Anatomy, histology, and nerve density of clitoris and associated structures: clinical applications to vulvar surgery

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BACKGROUND: A precise understanding of structures comprising the female external genitalia is essential in obstetric and gynecologic practice.
OBJECTIVE: To further characterize the anatomy, histology, and nerve density of the clitoris and associated structures, and to provide clinical correlations to vulvar surgery.
MATERIALS AND METHODS: Unembalmed female cadavers were examined. The length and width of the body, glans, and crura of the clitoris were measured. Distances from the glans to the urethra and from the dorsal surface of the clitoral body to the mid pubic arch were recorded. The path of the dorsal nerve of the clitoris was examined, and the nerve width was measured as it emerged from the lateral surface of crura and at the distal clitoral body. Distances from where the dorsal nerve emerged from the perineal membrane to the posterior surface of the membrane and to mid pubic arch were measured. Connective tissue layers associated with the clitoris were examined. Tissue was harvested from additional unembalmed cadavers, and nerve density of the labia minora, glans, and clitoral body were analyzed. Histological examination was performed on vulvar structures to clarify tissue composition. Descriptive statistics were used for data analyses.
RESULTS: A total of 27 cadavers (aged 48—96 years) were examined, 22 grossly and 5 histologically. The median length and width of clitoral body were 29 mm (range, 13—59 mm) and 9 mm (range, 5—14 mm), respectively. The glans was 8 mm (range, 5—12 mm) long and 4 mm (range, 3—10 mm) wide. The length of the crura was 50 mm (range, 25—68 mm), and the width at the anterior portion was 9 mm (range, 2—13 mm). The closest distance from the glans to the urethra was 25 mm (range, 14—37 mm) and from the clitoral body to the mid pubic arch was 29 mm (range, 14—46 mm). The widths of the dorsal nerve at the lateral crura and at the distal clitoral body were 3 mm (range, 2—4 mm) and 1 mm (range, 1—2 mm), respectively. The distance from the dorsal nerve as it emerged from the perineal membrane to the mid pubic arch was 34 mm (range, 20—48 mm) and to the posterior surface of the membrane was 20 mm (range, 8—31 mm). The dorsal nerve and artery of the clitoris coursed adjacent to the medial surface of the inferior pubic ramus surrounded by a dense fibrous capsule adherent to the periosteum. The nerve and artery then coursed deep to dense connective tissue layers, which were contiguous with the suspensory ligament and fascia of the clitoris. Histologic examination revealed the presence of erectile tissue in the clitoral body, crura, and vestibular bulbs, but such tissue was absent in the glans and labia minora. Nerve density analysis revealed statistically significant greater density in the dorsal compared with ventral half of the clitoral body. Although not statistically significant, there was increased nerve density in the distal compared to the proximal half of the labia minora.
CONCLUSION: Precise knowledge of clitoral anatomy and associated neurovascular structures is essential to safely complete partial vulvectomies, clitoral and vulvar reconstructive procedures, anti-incontinence surgeries, and repair of obstetric lacerations. Understanding the range of anatomic variations and awareness of the areas of increased nerve density is important during counseling and surgical planning. Although the dorsal nerve of the clitoris courses deep to dense connective tissue layers, inadvertent injury may occur in the setting of deep dissection or suture placement. The dorsal nerve seems most vulnerable with surgical entry or lacerations that extend from the midline of the prepuce to the inferior pubic rami.

Key words: clitoral anatomy, clitoris, dorsal nerve of clitoris, erectile tissue, labia minora, nerve density, vestibular bulbs

A thorough knowledge of structures comprising the female external genitalia is essential in obstetric and gynecologic practice. However, descriptions of the clitoris and associated vulvar structures are underrepresented in current anatomy and gynecology textbooks[1–6] compared with detailed descriptions of penile anatomy.[4,7] Conflicting data exist on the tissue composition of the clitoris, vestibular bulbs (VB), and labia minora. Although most studies support the presence of erectile tissue in the clitoral body (CB), crura, and VB,[8] some studies suggest that erectile tissue also exists in the labia minora[5,9] and glans of the clitoris.[4,10–12] Furthermore, limited and inconsistent reports exist on the arrangement of connective tissue layers comprising the suspensory ligaments of the clitoris.[6,13,14] There is also scarce information on the precise path and anatomic relationships of the dorsal nerve of the clitoris (DNC).

The DNC, a terminal branch of the pudendal nerve, can potentially be injured anywhere along its path through the perineum. Injury may lead to loss of sensation to the glans and vulvar skin, chronic pain syndromes, and sexual dysfunction.[15,16] The incidence of DNC injury associated with vulvar procedures is unknown but is likely underreported. Injury has been reported with placement of midurethral slings,[15,17] and injury risk theoretically exists during repair of obstetric lacerations, periclitoral mass resections, prepuce reductions, and wide local vulvar excisions. In addition, labia minora reductions are becoming increasingly more common,[18] and scarce

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AJOG at a Glance

Why was this study conducted?

To further characterize the anatomy, histology, and nerve density of the clitoris and associated structures, and to provide clinical applications to vulvar surgery.

Key findings

The dorsal nerves of the clitoris have a consistent and reproducible path; their distal segments may be susceptible to injury during prepuce reduction and other vulvar procedures. Erectile tissue is present in the clitoral body, crura, and vestibular bulbs but is absent in the glans and labia minora. Although not statistically significant, there is increased nerve density in the distal versus proximal segment of the labia minora.

