

# Surgical Anatomy of Urogenital Diaphragm and Course of Its Vessels in Exstrophy-Epispadias

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<b>OBJECTIVES</b>	To report the surgical anatomy of the muscles of the urogenital diaphragm and the pattern of its vessels in the classic exstrophy bladder and incontinent epispadias.
<b>METHODS</b>	A total of 11 patients, 9 with unoperated classic exstrophy and 2 with incontinent epispadias, who were >5 years old at presentation, were selected for the present study. Magnetic resonance imaging of the pelvis was performed using a 3.0 T magnetic resonance imaging scanner and an 8-channel coil. Computed tomography was performed for 5 patients using a multidetector row helical computed tomography scanner. Angiograms of the vessels of the urogenital diaphragm were also obtained using magnetic resonance imaging and computed tomography.
<b>RESULTS</b>	A central perineal body was seen in all the patients, with attachment of the bulbospongiosus anteriorly, superficial transverse perinei laterally, and anal sphincter posteriorly. At the root of corpora, the ischiocavernosus muscle was also seen. The triangle among the ischiocavernosus, bulbospongiosus, and superficial transverse perinei muscle was accentuated and contained the perineal artery, indirectly indicating the course of the perineal nerve. The dorsal penile artery was nearer to the posterior edge of the ischiopubic ramus, before coursing on the lateral aspect of the anterior segment of the corpora. The deep transverse perinei muscle and laid open external urethral sphincter were also seen in the proximal planes of the urogenital diaphragm.
<b>CONCLUSIONS</b>	First, all the muscles of the urogenital diaphragm, including the external urethral sphincter, were present in the exstrophy bladder. Second, the perineal artery and its sphincteric branches were in the triangular space between the ischiocavernosus, bulbospongiosus, and superficial transverse perinei muscle. Finally, the dorsal penile artery ran along the inner edge of the ischiopubic ramus before lying on lateral aspect of the corpora. UROLOGY 78: 159–163, 2011. © 2011 Elsevier Inc.

The surgical anatomy of the exstrophy bladder has been described by Brock and O’Neil as follows: “Classic bladder exstrophy may be conceptualized by the visual image of what would occur if one blade of a pair of scissors were passed through the urethra into the bladder of a normal person, the other blade were used to cut through the layers of the skin, abdominal wall, anterior wall of the bladder and urethra, the symphysis pubis and the cut ends were unfolded laterally as if the pages of a book were being opened.”<sup>1</sup> Trendelenburg in 1906 reported, “the physiological factors necessary both for urinary retention and [for] voluntary micturition are present.”<sup>2</sup> If this is true, in the exstrophy bladder, all the muscle of the urogenital diaphragm (ie, the pair of ischiocavernosus and transverse perinei muscles and cen-

tral bulbospongiosus muscle), and, proximal to the bulbospongiosus muscle, the external urethral sphincter should be present. However, studies using 3-dimensional computed tomography (CT) and 3-dimensional magnetic resonance imaging (MRI) have reported other anatomic details of the exstrophy bladder.<sup>3–7</sup> In contrast, the surgical anatomy of the urogenital diaphragm and its vessels has never been described.

The aim of the present study was to determine the anatomy of the muscles of the urogenital diaphragm and its vessels in the exstrophy bladder, so the knowledge can be applied to improve the quality of repair of the exstrophy bladder.

## MATERIAL AND METHODS

The present study was conducted only on male patients with an exstrophy bladder and included 9 patients with a classic exstrophy bladder and 2 with incontinent epispadias. Only those patients who presented at ≥5 years of age without previous surgery and had volunteered to undergo MRI of the pelvis were included in the study group. In addition to MRI, 5 patients, in whom the testes were not retractile and could be covered by an

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indigenously designed gonadal shield, also underwent CT of the urogenital diaphragm with angiography.

