, preperitoneal space, space of Bogros, space of Retzius, and deep inguinal ring [5, 9–13]. Prior studies emphasize that the transversalis fascia, preperitoneal fascia, and preperitoneal space should not be regarded as simple and interchangeable layers but as parts of a complex posterior inguinal anatomy relevant to hernia repair [5, 9–11, 13]. Recent surgical-anatomical descriptions have shifted attention from a two-dimensional layer-based view toward a three-dimensional understanding of the preperitoneal and extraperitoneal spaces around the deep inguinal ring [5, 13].

These fascia-, space-, and ring-based concepts, however, primarily describe membranous boundaries, surgically relevant planes, potential spaces, and anatomical apertures and do not fully address what occupies the region between the transversalis fascia and peritoneum or how the adipose tissue within this region is internally organized. Furthermore, it remains unclear whether the tissue deep to the posterior wall of the inguinal canal represents a uniform layer of preperitoneal fat or is organized in association with specific anatomical structures, such as the inferior epigastric vessels, ductus deferens, testicular vessels, medial umbilical ligament, and vesical vessels.

A compartment-like approach to adipose tissue may help address this unresolved issue. Our recent anatomical studies of the retroperitoneal region around the kidney have shown that adipose tissue is not merely amorphous filler tissue but can be organized into structure-associated adipose compartments separated by membranous or fascial structures [14–16]. These studies suggest that adipose tissue can serve as an anatomical indicator of how vessels, organs, and fasciae are spatially organized within the retroperitoneum. The region deep to the posterior wall of the inguinal canal is also an extraperitoneal or preperitoneal region located between the body wall and peritoneum. A similar compartment-like approach may therefore be useful for understanding the tissue between the transversalis fascia and peritoneum around the deep inguinal ring. This study aimed to develop a compartment-like three-dimensional morphological model of this adipose tissue and to clarify the boundaries, continuity, and spatial relationships of its structure-associated fibroadipose units and territories. Because thin membranous boundaries within adipose tissue are difficult to preserve and follow by manual dissection alone, stepwise macroscopic dissection was combined with serial block-face imaging and three-dimensional reconstruction.

METHODS

Cadaveric specimens and ethical approval

This study used three adult male cadavers donated to the Institute of Science Tokyo for anatomical education and research with written informed consent provided by each donor before death. All procedures were conducted in accordance with the ethical principles for the use of donated human bodies for anatomical research, and the study protocol was approved by the Ethics Committee of our institution (approval number: M2024-091).

The cadavers were aged 77, 86, and 89 years, and five inguinal regions were examined. None of the examined cadavers showed obvious surgical scars, marked deformity, or severe disruption of the inguinal or pelvic region.

Macroscopic dissection

Macroscopic dissection was performed to examine the relationship between the posterior wall of the inguinal canal and the extraperitoneal adipose tissue around the deep inguinal ring. The right inguinal region of the 77-year-old cadaver was dissected from the anterior aspect. The left inguinal region of the 86-year-old cadaver and both inguinal regions of the 89-year-old cadaver were dissected from the peritoneal aspect.

For the anterior approach, the skin, subcutaneous adipose tissue, and abdominal wall muscles were sequentially removed to expose the transversalis fascia. The external oblique aponeurosis and spermatic cord were reflected to observe the posterior wall of the inguinal canal. The transversalis fascia was then cut and reflected, and the underlying inferior epigastric vessels, ductus deferens, medial umbilical ligament, testicular vessels, urinary bladder, and associated adipose tissue were examined by stepwise dissection.

For the peritoneal approach, the inguinal region was observed from the pelvic cavity side. The peritoneum was removed to expose the extraperitoneal structures. The testicular vessels, ductus deferens, ureter, urinary bladder, medial umbilical ligament, median umbilical ligament (urachus), vesical vessels, inferior epigastric vessels, and their surrounding adipose tissue were sequentially identified. Each structure and its surrounding adipose tissue were then cut and removed in a stepwise manner to clarify the spatial arrangement of the fibroadipose units and territories around the posterior wall of the inguinal canal.

Operational definition and classification of compartment-like fibroadipose units

In this study, a fibroadipose unit was operationally classified as structure-associated when it surrounded or accompanied a specific macroscopic structure and satisfied at least two of the following criteria: (1) a membranous boundary separating it from adjacent adipose tissue; (2) traceability over a continuous range of serial sections; (3) continuity along a specific anatomical structure; (4) distinction by both

macroscopic and sectional anatomy; and (5) a similar topographic relationship in more than one specimen.

These criteria were assessed across the complementary methods and available specimens; confirmation of every unit by every method was not required. Accordingly, the term “compartment” and the adipose compartment (AC) abbreviations are used only as operational descriptors within a compartment-like morphological model; they do not imply that any unit constitutes a histologically closed or independent anatomical space.

The adipose units surrounding the inferior epigastric artery and vein, ductus deferens, and testicular artery and veins were designated the adipose compartment of the inferior epigastric artery and vein (AC-IEA/V), adipose compartment of the ductus deferens (AC-DD), and adipose compartment of the testicular artery and veins (AC-TA/V), respectively. Adipose tissue surrounding the ureter was designated the adipose compartment of the ureter (AC-Urt). Because the AC-Urt was encountered posteriorly during deeper pelvic dissection, it was considered an adjacent retroperitoneal compartment and was not included among the compartments directly related to the deep inguinal ring.