What does this add to what is known?

Histologic confirmation of tissue composition of the clitoris, vestibular bulbs, and labia minora. Description of regional nerve density within the body and glans of the clitoris and labia minora. Precise characterization of path and anatomic relationships of the dorsal nerve of the clitoris with clinical correlations.

information exists regarding nerve density within this tissue.

Precise knowledge of vulvar anatomy is important in surgical planning and prevention of nerve injury, which may result in loss of sensation, chronic pain syndromes, and sexual dysfunction. The objectives of this study are to further characterize the anatomy, histology, and nerve density of the clitoris and associated structures, and to provide clinical correlations to vulvar surgery.

Materials and Methods

Vulvar dissections and microscopic examination with nerve density assessment of the clitoris, labia, and VB were performed in unembalmed cadavers obtained from the Willed Body Program at University of Texas Southwestern Medical Center (UTSW) in Dallas. Cadavers were excluded if they had a history of gynecologic cancer or evidence of metastatic cancer to the vulva. This study was exempt from review by UTSW Medical Center Institutional Review Board in accordance with Code of Federal Regulations, Title 45. Age, race, height, weight, and cause of death were obtained. Three preparatory dissections were performed by the senior author (M.M.C.) with the remaining authors present to establish a standard method of dissection and data recording. Three authors (L.A.J., A.M.H., J.J.H.) performed all dissections and data recording with senior author supervision. Measurements were taken by 2 authors (L.A.J., A.M.H.) using the same steel electrocardiogram caliper and ruler. Each author took 1 measurement, and an average of these 2 measurements was used for analysis. Descriptive statistics were used for data analysis and reporting using Microsoft Excel (2011; Microsoft Corporation, Redmond, WA).

Gross dissections

Superficial vulvar structures

Figure 1 (dotted lines) illustrates the location where length and widths were measured and distances between structures were obtained.

Prior to dissection, the length and width of the glans and the length and longest extent of the labia minora were recorded. Glans length was measured from its junction with the prepuce skin to the most distal extent, and width was measured at the former point. The clitoral index was calculated by multiplying the length and width of the glans.[19] The closest distance between the glans and the external urethral orifice was obtained to examine spatial relationships between these structures. The skin along the length of the prepuce was sharply transected at the 11 and 1 o'clock positions. Incisions were extended to the mons pubis, cephalad to the anterior labial commissure, and over the ischiopubic rami (IPR) to the ischial tuberosities and then medially to the perineal body. Skin, underlying subcutaneous tissue, and superficial perineal fascia overlying perineal muscles were sharply excised until the CB, crura, and VB were identified. Fibers of the ischiocavernosus and bulbospongiosus muscles were removed. Layers transected prior to identification of the CB and crura were evaluated. Relationships of these layers to suspensory ligaments of the clitoris were examined. Length and width of the VB were recorded.

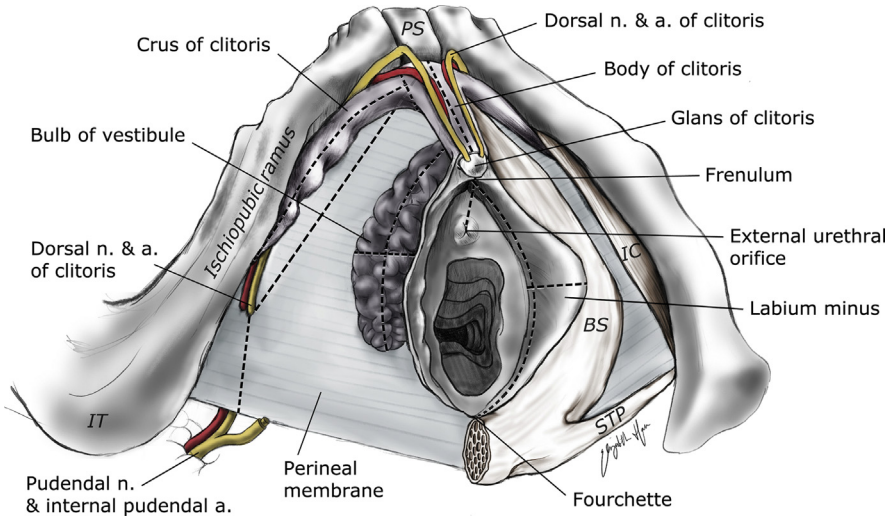
Body and crura of clitoris

The CB was defined as the paired corpora cavernosa with the investing thin connective tissue layer known as the tunica albuginea. CB length was measured along its dorsal surface, and width was measured at the midpoint. Width included all tissue layers surrounding the CB, as this measurement was taken prior to removal of surrounding layers. The length and width of the crura were recorded. To evaluate the relative position of the CB to the pubic symphysis, distances from the mid pubic arch to the most anterior aspect of the CB, which is conventionally called the dorsal surface, were recorded.

Dorsal nerve of clitoris

Bilaterally, the mid segment of the crus was sharply dissected off the IPR to expose the DNC and associated vascular structures. The DNC width was measured where it first emerged from the lateral surface of the crus, as this may represent a vulnerable location during vulvar surgeries. The DNC width was measured at the distal CB, before it perforated the glans, to determine whether nerve width diminished after giving off cutaneous branches to the prepuce. In 7 specimens, a section of DNC was excised for histologic confirmation of nerve tissue. Branching patterns and endpoints of the DNC were annotated. The crus was dissected off the IPR, and the DNC was followed posteriorly to where it passed from the deep perineal space to the superficial space of the anterior perineal triangle by piercing

FIGURE 1
Clitoris and associated vulvar structures



Schematic view of exposed superficial space of anterior perineal triangle showing structures evaluated. Dotted lines represent location where length and widths were measured and distances between structures obtained.

