Surgical Anatomy of the Penis in Hypospadias: Magnetic Resonance Imaging Study of the Tissue Planes, Vessels, and Collaterals

Shiv Narain Kureel, Archika Gupta, Kanoujia Sunil, Yadvendra Dheer, Manoj Kumar, and Vinod Kumar Tomar

OBJECTIVE To report the surgical anatomy of the penis in hypospadias with study of vessels in relation to fascial planes, glans, corpora cavernosa, and corpus spongiosum using magnetic resonance imaging.

MATERIALS AND METHODS Twelve hypospadias presenting at older age (8-20 years) were studied with 1.5-T magnetic resonance imaging scanner and a 3-inch surface coil. Precontrast and postcontrast images were acquired using fast-spin echo sequences in sagittal, coronal, and transverse planes. The findings were processed in Volume Share 4.5, version Workstation, of General Electric Healthcare. Anatomic findings were verified during surgery. With imaging and surgical findings, a 3-dimensional conceptual diagram of surgical anatomy was created.

RESULTS Distinct layers of the skin, dartos fascia, Buck fascia, tunica albuginea, glans urothelium, lamina propria of glans, and corpus spongiosum were delineated with their spatial relationship. Axial pattern vessels of the dartos and its anastomosis with branches of dorsal penile vessels at the coronal sulcus, perforators along the corpus spongiosum, subglanular extension of the fascia, and intraglanular branches of the dorsal penile artery forming an arcade were visualized.

CONCLUSION Dorsomedial and dorsolateral axial pattern vessels are present in penile dartos with relative avascularity at dorsal midline in most cases. Subglanular extension of Buck fascia fused with the basal lamina propria of glans forms a barrier between the tip of corpora and the intraglanular arcade of vessels. Collaterals are present at coronal sulcus, along the bifurcated corpus spongiosum, and the dartos enabling blood flow between the terminal most branches of the external and internal pudendal vessels. UROLOGY 85: 1173–1178, 2015. © 2015 Elsevier Inc.

Normal anatomy of the penis describing its gross and histologic structures, fascial planes, and the pattern of vascularity are well reported in literature.[1-3] The published literature on surgical anatomy of hypospadias is based on histologic studies and other methods.[4-9] Although magnetic resonance (MR) study of normal penis has been described,[10-12] there is no report in literature describing the MR imaging (MRI) study of hypospadiac penis to look into the undisturbed anatomy with particular reference to superficial vessels in the penile dartos, fascial planes, intraglanular vasculature, and pattern of collateral network of vessels. The science and art of surgery of hypospadias has always evolved from earlier descriptions by Dennis Browne to modern surgical methods described by Snodgrass[13] and others.[14-17] However, postoperative complications of varying incidences and types are reported in literature, and sometimes, these complications are recurrent adding to mounting frustrations for surgeons and patients.[18,19] The scope of further refinement in science and art of reconstruction of hypospadias is also based on better understanding of surgical anatomy facilitating improved tissue handling, preservation of vascularity, tension-free reconstruction, and designing of new or modified surgical techniques for improved aesthetic appearance with minimal complications. Therefore, this study was undertaken to visualize the anatomy of fascial planes, pattern of both superficial and deep vessels of penis, locations and quality of collateral network, anatomy of intraglanular extension of fascia and the vessels, and overall revisit to describe the facts of anatomy in hypospadiac penis with the help of MRI with possible surgical implications.

Financial Disclosure: *The authors declare that they have no relevant financial interests.*

From the Department of Pediatric Surgery, King George's Medical University, Lucknow, India; the Department of Radiodiagnosis, King George's Medical University, Lucknow, India; and the Magnetic Resonance Unit, Department of Radiodiagnosis, King George's Medical University, Lucknow, India

Address correspondence to: Shiv Narain Kureel, M.Ch. (Paed Surg), Department of Pediatric Surgery, King George's Medical University, Lucknow 226001, India. E-mail: snkkgmu@rediffmail.com