The medial umbilical ligament was regarded as a remnant of the umbilical artery and as a structure continuous with the superior vesical artery. The vesicoumbilical fibroadipose territory (VFT) was defined as a continuous territory of fibroadipose tissue distributed along the medial umbilical ligament and vesical vessels, continuing with the fibroadipose tissue on the anterolateral surface of the urinary bladder, and extending medially along the median umbilical ligament (urachus). The median umbilical ligament and its associated fibroadipose tissue were included in the VFT because the urachus is continuous with the apex of the urinary bladder, although it is not part of the vesical arterial system. The term VFT was therefore adopted to encompass both vascular and nonvascular continuities in the vesicoumbilical region without implying an exclusively arterial system or a histologically closed compartment. Adipose tissue in the median to paramedian prevesical region lacked an obvious association with a specific macroscopic structure and had weaker evidence for a separate enclosing boundary. It was therefore designated the median-paramedian adipose region (MPAR), rather than an independent compartment.

The resulting classification thus comprised three structure-associated fibroadipose units in the posterior inguinal region (AC-IEA/V, AC-DD, and AC-TA/V), one adjacent retroperitoneal compartment (AC-Urt), one vesicoumbilical territory (VFT), and one median-paramedian region (MPAR).

Serial block-face imaging using the CoMBI system

To define the fine three-dimensional anatomy of the fibroadipose tissue and its thin membranous boundaries, which were difficult to trace continuously by manual dissection alone, serial block-face images were obtained from the left inguinal region of the 77-year-old cadaver using the correlative microscopy and block-face imaging (CoMBI) system. In our previous study, this system permitted

correlation of block-face images with histological sections and proved suitable for three-dimensional analysis of fibroadipose tissues [16]; the present study analyzed the block-face images only. The specimen included the anterior abdominal wall, inguinal canal, deep inguinal ring, spermatic cord, extraperitoneal tissue, and adjacent pelvic structures.

The specimen was fixed and embedded in opaque paraffin containing 6.25% w/w white crayon. The specimen block was oriented such that the cutting plane passed obliquely in the sagittal direction through the inguinal canal. The block was cut into 5-μm sections using a rotary-type microtome (RX-860; Yamato Kohki Industrial Co. Ltd., Saitama, Japan), and the exposed block face was photographed using a digital camera (Nikon D5100; Nikon Corporation, Tokyo, Japan) equipped with a macro lens (AF-S DX Micro NIKKOR 40 mm f/2.8G; Nikon Corporation). Block-face images were captured after every 20 sections, yielding serial images at 100-μm intervals.

A total of 623 serial block-face images were obtained and used to evaluate the layered arrangement of the inguinal region and the adipose tissue between the transversalis fascia and peritoneum, with particular attention to thin membranous boundaries and the continuity of structure-associated fibroadipose units and territories.

Segmentation and three-dimensional reconstruction

Three-dimensional reconstruction was performed from the serial block-face image dataset. For segmentation and reconstruction, every fifth image was selected from the original 623 images, generating a reduced dataset of 124 images at 500-μm intervals.

Structures of interest, including the peritoneum, spermatic cord, ductus deferens, testicular vessels, inferior epigastric vessels, medial umbilical ligament, urinary bladder, structure-associated fibroadipose units, VFT, and MPAR were segmented on the selected serial images using SegRef3D, a segmentation support tool developed for serial morphological images [17]. The segmentation masks were exported in NIfTI format using the export function of SegRef3D. The NIfTI data were then imported into 3D Slicer, where three-dimensional reconstruction and visualization were performed [18].

The reconstructed three-dimensional segments were used to assess the boundaries, continuity, and spatial relationships among the structure-associated fibroadipose units, VFT, and MPAR, including their relationships to the deep inguinal ring and posterior wall of the inguinal canal. To clarify their relative positions, selected structures were sequentially removed from the display during visualization.

Anatomical terminology

Anatomical terms were used according to standard anatomical nomenclature. The term “deep inguinal ring” was used throughout the manuscript for the anatomical structure clinically referred to as the internal inguinal ring. The term “ductus deferens” was used as the primary anatomical term for the vas deferens.

RESULTS

Macroscopic dissection from the anterior aspect of the inguinal region

During stepwise anterior dissection of the anterior abdominal wall and inguinal region, the skin, subcutaneous adipose tissue, and abdominal wall muscles, including the external oblique, internal oblique, transversus abdominis, rectus abdominis, and pyramidalis muscles, were sequentially removed. The transversalis fascia was then observed deep to the transversus abdominis muscle. When the spermatic cord was reflected to expose the posterior wall of the inguinal canal, the transversalis fascia was found to continue into the posterior wall of the inguinal canal and to constitute this wall (Fig. 1a).

After the transversalis fascia was cut and reflected, the inferior epigastric artery and vein were identified. These vessels were surrounded by adipose tissue, which was operationally designated the AC-IEA/V (Fig. 1b).

After removal of the inferior epigastric vessels and AC-IEA/V, the ductus deferens was observed extending from the spermatic cord toward the pelvic cavity, accompanied by its own surrounding adipose compartment, which was operationally designated the AC-DD (Fig. 1c). More medially, the medial umbilical ligament, corresponding to the obliterated umbilical artery, and adjacent fibroadipose tissue were identified. This tissue extended along the medial umbilical ligament and vesical vessels and was designated the VFT. Further medially, adipose tissue without an obvious association with a specific macroscopic structure was identified as the median-paramedian adipose region (MPAR), rather than as a discrete compartment.

After removal of the medial umbilical ligament and superior reflection of the peritoneum, deeper structures were examined. The testicular artery and veins and their associated adipose tissue were identified and operationally designated the AC-TA/V (Fig. 1d). The surface of the urinary bladder was exposed, and the VFT continued along the anterolateral surface of the bladder and associated vesical vessels.