BS, bulbospongiosus muscle; *IC,* ischiocavernosus muscle; *IT,* ischial tuberosity; *PS,* pubic symphysis; *STP,* superficial transverse perineal muscle.

Jackson et al. Clitoral anatomy and histology with clinical applications to vulvar surgery. Am J Obstet Gynecol 2019.

the perineal membrane (PM). Distances from this point to the posterior edge of the PM and midpoint of the pubic arch were measured to examine the location of the DNC as it entered the superficial perineal space. Within this space, the DNC might be more vulnerable than in the deep space, which is not commonly entered during vulvar surgeries. The distance from where the DNC pierced the PM to the most distal edge of the IPR was measured to provide a visual understanding of attachments of the PM relative to the IPR.

Connective tissue joining the clitoris to the pubic symphysis and anterior surfaces of the pubic bones was transected, and the clitoris was retracted posteriorly to expose structures passing under the pubic arch. The position of the dorsal veins of the clitoris relative to the mid pubic arch was annotated.

Microscopic examination

In separate cadavers, tissue was harvested within 24 hours from the time of death for histologic analysis. Cross-sections of the glans, CB, and surrounding tissue layers, crura, labia, and VB were harvested. The glans was sharply transected in cross-section at the level of its junction with the prepuce. Two cross-sections of the proximal half of the CB, 1 cm apart, were obtained. After exposing the crura, cross-sections of each crus were sharply excised at the level of the junction with the CB. Cross-sections of each labia minora, right and left, where they extended farthest from the vestibule, and a cross-section through the mid portion of the VB, from the hymen medially toward the IPR laterally, were obtained. Harvested tissue was immersed in 10% formalin solution for 48 hours and submitted in cassettes for processing.

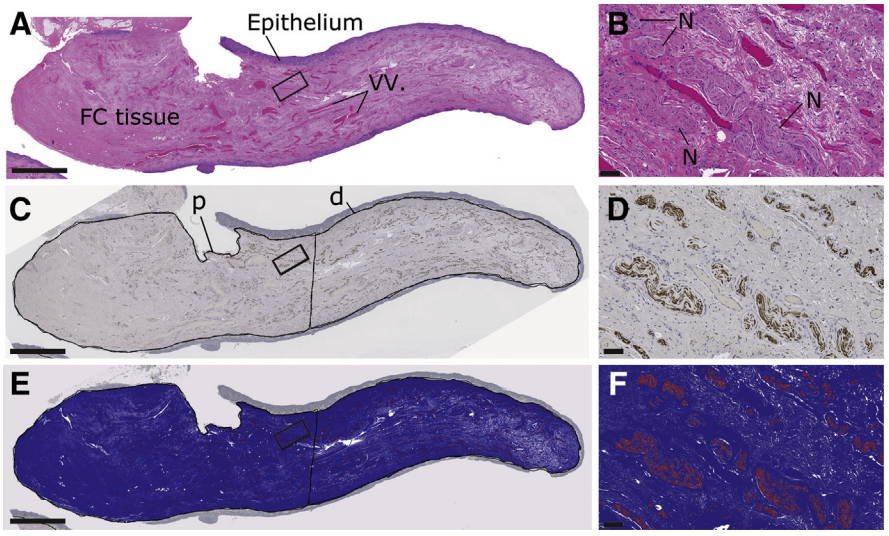
Fixed tissues were processed, embedded, and sectioned using standard methods, then stained with hematoxylin and eosin (H&E) and Gomori Trichrome for structural identification, and with antibodies against βIII tubulin (a specific marker of neuronal axons), and detected using standard colorimetric immunostaining protocols (Figure 2). The H&E and Gomori Trichrome staining were performed with standard technique by UTSW Histo Pathology Core. Microscopic slide analysis, using a Nikon Eclipse 80i microscope (Nikon Inc, Los Angeles, CA), was performed by a gynecologic pathologist (K.S.C.) with 2 authors (L.A.J., M.M.C.) present for review. Relevant microscopic features were noted, including tissue composition, connective tissue layers, and location of nerve and vascular structures. βIII tubulin immunohistochemistry and nerve density analyses were performed as previously described by Jackson et al.[20] Nerve density was analyzed in cross-sections through the CB, glans, and labia minora. Two tissue sections from 5 cadavers were included in analysis of the CB, which included all tissue deep to clitoral fascia in order to incorporate main branches of DNC. Given the relatively small size of the glans, nerve density analysis was performed at only 1 cross-sectional level. Four cadaver specimens had discernible labia minora that could be harvested for analysis. Under microscopic guidance, the glans and CB were divided into dorsal and ventral halves and the labia minora into distal and proximal halves. Average measurements of nerve density were statistically compared by means of a 2-tailed t test using Microsoft Excel (2013; Microsoft Corporation, Redmond, WA). A value of $P < 0.05$ was considered statistically significant.