Submitted: December 27, 2014, accepted (with revisions): February 17, 2015

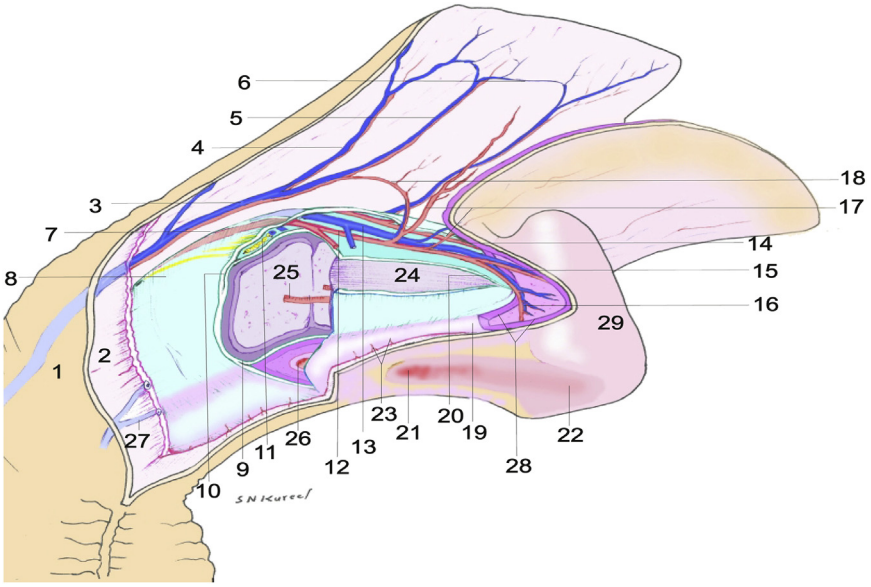

Figure 1. Schematic diagram, on the basis of magnetic resonance and operative findings, showing the relevant surgical anatomy of tissue planes and the vessels in a case of distal hypospadias. Inner preputial skin with lamina propria is shown as split off of the preputial dartos and outer preputial skin to show the arrangement of vessels in preputial dartos and the penile dartos. The part of the penile skin and dartos from the right lateral aspect of the penile shaft is shown as schematically removed. Just proximal to the hypospadiac meatus, transverse wedge of tissue from the lateral aspect of the penile shaft is shown as removed. A slice of tissue from the lateral aspect of the corona, glans, and corporoglanular junction is also shown as removed. Dorsal split of Buck fascia is shown as opened up at the subcoronal level to show the arrangement of vessels and subglanular extension of Buck fascia. Parallel to bifurcated corpus spongiosum on the lateral aspect of corpora cavernosa, the Buck fascia is shown as opened up to show the subfascial plane. (1) Penile shaft skin, (2) Penile dartos, (3) Dorsal superficial penile vessels coming from external pudendal vessels running in the dartos fascia and dividing into (4) dorsolateral and (5) dorsomedial transverse branches. (6) Just proximal to preputial edge transversely oriented terminal bifurcations anastomose with similar vessels of contralateral side. Midline is relative avascular. (7) The plane of loose areolar tissue between the penile dartos and (8) Buck fascia. (9) Ventral splitting of Buck fascia to encase corpus spongiosum. (10) Dorsal splitting of Buck fascia to encase (11) dorsal nerve, (12) dorsal penile artery, and (13) dorsal penile vein. (14) Dorsal penile vessels entering the base of glans at the coronal sulcus and remain dorsal to Buck fascia and the tunica albuginea, but perforating the lamina propria of the base of glans. (15) Medial terminal branches of dorsal penile artery run as straight branches into the glans, while (16) lateral terminal branches run as arcade towards the laid open glanular meatus. (17) Branches from the dorsal penile arteries to the inner prepuce and the preputial dartos. (18) Anastomosis between the dorsal penile branches and dartos vessels at the coronal sulcus. (19) Bifurcated corpus spongiosum continuous with glans tissue. (20) Subfascial plane between Buck fascia and the tip of corpora for glans wing mobilisation. (21) Hypospadiac meatus, (22) external meatal groove ventrally migrated and shallow, (23) perforators between corpus spongiosum and paraurethral dartos, (24) tunica albuginea of the corpora cavernosa. (25) right cavernosal artery, (26) urethra, (27) attenuated ventral dartos vessels from anterior scrotal vessels, (28) lamina propria of the glans, and (29) Flattened glans. (Color version available online.)

