

The clitoris: A unified structure. Histology of the clitoral glans, body, crura and bulbs

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ABSTRACT. A series of detailed dissections and histological observations were performed on clitoral and bulbar tissues from both fresh and embalmed cadavers. The clitoral body, crura and bulbs all contained cavernous tissue. The clitoral body and crura, but not the bulbs, were invested in a dense layer of connective tissue, which extended to divide the body sagittally. Around the clitoral body, most prominent anteriorly, lay large neurovascular bundles. The glans of the clitoris contained minimal spongy tissue but many prominent nerve trunks. The bulbs were intimately associated with the Bartholin's glands and ducts. Histologically, the clitoral body, crura and bulbs were cavernous structures containing trabeculae of smooth muscle around sinusoidal spaces. Clitoral and penile histology appears to be very similar.

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BACKGROUND

Recent gross anatomical studies of the clitoris have provided new insight into the structure of the clitoris and the shortcomings of typical illustrations in anatomical textbooks (1). The clitoris appears to be a complex of erectile structures consisting of the corpora, crura and bulbs surrounding the urethra and flanking the distal vaginal wall. We were not able to find a previous report describing and comparing the histology of each clitoral component: bulbs, crura, as well as the corpora and glans.

Greater interest in female sexuality and female sexual dysfunction has been evident in recent years with a significant increase in anatomical investigation in the last 7 years. A number of studies have investigated the clitoris, using modern techniques, with the aim of understanding normal clitoral structure and function. The conclusions of some of these studies, while valu-

able, have been limited by the source material, collected during gender re-assignment surgery, surgery to remove clitoral tumours or from fetuses (2-6). A recent report (7) presented histological findings from a series of 15 fresh cadavers and 3 patients undergoing clitoral surgery. The younger patients whose tissue was analysed had pathological conditions of the clitoris, namely congenital adrenal hyperplasia and genital lymphangioma. The effects of ageing on the clitoral histology were investigated, the majority of the patients being studied having major systemic illness (cardiovascular disease, hepatic cirrhosis, advanced malignancy). In each of these studies, the relationship to normal clitoral anatomy is unclear.

Histological study of the clitoris has been limited typically to investigations of the glans clitoris or the body of the clitoris. Lack of recognition of the clitoral (vestibular) bulbs as part of the clitoris has compounded the issue. Specific investigation of the bulbs has also been limited although a description and diagrams without histological photographs of the related structure, the corpus spongiosum, has been reported (5).

Herein we report on structural and histological studies on a series of fresh and fixed cadavers in whom no clitoral pathology was present. We have compared the histology of the cavernous tissue of each of the clitoral components.

RESEARCH APPROACH

Methodology

Tissue samples were obtained from 11 fresh female cadavers, age range 10 weeks to 51 years. Tissue from two adult embalmed cadavers was also obtained. Ethics approval for this study was obtained from the Institutional review boards of the Royal Melbourne Hospital, Royal Children's Hospital and the Victorian Department of Forensic Pathology.

Tissue taken from fresh cadavers, or cadavers embalmed in 2% formaldehyde in a mixture containing ethanol, glycerol and phenol in saline, was processed for routine paraffin-embedded histology. This tissue was further fixed for a minimum of 24 h in 10% neutral formalin before embedding in paraffin and sectioning at 5 μ m. Sections were stained using haematoxylin and eosin.

Results

The clitoris is a tri-planar complex composed of several conjoined structures, the body, crura, glans and bulbs (Fig. 1A). The body up to 4 cm in length comprises paired corpora which lie in the sagittal plane and project externally from the undersurface of the pubic symphysis outward in a curved shaped, convex superficially to reach the glans. The glans clitoris is a superficial structure, projecting as the external tip of the clitoral body. The crura are the internal continuation of the corpora. At the pubic symphysis the corpora bifurcate and then each corpus descends adherent to the ischiopubic rami for up to 9 cm. The bulbs lie ventral to the urethra, and descend on either side lateral to the vaginal introitus on the lateral wall of the distal vagina. They extend posteriorly to a variable extension but always flank at least as far dorsally as the urethra. They are straddled by the crura and lie dorsal to the clitoral body. An extensive connective tissue suspensory ligament secures the clitoris to the labia, fascia of the mons pubis and the pubic symphysis (8).

