Journal of Andrology, Vol. 25, No. 3, May/June 2004

Anatomy of the Human Penis: The Relationship of the Architecture Between Skeletal and Smooth Muscles

GENG-LONG HSU,*† CHENG-HSING HSIEH,* HSIEN-SHENG WEN,* WEN-LONG HSU,* CHIH-HSIUNG WU,* TSORNG-HARN FONG,‡ SHYH-CHYAN CHEN,† AND GUO-FANG TSENG†

*From the *Microsurgical Potency Reconstruction Center, Taiwan Adventist Hospital, Taipei Medical University Hospital, the ‡Department of Anatomy, College of Medicine, Taipei Medical University, and the †Department of Anatomy and Cell Biology, College of Medicine, National Taiwan University, Taipei, Taiwan, Republic of China.*

ABSTRACT: To investigate the anatomy of the ischiocavernosus muscle, bulbospongiosus muscle, and tunica albuginea and to determine their relationships to smooth muscle, which is a key element of penile sinusoids, we performed cadaveric dissection and histologic examinations of 35 adult human male cadavers. The tunica of the corpora cavernosa is a bilayered structure that can be divided into an inner circular layer and an outer longitudinal layer. The outer longitudinal layer is an incomplete coat that is absent between the 5-o'clock and 7-o'clock positions where 2 triangular ligamentous structures form. These structures, termed the ventral thickening, are a continuation of the anterior fibers of the left and right bulbospongiosus muscles. On the dorsal aspect, between the 1-o'clock and 11-o'clock positions, is a region called the dorsal thickening, a radiating aspect of the bilateral ischiocavernosus muscles. In the corpora cavernosa, skeletal muscle contains and supports smooth muscle, which is an essential element in the sinusoids. This relationship plays an important part in the blood vessels' ability to supply the blood to meet the requirements for erection, whereas in the corpus spongiosum, skeletal muscle partially entraps the smooth muscle to allow ejaculation when erect. In the glans penis, however, the distal ligament, a continuation of the outer longitudinal layer of the tunica, is arranged centrally and acts as a trunk of the glans penis. Without this strong ligament, the glans would be too weak to bear the buckling pressure generated during coitus. A significant difference exists in the thickness of the dorsal thickening, the ventral thickening, and the distal ligament between the potent and impotent groups ($P \leqq .01$). Together, the anatomic relationships between skeletal muscle and smooth muscle within the human penis explain many physiologic phenomena, such as erection, ejaculation, the intracavernous pressure surge during ejaculation, and the pull-back force against the glans penis during anal constriction. This improvement in the modeling of the anatomic-physiologic relationship between these structures has clinical implications for penile surgeries.

Key words: Corpora cavernosa, corpus spongiosum, bulbospongiosus muscle, ischiocavernosus muscle, distal ligament, tunica albuginea.

J Androl 2004;25:426–431

In 1992, we explored the 3-dimensional structure of the human tunica albuginea and, through the use of gross and microscopic dissection and study with light and electron microscopy, reported it to be a bilayered structure with multiple sublayers (Hsu et al, 1992). The inner circular layer is circumferentially uniform, and the intracavernosal pillars are an extension of this structure. The outer longitudinal layer, however, varies in thickness as well as in the distribution of collagen bundles, which condense to form the ventral thickening at the 5-o'clock and 7-o'clock positions. The dorsal thickening is conspicuous between the 1-o'clock and 11-o'clock positions (Hsu et al, 1994; Brock et al, 1997). Why and how these thick ligamentous structures form remain unanswered.

Concerning the bulbospongiosus, ischiocavernosus, and perineal muscles, the literature appears to be in general agreement (Gray, 1989; Putz and Pabsteds, 2001). The bulbospongiosus muscle has anterior, middle, and posterior fibers. The anterior fibers radiate over the side of the corpus cavernosum and insert partially into it. They contribute to penile erection by compressing the deep dorsal vein of the penis. The middle fibers encircle the bulb and adjacent parts of the corpus spongiosum and assist in erection of the spongiosum by compressing the erectile tissues of the bulb (Wespes et al, 1990; Shafik, 1995). The ischiocavernosus muscle is paired with and compressed to the crus penis, retarding the return of blood through the veins to assist in maintaining an erection (Lavoisier et al, 1988; Claes et al, 1996; Kawanishi et al, 2001).

