Urethral Reconstructive Surgery

Current Clinical Urology

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Urethral Reconstructive Surgery

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Humana Press

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Cover illustrations: (*Clockwise from top*) Postoperative urethrogram with widely patent bulbar urethra and characteristic shelf-like appearance, after a dorsal, augmented anastomotic urethroplasty (Fig. 13.14; *see* discussion on p. 149); long bulbar urethral stricture with tight proximal segment and an adjacent, distal portion of affected urethra (Fig. 13.5; *see* complete caption on p. 145); buccal mucosal graft augmented by a gracilis muscle flap, in the repair of a prostato-rectal fistula (Fig. 22.11; *see* complete caption on p. 260); retrograde urethrogram showing restenosis by hypertrophic tissue within tandem placed Urolume stents in the bulbar urethra (Fig. 8.3; *see* discussion on p. 88); and bulbar urethral mobilization for dorsal placement of a buccal mucosal graft urethroplasty (Fig. 11.21; *see* complete caption on p. 128).

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Preface

Urethral reconstructive surgery can often be complex, time consuming, and demanding. Most urologists today have had little exposure or experience with urethral surgery during their training or in practice. This general lack of exposure, and thus lack of knowledge, has led to the popularity of temporizing procedures such as urethrotomy and dilation. Most urologists treat strictures by a "reconstructive ladder" approach, where definitive urethroplasty is only considered after successive failed dilations or urethrotomies. Furthermore, major textbooks in urology only devote a cursory view of urethral reconstructive surgery. Clearly, the gap in contemporary urology training and textbooks needs to be bridged.

The following volume aims to enlighten urologists in a practical manner on how to evaluate and manage complex urethral problems and how to end the cycle of just performing short-lived, temporizing procedures. The chapters initially lay a groundwork on the anatomy and blood supply of the urethra and genital skin, as well as the practical aspects of wound healing and applicable plastic surgical techniques. The chapters then focus on the etiologies for urethral strictures and the methods for evaluating their extent and degree. The remaining chapters are a practical and comprehensive review, with concentrations in each of the typical surgical techniques that are currently employed in the reconstructive armamentarium. In addition, chapters focus on managing surgical complications and particularly difficult and unusual problems, such as Lichen Sclerosus, the irradiated urethra, hypospadias "cripple," panurethral strictures, failed urethroplasty, urethral stent extraction, postprostatectomy strictures, and follow-up strategies. The promise of tissue engineering trends and "off the shelf" graft repair are also detailed. We have been diligent to make our text broad, as well as specific, so that the reader will have a comprehensive review of adult urethral reconstructive surgery. We also have condensed into a chapter, pre and intra-operative decision making - imparting skills and experience that often takes years of practice to develop. We also hope that we have made a text that is visually appealing, so that it can function as a sort of surgical atlas. Overall, we have striven to make our text evidence based, as well as a distillation of the knowledge, clinical experience, and surgical acumen of current leading world experts and their historical predecessors. Enjoy.

Steven B. Brandes, MD, FACS

Introduction

"Cure occasionally, relieve often, console always."
Ambroise Pare (1510–1590)

Over the years, I have often been asked by Urology Residents in training and by my patients for words of wisdom about surgery. Their most frequent question being, "what are the best aphorisms about surgery you have heard over the years?" When it comes to education and learning, the following comes to mind.

"Hear and you forget
See and you remember
Do and you understand"

I hope this text will give you the principles and basic fund of knowledge to at least remember what to do when it comes to urethral reconstructive surgery. I leave it in the good reader's hands to put into practice what we have written. Only by your own experience will you eventually understand.

The next aphorism that comes to mind is one not just for the operating room, but a general rule for life.

"Think fast and move slow."

The best and quickest surgeons I have known over the years all seemed not to be moving quickly at all. They never rushed or seemed anxious. They seemed very even keeled in motion and in temperament. They utilized paucity of motion, and when they did move or cut something, it was with great deliberation and accuracy. No motion was ever wasted. Moreover, while they seemed not to be doing much or moving much, before you realized, the surgery was completed or the organ was removed. As to their thought process, they were always thinking quickly and numerous steps ahead; always moving forward and not deterred by unanticipated events during the surgery.

Aside from thinking quickly and moving slowly, what makes a good and quick surgeon is having a sound surgical plan, knowing how to properly expose the surgical field ("for a monkey could do the surgery as long as you set it up for him and made the intra-operative decision making"), and thinking about the next and multiple steps ahead. It is said that what makes a chess player a grand champion is his ability to think multiple steps into the future and his ability for anticipation and contingency plans for those future moves. The same holds for surgery – good hands make a good surgeon, but what makes a great surgeon is a beautiful mind, a quick wit and great decision making skills.

So, dear reader I will leave you with another parting word of wisdom about good surgical principles:

"Selection is the silent partner of the surgeon."

In other words, often times, it is more important to know when not to operate and who not to operate on, than being able to do the surgery. Timing of surgery, the quality of the tissues, and the protoplasm of the patient will often determine the surgical outcomes more then the so-called "quality" of the surgery. In other words, no matter how good the reconstruction looks at the end of the surgery, if it all falls apart or fails postoperatively, it typically has more to do with selection and timing then any perceived lack of technical skill. In other words, as my mentor would often say, in his Texan drawl, "well, you can't make a silk purse out of a sow's ear".