MRI of the pelvis was performed using a 3.0 Tesla MRI scanner (GE Signa HDX scanner, General Electric, Milwaukee, WI). The following sequences were done using an 8-channel coil. First, pre- and postcontrast 3-dimensional liver acquisition with volume acquisition- extended view sequences were done using the following experimental parameters: repetition time, 4.5 ms; echo time, 2.1 ms; field of view, 440 mm; NEX, 0.72; and matrix size, 320 × 192. The scanning was done in the axial planes with a slice thickness of 1.0 mm, and postprocessing was done in the coronal and sagittal planes. A gadolinium dose of 0.2 mmol/kg body weight was used for the angiography sequence. Second, a T<sub>2</sub>-weighted 3-dimensional cube sequence was done using the following experimental parameters: repetition time, 2400 ms; NEX, 1; field of view, 240 mm; and matrix size, 288 × 288, with a slice thickness of 1.0 mm.

After performing these sequences, surface and volume-rendered images were reconstructed using standardized protocols on an ADW, version 4.4, Advantage Workstation (General Electric Health Care, Milwaukee, WI).

CT of the pelvis was performed on a multidetector, 64-slice, row helical CT scanner (Philips Brilliance 64, version 3.5, scanner; Philips Medical Systems, Highland Heights, OH) with Essence technology, which provides a spatial resolution to the images. This multidetector row helical CT scan was performed for area of interest limited to the urogenital diaphragm with a 0.75 second/turn rotation time, 54 mm/s table speed, 64 × 0.625-mm collimation, 512 × 512 image matrix, 2-mm slice thickness, 1-mm pitch, 3-mm reconstruction, and automated dose modulation to minimize the radiation exposure. Nonionic contrast medium iohexol-350 in dose of 2.5-5.0 ml/kg body weight at the rate of 2-5 mL/s and with a pressure of 250-300 psi was used for the angiography sequence.

After obtaining the angiography sequence, 3-dimensional reconstruction of the images was done using various software protocols (cardiac, orthopedic, volume-rendered, maximum intensity projection) preloaded with on Extended Brilliance 190-P workstation (Philips Medical Systems, Highland Heights, OH) to directly analyze the muscle orientation in the urogenital diaphragm and the course of the pudendal vessel. Furthermore, to explore the course of the perineal artery, deep penile artery, and dorsal penile artery, limited digital dissection of the volume-rendered images was performed on this workstation, and the images were stored.

## RESULTS

### Urogenital Diaphragm and Its Muscles

The perineal view of the 3-dimensional reconstruction of the urogenital diaphragm in the patients with an exstrophic bladder revealed a well-defined perineal membrane stretched between the right and left ischiopubic rami posterior to the laid-open urethral plate. Over the perineal membrane, the bulbospongiosus muscle was present in midline. The pairs of ischiocavernosus muscles along the ischiopubic rami over the root of corpora and the transverse perinei muscles along the base of urogenital triangle were also present. Stretched between the diverted ischiopubic rami, the shape of the urogenital diaphragm was not triangular but was rather rectangular

or trapezoid, depending on the degree of diastases between the pubic bones (Fig. 1A).

The central perineal body was identifiable in all the patients with an exstrophy bladder as a midline node with attachment of the fibers of the external anal sphincter on posterior side, the bulbospongiosus muscle on the anterior side, and the transverse perinei muscles on each side of the perineal body (Fig. 1A). The bulbospongiosus muscle was present on the perineal surface of the urogenital membrane under the laid-open urethral plate in all patients; however, its shape was short and stubby (Fig. 1A).

The ischiocavernosus muscle was also present at the root of the corporal body in all the patients, with no apparent shortening or attenuation of the ischiocavernosus muscle in any of the patients and an orientation of the fibers similar to the description of the normal anatomy (Fig. 1A).

The superficial transverse perinei muscle was very well developed in 7 patients but was absent in 3 patients; however, the orientation of the fibers and the shape and site were similar to that of the normal anatomy (Fig. 1A).

