Surgical Anatomy of Penis in Exstrophy-epispadias: A Study of Arrangement of Fascial Planes and Superficial Vessels of Surgical Significance

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OBJECTIVE
To study the anatomic arrangement of the fascial planes and superficial vessels in relationship to the laid-open urethral plate, glans, corpus spongiosum, and corpora cavernosa in the penis of patients with exstrophy or epispadias.

MATERIALS AND METHODS
Of 6 patients, 4 had classic exstrophy and 2 had incontinent epispadias. These patients had presented beyond adolescence without previous intervention and were selected for the present study. Using a 1.5-T magnetic resonance imaging scanner and compatible 3-in. surface coil, the epispadiac penises were studied using fast spin echo sequences and contrast-enhanced sequences. In 2 patients, angiography of the superficial vessels was also performed using multidetector row helical computed tomography. The imaging findings were also verified during the subsequent reconstructive surgery.

RESULTS
A clear demarcation of the skin, dartos fascia, Buck’s fascia, corpora cavernosa, corpus spongiosum, and the intraglanular planes were seen with the course of the blood vessels. The penile dartos received axial pattern vessels from the external pudendal vessels, with collateral branches from the dorsal penile artery as transverse branches at the shaft of the penis and preputial branches at the coronal sulcus. Buck’s fascia sleeved the corpora cavernosa, enveloped the neurovascular bundle, and fused with the corpus spongiosum without crossing the midline. Intraglanular extension of Buck’s fascia separated the intraglanular vascular arcade from the tip of the corpora.

CONCLUSION
Parallel to the ventral midline, axial pattern vessels to the skin—dartos complex are present, with an additional supply to the prepuce from the terminal penile arteries. These findings can be used for designing the skin coverage. The subfascial plane between the tip of the corpora and the intraglanular vascular arcade and the plane of cleavage between the cavernosa–spongiosum interface can be used for efficient corporal urethral separation.

Precise knowledge of the surgical anatomy of any birth defect is a mandatory prerequisite for accurate surgical reconstruction without complications. The surgical anatomy of the exstrophy–epispadias complex can be simply envisaged using the description by Brock and O’Neil1 as “if one blade of a pair of scissors was passed through the urethra of a normal person; the other blade over the midline dividing the skin, abdominal wall, anterior wall of bladder and urethra and symphysis pubis in midline and laying it open like a book.” Several reports have described the anatomy of epispadias, with emphasis on the corpora, glans, course of the neurovascular bundle, and the urethral plate, from either dissection during surgery or imaging modalities.2-9 However, no report has described the anatomy of the fascial planes (ie, Buck’s fascia, the dartos fascia, and the superficial vessels of the skin–dartos complex) using magnetic resonance imaging in the epispadiac penis before the distortion of the anatomy that can occur during surgical dissection. To enhance the precision in the surgical technique of epispadias repair, we studied the arrangement of the fascial planes, in particular, Buck’s fascia and the course of the superficial vessels in the epispadiac penis using magnetic resonance imaging of the penis in cases of the exstrophy–epispadias complex.