Results

A total of 22 adult female cadavers were examined grossly; 21 were of white ethnicity and 1 African American. Age was a median of 70 years (range, 48−89); body mass index was 21.5 kg/m^2 (range, 13.3−34.3 kg/m^2). The most common cause of death was metastatic cancer (n = 11), with breast cancer being the most common. Tissue from 5 additional cadavers (aged 52−96 years) was examined microscopically. Available medical histories and dissections revealed no evidence of prior vulvovaginal surgery or vulvar malignancies.

Gross dissection findings are presented in Tables 1 and 2, and histologic findings are summarized in Figures 3

FIGURE 2
Nerve density analysis in representative cross-section of labium minus



Left panels depict whole-slide images of serial tissue sections stained with hematoxylin and eosin (H&E; panel **A**) and antibodies against the nerve marker βIII tubulin (panel **C**). Note fibroconnective (*FC*) tissue with interspersed blood vessel (*VV*) throughout (panel **A**). Panel **C** illustrates the proximal (*p*) and distal (*d*) halves of the tissue selected for analysis outlined in black. The epidermal layer was excluded from analysis. Panel **E** shows the corresponding pixel classification image where βIII tubulin positive nerve fibers are represented in yellow, orange and red and βIII tubulin—negative non-neuronal tissue is represented in blue. Right panels (**B, D,** and **F**) depict enlarged areas containing individual nerves (*N*) as in the small boxed areas in the respective whole-slide images. Scale bar in panels A, C, and E is 2 mm; scale bar in Panels B, D, and F is 100 μm. Tissue harvested from a 52-year-old female individual within 24 hours of death.

Jackson et al. Clitoral anatomy and histology with clinical applications to vulvar surgery. Am J Obstet Gynecol 2019.

and 4. The closest distance between the glans and the external urethral orifice was 25 mm (range, 14–37 mm) and between the midpoint of the pubic arch and the dorsal CB was 29 mm (range, 14–46 mm). The proximal CB was always found cephalad to the mid pubic arch, on the anterior surface of the pubic symphysis. The clitoral index was 30 mm^2 (range, 16–100 mm^2).

TABLE 1
Dimensions of clitoris and associated structures in 22 unembalmed female cadavers

Measurements	Length	Width
Clitoris		
Glans	8 (5–12)	4 (3–10)
Body	29 (13–59)	9 (5–14)
Crus	50 (25–68)	9 (2–13)
Vestibular bulb	54 (13–69)	18 (9–29)
	Length	**Longest extent**
Labia minora	30 (13–52)	9 (3–29)

Data are median (range), in millimeters.

Jackson et al. Clitoral anatomy and histology with clinical applications to vulvar surgery. Am J Obstet Gynecol 2019.

Connective tissue layers and suspensory ligaments of clitoris

Distinct subcutaneous tissue layers were noted during all dissections. After removing fatty subcutaneous tissue of the mons and labia majora, suspensory ligaments of the clitoris were encountered, which consisted of 2 layers of dense connective tissue suspending the clitoris to the pubic bones and overlying subcutaneous tissue. First, a superficial broad-based section of tissue extended from the dorsal and lateral surfaces of the CB to the membranous layer of subcutaneous tissue over the pubic symphysis and lower anterior abdominal wall. This layer had to be excised laterally in order to see the muscles in the superficial space of the anterior perineal triangle. The second layer of "suspensory" connective tissue encountered appeared denser and more midline, extending from the CB to the pubic bones, and was continuous with the superficial perineal fascia, which invested the superficial perineal muscles. This layer surrounded the corpora cavernosa and investing tunica albuginea, and was the last layer transected prior to directly visualizing the distal course of the DNC. This was consistent with descriptions of the clitoral fascia.[21]

Dorsal nerve of clitoris

The dorsal nerve and artery of the clitoris were consistently found posterior to the mid segment of crus, encapsulated in a dense connective tissue sheath adherent to the medial aspect of the IPR. All biopsied segments of what was grossly identified as DNC confirmed the presence of nerve during histologic analysis. Figure 5 illustrates the path of the DNC and its branches, and Figure 6 illustrates the relationship of the DNC to the CB. In all specimens, the DNC emerged onto the superficial pouch of the anterior perineal triangle by piercing the PM adjacent to the medial surface of IPR.

Crura, body, and glans of clitoris

The length and width of the CB and surrounding tissue, glans, and crura are given in Table 1. The CB comprised 2 paired erectile tissue structures

TABLE 2
Dorsal nerve of clitoris widths and anatomic relationships in 22 unembalmed female cadavers

Widths and distances to surrounding structures	Median (range), mm
Width of DNC at:	
Point that it emerged from lateral surface of crus	3 (2–4)
Distal body of clitoris	1 (1–2)
Distances from DNC at point that it emerged from PM to:	
Posterior surface of PM	20 (8–31)
Mid pubic arch	34 (20–48)
Distal-most edge of IPR	15 (9–22)