MATERIALS AND METHODS

From 2010 to 2014, the study was conducted in those patients of hypospadias who presented for repair between the age of 8 and 20 years to our center without previous intervention of any kind. The informed written consent was taken. The MRI study was planned in older patients to ensure full cooperation regarding elimination of pelvic movements during the study without the need of sedation or anesthesia and to enhance the precision of imaging of fascial planes and the vessels in a grown penis. Using a 1.5-T 8-channel MRI scanner (GE Signa HDx scanner; General Electric Healthcare, Milwaukee, WI) and a 3-inch surface coil, MRI of hypospadiac penis was performed without disturbing its natural lie and the position. No attempt was made for artificial erection or local intervention of any kind. Both precontrast and postcontrast images in T1- and T2-weighted fast-spin echo sequences were obtained using the following technical protocols: repetition time, 3500-4400 ms; field of view, 144 cm (12 × 12 cm); NEX, 4.0; and matrix size, 256 × 256. Keeping spacing of 0.2-0.5 mm and thickness of 2.0-3.0 mm, transverse, sagittal, and coronal sections of the penis were obtained. Postcontrast study was performed with intravenous gadolinium in doses of 0.2 mmol/kg body weight to confirm the course and location of vessels seen in T2 sequences.

After performing these sequences, surface- and volume-rendered images were obtained using standardized protocols in Volume Share 4.5, version Workstation, of General Electric Healthcare (Milwaukee, WI). In the 3-dimensional and maximum intensity projection images, course of superficial vessels was traced back proximally up to its origin from known named larger vessels, from which the superficial vessels were branching out. The anatomic findings of transverse, coronal, sagittal, and parasagittal sections were correlated with each