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MATERIAL AND METHODS

Patients with exstrophy—epispadias were included in the study if they had been unable to attend the hospital because of socio-economic reasons, had attained adolescence without any previous surgical intervention, and had presented to our center for reconstruction. The patients’ age at presentation ranged from 17 to 22 years. Of the 6 patients included in the present study during a 4-year period, 4 had a classic exstrophy bladder and 2 had incontinent epispadias. The present study was planned to facilitate a better appreciation of the anatomic planes and structures in adult patients with an epispadiac penis and to ensure better cooperation regarding the control of body movement during the imaging studies without the need for sedation. Magnetic resonance imaging of the penis was done using a 1.5-T, 8-channel magnetic resonance imaging scanner (GE Signa HDX scanner, General Electric Healthcare, Milwaukee, WI) using a compatible 3-in. surface coil. The natural lie and position of the scanner, General Electric Healthcare, Milwaukee, WI) using Volume-share, version 4.5, software. These 3-dimensional, volume-rendered images were obtained using a multidetector, 64-slice, row helical computed tomography scanner (Philips Brilliance 64, version 3.5, Philips Medical Systems, Highland Heights, OH) with Essence technology. In the volume-rendered images, the threshold was set to 60 Hounsfield units, which allowed the depiction of small vessels with a study of the perfusion of the areas being examined. The threshold was standardized protocols on a GE Workstation (General Electric Health Care, Milwaukee, WI) with Essence technology maximum intensity projection images, the vessels of the neurovascular bundles at the level of the dartos fascia were studied in the transverse, sagittal, and coronal sections on the T2-weighted images. The vessels of the neurovascular bundles and the superficial vessels at the level of the dartos fascia were studied on the T1- and T2-weighted images. Enhancement of the vessels seen as linear structures was verified in the postcontrast-enhanced sequences. After performing these sequences, surface- and volume-rendered images were reconstructed using standardized protocols on a GE Workstation (General Electric Health Care, Milwaukee, WI) using Volume-share, version 4.5, software. These 3-dimensional, volume-rendered images were also studied at the Workstation using the facility of volume rendering of small vessels with a study of the perfusion of the areas supplied by them. In the maximum intensity projection images and high-definition maximum intensity projection images, the course of the vessels was traced back to their origin to the known larger vessels from which superficial vessels were arising. In 2 patients without retractile testes in whom the gonads could be covered with an indigenously designed gonadal shield, computed tomography with angiography of the common iliac and proximal femoral arteries and its genital branches was also obtained using a multidetector, 64-slice, row helical computed tomography scanner (Philips Brilliance 64, version 3.5, Philips Medical Systems, Highland Heights, OH) with Essence technology. In the volume-rendered images, the threshold was set to 60 Hounsfield units, which allowed the depiction of small vessels with a study of the perfusion of the areas being examined. The threshold was set to 60 Hounsfield units, which allowed the depiction of small vessels with a study of the perfusion of the areas being examined. In the transverse sections, the corpus spongiosum was seen as a wedge-shaped structure between the pair of corpora cavernosa, up to the bulb of the penis proximally and the tip of the glans distally (Fig. 1C). Its tissue continued with the tissue of the glans (Figs. 1A, 2A, 2A). On either side of the wedge-shaped corpus spongiosum, the pair of corpora cavernosal bodies were seen as somewhat bean-shaped oval structures (Fig. 1C,D). The dorsum of the wedge-shaped corpus spongiosum was covered with the laid-open urethral plate, continuous with the penile skin laterally on both sides. However, no fascia was seen separating the tissue of the corpus spongiosum and the dorsal urethral plate.

The neurovascular bundles were seen in the transverse sections of magnetic resonance imaging images as cross sections of multiple branches running on the dorsolateral aspect of the corpora cavernosa. Transverse branches were also seen running around the corpora cavernosa and in the dartos fascia as circumflex branches of the dorsal penile artery (Fig. 1C). The terminal branches of the neurovascular bundles almost always entered the glans lateral to the junction of the laid-open glanular urethral plate with the corona. This finding was verified during corporal urethral separation from the dorsal side during surgery for epispadias (Fig. 2D). The intraglanular course of the dorsal penile artery was seen in the coronal sections as a terminal intraglanular coronal arcade running deep, but very close, to the lamina propria and quite adjacent to the tunica albuginea (Fig. 1B). Thus, a potential space of cleavage between the glans and the apex of the corpora cavernosa was found; however, it was in very close

RESULTS

In the coronal magnetic resonance imaging sections, a pair of corpora cavernosa flanking the central corpus spongiosum was well visualized. The posterior segments of the corpora cavernosa were divergent but well-formed and the anterior segments were shortened (Fig. 1A). Capping the tip of the pair of corpora cavernosa, a fore-shortened and flattened glans was well visualized with demarcation of the surface urothelium of the glans. Under the urothelium, the layer of the lamina propria was also seen encasing the erectile tissue of the glans (Fig. 1A). The central tissue of the glans was seen to continue into the tissue of the corpus spongiosum in the midline (Fig. 1A).