Figure 1B-F demonstrates the histology of each of the clitoral components. A dense connective tissue sheath, the tunica albuginea, surrounds the body of the clitoris (Fig. 1B-C), which is made up of cavernous sinuses and smooth muscle trabeculae. The tunica albuginea has an incomplete midline septum dividing the clitoral body into two corpora that run in a sagittal plane (Fig. 1C). Superficial to the tunica albuginea lie the ventral clitoral

neurovascular bundles. The bulk of the nerve trunk appears to enter the glans clitoridis intact (Fig. 1B) although branching is observed along the length of the clitoral body. Pacinian corpuscles are clearly seen in association with the nerve trunks and in the glans. Large arteries and veins run with the nerve trunks along the length of the body. The cavernous tissue of the clitoral body within the tunica is highly vascular, composed of vascular sinuses surrounded by smooth muscle trabeculae and connective tissue. The sinuses have an endothelium but no obvious smooth muscle in their walls. A moderately large artery (cavernosal artery) is present medially bilaterally in the clitoral body close to the septum. The cavernous tissue and its surrounding tunica albuginea extend into the proximal aspect of the glans (Fig. 1C). The midline septum continues into the glans but the cavernous tissue does not reach the tip of the glans. Hairless thin skin overlies the glans while deep to this is a dense, vascular dermis.

The bulbs of the clitoris are also composed of cavernous tissue. The vascular spaces are larger than those of the body and crura and the trabeculae appear to be thicker than in the other clitoral cavernous tissues (Fig. 1E). Large vascular and neural channels are not a feature. The greater vestibular glands lie between the vaginal wall and bulbs (Fig. 1D). The bulbs are not surrounded by a dense tunica. The bulbs in every specimen examined, and most obviously in the fixed specimens, were a different colour than the other clitoral components i.e. blue-purple versus red, which appears to relate to the presence of the dense capsule overlying the body and crura being absent over the bulbs.

The crura (Fig. 1F) are also composed of cavernous tissue strongly resembling male cavernous tissue. The crura are not completely surrounded by a tunica, it being absent laterally where the crura attach to the bone and where the ischiocavernosus skeletal muscles insert. Large nerve and vascular trunks do not appear within the crura.

PRACTICAL MESSAGES

To achieve orgasm women require either direct or indirect clitoral stimulation (9). Anatomical research including gross and histological studies may help to further knowledge of normal female sexual function and the ways it can be preserved during surgical procedures. Research into female sexual anatomy and physiology is in its infancy though considerable progress has occurred in recent years.

We showed, in agreement with others, the presence of cavernous tissue in the clitoral body and crura. However, while both structures are associated with Pacinian corpuscles, their neurovascular patterns do differ, the body being surrounded by large neurovascular trunks external to the thick fibrous tunica. Baskin (6) observed that the glans is anatomically distinct from the corpora and reported "large bundles that fanned out laterally" on the ventral surface of the clitoral bodies. The cavernous tissue of the bulbs has a different character again, the sinusoids being larger and the trabeculae thicker but without any obvious presence of large neurovascular bundles.

Histological analysis of a series of clitoral specimens of varying ages showed significant changes with increasing age. In the more elderly specimens studied and particularly those with known cardiovascular disease-related mortality, significant fibrosis was observed. This type of analysis may be useful if a simple biopsy technique becomes available for the investigation of female sexual function.

The only other existing histological study of the bulbs and their relationship to the urethra recently suggested an important role in urethral sphincteric function (10). The study also revealed the junction of the bulbs directly caudal to the clitoral body; tissue that van Turnhout et al. (5) refer to as the "corpus spongiosum". We were not able to verify that finding with this study, although several of the dissections of cadavers had tissue consistent with this anatomical structure.