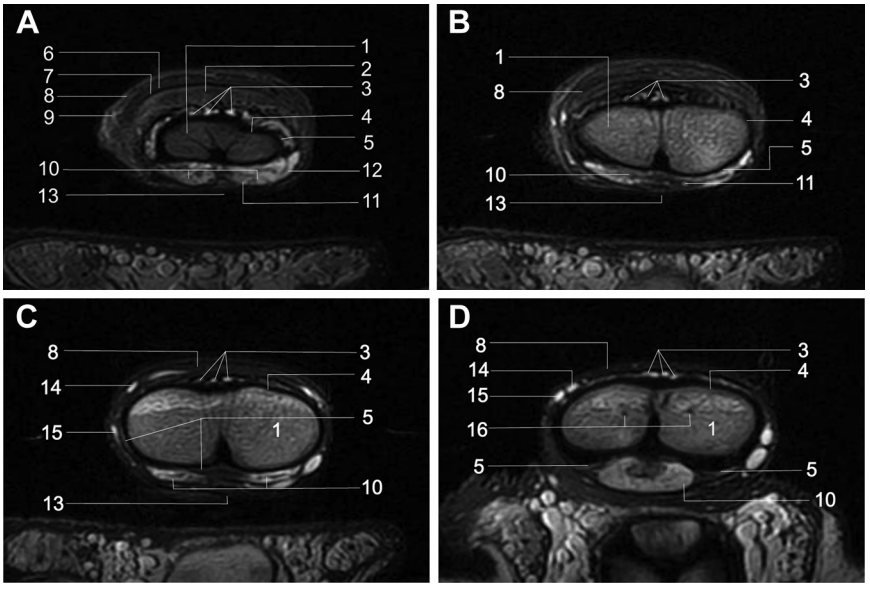

Figure 2. T2-weighted fast-spin echo sequence images of transverse sections of the penis with distal hypospadias obtained at **(A)** the level of glans, **(B)** corona, **(C)** just distal to hypospadiac meatus, and **(D)** proximal to hypospadiac meatus showing the following structures: **(A)** Transverse section image at the level of glans showing (1) the tip of corpora cavernosa with incomplete septum, (2) glans cap molded over the corpora cavernosa, location of terminal intraglanular branches of (3) dorsal penile vessels in the plane dorsal to (4) the tunica albuginea and (5) the subglanular extension of Buck fascia, (6) glans urothelium, (7) lamina propria under the glans urothelium, (8) preputial dartos showing (9) transversely oriented terminal most branches of dartos vessels, (10) bifurcated and laid open corpus spongiosum continuous with glans tissue, (11) vessels in the corpus spongiosum, (12) vascular connections between the vessels of dartos and corpus spongiosum, and (13) laid open urethral plate. **(B)** Transverse section image at the level of corona showing (1) the corpora cavernosa, terminal intraglanular branches of (3) dorsal penile vessels, (4) the tunica albuginea, (5) Buck fascia extending across the (10) laid open corpus spongiosum with its (11) vessels, and (13) laid open urethral plate. (8) Preputial dartos. **(C)** Transverse section image just distal to the hypospadiac meatus showing (1) corpora cavernosa, (3) dorsal penile vessels in the plane dorsal to (4) the tunica albuginea, (5) Buck fascia, (8) penile dartos containing terminal (14) dorsomedial and (15) dorsolateral branches of superficial vessels of dartos, (10) bifurcated and laid open corpus spongiosum, and (13) laid open urethral plate. **(D)** Transverse section image proximal to hypospadiac meatus showing (1) corpora cavernosa each containing (16) cavernosal artery, (3) dorsal penile vessels, (4) the tunica albuginea (double layered seen here), (5) Buck fascia, splitting and encasing (10) corpus spongiosum, (8) penile dartos containing dorsal dartos vessels with (14) dorsomedial and (15) dorsolateral branches.

other to draw a 3-dimensional conceptual diagram of surgical anatomy of hypospadiac penis (Fig. 1). MR findings of vessels in superficial planes were also verified during surgical reconstruction of hypospadias. Seven distal penile and 5 midpenile hypospadias were studied.

RESULTS

In proximal cross-sections, 3 principal bodies, that is, a pair of corpora cavernosa and, on its ventrum along the midline, corpus spongiosum encasing the urethra were well visualized (Fig. 2D). Distal to the hypospadiac meatus, bifurcated and flattened corpus spongiosum parallel to the laid open urethral plate was seen merging into the corona of the glans distally (Fig. 2A-C). Molded on top of the tip of corpora cavernosa, cap of the glans and continuity of the central glans tissue with corpus spongiosum was also seen (Figs. 2A, 3D). Spatial relationship between the glans, tip of the corpora, and the continuity of fascia between the corporal-glanular interface and the course of intraglanular vessels deep to the lamina propria were well visualized (Fig. 3A,D).

Outer urothelial layer of the glans was seen as a distinct signal density layer overlying the lamina propria of glans that was noted as a separate layer encasing the central glans tissue (Fig. 3D). Lamina propria at the base of glans was seen to fuse with intraglanular extension of the Buck fascia coursing over the tip of corporal bodies (Figs. 2A, 3A,D). From the base of glans, the lamina propria continued into the lamina propria of laid open corpus spongiosum (Figs. 2A, 3D). Dorsal to the lamina propria of laid open and bifurcated corpus spongiosum, Buck fascia extended across the midline merging with the lamina propria of laid open corpus spongiosum (Fig. 2B,C).

The tunica albuginea encasing the pair of corpora cavernosa was seen as a low—signal density layer all around with a distinct 2-layered structure confirming to the described outer longitudinal and inner circular layers of the tunica albuginea. However, at the tip of the corpora cavernosa, only single-layered tunica albuginea was noted (Fig. 3D).

The glans—corpora cavernosa interface was seen as a distinct plane with tunica albuginea of the corporal tip on