The tunica albuginea encasing the corpora cavernosa was seen as a distinct 2-layer structure on the lateral aspect but as only a thin single-layer structure on the medial aspect of the corpora cavernosa. The corpus spongiosum was distinctly separate from the side and tip of the tunica albuginea of the corpora cavernosa with the intervening Buck fascia. The tunica albuginea at the tip of the corpora cavernosa was also seen as a single-layer, thin structure. However, a distinct plane was present between the granular erectile tissue and the intraglanular tip of the corpora cavernosa, with lamina propria and Buck’s fascia in between, as seen on the coronal sagittal magnetic resonance images (Figs. 1A, 2A,B). These findings were also verified during surgery while performing the corporal urethral separation for epispadias repair (Fig. 2C-E).

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proximity to the intraglanular vessels, which can be injured if the lamina propria is violated during dissection (Figs. 1B and 2A).

Buck’s fascia was seen as a white fascial layer deep to the penile dartos and surrounding the tunica albuginea of the corpora cavernosa on both sides. On the dorsolateral side, splitting of Buck’s fascia to encircle the neurovascular bundles was seen (Fig. 1C,D). At the dorsal surface of the corpora cavernosa, Buck’s fascia did not cross the midline but coursed between the wedge-shaped corpus spongiosum medially and the thin, single-layer tunica albuginea laterally toward the ventral midline. At the ventral midline, guarding the apex of the wedge-shaped corpus spongiosum, Buck’s fascia fused with the corresponding fascia on the opposite side (Fig. 1C,D). This arrangement of Buck’s fascia could also be verified during corporal urethral separation from the dorsal and ventral sides during surgery for epispadias (Fig. 2C-E).

Distally, Buck’s fascia was seen to continue into the intraglanular portion and to fuse with the lamina propria layer of the glans covering the apex of the corpora (Figs. 1A,B and 2A,B). Thus, a subfascial plane between the tunica albuginea of the intraglanular corpora cavernosa and the lamina propria of the glans was present that can be used to help guard the erectile tissue and glanular vessels during dissection. Proximally, Buck’s fascia was seen extending up to the posterior segment of the corpora cavernosa, blending with the fascia over the ischiocavernous muscle (Fig. 2B).

Dartos fascia was seen as an intermediate signal density layer distinctly between the skin and Buck’s fascia. It was seen as a well-developed and thicker layer at the midline on the ventral aspect of the penis. Proceeding dorsally toward the urethral plate, it gradually thinned out and vanished near the margin of the urethral plate (Fig. 1C). The superficial vessels studied on the T2-weighted images, with their linear enhancement confirmed after contrast enhancement, demonstrated longitudinally oriented, axial pattern, vessels running and branching parallel to the midline on the ventral side (Fig. 3A). These axial pattern vessels in the dartos were also seen during surgery for extrophy and epispadias using a midline scrotal...
The perineal approach (Fig. 3B). The dartos on the dorsolateral aspect was seen to receive collateral branches arising from the neurovascular bundles running on the dorsolateral aspect of the corpora cavernosa lateral to the margin of urethral plate (Fig. 1C,D). The axial pattern vessels could be traced proximally to arise from the femoral vessels as branches of the external pudendal vessels (Fig. 3C). The parasagittal view demonstrated the presence of collateral branches coming from the glanular branches of the dorsal neurovascular bundles (Fig. 3D). Thus, the dartos has a triple blood supply in the epispadiac penis: axial pattern vessels from the superficial external pudendal vessels and preferentially running on the ventral aspect of the penis parallel to the midline; collateral vessels from the branching of the neurovascular bundles, supplying the dorsolateral aspect of the penile dartos; and collateral vessels from the glanular branches supplying the prepucial dartos.

From our magnetic resonance imaging and operative findings, the details of the surgical anatomy of the fascial planes and vessels in the epispadiac penis are shown in a schematic diagram in Figure 4.