DNC, dorsal nerve of clitoris; *IPR,* ischiopubic ramus; *PM,* perineal membrane.
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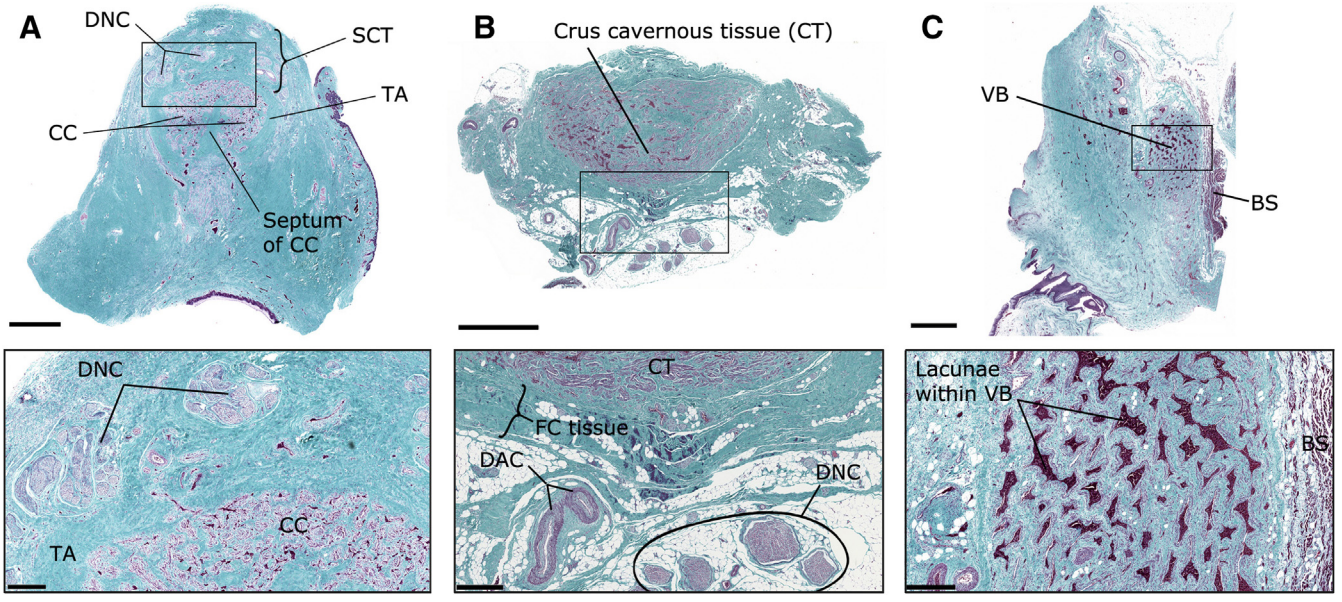
consistent with the corpora cavernosa, which originated from each crus. These 2 structures were invested by a thin connective tissue sheath consistent with the tunica albuginea. The CB and investing tunica albuginea were surrounded by 2 separate and grossly distinct layers of connective tissue (Figure 5). The outer layer was continuous with the membranous layer of the subcutaneous vulvar tissue, as described above. The inner layer, consistent with the clitoral fascia, invested the CB and was continuous with the superficial perineal fascia investing the perineal muscles, VB, and crura. Both layers had to be transected to directly follow the path of the DNC along the dorsal CB. The DNC consistently coursed between the clitoral fascia and tunica albuginea (Figure 7). A connective tissue septum between the paired erectile tissue structures was noted during all gross dissections. Absence of this septum was noted at the 12 o'clock position in all histologic examinations.

Evaluation of the tissue passing under the pubic arch after the suspensory tissue was resected consistently revealed

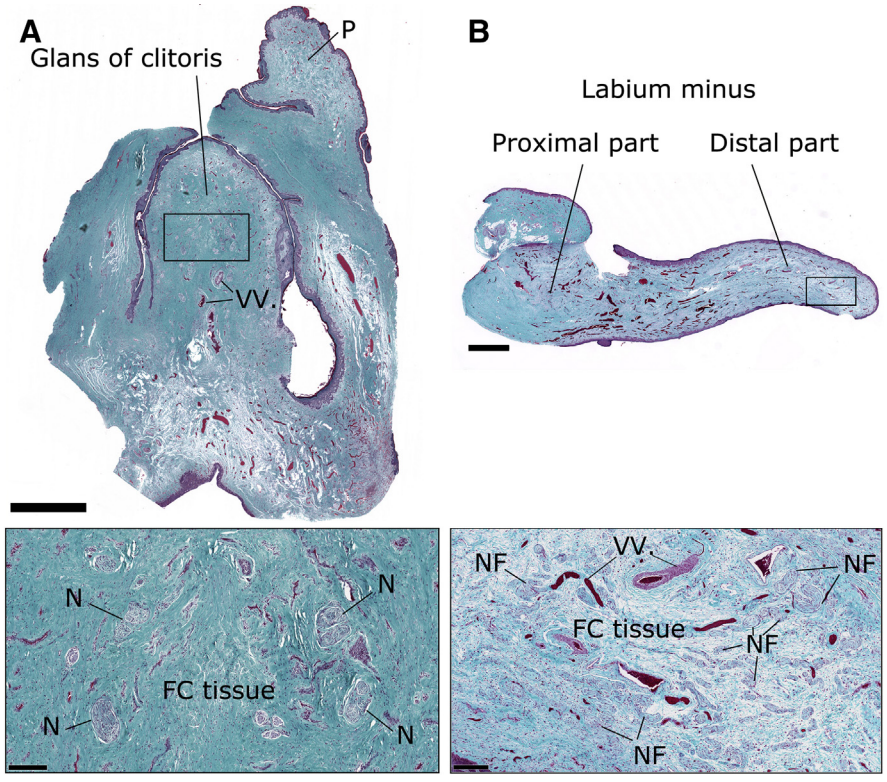
FIGURE 3
Key histologic findings of vulvar erectile structures