Although recent advances in our knowledge of penile erection have been remarkable (Lue, 2000), the relationships among the outer layer of the tunica albuginea and the above muscles have not been elucidated. Moreover, the obscurity of the relationship between skeletal and smooth muscles prompted us to perform further studies with the ultimate goal of improving anatomic knowledge, which, in turn, can provide a foundation for penile surgery.

Correspondence to: Dr Geng-Long Hsu, Microsurgical Potency Reconstruction Center, Taiwan Adventist Hospital, 424 Pa-Te Rd, Sec 2, Taipei 10558, Taiwan, Republic of China (e-mail: glhsu@tahsda.org.tw).

Received for publication July 28, 2003; accepted for publication December 3, 2003.

Materials and Methods

From November 1997 to March 2003, the penises of adult male cadavers were studied. Their medical histories were reviewed, and those who sustained a disease directly involving the exogenitalia were excluded from this study. Thirty-five case-patients, ranging in age from 23 to 93 years (average, 66.3 ± 16.2 years), were included in the study. The underlying causes of death included 13 of coronary artery diseases, 7 of hepatoma, 6 of lung cancer, 3 of brain tumor, 2 of lymphoma, 2 of pancreatic cancer, and 2 young suicides.

Six young cadavers of sexually active men, classified as the potent group, were used for the dissection of the ischiocavernosus muscle, bulbospongiosus muscle, perineal muscle, levator ani, and periosteum of the pubic angle. Among the remaining 29 cadavers, classified as the impotent group, 7 were used to investigate the structure of the pendulous portion.

Under a dissecting microscope, the muscle configuration and relationship with the tunica albuginea were observed, and each muscle was dissected, bundle by bundle, until the proximal end was encountered (Figure 1). In 11 cadavers, serial cross sections at 2.5-cm intervals were taken from the tip of the penis continuing proximally until a complete septum was encountered. Each cut surface was examined for tunical thickness at specific locations (eg, 5 o'clock, 7 o'clock, 12 o'clock), the inner and outer layers were defined, and distributions of the intracavernosal fibrous structures (pillars) were detailed. Measurement was made of the dorsal thickening as well as of the distal ligament and the ventral thickening. Statistically, the Student's *t* test was applied whenever necessary. The components of the tunica were stripped off bundle by bundle to determine its interactions with other structures. A sagittal section was made on the tissue block of the glanular penis. Finally, penile tissue from 11 cadavers was used for histologic examination in which hematoxylin and eosin, Masson trichrome, and orcein stains were used.

Results

The bulbospongiosus muscle (Figure 1A), a bipinnate muscle, arises from the perineal body. The most posterior fibers form a thin layer and join the urogenital diaphragm. The middle fibers originate from the median raphe and encircle the proximal part of the corpus spongiosum; on its ventral surface, conspicuous fleshy fibers aggregate. The anterior fibers (Figure 1B) partially radiate to encircle the corpus cavernosum and mostly insert into the ventral thickening (Figure 1C) of the tunica.

The ischiocavernosus (Figure 1A) muscle is paired with and situated at the lateral boundary of the perineum. It arises from the ischial tuberosity and divides into ventral and dorsal fibers. The ventral fibers (Figure 2A) are shorter, have a shiny appearance, and run along the medial border of each crus. These fibers continue with the outer longitudinal collagen bundles of the tunica albuginea. The dorsal fibers run along the lateral border of each crus between the crus and the periosteum of the ischial border.

