Computed tomography (CT) remains a valuable technique in the assessment of the female pelvis. The CT appearance of the normal ligamentous, vascular, and visceral anatomy of the female pelvis can be confusing. Newer high-resolution CT scanners combined with mechanical intravenous contrast medium injectors and thinner sections have substantially improved the imaging of female genital anatomy. In addition to the cardinal, uterosacral, and round ligaments, the ovaries and their ligamentous attachments, as well as the blood supply to the female internal organs, can now be visualized. Inferior-to-superior image acquisition following bolus administration of intravenous contrast material with an angiographic injector facilitates precise identification of the uterine artery and its relationship to the pelvic ureter and the vascular plexus supplying the vagina, ovaries, and uterine body. Ideally, familiarity with variations in the CT appearance of normal female pelvic anatomy will enable more accurate evaluation of pelvic abnormalities.

INTRODUCTION
The computed tomographic (CT) appearance of the normal ligamentous, vascular, and visceral anatomy of the female pelvis can be confusing unless one is familiar with the basic anatomy of these structures and normal variations in their appearance. High-resolution CT scanners and techniques tailored to examination of the pelvis now permit detailed visualization of the ovaries, uterus, and cervix, as well as precise identification of their ligamentous attachments and vascular supply. In this article, we review the normal anatomy and CT appearance of the female internal genitalia and discuss techniques that facilitate visualization of these structures.

Index terms: Computed tomography (CT), thin-section, 85.12118 • Pelvic organs, 85.12118, 85.92 • Pelvic organs, neoplasms, 85.32


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See the commentary by Hattery et al following this article.
Figure 1. Posterior view of the female ligaments and viscera. Drawing illustrates the broad, round, cardinal, uterosacral, and ovarian ligaments and their relationships to the uterus, ovaries, and pelvic ureters.

PATIENT POPULATION AND IMAGING TECHNIQUES

CT images were selected from a review of 135 pelvic CT examinations performed on 125 women ranging in age from 22 to 83 years. A group of 80 patients (15 with normal findings and 65 with abnormal findings) and another group of 45 patients (10 with normal findings and 35 with abnormal findings) underwent imaging performed with two different scanners. Diagnoses in the patients with abnormal findings were cancer of the ovary, endometrium, cervix, vagina, and vulva.

All images were acquired with a Somatom Plus CT scanner with an Impress detector system (Siemens, Iselin, NJ) or a GE 9800 Quick CT scanner (Milwaukee, Wis). All studies utilized a tailored pelvis protocol consisting of (a) a bolus intravenous injection of 100–150 mL of 60% iodinated contrast material administered with an angiographic injector at 2 mL/sec; (b) inferior-to-superior image acquisition with an 8–10-mm section thickness from the pubis to the iliac crest, a 1-second scan time, and a 5.0–6.5-second interscan delay; (c) delayed 2–5-mm sections through the pelvic abnormality or region of interest; and (d) oral administration of 750 mL of 2% barium during the 2 hours before the examination to optimize colonic opacification at image acquisition.
The purpose of the tailored pelvis protocol was fivefold: (a) to help differentiate pelvic blood vessels from lymph nodes and parametrial tumor extension; (b) to enhance uterine myometrium and epithelium and delineate the endometrial cavity; (c) to enhance the cervical stroma and epithelium; (d) to demarcate tumor from normal uterine and cervical parenchyma; and (e) to opacify the bladder and pelvic ureters, further delineate abnormalities, and eliminate partial volume averaging on delayed thin sections.

**PELVIC LIGAMENTS**
The broad ligament is formed by two layers of peritoneum, which drape over the uterus and extend laterally from the uterus to the pelvic sidewall (Figs 1, 2) (1–5). The superior free edge is formed by the fallopian tube medially and the suspensory ligament of the ovary laterally (2,4–6). The lower margin of the broad ligament ends at the cardinal ligament (Fig 1). Between the two leaves of the broad ligament is loose extraperitoneal connective tissue, smooth muscle, and fat known as the parametrium, which contains the fallopian tube, round ligament, ovarian ligament, uterine and ovarian blood vessels, nerves, lymphatic vessels, mesonephric remnants, and a portion of the ureter (1,2,7,8). Although the broad ligament is rarely seen unless ascites is present, its position can be determined by structures that it abuts or contains.