Top row comprises whole-slide images of tissue (scale bars, 2.5mm); bottom row is zoomed in area outlined by rectangular boxes located in top row (scale bars, 250 μm). **A,** Clitoral body, dorsal aspect positioned at top of image. The paired corpora cavernosa (*CC*), composed of relatively dense erectile tissue, are surrounded and partially separated by dense fibrous connective tissue corresponding to the tunica albuginea (*TA*) and the septum of the CC. There is focal vascular communication between the CC dorsally. The paired dorsal nerves of clitoris (*DNC*) are identified, with extension of neural bundles laterally. The dorsal vein and paired dorsal arteries of clitoris were also noted (not labeled). No discrete clitoral fascia is discernible peripheral to the clitoral body, although the structures forming the body are enveloped in relatively dense fibroconnective tissue, which shows a subtle but discernible distinction from the subcutaneous tissue (*SCT*) with its variably prominent adipocytes. **B,** Crus, with medial aspect at top of image. The crura are composed of relatively dense erectile tissue similar to that forming the CC, and are ensheathed in dense fibroconnective tissue. Please note that the DNC and dorsal artery of clitoris (*DAC*) are located at lateral aspect of the crus. **C,** Vestibular bulb, with medial aspect on right side of image. The VB is composed of erectile tissue that is less dense than that forming the crura and body of the clitoris, with wider lacunae and finer fibromuscular trabeculae. *BS,* bulbospongiousus muscle.

Jackson et al. Clitoral anatomy and histology with clinical applications to vulvar surgery. Am J Obstet Gynecol 2019.

FIGURE 4
Key histologic findings of glans and labia minora



Top row comprises whole-slide images of tissue (scale bars, 2.5 mm); bottom row is zoomed in area outlined by rectangular boxes located in top row (scale bars, 500 μm). **A,** Glans, dorsal aspect positioned at top of image with part of distal prepuce (*P*) noted. The glans is composed of relatively dense fibroconnective tissue with interspersed small blood vessels (*VV*). Nerve bundles (*N*) are prominent and have a paired distribution corresponding to the paired dorsal nerves of the clitoris. No erectile tissue is present. **B,** The labium minus is composed of relatively dense fibroconnective tissue with interspersed nerves and small blood vessels. Nerve fibers (*NF*) are prominent in this example, especially distally, but varied in number and prominence between harvested samples. No erectile tissue is present.

Jackson et al. Clitoral anatomy and histology with clinical applications to vulvar surgery. Am J Obstet Gynecol 2019.

vessels coursing from the midline of the dorsal aspect of the clitoris and passing under the pubic arch at the 10 and 2 o'clock positions relative to the mid pubic arch. These were consistent with the dorsal veins of the clitoris.

Nerve density analysis

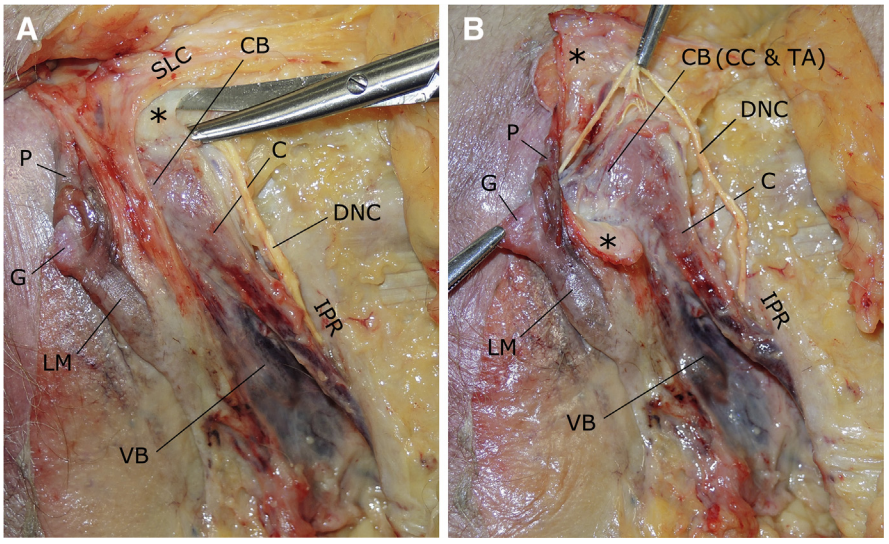
Nerve density analysis of cross-sections of the CB and surrounding tissue, clitoral glans, and labia minora are presented in Table 3. Quantification of βIII tubulin−positive immunostaining demonstrated increased nerve density in the dorsal compared to the ventral half of the CB. No significant difference in nerve density was found between the dorsal and ventral halves of the glans. Although not statistically significant, in all specimens examined, there was consistently greater nerve density in the distal compared to the proximal part of the labia minora.