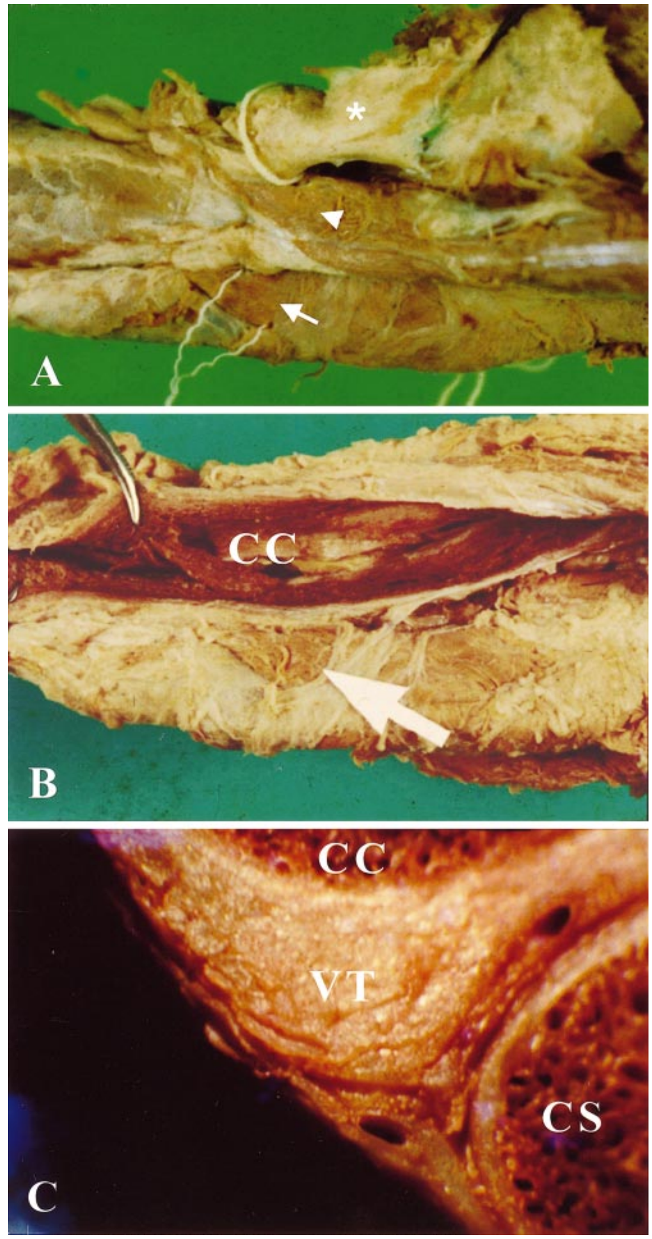

Figure 1. Bulbospongiosus muscle in the human penis. **(A)** This is an image of the junction (silk suture) between the pendulous and crural portions. Note that the anterior fibers of the bulbospongiosus muscle (white arrow) are conspicuous. The distal portion of the ischiocavernosus muscle (arrowhead) can readily be seen if the pubic periosteum (asterisk) is detached. **(B)** The corpus cavernosum (CC) was opened along the 5-o'clock position. The proximal tunica (right) is thin, but it becomes thicker distally because the muscle fibers (white arrow) join it to form the ventral thickening. **(C)** This is an image of the cross section of the ventral thickening at the 7-o'clock position. It is cut from the level distal to the insertion of the bulk of the bulbospongiosus muscle. These anterior fibers insert into the outer longitudinal layer of the tunica albuginea to form the ventral thickening (VT). Note that the thickness of the tunica of the corpus spongiosum (CS) is consistently paper thin, whereas it varies markedly in the CC (reduced from 7× magnification).