**Figure 2.** Axial view of the female pelvic viscera and ligaments at the level of the uterine body. Drawing illustrates the uterine body and the ovaries and their relationships to the round, broad, and ovarian ligaments.
Figure 3. Normal round ligaments. (a) CT scan through the uterus (U) and a right ovarian cyst (0) shows normal round ligaments bilaterally (black arrows). The left ligament tapers distally (small white arrow), where it crosses the left external iliac artery and vein anteriorly (large white arrows). (b) CT scan through an enlarged uterus (U) shows fine round ligaments (small white arrows) that cross anteriorly toward the inferior epigastric vessels (large white arrow), where the ligaments enter the internal inguinal ring. The necrotic cavity (N) and metastatic right obturator lymph node (L) are due to recurrent cervical carcinoma. (c) CT scan through the uterus (U), normal pelvic ureters (white arrows), and right ovary (0) shows a normal asymmetric left round ligament (black arrows) resulting from a variation in uterine position. Note the triangular shape of this round ligament, with gradual distal tapering.

Figure 4. Axial view of the cardinal and uterosacral ligaments. Drawing illustrates the relationship of the cardinal and uterosacral ligaments to the cervix.
The round ligament is a band of fibromuscular tissue that attaches to the anterolateral uterine fundus just below and anterior to the fallopian tube and anterior to the ovarian ligament (Figs 1, 2) (1,2,4,6,7). It is positioned anterolaterally in a curved course within the broad ligament to enter the internal inguinal ring and terminates in the labia majora (Fig 2) (1–3,5,7). The round ligament is frequently seen on CT scans as a thin soft-tissue band that extends laterally from the fundus and gradually tapers from its relatively broad base at the uterus (9). Its appearance is variable (Fig 3).

The cardinal ligament (transverse cervical ligament, Mackenrodt ligament) forms the base of the broad ligament and provides the primary ligamentous support for the uterus and upper vagina (2,7). It extends laterally from the cervix and upper vagina to merge with a fascia overlying the obturator internus muscle (Figs 1, 4) (2,7). The uterine artery runs along its superior aspect (1). The cardinal ligament is usually seen on CT scans as a triangular soft-tissue structure with the base of the triangle abutting the cervix and the apex tapering toward the pelvic sidewall (10,11). There is a wide variation in thickness, shape, and contour of the normal cardinal ligament (Fig 5).
**Figure 6.** Normal and abnormal uterosacral ligaments. (a) CT scan through a normal cervix (c) shows the typical appearance of uterosacral ligaments (arrows) tapering posteriorly from the posterolateral margin of the cervix toward the sacrum (s). (b) CT scan of a thin 4-mm section through a normal cervix (c) shows very fine uterosacral ligaments (arrows). These ligaments were not identified on the standard, 8-mm pelvic CT sections. s = sacrum. (c) CT scan through the cervix (c) in a patient who underwent radiation therapy for squamous cell carcinoma of the cervix shows thickening of the tissue planes of and adjacent to the uterosacral ligaments (arrows) bilaterally. These changes are typical after pelvic irradiation for female genital tract cancer.

**Figure 7.** Normal ovarian ligament. CT scan through the uterus (U) shows both ovaries (o) and the left ovarian ligament (arrow), which lies between the ovary and the body of the uterus. Note also the normal anterior location of the left round ligament (arrowhead).
The uterosacral ligament extends posteriorly from the lateral cervix and vagina at the level of the internal cervical os and forms a curved arc toward the anterior body of the sacrum at S-2 or S-3 (4,5,7,10,11). Its fibers fuse medially with posterior fibers of the cardinal ligament (Figs 1, 4) (2,4,11). Although the uterosacral ligament is only a few millimeters thick, it is frequently seen with high-resolution CT scanners (Fig 6).

The ovarian ligament (round ligament of the ovary) extends medially from the ovary to the uterus, just inferior and posterior to the fallopian tubes and round ligaments (Figs 1, 2) (3,4,9). Its position varies with the ovaries. This structure is not usually identified on CT scans (Fig 7).

The suspensory ligament of the ovary (infundibulopelvic ligament) occupies the lateral aspect of the free upper edge of the broad ligament (Fig 1) (3,4). It extends from the ovary anterolaterally over the external iliac vessels to fuse with connective tissue over the psoas muscle (1). The suspensory ligament transmits the ovarian artery and vein and is rarely seen on CT scans (Fig 8) (1,3,6).

Figure 8. Normal suspensory ligament of the ovary. (a-c) Serial inferior-to-superior sections through a large central endometrial tumor (T). (a) Scan shows the base of the left round ligament (arrow). (b) Scan shows a portion of the left suspensory ligament of the ovary (white arrow) posterior to the round ligament (black arrow). (c) Scan shows the normal left ovary (O) with its suspensory ligament (arrow).
**Figure 9.** Posterior view of the pelvic vascular supply. Drawing illustrates the course of the uterine and ovarian blood vessels and their relationships to the pelvic viscera and ligaments.