Macroscopic dissection from the peritoneal aspect

The inguinal region was then examined from the peritoneal aspect. Initially, the median umbilical fold and medial umbilical ligament were identified anteriorly, whereas the psoas major muscle and common iliac artery and vein were identified posteriorly (Fig. 2a).

After removal of the peritoneum, the testicular artery and veins were observed running from the posterolateral side toward the deep inguinal ring. These vessels were accompanied by the AC-TA/V (Fig. 2b). The AC-TA/V formed a tubular structure around the testicular vessels and entered the deep inguinal ring together with them.

After the testicular vessels and AC-TA/V were cut and removed, the ductus deferens and AC-DD were observed extending from the medial side toward the deep inguinal ring (Fig. 2c). The lateral border of the AC-DD corresponded to the region previously occupied by the AC-TA/V.

After the ductus deferens and AC-DD were cut and removed, the ureter and its surrounding adipose compartment were identified near the common iliac artery and vein posteriorly. This tissue was designated the AC-Urt and interpreted as an adjacent retroperitoneal compartment encountered during deeper pelvic dissection, rather than as a compartment directly related to the deep inguinal ring (Fig. 2d).

After removal of the ureter and AC-Urt, the VFT was observed as a continuous fibroadipose territory distributed along the medial umbilical ligament and vesical vessels, continuing with the fibroadipose tissue on the anterolateral surface of the urinary bladder, and extending medially along the median umbilical ligament (urachus), which was continuous with the apex of the urinary bladder (Fig. 2e). Thus, the VFT was not interpreted as a closed compartment enclosing the urinary bladder but as a territory associated with the vesicoumbilical continuum.

When the VFT and its associated structures were cut and removed together, adipose tissue distinct from the VFT remained anterior to the urinary bladder in the median to paramedian region. This tissue was designated the MPAR (Fig. 2f). No specific macroscopic structure was identified within the MPAR, and it was therefore treated as an adipose region rather than a confirmed independent compartment.

After removal of the MPAR, the inferior epigastric artery and vein and their associated adipose compartment, AC-IEA/V, were identified on the anterior abdominal wall (Fig. 2g).

After removal of the inferior epigastric vessels and AC-IEA/V, the transversalis fascia was exposed and was confirmed to form the posterior wall of the inguinal canal (Fig. 2h).

Taken together, the anterior and peritoneal dissections showed that the tissue deep to the transversalis fascia was not a single uniform adipose layer. The thinnest membranous boundaries, however, could not be traced continuously by manual dissection alone; this limitation was addressed using serial block-face imaging.

Fine anatomy of the inguinal region revealed by serial block-face imaging

We found that the inguinal region was arranged in layers, with the external oblique aponeurosis, internal oblique and transversus abdominis muscles, transversalis fascia, and peritoneum located sequentially from the ventral side toward the deeper pelvic side; the interval between the transversalis fascia and peritoneum contained adipose tissue (Fig. 3b-e).

At the level where the inferior epigastric vessels were observed, the adipose tissue between the transversalis fascia and peritoneum was divided into multiple compartment-like fibroadipose units by vertically oriented membranous structures (Fig. 3c, e). By tracing the serial block-face images shown in

Online Resource 1, the structures associated with each unit were identified. Moving in the anterior-to-posterior direction, the AC-IEA/V surrounding the inferior epigastric vessels, VFT along the medial umbilical ligament and vesical vessels, and AC-DD containing the ductus deferens were identified (Fig. 3c, e). More laterally, the AC-TA/V containing the testicular vessels was identified, whereas more medially, the MPAR was observed in the median to paramedian region without an accompanying specific macroscopic structure.

Three-dimensional reconstruction and in silico dissection of the fibroadipose units and territories

A three-dimensional model of the inguinal region was generated by segmenting the fibroadipose units, territories, and other structures of interest and was examined from the posteromedial peritoneal side by *in silico* dissection (Fig. 4a-f). After the peritoneum was removed from the display, the AC-DD and AC-TA/V were observed immediately beneath it (Fig. 4b). These units extended toward the deep inguinal ring along the ductus deferens and testicular vessels, respectively.

After the AC-DD and AC-TA/V were removed from the display, the medial umbilical ligament and the VFT along it were visualized (Fig. 4c). After the VFT was removed, the MPAR was observed as a localized adipose region medially (Fig. 4d). After the MPAR was removed, the AC-IEA/V surrounding the inferior epigastric vessels became visible (Fig. 4e). After the AC-IEA/V was removed, the remaining structures demonstrated that these fibroadipose units and territories were arranged posterior to the spermatic cord and along the posterior wall of the inguinal canal (Fig. 4f).

DISCUSSION

This study supports a compartment-like three-dimensional morphological model of the adipose tissue between the transversalis fascia and peritoneum around the deep inguinal ring rather than establishing histologically closed, independent anatomical compartments. The tissue was not arranged as a homogeneous preperitoneal fat layer but displayed structure-associated organization. Three structure-associated fibroadipose units were delineated in relation to the inferior epigastric vessels (AC-IEA/V), ductus deferens (AC-DD), and testicular vessels (AC-TA/V); the VFT, which included the median umbilical ligament (urachus) and its associated fibroadipose tissue, and the MPAR occupied adjacent territories. Concordant compartment-like patterns were observed using complementary anatomical methods. Although three-dimensional analysis was performed on only one side of one cadaver and not every unit was confirmed by every method in every specimen, these complementary observations provide an operational model for understanding the posterior inguinal region.