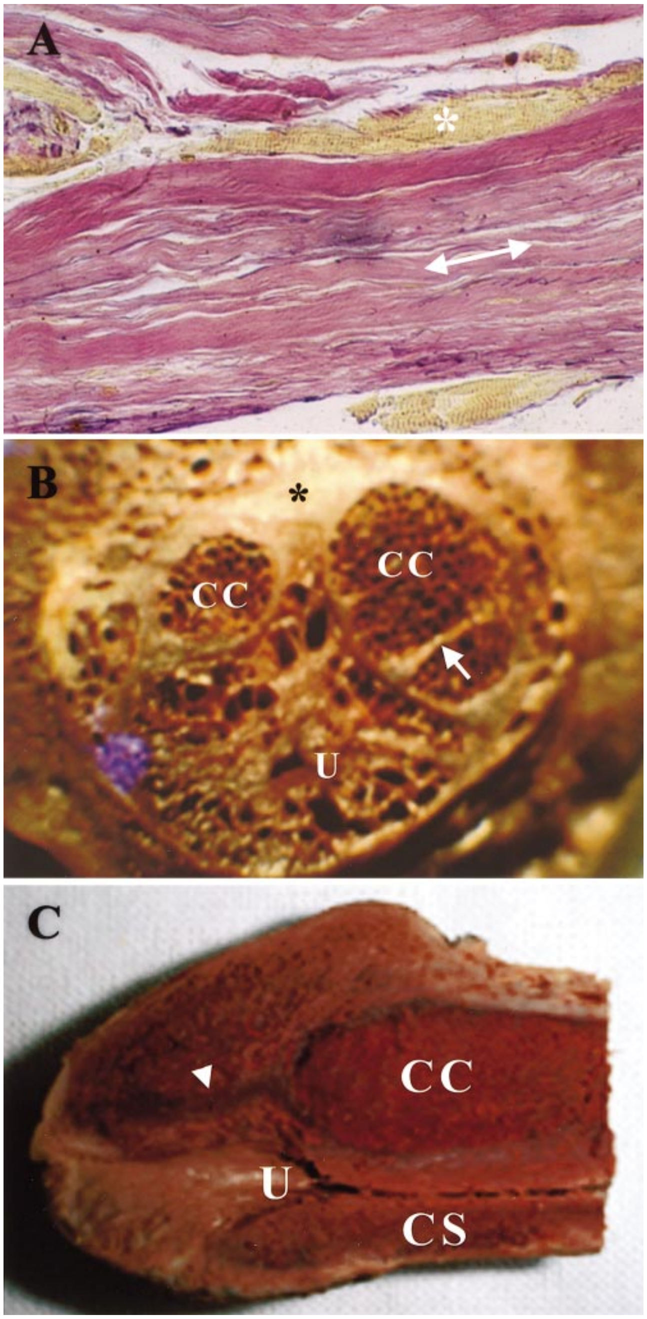

Figure 2. Ischiocavernosus muscle. **(A)** A single muscle fiber at the level of the penile crus. It was chosen from the distal and medial borders of the penile crus (shiny appearance in Figure 1A). These skeletal muscles (asterisk) are evidenced by their characteristically unique striation within the collagen bundle (double-headed arrow, Masson trichrome, 400× magnification). **(B)** Cross section at the glanular level showing the distal ligament. The dorsal thickening of the tunica albuginea becomes conspicuous because these ischiocavernosus muscle fibers have joined it. Progressing distally, the dorsal thickening becomes prominent and is grouped into the glans penis to form the distal ligament (asterisk). Note that the distal end of the corpora cavernosa (CC) is apparent in spite of a variation in the apparent size bilaterally that results from an asymmetric cut and the position of the distal urethra (U). Not surprisingly, there is an intracavernosal pillar (arrow) within the larger corpus. **(C)** This image is of the sagittal section of the glans penis showing the distal ligament (arrowhead). This structure is aggregated from the collagen bundles of ← the outer longitudinal layer of the tunica in the CC. It is a strong trunk within the glans and is located at the 12-o'clock position of the distal U, which is centrally located in the corpus spongiosum (CS).

Some muscle fibers that arise from the inner surface of the pubis and ischium join these long, fleshy fibers as they run along the crus. They then insert into the outer longitudinal collagen bundles of the tunica. At the penile crus, both the ischiocavernosus and bulbospongiosus muscles encircle their corresponding corpus. Where the 3 bodies are not in close contact, fleshy fibers are conspicuous; where the 3 bodies are in direct contact, the structure between them is thin and tendinous. This tissue was further confirmed as skeletal muscle, because histologic staining showed the striations that are unique to skeletal muscle (Figure 2A).