**Figure 10.** Detailed anterior view of the pelvic internal organ vascular supply. Drawing illustrates the course of the uterine and ovarian arteries and veins, their branches, and their rich anastomotic networks. Note particularly the relationship of the uterine artery to the pelvic ureter as the ureter passes below the uterine artery.

**VASCULAR SUPPLY TO THE PELVIC ORGANS**

The paired uterine arteries provide the primary blood supply to the uterus (Figs 9, 10) (1,7). These large arteries are branches from the anterior (visceral) trunk of the internal iliac (hypogastric) arteries (2,3,7). The uterine artery courses medially above the cardinal ligament in the base of the broad ligament and crosses anterior to the pelvic ureter en route to the cervix (Fig 10) (1,3–6,12–14). The artery divides and sends a smaller cervicovaginal branch inferior to the vagina and lower cervix and a larger uterine branch superior to the uterus (Figs 9, 10) (3,7,15). Each of these branches is tortuous and forms extensive vascular networks lateral to the vagina and uterus, respectively (4,7,14). The uterine artery ultimately trifurcates at the upper uterus with branches to the fallopian tube, the uterine fundus, and the ovary (1,2,5).

The vagina is also supplied by vaginal arteries that arise directly from the internal iliac arteries (1). The uterine arteries, their branches and rich anastomotic networks, and their anatomic relation to the pelvic ureters can often be precisely identified with high-resolution CT scanning techniques tailored to the pelvis. The arteries, which demonstrate the most intense opacification when the arterial bolus of contrast material reaches the pelvis, enhance along with the internal and external iliac arteries. The CT appearance of the uterine arteries is variable (Figs 11, 12).
Figure 11. Normal uterine arteries. (a) CT scan at the level of the cervix (c) shows a prominent enhanced left uterine artery (arrow). Note the concurrent opacification of the external iliac arteries (arrowheads). (b) CT scan obtained at a slightly higher level than a shows that the artery (arrows) courses superiorly along the lateral aspect of the uterus (U) and lower uterine segment. (c) CT scan through a normal cervix (c) shows a beaded appearance of the opacified right uterine artery (arrow). (d) CT scan through an anteverted uterus shows prominent enhancing uterine vessels (arrows) ascending along the lateral aspect of the uterus, where they will eventually anastomose with branches of the ovarian vessels. These vessels most likely represent uterine arteries, given the concurrent enhancement of the external iliac arteries (arrowheads). (Reprinted, with permission, from reference 18.) (e) CT scan through the cervix (c) in an elderly diabetic woman shows characteristic calcification in both uterine arteries (arrows).
Venous drainage of the upper vagina, cervix, uterus, and ovaries is via an extensive plexus of thin-walled, valveless veins that lie between the layers of the broad ligament within the parametrium (1,3,5,12). This plexus eventually forms veins that largely parallel the arterial blood supply (1,4,5,7). The left ovarian vein, however, drains into the left renal vein instead of the inferior vena cava (4,5). The veins and their companion arteries can be seen on CT scans as enhancing vascular networks or a plexus in the pelvic fat. Their appearance varies from prominent vessels to very delicate strands (Fig 13).

The paired ovarian arteries (gonadal arteries) arise directly from the aorta just below the origin of the renal arteries (2,3,7). Once the ovarian artery descends to the pelvis, it enters the broad ligament through the suspensory ligament of the ovary (Figs 9,10) and sends multiple branches to the ovary via the mesovarium (1,2,5,7). The artery continues medially to anastomose with the ovarian branch of the uterine artery (Figs 9,10) (1,3,5,7). This vessel is infrequently visualized, even with high-resolution dynamic scanning techniques (Fig 14).

**PELVIC VISCERA**

Improved high-resolution CT scanning capabilities, combined with dynamic inferior-to-superior image acquisition, utilize the rich vascular supply to the uterus, cervix, and vagina to better define normal and disease processes not previously visualized on CT scans. Endometrium and myometrium cannot yet be differentiated from one another on CT scans. However, endometrial and myometrial...
Figure 13. Cervical and vaginal vascular plexus. (a) CT scan through a normal cervix (c) shows a very delicate, enhancing vascular network (arrows) along the lateral aspects of the cervix and in the lateral paracervical fat. (b) CT scan through a central cervical tumor (T) surrounded by normal peripheral cervical stroma shows a prominent bilateral, opacified cervicovaginal vascular plexus (arrows). (c) CT scan obtained at the level of the vagina (V) shows that the bilateral paravaginal vascular plexus (arrows) is prominent lateral to the rectum (r) and adjacent to the pelvic sidewall.