The proposed model distinguishes fibroadipose units that extend directly toward the deep inguinal ring from territories that lie adjacent to it. The AC-DD and AC-TA/V followed the ductus deferens and testicular vessels, respectively, toward the ring. By contrast, the AC-IEA/V occupied a body-wall vascular territory along the posterior inguinal wall, the VFT occupied a vesicoumbilical territory, and the MPAR occupied the median prevesical region. These mediolateral changes in the spatial relationships among

the fibroadipose units and territories are summarized schematically in sagittal sections in Fig. 5. These fibroadipose units and territories converged spatially around the posterior inguinal wall but were not interpreted as histologically independent or overlapping closed spaces. The AC-Urt was encountered more posteriorly during deeper pelvic dissection and was therefore treated as an adjacent retroperitoneal compartment, not as part of the fibroadipose model directly related to the deep inguinal ring.

This organization can be interpreted in relation to established fascial anatomy of the groin. The AC-DD and AC-TA/V represent spermatic cord-associated fibroadipose units and may be topographically related to the internal spermatic fascia or spermatic sheath. The AC-IEA/V represents a body-wall vascular unit on the transversalis fascia side, whereas the VFT represents a vesicoumbilical territory related to the medial umbilical ligament, median umbilical ligament (urachus), vesical vessels, anterolateral surface of the urinary bladder, and urogenital fascial system. The MPAR corresponds topographically to median prevesical adipose tissue near the space of Retzius [5, 9–13, 19]. These proposed relationships are topographic and do not establish histological identity. Nevertheless, fascia-, space-, and compartment-like concepts may provide complementary descriptions of a shared three-dimensional fibroadipose region at different observational scales and from different surgical perspectives.

The model may also provide a more specific framework for interpreting posterior and laparo-endoscopic groin dissection. During TAPP, TEP, robotic TAPP, and related approaches, development of the preperitoneal plane and parietalization of the spermatic cord require dissection around the ductus deferens and testicular vessels, while the inferior epigastric vessels define a body-wall vascular territory and medial dissection approaches vesical and prevesical tissues [3–5, 7]. The distinction between ring-directed AC-DD/AC-TA/V and adjacent AC-IEA/V, VFT, and MPAR may help explain variations in tissue continuity and membranous boundaries across the posterior operative field. The present findings do not prescribe a specific operative technique or dissection plane but provide a structure-based morphological framework for interpreting the tissues encountered during these procedures.

Several limitations should be considered. The study included only three elderly male cadavers, and three-dimensional analysis was limited to one side of one cadaver. Pathological inguinal hernias, younger individuals, and female specimens were not examined. Formalin fixation, paraffin embedding, and stepwise removal of adjacent structures may have altered the volume and apparent boundaries of the adipose tissue. The histological composition and continuity of the membranous boundaries were not determined, and the operational criteria were not tested by blinded or interobserver reproducibility analysis. Increasing the number of specimens, performing detailed histological analyses, and correlating the findings with operative observations will therefore be required to examine their generalizability and determine whether the proposed units and territories are anatomically independent. Despite these limitations, our current findings support a compartment-like fibroadipose arrangement in which spermatic cord-associated units extend toward the deep inguinal ring, whereas body-wall vascular, vesicoumbilical, and median prevesical adipose territories occupy adjacent regions. This layered model

may help clarify the internal fibroadipose arrangement at the posterior inguinal wall in relation to established fascia-, space-, and ring-based concepts.