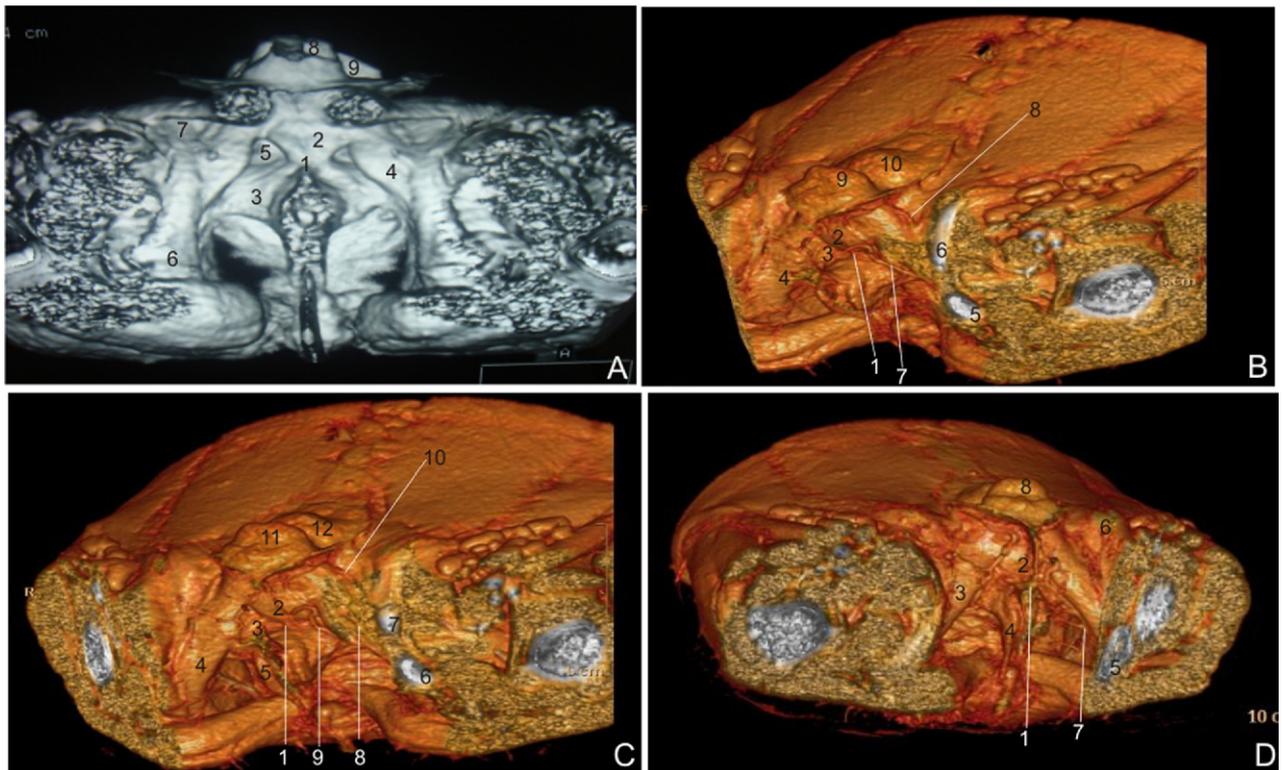
Posterior to the perineal body and around the anorectum, the striated muscle complex of the external anal sphincter was seen and well developed in all the patients, with anterior displacement of the perineal body, external anal sphincter, and anorectum.

The triangular space between the ischiocavernosus, bulbospongiosus, and superficial transverse perineal muscles was not only a potential space but had opened up as an accentuated space through which the perineal membrane (inferior fascia of urogenital diaphragm) was clearly visualized on the 3-dimensional image of the urogenital diaphragm (Fig. 1A). It was found that this space contained the perineal artery and its branches on the MRI angiogram and CT angiogram (Figs. 1B and 2A).

### Vessel Course in Urogenital Diaphragm

The CT angiogram and MRI angiogram revealed the course of the internal pudendal artery in the Alcock's canal well above the ischial tuberosity (Fig. 1D), giving its muscular branches to the external anal sphincter.