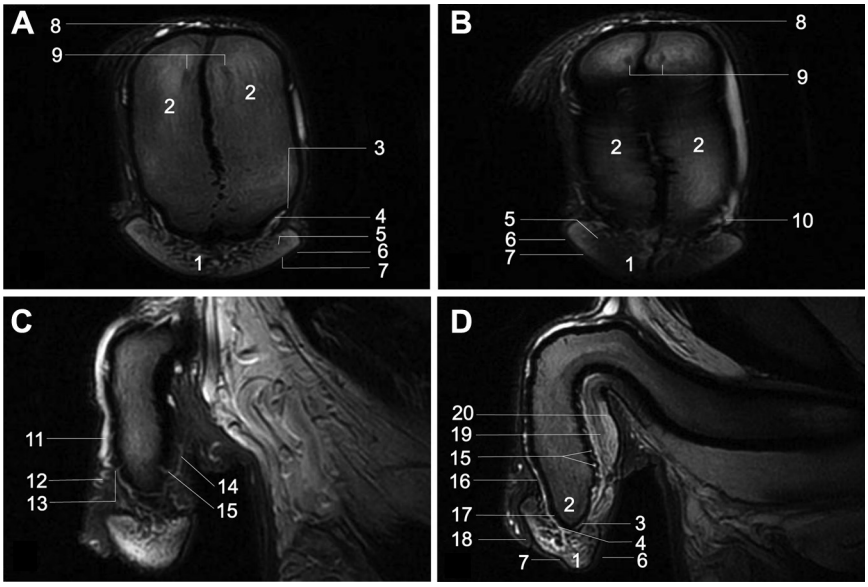

Figure 3. (**A** and **B**) T2-weighted coronal section of the hypospadiac penis showing (1) flattened glans mounted over the (2) corpora cavernosa. Under (3) the Buck fascia, (4) terminal and lateral branches of dorsal penile vessels are coursing to form arcade sending offshoots into (5) the glans tissue, (6) glans urothelium, (7) lamina propria encasing the dartos fascia, (8) dorsal neurovascular bundle at the root of the penis, (9) cavernosal artery, (10) anastomosis between the branches of deep dorsal artery at the base of glans and terminal branches of dartos vessels. **(C)** T2-weighted parasagittal view of the hypospadiac penis showing (11) superficial dartos vessels, (12) its terminal branches coursing in preputial dartos (13) branches anastomosing with vessels at the base of glans, (14) vessels in corpus spongiosum with (15) perforators to corpora cavernosa. **(D)** T2-weighted sagittal view of the hypospadiac penis showing (1) glans mounted over the (2) tip of corpora cavernosa, (16) dorsal penile vessels entering the glans and forming (4) coronal arcade sending intraglanular branches at the base of glans over the (17) tunica albuginea, and (3) Buck fascia. (18) Preputial dartos, (19) urethra, and (20) corpus spongiosum with (15) perforators between corpora cavernosa and corpus spongiosum.

one side and intraglanular extension of the Buck fascia fused with the lamina propria at base of the glans on the other side (Fig. 3A,D). Just adjacent to the lamina propria, consistent intraglanular course of the terminal and lateral branches of dorsal penile vessels were seen as intraglanular arcade of vessels coursing distally from the corona toward the laid open external urethral meatus (Fig. 3A,D). From the intraglanular arcade and medial most terminal branches of dorsal penile artery, offshooting of multiple straight intraglanular branches into the glans substance was also seen (Fig. 3D). All these branches were longitudinally oriented toward the tip of glans with no oblique or transverse vessels.

Encasing the 3 principal bodies, that is, 2 corpora cavernosa and 1 corpus spongiosum, the Buck fascia was seen as a white color, distinct, signal density layer. In transverse sections proximal to hypospadiac meatus, the Buck fascia was seen to split ventrally to envelop the corpus spongiosum and on the dorsolateral aspect to envelop the dorsal penile vessels and its branches (Fig. 2D). However, on lateral aspect, only a single layer of Buck fascia could be delineated. Dorsal neurovascular bundle comprising deep dorsal vein and dorsal penile artery was seen encased within the split layers of Buck fascia (Figs. 2D, 3A,B).

Distal to hypospadiac meatus, absence of ventral splitting of the Buck fascia was noted. Single-layered Buck fascia extending across the midline dorsal to laid open corpus spongiosum was inconspicuous (Fig. 2C) and traversed with multiple perforating vessels across the spongiosum and erectile tissue of corpora cavernosa (Fig. 3D).

Outside the layer of Buck fascia, the dartos fascia was seen as an intermediate—signal density layer in T2-weighted images. It was thicker on the dorsolateral side but thinned out on the ventral side parallel to the urethral plate (Fig. 2B,C). Distally on the dorsal side, the dartos fascia extended up to the preputial edge (Fig. 3C,D).