Declarations

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Figures

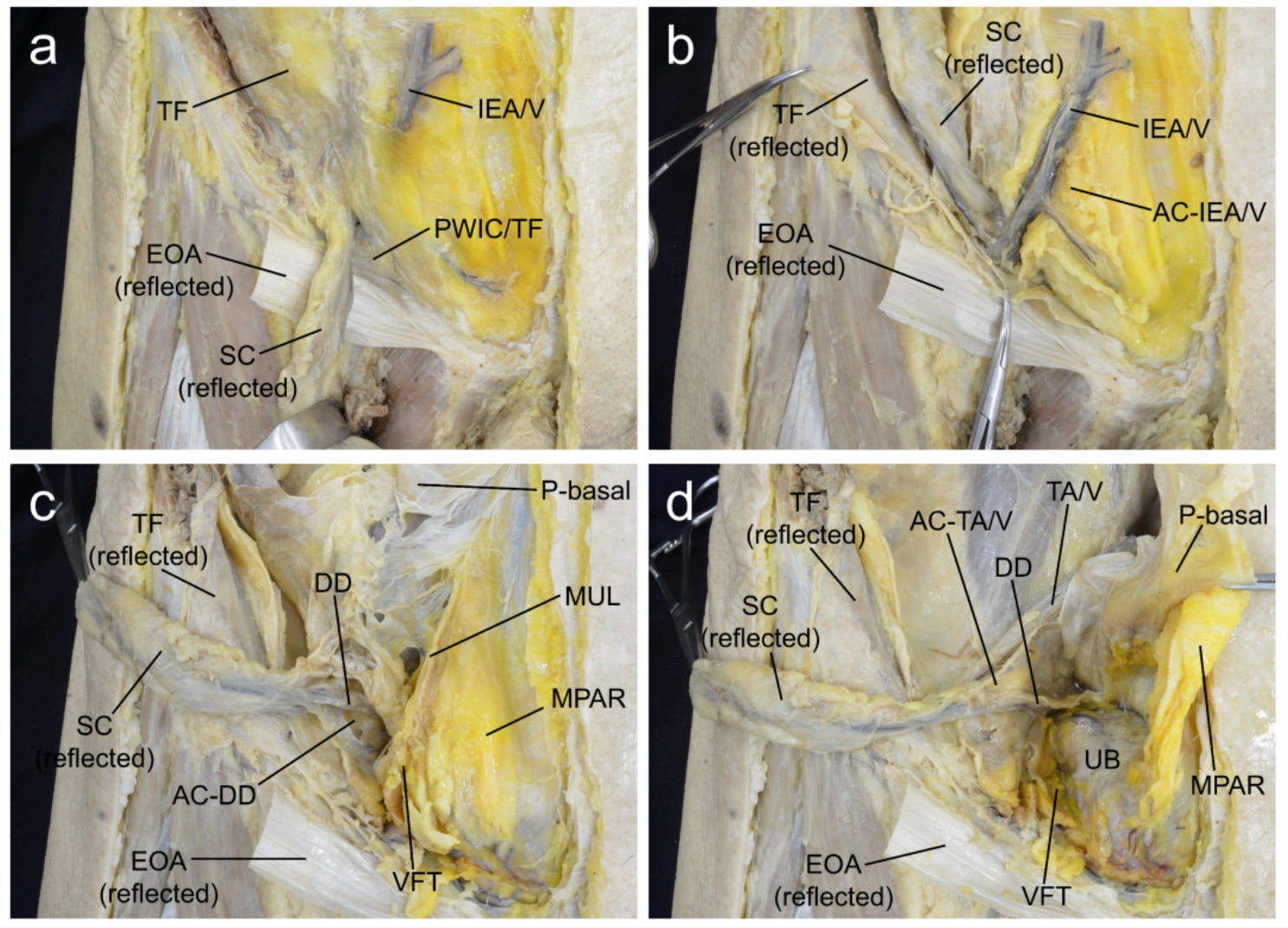


Figure 1

Stepwise macroscopic dissection of the right inguinal region from the anterior aspect

(a) After reflection of the external oblique aponeurosis and spermatic cord, the transversalis fascia was observed deep to the transversus abdominis muscle. The transversalis fascia continued into the posterior wall of the inguinal canal.

(b) After the transversalis fascia was cut and reflected, the inferior epigastric artery and vein were exposed. These vessels were surrounded by a distinct fibroadipose unit, operationally designated the AC-IEA/V.

(c) After removal of the inferior epigastric vessels and AC-IEA/V, the ductus deferens and its surrounding adipose compartment (AC-DD) were identified. More medially, the VFT along the medial umbilical ligament and the MPAR in the median to paramedian region were observed.

(d) After removal of the medial umbilical ligament and superior reflection of the peritoneum, the testicular artery and veins and their surrounding adipose compartment (AC-TA/V) were identified. The

VFT was observed along the anterolateral surface of the urinary bladder.

AC-DD, adipose compartment of the ductus deferens; AC-IEA/V, adipose compartment of the inferior epigastric artery and vein; MPAR, median-paramedian adipose region; AC-TA/V, adipose compartment of the testicular artery and veins; DD, ductus deferens; EOA, external oblique aponeurosis; IEA/V, inferior epigastric artery and vein; MUL, medial umbilical ligament; P-basal, basal side of the peritoneum; PWIC/TF, posterior wall of the inguinal canal formed by the transversalis fascia; SC, spermatic cord; TA/V, testicular artery and veins; TF, transversalis fascia; UB, urinary bladder; VFT, vesicoumbilical fibroadipose territory.