Comment

In this cadaver study, we provide further characterization of the path and anatomic relationships of the DNC, and discuss possible clinical applications to obstetric and gynecologic procedures. As this nerve provides sensory innervation to the glans, injury may result in decreased sensation, pain syndromes, and possible sexual dysfunction. Similar to other descriptions, we found that after emerging from the PM, the DNC was consistently encased in a dense connective tissue sheath adherent to the medial surface of the IPR at the posterior aspect of the crus.[14] Thus, in this region, the nerve is protected and may be less susceptible to injury during vulvar procedures. Although DNC injury has been reported with transobturator slings[17] and risk theoretically exists with retropubic sling procedures,[22] our findings agree with Montoya et al that minimal risk exists if trocars are passed as recommended.[23] After emerging from the lateral aspect of the crus, the DNC courses deep to subcutaneous tissue layers of the vulva prior to assuming a consistent course on the dorsal CB. In this region, the DNC is no longer protected by bony structures or crura, and therefore may be more susceptible to injury. Procedures such as prepuce reductions, repair of anterior obstetric lacerations, periclitoral mass resections, and vulvectomies may lead to nerve injury, especially when deep subcutaneous tissue layers are breached between the midline of the CB and the inferior pubic ramus. In its course along the dorsal surface of the CB, the DNC is consistently found at the 11 and 1 o'clock positions relative to the body, superficial to the tunica albuginea but deep to the clitoral fascia. Thus, removal of prepuce and vulvar skin lateral to the midline of the CB might lead to injury during "deep" dissection or suture placement to reapproximate connective tissue or to secure hemostasis. Awareness of this nerve's course once it emerges from the lateral surface of the crus and along the dorsal CB should aid surgeons in avoiding injury.

Clitoromegaly is commonly diagnosed by a clitoral index (CI) of >35 mm^2.[19] Our median calculated CI of 30 mm^2 (range, 16−100 mm^2) is consistent with that reported by Huffman, who noted that the CI increased with increasing age, and found a CI of 30 mm^2 in postmenopausal women.[24] Based on this definition, we encountered 1 specimen with clitoromegaly, with a CI of 100 mm^2.[19] Understanding the range of

FIGURE 5
Course of dorsal nerve of clitoris

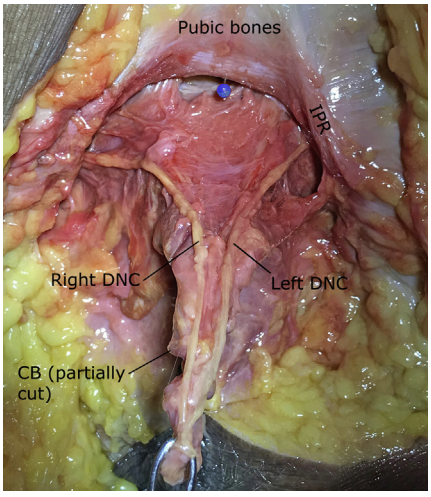


Dissected left vulva in unembalmed cadaver. Note suspensory ligament of clitoris (*SLC*) with distal and proximal attachments to clitoral body (*CB*) and to pubic bones (not labeled), respectively. **A,** dorsal nerve of clitoris (*DNC*) emerging from deep and lateral surface of crus (*C*), on medial surfaces of ischiopubic ramus (*IPR*). The DNC then passes deep to dense connective tissue layers that blend with the SLC and clitoral fascia (*). **B,** distal course of DNC toward the glans (*G*). The DNC passes between the tunica albuginea (*TA*), a thin connective tissue layer surrounding the corpora cavernosa (*CC*), and a dense connective tissue layer consistent with the clitoral fascia. *Transected edges of clitoral fascia.

LM, labia minora; *P,* prepuce; *VB,* vestibular bulb.

Jackson et al. Clitoral anatomy and histology with clinical applications to vulvar surgery. Am J Obstet Gynecol 2019.

FIGURE 6
Dorsal nerve of clitoris position relative to clitoral body



Superior view of dorsal nerves of clitoris (*DNC*) in dissected unembalmed cadaver. Suspensory ligament of clitoris was transected from pubic bones, and distal clitoral body (*CB*) is pulled down with clamp. Note that the DNC from left and right sides courses on dorsal surface of CB approximately at the 11 o'clock and 1 o'clock positions, prior to entering the glans of the clitoris. Blue pin indicates midpoint of pubic arch.

IPR, inferior pubic ramus.

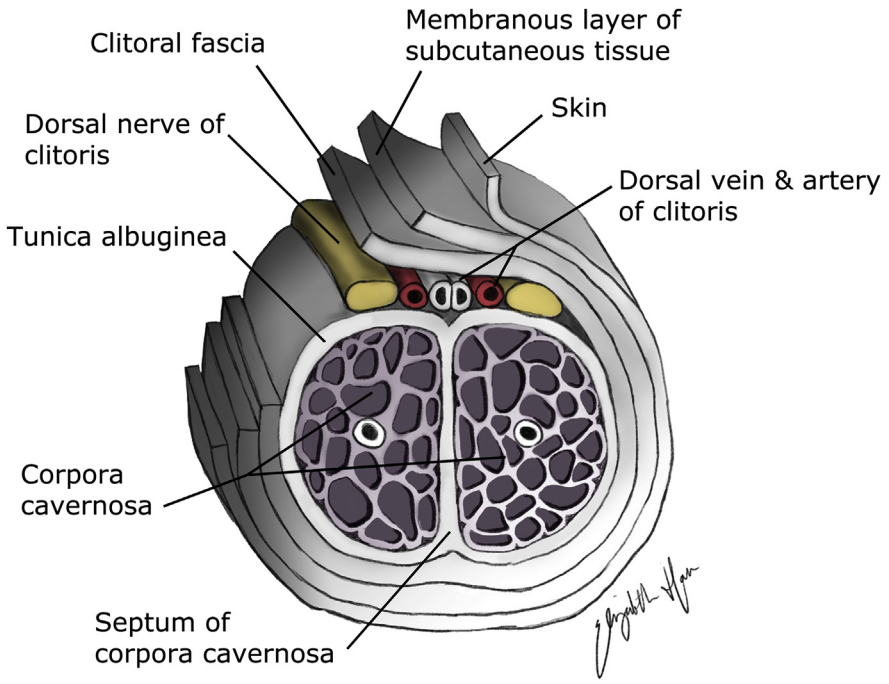
Jackson et al. Clitoral anatomy and histology with clinical applications to vulvar surgery. Am J Obstet Gynecol 2019.