**COMMENT**

Irrespective of the technique chosen for surgery for epispadias reconstruction, certain basic steps remain universal to all the techniques, with few modifications. These basic steps involve penile degloving in the subdartos plane, separation of the corporal bodies off the dorsally placed urethral plate with an intact wedge of corpus spongiosum on its ventral side, dissection with preservation of the neurovascular bundles, and creation of glans wings for glansplasty. Reconstruction will involve urethroplasty with its ventral translocation, glansplasty, chordee correction with or without a dorsal patch graft or cavernocavernostomy, and provision of a vascularized skin cover. The unique blood supply of the corpus cavernosa and glans has been exploited by Mitchell and Bagli in complete penile disassembly for epispadias repair. The significance of the knowledge of the pattern of
vascularity, course of the axial pattern vessels, and sites of the collateral vessels and familiarity with the arrangement of the fascial planes in the epispadiac penis cannot be overemphasized in view of the reported complications such as corporal loss, skin necrosis, poor skin management, and a less-than-optimal aesthetic appearance.\textsuperscript{7,11-13}

The described anatomy for dartos fascia and Buck’s fascia in the normal penis has revealed that Buck’s fascia, superficial to the tunica albuginea and deep to the dartos, surrounds the corpora cavernosa and corpus spongiosum but splits to envelop the neurovascular bundle dorsally and corpus spongiosum ventrally.\textsuperscript{14} In the epispadiac penis, the urethral plate is laid open to occupy a dorsal position over the ventrally placed wedge-shaped corpus spongiosum, with ventrolateral displacement of the corpora cavernosa and neurovascular bundle occupying the dorsolateral positions. With this change in the anatomy, alterations could occur in the arrangement of Buck’s fascia and the superficial vessels. Although several reports have described the surgical anatomy of epispadias,\textsuperscript{2-9} alterations in the fascial planes and the superficial vessels have not previously been documented using magnetic resonance imaging.

In the normal penis, collateral vessels supplying the inner prepuce from the branches of the dorsal penile artery and the axial pattern vessels of the penile skin—dartos complex arising from the superficial external pudendal vessels have been reported.\textsuperscript{15} By assuming that the same arrangement persists in the epispadiac penis, a method of skin coverage based on this anatomy has also been described.\textsuperscript{13} Nevertheless, these collateral vessels had not been previously documented using magnetic resonance imaging in the epispadiac penis.

In the present study, we have documented the following facts of the penile anatomy. First, similar to the arrangement of the axial pattern vessels of the skin—dartos complex arising from superficial external pudendal vessels in the normal penis, the axial pattern
vascularity to either layer. These can be split into 2 layers without jeopardizing the (Figs. 3D and 4). Therefore, the inner and outer prepuce vessels from the terminal branches of axial pattern vessels of dartos. These vessels are also present in the epispadiac penis. However, they will be located on the ventral aspect, rather on the dorsolateral aspect, with relative avascularity in the ventral midline along the median raphe (Fig. 3A). This axial pattern supply should be respected when providing skin coverage in epispadias repair. Second, the collateral vessels from the terminal glanular branches of the dorsal penile artery provide an additional supply to the prepuce vessels from the terminal branches of axial pattern vessels of dartos. These findings have formed the basis for the subfascial plane of cleavage for corporal urethral separation and glans wing creation.

CONCLUSION
The results of our study have demonstrated that the dartos fascia in the epispadiac penis is an incomplete sleeve around the penile shaft, with interruption of continuity along the margin of the dorsal, laid-open, urethral plate. From the lateral side, the external pudendal vessels send axial pattern vessels to the dartos fascia and mainly course in the ventral penile skin—dartos fascia parallel to the midline, with relative avascularity at the midline. The prepucial dartos receives an additional blood supply from the terminal branches of the dorsal penile artery at the coronal sulcus. These findings have formed the rationale of the design of skin coverage during surgical repair of epispadias. The sleeve of Buck’s fascia surrounds the corpora cavernosa and splits to envelop the dorsolateral neurovascular bundles. Medially, it does not cross the midline, but, instead, blends with the fascia on the lateral aspect of the wedge-shaped corpus spongiosum. Intraglanular extension of Buck’s fascia separates the intraglanular vascular arcade from the tips of the corpora cavernosa. These findings have formed the basis for the subfascial plane of cleavage for corporal urethral separation and glans wing creation.

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