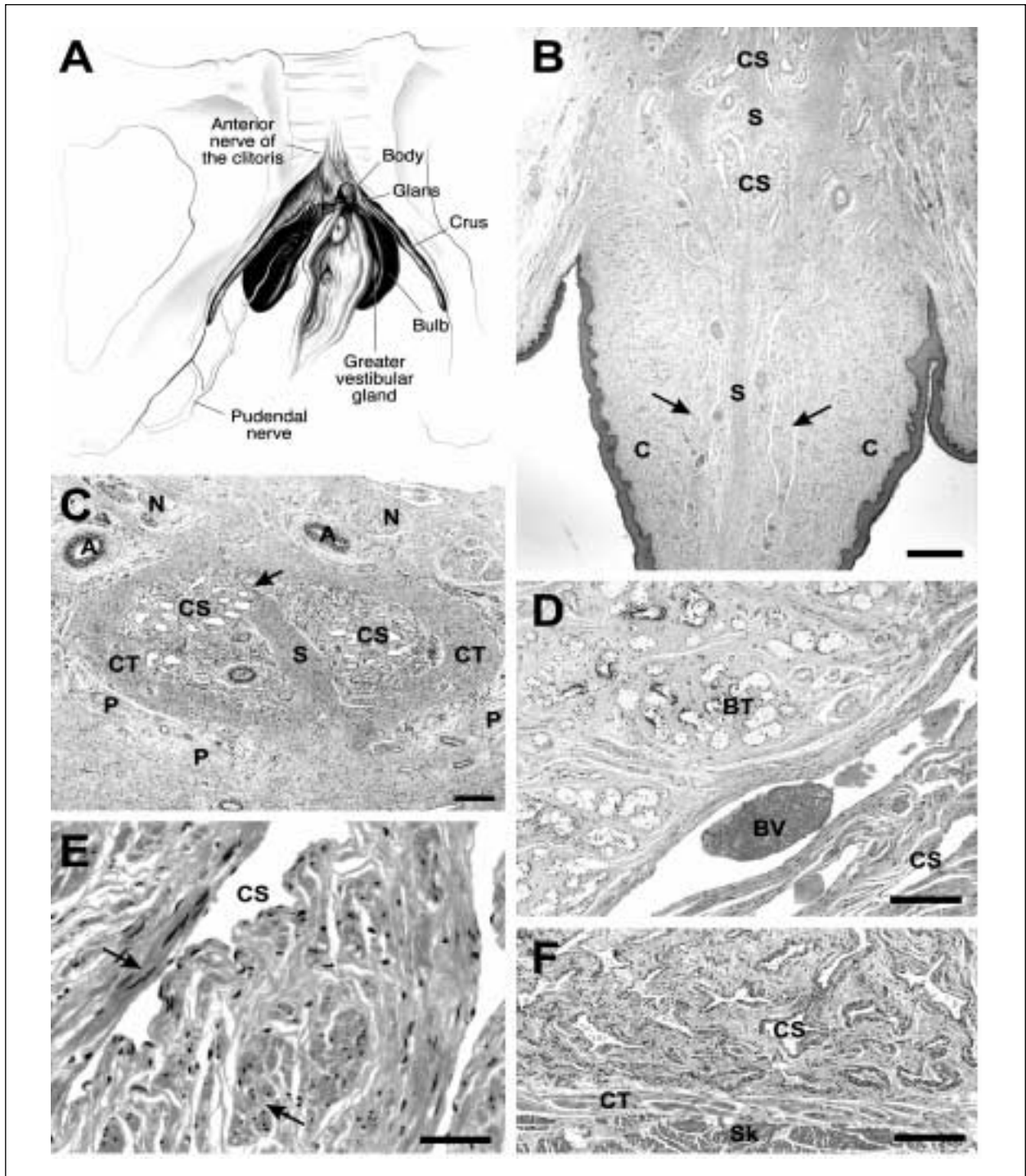


Figure 1 - All micrographs are stained with haematoxylin and eosin.
 A. Artist's rendition of anatomy of clitoris from oblique view. This anatomy is based on dissections of fixed tissue and therefore may not truly represent the anatomy in the live state and does not represent the aroused state. It shows the relationships between structures, the approximate size of the anterior clitoral nerves and the structure of the clitoris as a whole including its components: glans, body, crura and bulbs (*Continued*).