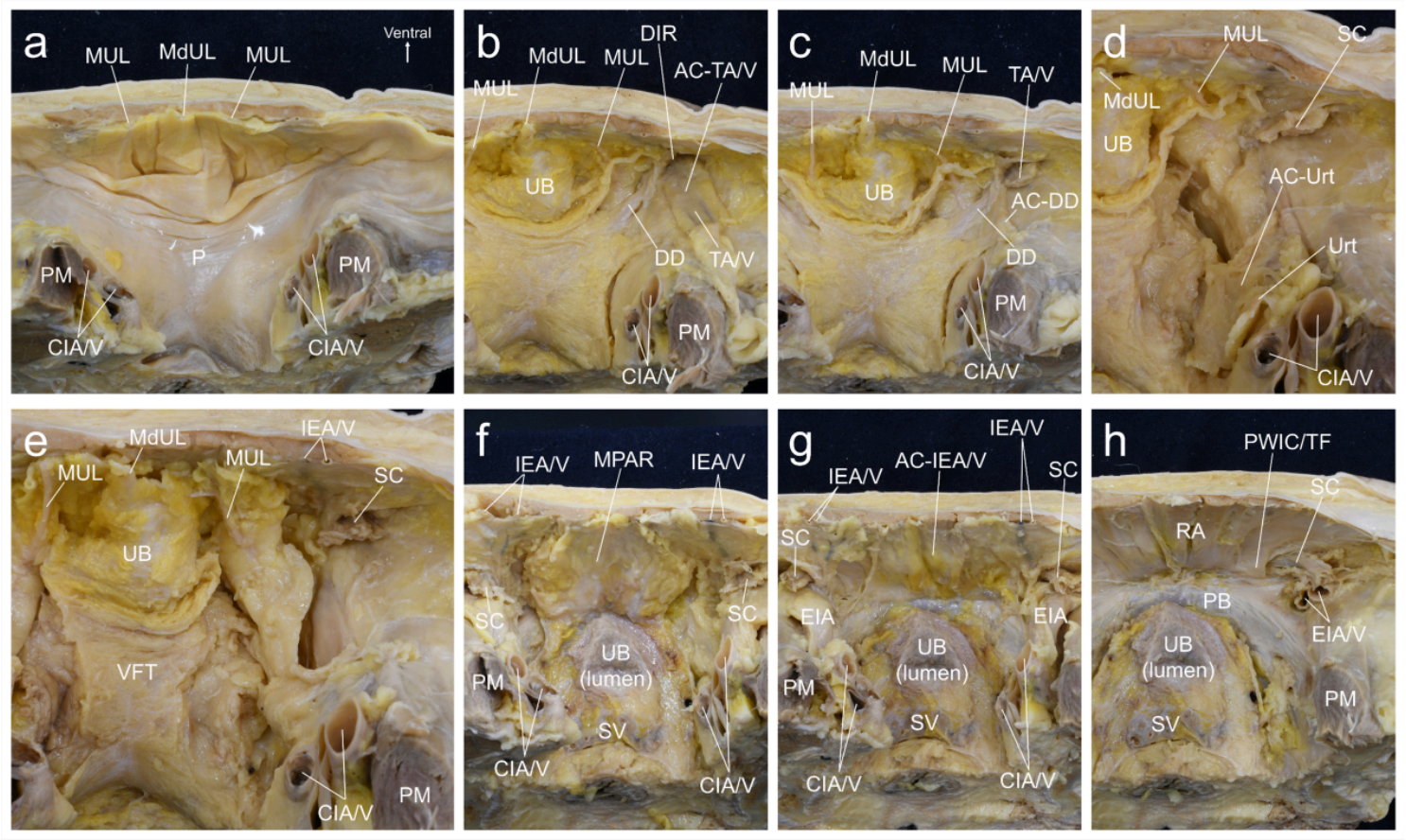


Figure 2

Stepwise macroscopic dissection of the inguinal region from the peritoneal aspect

(a) Initial view from the peritoneal aspect. The median umbilical ligament, medial umbilical ligament, psoas major muscle, and common iliac artery and vein were identified.

(b) After removal of the peritoneum, the testicular artery and veins and their surrounding adipose compartment (AC-TA/V) were observed running from the posterolateral side toward the deep inguinal ring.

(c) After removal of the testicular vessels and AC-TA/V, the ductus deferens and its surrounding adipose compartment (AC-DD) were observed extending from the medial side toward the deep inguinal ring.

(d) After removal of the ductus deferens and AC-DD, the ureter and its surrounding adipose compartment (AC-Urt) were identified near the common iliac artery and vein. The AC-Urt was an adjacent retroperitoneal compartment and was not included among the adipose structures directly related to the deep inguinal ring.

(e) After removal of the ureter and AC-Urt, the VFT was observed along the medial umbilical ligament and vesical vessels, continued with fibroadipose tissue on the anterolateral surface of the urinary bladder, and extended medially along the median umbilical ligament (urachus).

(f) After removal of the VFT and its associated structures, the MPAR remained anterior to the urinary bladder in the median to paramedian region.

(g) After removal of the MPAR, the inferior epigastric artery and vein and AC-IEA/V were identified on the anterior abdominal wall.

(h) After removal of the inferior epigastric vessels and AC-IEA/V, the transversalis fascia was exposed and confirmed to form the posterior wall of the inguinal canal.

AC-DD, adipose compartment of the ductus deferens; AC-IEA/V, adipose compartment of the inferior epigastric artery and vein; MPAR, median-paramedian adipose region; AC-TA/V, adipose compartment of the testicular artery and veins; AC-Urt, adipose compartment of the ureter; CIA/V, common iliac artery and vein; DD, ductus deferens; DIR, deep inguinal ring; EIA/V, external iliac artery and vein; IEA/V, inferior epigastric artery and vein; MdUL, median umbilical ligament; MUL, medial umbilical ligament; P, peritoneum; PB, pubic bone; PM, psoas major muscle; PWIC/TF, posterior wall of the inguinal canal formed by the transversalis fascia; RA, rectus abdominis muscle; SC, spermatic cord; SV, seminal vesicle; TA/V, testicular artery and veins; UB, urinary bladder; Urt, ureter; VFT, vesicoumbilical fibroadipose territory.

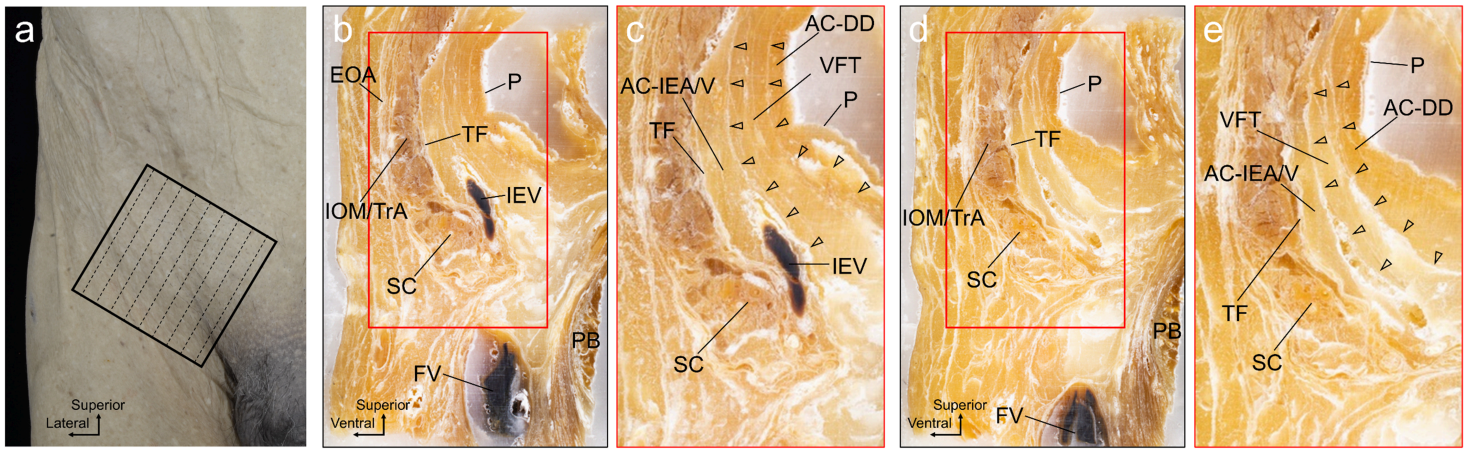


Figure 3

Serial block-face images through the inguinal canal

(a) Surface view of the cadaver. The box indicates the excised inguinal-region specimen, and the dotted lines indicate the direction of sectioning for serial block-face imaging.