Just at the border of the ischium, deep to the attachment of the corpora, 3 terminal divisions of the internal pudendal artery were very well visualized. First, a dorsal artery to the penis was seen ascending up along the inner edge of the ischiopubic ramus and left the ischiopubic ramus in the middle to lie on the lateral aspect of corporal body on each side (Fig. 1B). Second, limited digital dissection of the corpora at its root demonstrated that the deep artery of the penis was entering the substance of the corporal body in its center just at the attachment of the corpora to the ischial tuberosity (Fig. 1C). Third, the perineal artery was seen coursing forward, superficial to the perineal membrane through the triangle between the ischiocavernosus, bulbospongiosus, and superficial transverse perineal muscles, giving branches



**Figure 1.** (A) Perineal view of 3-dimensional reconstruction of urogenital diaphragm in patient with exstrophy showing perineal body (1), bulbospongiosus muscle (2), transverse perineal muscle (3), ischiocavernosus muscle (4), perineal membrane seen through accentuated triangular space between ischiocavernosus, bulbospongiosus, and transverse perineal muscle (5), ischial tuberosity (6), pubic bones (7), glans (8), and bladder plate (9). (B) Volume-rendered 3-dimensional reconstruction of urogenital diaphragm with CT angiogram, perineal view (oblique), in patient with exstrophy showing perineal body (1), bulbospongiosus muscle (2), attenuated transverse perineal muscle (3), ischiocavernosus muscle (4), ischial tuberosity (5). Digital dissection of volume-rendered image at root of left corpora revealing ischiopubic ramus (6), perineal artery passing through triangular space with its branches as posterior scrotal artery and artery to bulb (7), dorsal penile artery along inner edge of ischiopubic ramus (8), glans (9), and bladder plate (10). (C) Volume-rendered 3-dimensional image of urogenital diaphragm with CT angiogram, perineal view (oblique), in patient with exstrophy showing perineal body (1), bulbospongiosus muscle (2), attenuated transverse perineal muscle (3), ischiocavernosus muscle (4), striated muscle complex around anorectum (5), and ischial tuberosity (6). Digital dissection of volume-rendered image at root of left corpora revealing ischiopubic ramus (7), deep penile artery (8), perineal artery passing through triangular space with its branches (9), dorsal penile artery (10), glans (11), and bladder plate (12). (D) Volume-rendered 3-dimensional reconstruction of urogenital diaphragm with CT angiogram, perineal view (oblique), in patient with exstrophy showing perineal body (1), bulbospongiosus muscle (2), ischiocavernosus muscle (3), striated muscle complex around anorectum (4), ischial tuberosity (5), pubic bones (6), course of internal pudendal artery in Alcock's canal and its muscular branches to external anal sphincter (7), and glans (8).

to the bulb and terminating as the posterior scrotal artery (Figs. 1B and 2A).

All the terminal bifurcations were proximal to the lateral attachment of the transverse perineal muscle at the border of the ischium. From the perineal artery coursing through the triangle, the branches coursed to the medial side toward the bulbospongiosus, but no branch was seen going to the lateral side and crossing the plane between the ischiocavernosus and bulbospongiosus muscles.

Cross-sectional 3-dimensional MRI of the urogenital diaphragm superior to the level of perineal membrane and the bulbospongiosus muscle demonstrated the deep transverse perineal muscle and the laid-open urethral sphincter (Fig. 2B).