At the junction between the pendulous and crural portions, ventral thickening and dorsal thickening are obvious. The ventral thickening predominates and forms the borders of the ventral groove that houses the corpus spongiosum, whereas the dorsal thickening begins to form a concave dorsal groove that houses the deep dorsal vein trunk. Progressing distally, the dorsal thickening becomes conspicuous, groups into the glans penis, and forms the distal ligament (Figure 2B and C), which is located at the 12-o'clock position of the distal urethra.

In the corpora cavernosa, skeletal muscle that is associated with the continuing tunica albuginea contains and supports smooth muscle, which is an essential element in the sinusoids. This relationship plays an important part in the blood vessels' ability to supply the blood to meet the requirements for erection. Thus, Pascal's law governing fluid pressures applies in the corpora cavernosa. The corpora cavernosa allows only vascular and nervous tissue to communicate with systemic circulation, whereas in the corpus spongiosum, skeletal muscle partially entraps the smooth muscle to allow ejaculation when erect. In the glans penis, however, the distal ligament, a continuation of the outer longitudinal layer of the tunica, is arranged centrally and acts as a trunk for the entire glans.

To provide a better understanding of the anatomic-clinical correlation, the Table summarizes the general data of these cadavers. In the potent group, the ischiocavernosus and bulbospongiosus muscles are much thicker than those in the impotent group. In the potent group, the thickness of ventral thickening, dorsal thickening, and distal ligament is 2.2 ± 0.3 mm, 1.9 ± 0.2 mm, and 2.0 ± 0.3 mm, respectively. The corresponding values are 1.6 ± 0.2 mm, 1.4 ± 0.1 mm, and 1.5 ± 0.1 mm in the impotent group. A statistically significant trend existed between the potent group and the impotent group ($P \leqq .01$ in each).

Summary of the skeletal components of 35 cadavers

Grouping	No. of Cadavers	Age, y	Thickness (mm) Ventral Thickening	Dorsal Thickening	Distal Ligament	Ischiocavernosus	Bulbospongiosus
Potent group	6	23–54 (38.2 ± 9.9)	2.2 ± 0.3	1.9 ± 0.2	2.0 ± 0.3	Remarkable	Remarkable
Impotent group	29	48–93 (71.1 ± 9.7)	1.6 ± 0.2	1.4 ± 0.1	15 ± 0.1	Slimmer	Slimmer
Total	35						
P-value*		<.001	<.001	.002	.01		

* Univariate comparisons were performed using the Student's *t*-test for parameters with continuous values.

Discussion

The human penis is composed of the glans penis, the corpus spongiosum with the bulb of the penis, and the paired corpora cavernosa in which skeletal muscle structures and the continuing tunica albuginea completely surround and contain smooth muscle structures, which intermingle with fibrous tissue to form the wall of the sinusoids (Goldstein and Padma-Nathan, 1990; Hsu et al, 1992, 1994; Brock et al, 1997). The corpus spongiosum is partially entrapped by the skeletal muscle. These encased tissues finally pass through and are regulated by the surrounding structures. The penis gives the appearance of being an independent organ because of its skeletal muscle structures. They are the tissue that determine the penile shape as well as an essential part in the establishment of a rigid penis.

The human penis mimics the structure of other parts of the human body where skeletal muscles and the skeleton encompass those visceral organs in which smooth muscles reside. It is a pendulous organ that is uniquely suspended from the front and strongly adheres to the pubic ramus and ischium via the tenacious periosteum. The organ leans on and is supported by a suspensory ligament that is an extension of the linea alba. An erect penis is analogous to an athletic diver without upper extremities who is standing on a springboard ready to dive. Thus, the glans penis corresponds to the head, and the penile shaft corresponds to the trunk of the body, with the penile crura corresponding to the legs. Whether the organ is healthy depends on its muscle integrity.