(b, d) Serial block-face images showing two section levels through the inguinal canal. The section shown in d is located 500 μm medial to that shown in b. These images demonstrate the layered organization of the inguinal region. From the ventral side to the deeper pelvic side, the external oblique aponeurosis, internal oblique and transversus abdominis muscles, transversalis fascia, and peritoneum were identified. The space between the transversalis fascia and peritoneum was filled with adipose tissue.

(c, e) Enlarged views of the boxed regions in b and d, respectively. The adipose tissue between the transversalis fascia and peritoneum was subdivided by vertically oriented membranous structures. By tracing serial block-face images, multiple compartment-like fibroadipose units and territories were identified, including the AC-IEA/V, VFT, and AC-DD.

Arrowheads indicate membranous structures separating the compartment-like fibroadipose units and territories. AC-DD, adipose compartment of the ductus deferens; AC-IEA/V, adipose compartment of the inferior epigastric artery and vein; EOA, external oblique aponeurosis; FV, femoral vein; IEV, inferior epigastric vessels; IOM/TrA, internal oblique and transversus abdominis muscles; P, peritoneum; PB, pubic bone; SC, spermatic cord; TF, transversalis fascia; VFT, vesicoumbilical fibroadipose territory.

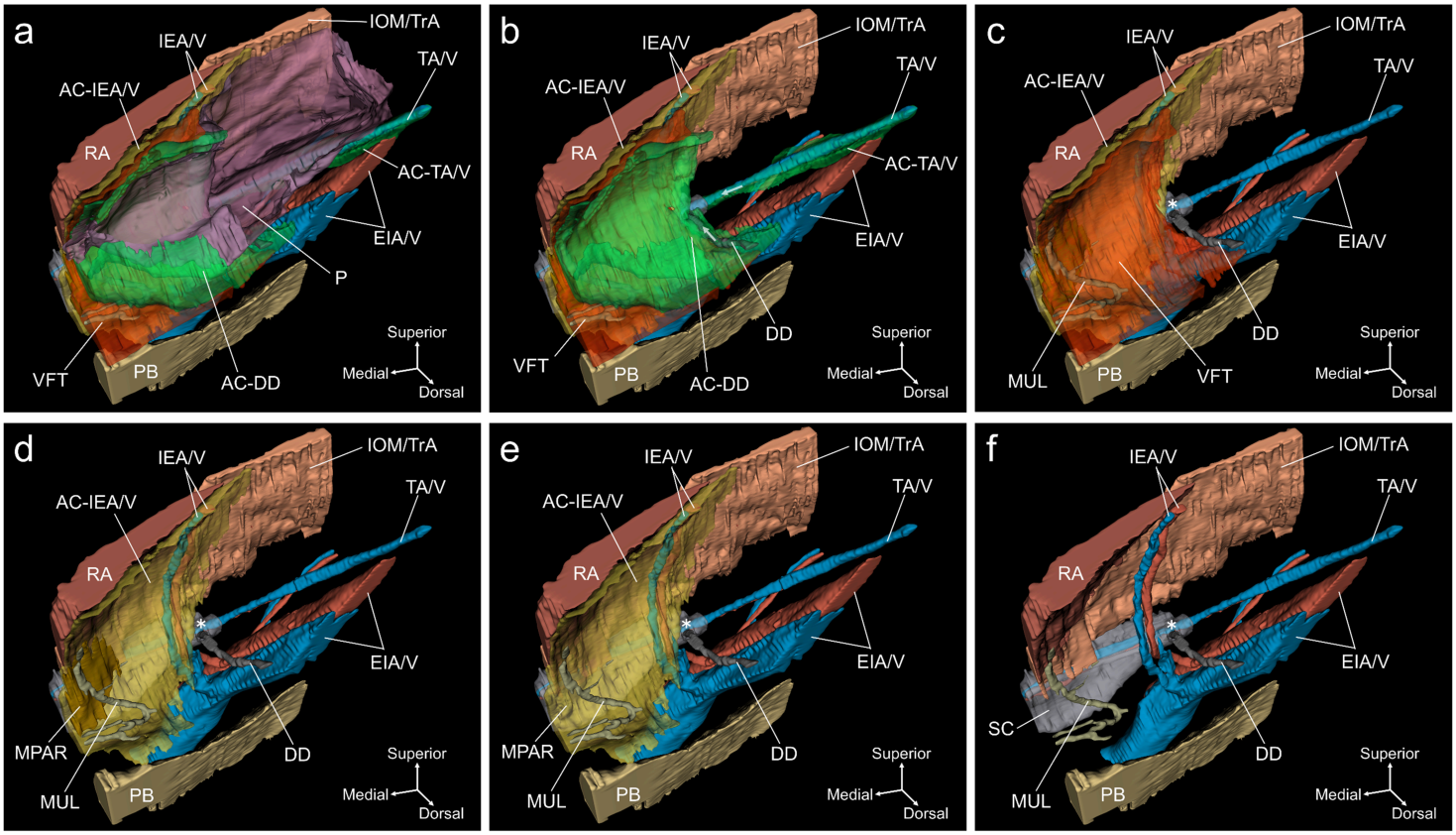


Figure 4

Compartment-like three-dimensional organization of fibroadipose units and territories around the posterior wall of the inguinal canal

The reconstructed images were viewed from the posteromedial peritoneal side. Asterisks mark the deep inguinal ring, and arrows indicate the ring-directed courses of the AC-DD and AC-TA/V. The color legend identifies the reconstructed fibroadipose units and territories, and the orientation triads indicate the superior, medial, and dorsal directions.