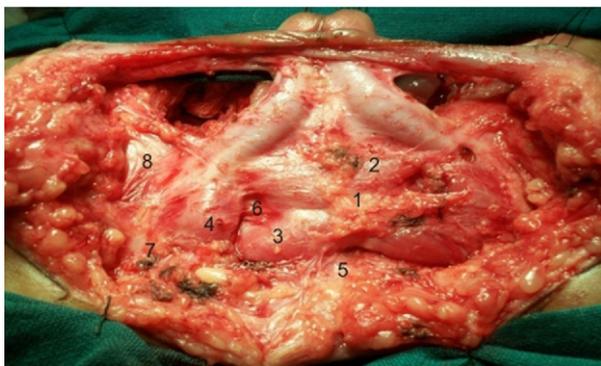
Using a surgical technique of a midline scrotoperineal approach for dissection of the muscles of the urogenital diaphragm, the presence of these muscles were confirmed by visual demonstration and electrostimulation of the muscles (Fig. 3).

From these findings of the 3-dimensional image reconstruction and study of the vascular anatomy using MRI angiography and CT angiography, we have summarized our concept of the applied anatomy of the urogenital diaphragm in a diagram (Fig. 4).

## COMMENT

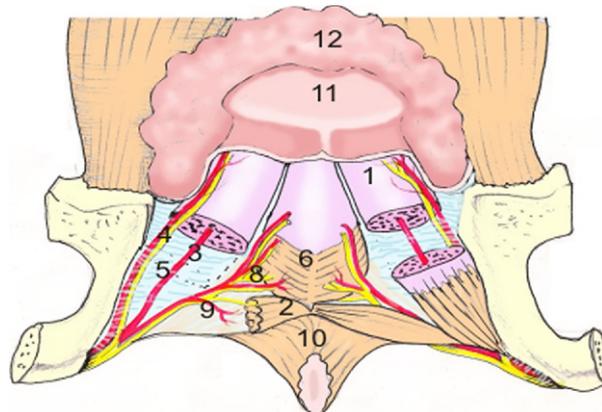
Since the description of the anatomy of the exstrophy bladder by Brock and O'Neil,<sup>1</sup> several studies have re-

**Figure 2. (A)** MRI angiogram with cross-sectional view of urogenital diaphragm showing perineal body (1), bulbospongiosus muscle (2), superficial transverse perinei muscle (3), root of corpora along with ischiocavernosus muscle (4), and course of perineal artery with artery to bulb (5). **(B)** MRI angiogram with cross-sectional view at level of deep perineal space of urogenital diaphragm showing perineal body (1), deep transverse perinei muscle (2), corporal bodies along with ischiocavernosus muscle (3), laid-open urethral plate and laid open external urethral sphincter (4), and 3 terminal divisions of internal pudendal vessels (5).



**Figure 3.** Perineal view of urogenital diaphragm as seen during surgery in patient with exstrophy through scrotoperineal approach showing perineal body (1), bulbospongiosus muscle (2), transverse perineal muscle (3), ischiocavernosus muscle (4), anal sphincter (5), accentuated triangular space between ischiocavernosus, bulbospongiosus, and transverse perineal muscle (6), ischial tuberosity (7), and pubic bones (8).

ported on the morbid anatomy of the exstrophy bladder related to the bone, viscera, muscle, and other soft tissue using 3-dimensional CT and 3-dimensional MRI. Spon-



**Figure 4.** Diagram showing panoramic view of undersurface of urogenital diaphragm in classic exstrophy bladder. Middle part of left corpora (1) and on right side, proximal corpora, ischiocavernosus muscle, and most of superficial transverse perineal muscle (2) shown as removed to show deep artery of penis (3) and course of dorsal penile artery and nerves (4) along ischiopubic ramus deep to perineal membrane (5) before leaving ramus to lie on lateral aspect of corpora. Triangular space between bulbospongiosus (6), ischiocavernosus (7), and superficial transverse perineal muscle containing branches of perineal artery and nerves, including sphincteric branches (8). Deep to perineal membrane shadow of deep transverse perineal (9) also shown. External urethral sphincter will be proximal to bulbospongiosus in plane deep to perineal membrane. External anal sphincter (10), glans (11), and bladder plate (12) also shown.

seller et al<sup>3</sup> and Stec et al<sup>4</sup> reported on the bony abnormalities in detail, and Stec et al,<sup>5</sup> Williams et al,<sup>6</sup> and Gorgollo et al<sup>7</sup> have described the abnormalities of the levator ani and other muscles. However, to date, the detailed anatomy of the muscles of the urogenital diaphragm and its vessels has not been reported. The description of the external urethral sphincter in the exstrophy bladder, which is also the content of the urogenital diaphragm, has also not been reported. Because the part of the continence mechanism lies in the urogenital diaphragm in the normal individual, the study of the changes in the urogenital diaphragm is mandatory to improve the surgical technique and fulfill the aim of complete correction of the morbid anatomy for patients with in exstrophy bladder.