The tunica albuginea of the corpora cavernosa is a bilayered structure. The inner circular layer completely contains and, along with the intracavernosal pillars, supports the sinusoids. There is a paucity of outer-layer bundles in the region between the 5-o'clock and 7-o'clock positions where there is close contact with the corpus spongiosum. Distally, they are grouped into the glans penis, which forms the distal ligament, a continuation of the outer longitudinal layer of the tunica, and is located at the 12-o'clock position of the distal urethra. Coital ability can be lost if the penis loses its intact distal ligament, even though its erectile function is normal (Hsu et al, 2001). This unique anatomic arrangement may explain why the glans penis is strong enough to bear the buckling pressure of coitus, as well as how an erect penis is sufficiently rigid but never compresses the corpus spongiosum, which otherwise would present an obstacle to ejaculation. A strong glans protects the reflexogenic erectile mechanism that may be evoked in response to global contraction of the perineal muscles, which in turn compresses the veins and erectile tissue to encourage penile rigidity and allows rhythmic ejaculation (Schmidt and Schmidt, 1993; Shafik, 1998).

Smooth muscle is an essential component of the sinusoids in the corpora cavernosa, the corpus spongiosum, and the glans penis. In the corpora cavernosa, the ischiocavernosus muscle and its continuation as the tunica albuginea contain and support the smooth muscle, and together, they meet the requirements for erection, whereas in the corpus spongiosum, the skeletal muscle partially entraps the smooth muscle to allow ejaculation when in a state of erection. The young cadavers (Figure 1) show, unequivocally, a remarkable muscle bulk, whereas elderly subjects sustaining chronic diseases tend to demonstrate a lighter skeletal muscle bulk and slimmer distal ligament (Figure 2C) as well as a thinner tunica albuginea.

Traditional anatomy states that there are 2 end-artery organs in the human body (ie, the retina and the kidney). However, we believe that the sinusoids of the corpora cavernosa, the corpus spongiosum, and the glans penis should be included in this grouping. In our study, most emissary veins often ran in an oblique path between the inner and outer layers of the tunica albuginea. However, the arteries take a more direct route through the tunica. The veins, therefore, play a passive, yet overwhelmingly important, role in erectile function.

In the area of the penis with a complete medium septum (Figure 3B), bulking is obvious in both the bulbospongiosus and ischiocavernosus muscles. The anterior fibers of the bulbospongiosus muscle are bulky, and similarly, the ischiocavernosus muscle bulk is apparent at this