(a) Overview showing the spatial arrangement of the peritoneum, transversalis fascia-related structures, vessels, fibroadipose units, VFT, and MPAR.

(b) After removal of the peritoneum from the display, the AC-DD and AC-TA/V were observed immediately beneath it. These units extended toward the deep inguinal ring along the ductus deferens and testicular vessels, respectively.

(c) After removal of the AC-DD and AC-TA/V from the display, the VFT along the medial umbilical ligament was visualized.

(d) After removal of the VFT from the display, the MPAR was observed as a localized adipose region medially.

(e) After removal of the MPAR from the display, the AC-IEA/V surrounding the inferior epigastric vessels became visible.

(f) After removal of the AC-IEA/V from the display, the remaining structures demonstrated that these adipose structures were arranged posterior to the spermatic cord and along the posterior wall of the inguinal canal.

AC-DD, adipose compartment of the ductus deferens; AC-IEA/V, adipose compartment of the inferior epigastric artery and vein; AC-TA/V, adipose compartment of the testicular artery and veins; DD, ductus deferens; DIR, deep inguinal ring; EIA/V, external iliac artery and vein; IEA/V, inferior epigastric artery and vein; IOM/TrA, internal oblique and transversus abdominis muscles; MPAR, median-paramedian adipose region; MUL, medial umbilical ligament; P, peritoneum; PB, pubic bone; RA, rectus abdominis muscle; SC, spermatic cord; TA/V, testicular artery and veins; VFT, vesicoumbilical fibroadipose territory.

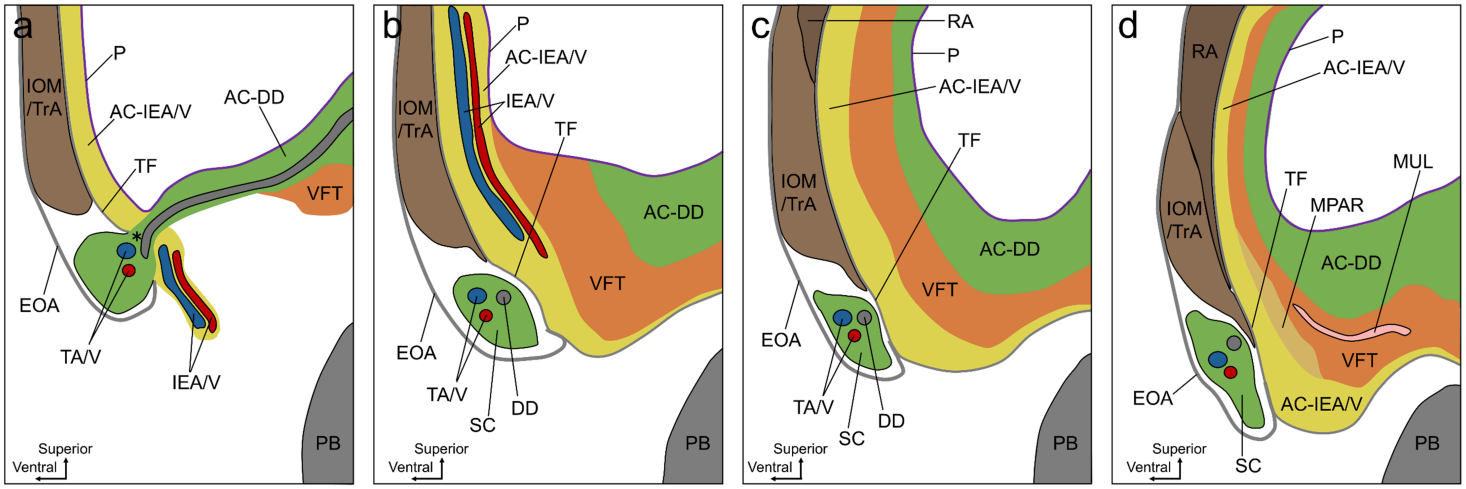


Figure 5

Schematic sagittal sections illustrating the compartment-like fibroadipose organization around the posterior wall of the inguinal canal

(a–d) Schematic sagittal sections through the inguinal region at four mediolateral levels, based on sagittal reslicing of the reconstructed three-dimensional dataset and arranged from lateral to medial.

(a) Section at the level of the deep inguinal ring. The asterisk indicates the deep inguinal ring.

(b) Section at the level of the inferior epigastric artery and vein.

(c) A more medial section.

(d) Section at the level of the medial umbilical ligament.

The diagrams illustrate the spatial relationships among the structure-associated fibroadipose units and adjacent territories between the transversalis fascia and peritoneum.

AC-DD, adipose compartment of the ductus deferens; AC-IEA/V, adipose compartment of the inferior epigastric artery and vein; DD, ductus deferens; EOA, external oblique aponeurosis; IEA/V, inferior epigastric artery and vein; IOM/TrA, internal oblique and transversus abdominis muscles; MPAR, median-paramedian adipose region; MUL, medial umbilical ligament; P, peritoneum; PB, pubic bone; RA, rectus abdominis muscle; SC, spermatic cord; TA/V, testicular artery and veins; TF, transversalis fascia; VFT, vesicoumbilical fibroadipose territory.

Supplementary Files

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