Figure 14. Ovarian vascular supply. (a) CT scan through the uterus (U) and both ovaries (o) shows an enhancing curvilinear vessel (arrow) along the posterior aspect of the right ovary. (b) CT scan of the same patient, obtained at a slightly higher level through the right ovary (o), shows the contrast-enhanced right ovarian blood vessels (arrow) in the right ovarian ligament.
Figure 15. Normal and abnormal uterus. (a) CT scan through an anteflexed uterus and a large central cervical tumor (T) shows a normal contrast-enhanced uterine myometrium (m) and central endometrial cavity (e). (b) CT scan through a uterine fluid collection (f) that contains a Copper-7 intrauterine device (arrow) (Searle Laboratories, Chicago, Ill) shows contrast enhancement of the myometrium (m), which helps to delineate a portion of the nonenhanced obstructing cervical tumor (T). (c) Dynamic CT scan through an adenosquamous carcinoma of the myometrium shows a round hypoattenuating tumor (T) invading the myometrium (m) and a dilated central endometrial cavity (e). (d) Delayed CT scan of the same patient shows almost complete washout of the initial myometrial enhancement (m). Some residual focal enhancement of the mass (arrow) is seen.

Enhancement helps to distinguish the endometrial cavity from the uterus and aids in the identification of lesions within the uterine wall (Fig 15). The CT spectrum of normal cervical and vaginal enhancement is still being determined. It is likely that the moderately enhancing peripheral portion of the cervix correlates with the fibrous stroma described in MR imaging and pathologic correlations (16,17). The highly enhancing inner zone is believed to represent cervical epithelium (Fig 16) (16). The intense central vaginal enhancement likely corresponds to vaginal mucosa that can be differentiated from the poorly enhancing vaginal wall (Fig 16) (16).

The ovaries lie tucked in the ovarian fossa on the posterior floor of the true pelvis (1,5). They are bordered anteriorly by the broad ligament, mesovarium, and hilus of ovary with its ovarian vessels; superiorly by the external iliac vessels; posteriorly by the ureter and internal iliac vessels; and medially by the ovarian ligament (Figs 1, 2) (1,3). These relationships, as well as the internal anatomy of the ovaries, are well delineated on CT scans (Fig 17). Ovarian position is extremely variable (3,7,10,11).
Figure 16. Cervix and vagina. (a) Dynamic CT scan through a normal cervix shows presumed normal central enhancement of the cervical epithelium (arrow). The peripheral cervical stroma enhances to a lesser degree (arrowhead). (b) CT scan through the vagina at the suprapubic level shows central intense contrast enhancement of the vaginal mucosa (black arrows) and the poorly enhancing vaginal wall (white arrows).

Figure 17. Normal ovaries. (a) CT scan through a normal uterus (U) and a small left ovarian cyst (o) shows the normal relationship of the pelvic ureter (white arrow) posteriorly and the round ligament (black arrow) anteriorly. (b) CT scan through an antverted uterine body (U) shows a normal right ovary with multiple large follicles (arrows). (c) Dynamic CT scan through a central small cervical tumor (T) shows an anatomic variation with a low position of the ovaries (o) bilaterally.
CONCLUSION

Advances in CT technology and protocols tailored to examination of the female pelvis make possible precise identification of structures previously not well delineated with CT. The utility of this knowledge in the evaluation of female pelvic abnormalities when compared with ultrasound and magnetic resonance imaging has not yet been definitively studied. Transvaginal ultrasound is ideally suited to the evaluation of the ovaries and characterization of pelvic masses.

Knowledge of ligamentous and visceral anatomy is currently helpful in identifying pelvic structures and distinguishing gynecologic from nongynecologic abnormalities on CT scans. Further investigation is necessary to fully define the usefulness of the precise vascular definition now available with CT and to determine its potential usefulness in tumor staging. It is hoped that familiarity with variations in the CT appearance of normal female pelvic anatomy will facilitate more accurate assessment of pelvic abnormalities.

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REFERENCES

Invited Commentary

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The preceding article contains three basic principles applicable to CT of the pelvis: CT technique, image quality, and knowledge of female pelvic anatomy. Accurate diagnoses, staging of neoplasm, assessment of postoperative changes or follow-up of a disease process for example, are dependent on impeccable technique, the highest quality of images, and recognition of normal anatomy.