clitoral sizes should allow for proper patient counseling; findings that clearly fall outside commonly reported ranges should alert clinicians to look further for underlying etiologies.

In our microscopic analysis, we did not find erectile tissue in the labia minora or glans. This finding differs from reports suggesting the presence of erectile tissue in the labia[5,9] and glans[4,10–12,25]; however, it is in agreement with findings reported by O'Connell et al[8] We found erectile tissue in the CB, crura, and VB. The erectile tissue of the crura and body were similar in density, whereas that of the VB was less dense. These findings suggest that the erectile tissue of VB is closer in composition to that of the male corpus spongiosum, whereas that of the crura and paired corpora cavernosa are more comparable to the corpora cavernosa in men.[26]

The labia minora are highly innervated structures that have direct connections to the glans and are adjacent to the erectile tissue of the VB. The American College of Obstetricians and Gynecologists recommends labial alteration procedures for medical indications such as repair of female genital cutting, treatment of labial hypertrophy or asymmetrical labial growth, chronic irritation, or excessive androgenic hormones.[27] Excision of the distal labia during labial reduction can result in decreased sensation and thus sexual dysfunction[28–31]; it can also lead to chronic pain syndromes requiring reconstruction.[27,30] Our analysis revealed a consistent increase in nerve density in the distal compared to the proximal half of the labia, although this comparison was not statistically significant. This finding is similar to that of a labial nerve density analysis study that showed a trend toward increased nerve density within the distal compared to the proximal labial tissue.[29] This knowledge is important during patient counseling and surgical planning of labial reduction, as surgical approaches that preserve the distal ends, such as wedge resection or a de-epithelialization approach, may be preferred to methods that remove the entire distal labia.[32]

FIGURE 7
Body of clitoris cross-section



Schematic view through mid clitoral body. Note relationship of dorsal nerve and vessels of clitoris to corpora cavernosa and connective tissue layers surrounding corpora.

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Limitations of this study are those inherent to cadaver studies. Distances between structures of interest could have been affected by dissection and manipulation; however, only the minimum amount of dissection required to accurately take measurements was performed. Demographic data on cadaver specimens were limited. Although menopausal status may be inferred based on specimen age at time of death, this information was not available. Furthermore, the average body mass index of our population was 21.5 kg/m^2. Although it is known that labial size decreases with age and may vary with body mass index,[33] the path of the DNC, histological composition, and areas of increased nerve density are unlikely to change. Limitations specific to histologic analyses include a small sample size and possible tissue changes that occur during fixation. Strengths of this study include a large sample size for gross examination as well as integration of both gross and microscopic analyses.

TABLE 3
Raw data for nerve density analysis presented as percentage of total tissue section area covered by positive nerve staining using anti-βIII tubulin (axonal marker) antibodies

		Clitoral body		Clitoral glans		Labia minora	
	Section no.	Dorsal	Ventral	Dorsal	Ventral	Proximal	Distal
Specimen 1	1	5.07%	3.85%	6.60%	5.75%	ND	ND
	2	8.29%	5.37%	ND	ND	ND	ND
Specimen 2	1	10.61%	10.16%	17.81%	17.88%	13.25%	15.98%
	2	6.14%	6.56%	ND	ND	13.13%	18.02%
Specimen 3	1	14.73%	7.46%	20.87%	23.72%	7.05%	7.23%
	2	9.81%	7.75%	ND	ND	5.88%	6.86%
Specimen 4	1	10.29%	4.07%	8.26%	12.19%	4.05%	6.20%
	2	17.61%	6.74%	ND	ND	3.54%	4.03%
Specimen 5	1	13.63%	10.33%	19.6%	19.9%	9.44%	16.89%
	2	8.13%	9.26%	ND	ND	12.85%	23.64%
Average		10.43%	7.15%	14.63%	15.89%	8.65%	12.36%
P value		0.035		0.779		0.224	

ND, no data.

Jackson et al. Clitoral anatomy and histology with clinical applications to vulvar surgery. Am J Obstet Gynecol 2019.

In summary, a precise knowledge of clitoral anatomy and associated neurovascular structures is essential for surgical planning and for avoidance of intraoperative and postoperative complications. Although the DNC courses deep to dense connective tissue layers, inadvertent injury may occur during deep dissection or suture placement. The DNC seems most vulnerable with surgical entry or lacerations that extend from the midline of the prepuce to the lateral surfaces of the IPR. Thus, partial resection of the prepuce, a procedure sometimes combined with central wedge resection of the labia minora,[34,35] may pose greater risk of DNC injury. Furthermore, understanding the range of anatomic variation of vulvar structures should further our understanding of this important anatomy, and assist with patient counseling and diagnosis of abnormal conditions. ■

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