Superficial vessels were studied in the plane of penile dartos. Vessels to the dartos were seen as superficial dartos vessels emerging out from the superficial external pudendal vessels. These vessels first coursed toward the midline at the root of penis but distally diverting out to lie on the lateral aspect of the penile shaft with axial pattern branching as the dorsomedial and dorsolateral branches (Fig. 4A,B,D).

However, in 10 cases, there was no vessel at the dorsal midline in the dartos layer, which in normal penis is described as superficial dorsal vessel. In these 10 cases, the dartos at the dorsal midline was relatively avascular in the hypospadiac penis (Fig. 2C,D, 4A,C). On ventrum of shaft penis along the paraurethral region, ventral dartos vessels were seen in 1 patient, whereas in the other, it was not

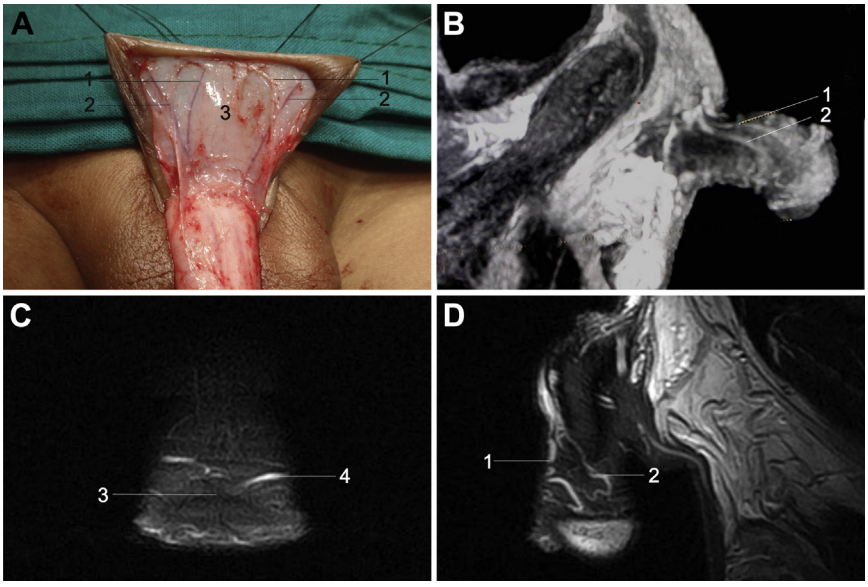

Figure 4. **(A)** The operative picture of preputial and penile dartos after detaching from the inner prepuce and degloving in the subdartos plane showing the axial pattern paired dorsal vessels to dartos bifurcating into (1) dorsomedial and (2) dorsolateral branches with (3) relative avascularity in the dorsal midline. **(B)** Magnetic resonance images of hypospadiac penis showing right lateral view of the penile shaft. (1) Dorsomedial and (2) dorsolateral branches of dorsal dartos vessels are seen. **(C)** T2-weighted fast-spin echo sequence coronal section at the level of the distal most preputial skin showing (4) transversely oriented vessels with (3) relative avascularity in dorsal midline. **(D)** T2-weighted fast-spin echo sequence parasagittal section of hypospadiac penis showing the pattern of dartos vessels on the left side dividing into (1) dorsomedial and (2) dorsolateral branches. Terminal offshoot of dorsomedial branch is going into the preputial dartos. (Color version available online.)

remarkable. In 2 patients, where midline superficial dorsal vessels were seen, lateral dartos vessels were unremarkable.

Three sites of collateral anastomosis were noted between the superficial system of vessels (ie, branches from external pudendal vessels) and the deep system of vessels (ie, branches from internal pudendal vessels). Sites of collateral anastomosis were (1) at coronal sulcus between dartos and terminal glanular branches of deep penile artery (Fig. 3C,D), (2) at paraurethral spongiosum between perforators from urethral artery and dartos vessels (Fig. 3C), and (3) on dorsum, between dorsal penile vein and dorsomedial branches of superficial artery (Fig. 3C).