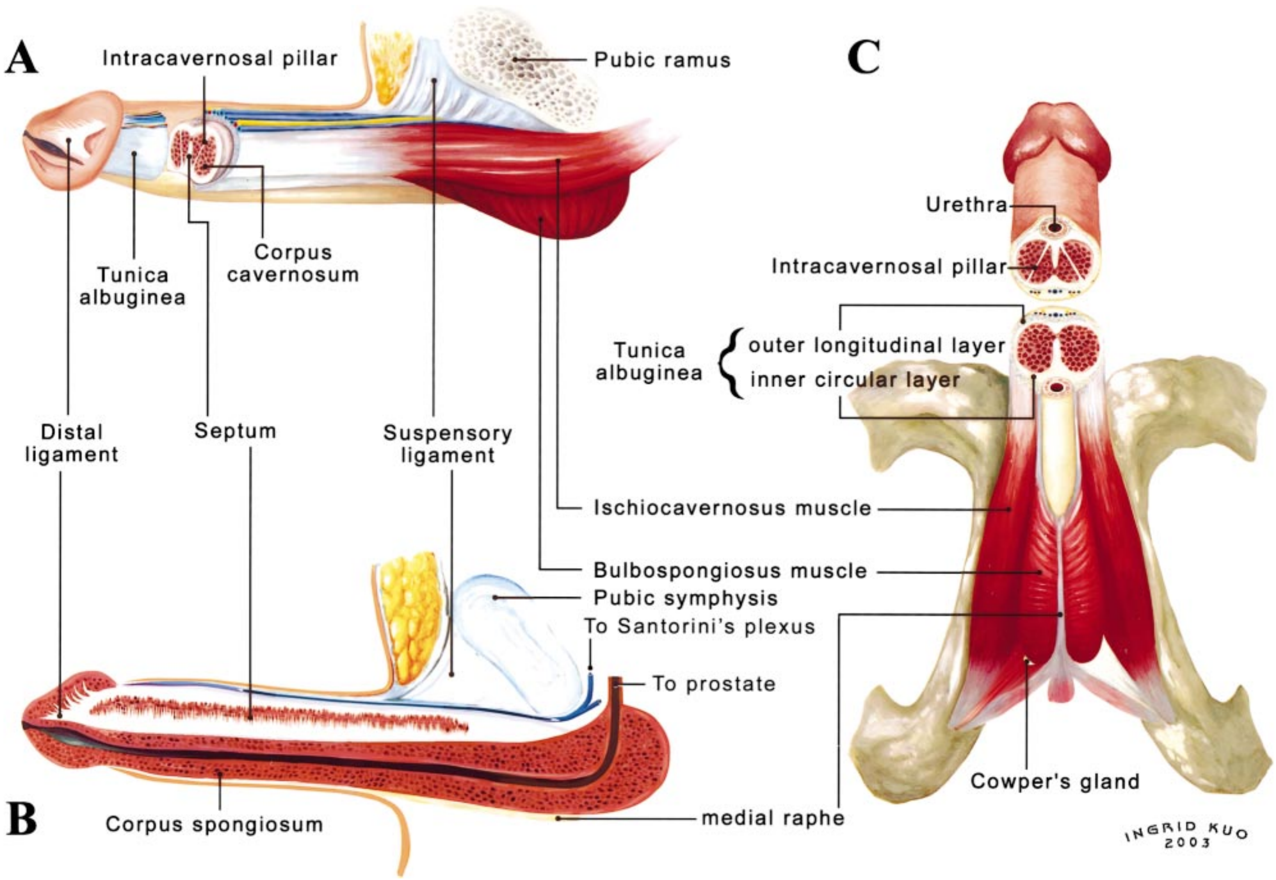

Figure 3. Schematic illustration of the human penis. **(A)** Lateral aspect. The penis leans on and is supported by a suspensory ligament, which is an extension of the linea alba. It is capped by the glans penis. Proximally, the corpus spongiosum (CS) is held by the bulbospongiosus muscle in which the fibers are mostly transverse. The corpora cavernosa (CC) is surrounded by the tunica albuginea, which is a bilayered structure (an inner circular and an outer longitudinal layer with multiple sublayers). The intracavernosal pillars, which may be considerably larger distally, are a continuation of the inner circular layer. The corpus cavernosum is entrapped in the ischiocavernosus muscle with the muscle fibers aligned in the longitudinal direction. **(B)** Medial aspect. The distal ligament is aggregated from the collagen bundles of the outer longitudinal layer of the tunica albuginea. It is an inelastic fibrous structure that forms the trunk of the glans penis. The incomplete septum is dorsally fenestrated. The CS contains the urethra. **(C)** Ventral aspect. The 3-dimensional structure of the human penis is evident. The ischiocavernosus muscle is paired with and situated at the lateral boundary of the perineum. Each segment covers its ipsilateral penile crus. Meanwhile, the anterior fibers of the bulbospongiosus muscle partially radiate to encircle the corpus cavernosum and mostly insert into the ventral thickening of the tunica.

level (Figure 1). Therefore, any surgical attempt, if erection is a concern, should spare these muscles (Mulhall et al, 2001). In penile-lengthening procedures, it is not wise to detach the pubic periosteum or to sever the collagen bundles, which anchor the muscle to the dorsal thickening, as the underlying ischiocavernosus muscle might not be saved (Shirong et al, 2000). Anatomic knowledge must be deemed a prerequisite for any surgeon. Local anesthesia for a penile implant and venous patch surgery should be delicately handled (Hsu et al, 2003), and irreversible iatrogenic damage of the muscles resulting from crural detachment or ligation must be avoided, if possible.