Figure 1 (*Continued*) - B. Coronal section through the glans clitoris of a 23 year old. Inferior is to the bottom of the image. The tissue forming the core of the glans (C) is vascular connective tissue, with no sign of the abundant sinuses that characterize cavernous tissue. The only cavernous sinuses visible (CS) are deep to the glans, where the distal part of the body of the clitoris can be seen, surrounded by a layer of dense connective tissue that is also present as a septum (S) that divides the body in two. The septum continues beyond the body into the glans. Note also the major bilateral nerve trunks that are the continuation of the dorsal nerves (arrows). Scale bar= 500 μ m.

C. Transverse section through the body of the clitoris from a two year old. Anterior is to the top of the micrograph. The mid-line is slightly twisted due to post mortem compression of the tissue. The body is divided into two corpora by a septum that is incomplete anteriorly (arrow). The tissue of the body consists of prominent cavernous sinuses (CT) with occasional arteries present, surrounded by a thick dense connective tissue layer (CT). Anterior to the body are a pair of prominent arteries (A) and also very large nerve trunks (N) that descend towards the glans. Present in the connective tissue surrounding the body are Pacinian corpuscles (P). Scale bar= 250 μ m.

D. Section from the medial boundary of the bulb from an 80 year old showing the intimate contact between Bartholin's gland (BT) and unencapsulated cavernous tissue of the bulbs (CS). Note that a large blood vessel (BV) lies on the boundary between the bulb and Bartholin's gland in this section. The mucous tubules and ducts of Bartholin's gland are embedded in connective tissue located between the bulbs and vestibule of the vagina. Scale bar= 200 μ m.

E. Section showing cavernous sinuses (CT) in the bulb. The smooth muscle bundles (arrowed) are cut both longitudinally and transversely in this section. Scale bar= 50 μ m.

F. Section of crus from a two year old along the boundary with skeletal muscle (Sk). The cavernous sinuses of the crus (CS) are separated from the skeletal muscle by a layer of connective tissue (CT). The cavernous tissue contains abundant trabeculae of smooth muscle and occasional arteries. Scale bar =200 μ m.

Pacinian corpuscles are associated with the body of the clitoris. Pacinian corpuscles are sensory receptors normally associated with the dermis. They are rapidly adapting receptors sensitive to vibration. Krantz (11) has previously commented on their association with large nerve trunks in the female genitalia and reported that they are more prevalent in association with the clitoris than with surrounding skin. In that study, the exact part of the clitoris examined was not described. The presence of Pacinian corpuscles surrounding the clitoral bodies may indicate a role in generating clitoral sensation when the clitoris is engorged. The clitoris is midway in sensitivity between the skin of the fingers and feet in response to a classical vibratory stimulus to assess Pacinian corpuscle sensitivity (12).

The glans is composed of hairless thin skin, a vascular dermis and nerve trunks. The structure of the clitoral body and crura, being composed of erectile tissue and surrounded by a dense fibrous capsule, is likely to result in "erection" when engorged with blood. Thus the term "erectile" appears valid for these structures although word better applies to the

pendular structure of the penis than the curved and fixed structure of the clitoris. The bulbs are composed of typical cavernous tissue, but with only a thin capsule. This suggests that during engorgement they are likely to expand and become turgid rather than "erect".

Toesca et al. observed that the clitoral body architecture differs from the penis in having a regular anterior tunical surface with no internal venous plexus (2). This plexus is believed to be required for penile rigidity.

The number of specimens available for study is very limited because of the restrictions on access to tissue for the purpose of human research. In a number of specimens we were only permitted to sample internal tissues, so that structures such as the glans were not accessible for study. In future research accurate delineation of histology from specimens would permit observation of the changes associated with ageing, parity, hormonal and other factors. It should be technically feasible to biopsy the bulbs through the anterior vaginal wall under ultrasound guidance. Biopsy of the bulbs via the labia would be expected to be associated with a significant bleeding risk.

CONCLUSIONS

The corpora, crura and bulbs are composed of cavernous tissue and form an almost completely internal structure. The glans is a densely innervated, non-cavernous structure. The corpora, glans and neurovascular bundles are associated with significant numbers of Pacinian corpuscles, indicating that deep sensation is part of their physiology. On the basis of recent research, clitoral pharmacology and physiology is expected to be very similar to penile tissue.

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