COMMENT

Despite multifaceted advances in surgery of hypospadias, the reports of complications in surgery with incidence of failure[18,19] are the indicators toward the ongoing need to study the detailed surgical anatomy of penis with particular reference to alterations in anatomy of fascial planes and the vascularity in hypospadiac penis. This knowledge is relevant for further refinement and improvement in surgical techniques for hypospadias repair. Numerous illustrated and detailed descriptions of surgical anatomy of normal penis are available in literature.[1-3] In context to normal penis vs hypospadias; if 1 blade of a pair of scissors is put into the anterior urethra through the external urethral meatus and the other blade on the median raphe at ventral midline of penis, all the tissues, that is, the skin, dartos, Buck fascia, corpus spongiosum, and the urothelium of penile urethra are cut and laid open; we could only partially be able to reproduce the morbid anatomy of hypospadias. There are other additional features like ventral curvature, flattened glans, shallow and ventrally displaced external urethral meatus, shallow urethral groove, short urethral plate, penoscrotal transposition, and other changes including the rotational defects. With change in anatomy as compared with normal penis, alterations at the level of different anatomic layers, change in pattern of superficial and deep vessels, sites of perforators, and collateral networks of vessels in hypospadiac penis remain to be studied. There are several reports in the literature describing the anatomy of hypospadias using methods of histology and computerized reconstruction described by Baskin et al[4] and other reports based on transillumination studies.

Although use of MRI to study the surgical anatomy of normal penis[10-12] and even epispadiac penis[20] has been described in literature, till date, there is no report describing the study of surgical anatomy of hypospadias using MRI. This study has helped us to revisit and visualize numerous points of surgical anatomy already described in literature and certain additional points not highlighted earlier. The points which were not highlighted earlier include the following: (1) At the level of dartos, superficial dorsal vessels are absent in most of the hypospadiac penis leaving the line of relative avascularity at dorsal midline with rich vascularity on dorsolateral aspects with axial pattern vessels, (2) On ventral aspect, ventral penile branch of anterior scrotal artery is not

always present, (3) lateral branches of dorsal penile artery enter the glans and run forward and medially toward the tip of glans forming the intraglanular arcade of vessels, which is protected by the lamina propria of the base of glans fused with the intraglanular extension of Buck fascia, and (4) The Buck fascia overlying the corpora cavernosa enters the base of glans and fuses with the lamina propria of the glans leaving a plane of cleavage between the tip of corpora cavernosa and the Buck fascia fused with the lamina propria of glans protecting the intraglanular course of vessels.

The other relevant details of surgical anatomy described for normal penis and revisited for hypospadiac penis include the following: (1) At the level of penile dartos, dorsolateral and dorsomedial branches of external pudendal vessels run at the lateral aspect of shaft in the area between 10- to 8-o'clock and 2- to 4-o'clock positions, (2) A rich collateral network is present at the base of glans cap over the tip of corpora cavernosa with anastomosis between terminal branches of superficial dartos vessels to preputial dartos and inner preputial skin branches of dorsal penile artery, and (3) distal to hypospadiac meatus, bifurcated corpus spongiosum and laid open urethral plate receive perforators from the corpora cavernosa and dartos fascia in addition to its blood supply from proximal corpus spongiosum.

These findings about the details of surgical anatomy can enhance the precision of science and art of delicate repair of hypospadias. Knowledge of perforators and collateral flow between the vessels can be exploited not only for preservation of the vascularity of fasciocutaneous flap but also to design newer flaps for reconstructive surgery of hypospadias. Details of fascial planes and the intraglanular course of vessels with respect to intraglanular extension and fusion of Buck fascia with lamina propria can be effectively used for safe glans wing mobilization. We will report the technical nuances of safe glans wing mobilization and other technical aspects of reconstructive surgery of hypospadias based on these facts of surgical anatomy after compilation of data acquisition subsequently. The knowledge of axial pattern vessels of dartos at dorsomedial and dorsolateral locations can either be used to create penile skin flaps or more appropriately to harvest dartos flap with axial pattern vessels, which may function as superior quality neourethral dartos coverage and minimizing the occurrence of urethrocutaneous fistula.

The limitation of this study is that the observations are based on a small sample size. With available coil configuration in our institution, it is not possible to obtain clear images of hypospadiac penis in younger children with small phallus. The study with a larger sample size can actually reflect actual incidences of the variations in anatomy.