In the human penis, the skeletal ischiocavernosus muscles, the bulbospongiosus muscles, and their extension as the tunica albuginea support and contain, completely in the corpora cavernosa or partially in the corpus spongiosum, the smooth muscle structures that intermingle with fibrous tissue to form the wall of the sinusoids. However, in the glans penis, the skeletal ligament is entrapped by the smooth muscle structures and serves as a trunk.

References

Brock G, Hsu GL, Nunes L, von Heyden B, Lue TF. The anatomy of the tunica albuginea in the normal penis and Peyronie's disease. *J Urol.* 1997;157:276–281.

Claes H, Bijnens B, Baert L. The hemodynamic influence of the ischiocavernosus muscles on erectile function. *J Urol.* 1996;156:986–990.

Goldstein AM, Padma-Nathan H. The microarchitecture of the intracavernosal smooth muscle and the cavernosal fibrous skeleton. *J Urol.* 1990;144:1144–1146.

Gray H. Myology: fascia and muscles of the trunk. In: Williams PL, Dyson M, Warwick R, eds. *Gray's Anatomy.* London: Churchill Livingstone; 1989:587–608.

Hsu GL, Brock GB, Martinez-Pineiro L, Nunes L, von Heyden B, Lue

TF. The three-dimensional structure of the tunica albuginea: anatomical and ultrastructural levels. *Int J Impot Res.* 1992;4:117–129.

Hsu GL, Brock G, Martinez-Pineiro L, von Heyden B, Lue TF, Tanagho EA. Anatomy and strength of the tunica albuginea: its relevance to penile prosthesis extrusion. *J Urol.* 1994;151:1205–1208.

Hsu GL, Hsieh CH, Wen HS, Hsieh JT, Chiang HS. Outpatient surgery for penile venous patch with the patient under local anesthesia. *J Androl.* 2003;24:35–39.

Hsu GL, Wen HS, Hsieh CH, Liu LJ, Chen YC. Traumatic glans deformity: reconstruction of distal ligamentous structure. *J Urol.* 2001;166:1390.

Kawanishi Y, Kishimoto T, Kimura K, Yamaguchi K, Nakatuji H, Kojima K, Yamamoto A, Numata A. Spring balance evaluation of the ischiocavernosus muscle. *Int J Impot Res.* 2001;13:294–297.

Lavoisier P, Proulx J, Courtois F. Reflex contractions of the ischiocavernosus muscles following electrical and pressure stimulations. *J Urol.* 1988;139:396–399.

Lue TF. Erectile dysfunction. *N Engl J Med.* 2000;342:1802–1813.

Mulhall JP, Martin D, Ergin E, Kim F. Crural ligation surgery for the young male with venogenic erectile dysfunction: technique. *Tech Urol.* 2001;7:290–293.

Putz R, Pabsteds R. Pelvic diaphragm [floor]: male and female external genitalia. In: Putz R, Pabsteds R, eds. *Sobotta Atlas of Human Anatomy.* Philadelphia, PA: Lippincott Williams & Wilkins; 2001:222–239.

Schmidt MH, Schmidt HS. The ischiocavernosus and bulbospongiosus muscles in mammalian penile rigidity. *Sleep.* 1993;16:171–183.

Shafik A. Response of the urethral and intracorporeal pressures to cavernosus muscle stimulation: role of the muscles in erection and ejaculation. *Urology.* 1995;46:85–88.

Shafik A. The mechanism of ejaculation: the glans-vasal and urethromuscular reflexes. *Arch Androl.* 1998;41:71–78.

Shirong L, Xuan Z, Zhengxiang W, Dongli F, Julong W, Dongyun Y. Modified penis lengthening surgery: review of 52 cases. *Plast Reconstr Surg.* 2000;105:596–599.

Wespes E, Nogueira MC, Herbaut AG, Caufriez M, Schulman CC. Role of the bulbocavernosus muscles on the mechanism of human erection. *Eur Urol.* 1990;18:45–48.