It has been described in “Greys’ Anatomy”<sup>8</sup> that the perineal artery, which courses forward between the bulbospongiosus, ischiocavernosus, and transverse perineal muscles, gives off muscular and sphincteric branches and the perineal nerve accompanies the course of the perineal artery. It has not been studied or demonstrated whether the perineal artery is present in the exstrophy bladder in a similar anatomic position between the bulbospongiosus, ischiocavernosus, and transverse perineal muscles. With the results from the present study, we now know that the artery is present in a similar anatomic triangle between the bulbospongiosus, ischiocavernosus, and transverse

perinei muscles, giving branches toward the medial side but no lateral branches toward the corpora. The triangle is also accentuated, instead of being a potential triangular space. We also know that while coursing forward deep to the transverse perinei muscle, the perineal artery is nearer to the bulbospongiosus muscle, with a clear avascular plane toward the ischiocavernosus muscle. This knowledge can be used in reconstructive surgery of the exstrophy bladder. Reports of dissection of the midline urethral plate and its tubularization by Grady and Mitchell<sup>9,10</sup> and reconstruction of the periurethral muscles by Caione et al<sup>11,12</sup> have not emphasized the precise location of the external urethral sphincter or the course of its innervations and vascular supply.

Reconstruction of an inadvertently denervated external sphincter might not offer any functional benefit to the anatomic reconstruction. With the knowledge from our findings, the external sphincter muscle can be approached and anchored to the tubularized urethra with preserved innervations, if the plane of dissection has been kept close to the ischiocavernosus muscle and corporal body.

We have also studied the course of the internal pudendal vessels in relationship to the ischiopubic ramus on the lateral side and the corporal body on the medial side. The course of the internal pudendal vessels has been described in detail. However, the course after it has divided into the perineal artery, cavernosal artery, and dorsal penile artery has not been described. It has been described that after leaving the ischiopubic ramus, the penile artery and the nerve lies on the lateral aspect of the corpora. However, in between these points, the precise course of the penile artery and nerve has been poorly described. We did not know whether it lies nearer to the anterior margin of the ischiopubic ramus or nearer to the posterior margin of the ischiopubic ramus. This would be important knowledge to ensure safe detachment of the corpora from the ischiopubic ramus. With the present study, the precise course of the penile artery in relationship to the ischiopubic ramus has been described. With this knowledge, we believe that if the periosteum along the anterior margin of the ischiopubic ramus has been thoroughly incised and the subperiosteal plane entered, we can safely detach the corpora with almost guaranteed preservation of the neurovascular bundle. Our experience with the safe detachment of the corpora from the ischiopubic ramus in >35 patients with exstrophy has so far proved it. Thus, with the aim of directly approaching the uro-

genital triangle, bulbospongiosus muscle, external urethral sphincter, and entire segment of the ischiopubic ramus; we have developed the midline scrotoperineal approach for reconstruction of exstrophy-epispadias. This technique has been described in a subsequent report.

## CONCLUSIONS

First, the results of our study have shown that all the muscles of the urogenital diaphragm, including the external urethral sphincter, are present in the exstrophy bladder. Second, the perineal artery and its sphincteric branches lie in the triangular space between the ischiocavernosus, bulbospongiosus, and superficial transverse perinei muscle. Finally, the dorsal penile artery runs along the inner edge of the ischiopubic ramus, before lying on the lateral aspect of the corpora.

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