CONCLUSION

Definitive axial pattern superficial vessels are present at dorsolateral and dorsomedial aspect in penile dartos with relative avascularity of dartos in dorsal midline in most cases. Subglanular extension and fusion of Buck fascia with the basal lamina propria of glans forms a barrier between the tip of corpora and the intraglanular arcade of vessels. Beyond hypospadiac meatus, with ventral splitting of Buck fascia around the corpus spongiosum, the dorsal layer extends across the midline but the ventral layer is interrupted along the urethral plate. Collaterals are present at coronal sulcus, along the bifurcated corpus spongiosum, and the dartos enabling blood flow between the terminal most branches of external and internal pudendal vessels.

References

1. Hinman FJ. Penis and male urethra. In: Hinman FJ, ed. *UroSurgical Anatomy*. Philadelphia: WB Saunders; 1993:418-470.
2. Velazquez EF, Barreto JE, Cold CJ, Cubilla AL. Penis and distal urethra. In: Mills SE, ed. *Histology for Pathologist*. Philadelphia: Lippincott Williams and Wilkins; 2007:983-997.
3. Quartey JK. Microcirculation of penile and scrotal skin. *Atlas Urol Clin N Am*. 1997;5:1-9.
4. Baskin LS, Erol A, Li YW, et al. Anatomical studies of hypospadias. *J Urol*. 1998;160:1108-1115.
5. Yucel S, Guntekin E, Kukul E, et al. Comparison of hypospadiac and normal preputial vascular anatomy. *J Urol*. 2004;172:1973-1976.
6. Erol A, Baskin LS, Li YW, et al. Anatomical studies of the urethral plate: why preservation of the urethral plate is important in hypospadias repair. *BJU Int*. 2000;85:728-734.
7. Beaudoin S, Delaage PH, Bargy F. Anatomical basis of surgical repair of hypospadias by spongioplasty. *Surg Radiol Anat*. 2000;22:139-141.
8. Baskin LS, Ebbers MB. Hypospadias: anatomy, etiology, and technique. *J Pediatr Surg*. 2006;41:463-472.
9. Cağrı Savaş M, Kapucuoğlu N, Gürsoy K, et al. The microvessel density of the hypospadiac prepuce in children. *J Pediatr Urol*. 2011;7:162-165.
10. Satragno L, Martinoli C, Cittadini G. Magnetic resonance imaging of the penis: normal anatomy. *Magn Reson Imaging*. 1989;7:95-100.
11. Vossough A, Pretorius ES, Siegelman ES, et al. Magnetic resonance imaging of the penis. *Abdom Imaging*. 2002;27:640-659.
12. Kirkham A. MRI of the penis. *Br J Radiol*. 2012;85:86-93.
13. Snodgrass W. Tubularized, incised plate urethroplasty for distal hypospadias. *J Urol*. 1994;151:464-465.
14. Asopa HS, Elhence IP, Atri SP, et al. One stage correction of penile hypospadias using a foreskin tube. A preliminary report. *Int Surg*. 1971;55:435-440.
15. Duckett JW. Transverse preputial island flap technique for repair of severe hypospadias. *Urol Clin North Am*. 1980;7:423-430.
16. Koyanagi T, Nonomura K, Yamashita T, et al. One-stage repair of hypospadias: is there no simple method universally applicable to all types of hypospadias? *J Urol*. 1994;152:1232-1237.
17. Bracka A. A versatile two-stage hypospadias repair. *Br J Plast Surg*. 1995;48:345-352.
18. Braga LH, Pippi Salle JL, Lorenzo AJ, et al. Comparative analysis of tubularized incised plate versus onlay island flap urethroplasty for penoscrotal hypospadias. *J Urol*. 2007;178:1451-1457.
19. Eliçevik M, Tireli G, Demirali O, et al. Tubularized incised plate urethroplasty for hypospadias reoperations in 100 patients. *Int Urol Nephrol*. 2007;39:823-827.
20. Kureel SN, Gupta A, Singh CS, et al. Surgical anatomy of penis in exstrophy-epispadias: a study of arrangement of fascial planes and superficial vessels of surgical significance. *Urology*. 2013;82:910-916.