Steven B. Brandes, MD, FACS

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1 Genital Skin and Urethral Anatomy

Peter A. Humphrey

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Summary An intimate knowledge of genital skin and urethral anatomy is essential for successful surgical management of male and female urethral strictures, fistulas and other anomalies. Of particular importance for urethral reconstruction is the prepuce, a mixture of skin and mucosa and anatomically divided into five layers – epidermis, dermis, Dartos, lamina propria, and epithelium. The urethra is divided into the anterior (bulbar, pendulous and fossa navicularis) and the posterior (membranous and prostatic). Urethral epithelium transitions from urothelial (transitional cell) (proximal), to pseudo-stratified or stratified columnar (distal), and then onto squamous (meatus). Location of the urethra within the spongiosum is also clinically important, where the more proximal (bulbar) the more eccentric and ventral.

Keywords Genital skin, prepuce, male urethra, anatomy, histology, female urethra, urothelial

1. Female Genital Skin

The female external genitalia may be defined as including the mons pubis, clitoris, labia majora, labia minora, vulvar vestibule and vestibulovaginal bulbs, urethral meatus, hymen, Bartholin's and Skene's glands and ducts, and vaginal introitus (**Fig. 1.1** *[1]*). The appearance of the female skin varies with age ***(2)***. Age-related changes occurring with puberty include hair growth on the mons pubis and lateral labia majora during puberty, increase in size (as the result of increased adipose tissue) and pigmentation of the labia and clitoral enlargement. After menopause, there is a degree of hair loss, and thinning (atrophy) of the epithelial lining of the vulvar skin. Histologically, the entire vulva, with the exception of the vulvar vestibule, is covered by a keratinized, stratified squamous epithelium (**Fig. 1.2**).

The clitoris consists of two crura and a glans. The crura comprise erectile tissue, which is characterized by cavernous veins and small muscular arteries. The glans is composed of squamous mucosa with a dense vascular dermis and a large number of sensory receptors, including numerous Pacinian corpuscles ***(1,3)***. Of relevance to this textbook on the urethra, the clitoris has been described as being intimately related to the perineal urethra ***(4)***, with the urethra surrounded by the erectile tissue complex (clitoris), with the clitoral body directly anterior to the urethra, which is flanked by clitoral bulb and crura ***(4)***.

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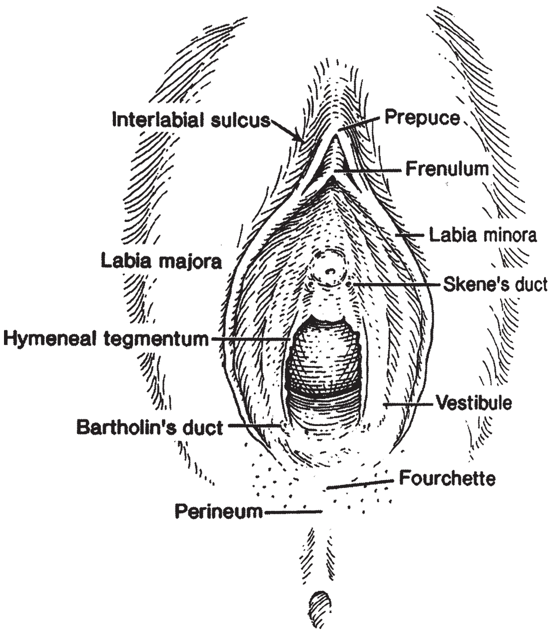

FIG. 1.1. Topography of the vulva (From Stacey E. Mills (ed) (2007) Histology for Pathologists, 3rd, Lippincott, Williams and Williams, Philadelphia, chapter 39)

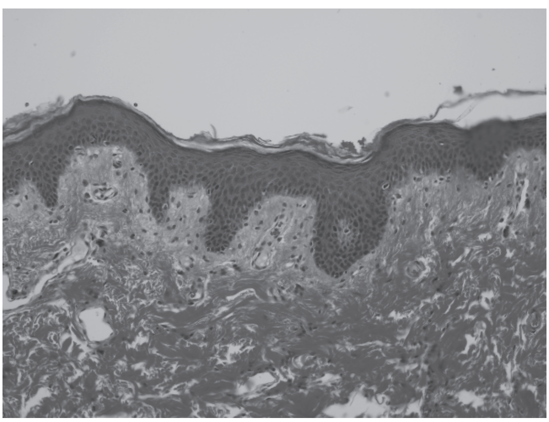

FIG. 1.2. Normal keratinized squamous epithelium of the vulva

The skin of the labia majora, in addition to lateral hair follicles, harbors sebaceous glands, which can be found with or without associated hair follicles ***(1)***. Sweat glands of apocrine and merocrine (eccrine) types also are present. The sulcus between the labia majora and minora has mammary-like glands. Deep in the dermis is a thin smooth muscle layer, beneath which is adipose tissue. There are abundant nerve endings and touch receptors, such as Meissner's corpuscles. The labia minora, unlike the labia majora, does not typically have skin appendages, although in the lateral aspects sweat and the sebaceous glands may be found ***(1)***. The subepithelial tissue is a vascular connective tissue, without fat.

The skin of the vulvar vestibule, which is bounded medially by external portion of the hymeal ring, posteriorly and laterally by the line of Hart, and anteriorly by the clitoral frenulum, has a nonkeratinizing squamous epithelium. Within the vestibule are the vaginal opening, openings of the major vestibular glands (Bartholin's glands) and minor vestibular glands, openings of the paired Skene's glands, and opening of the urethral orifice ***(1)***. Bartholin glands are tubuloalveolar glands with acini having simple, columnar mucous-secreting epithelium. Bartholin gland ducts open on the posterolateral aspect of the vestibule and distally have a transitional epithelium that merges with the surface squamous epithelium of the vestibule. The minor vestibular glands, which are also mucus-producing, ring the vestibule. Skene's glands are paraurethral, being located immediately adjacent to and posterolateral to the urethra. Skene's glands are no greater than 1.5 cm in length and are lined by a pseudostratified mucus-secreting columnar epithelium. Skene's glands are thought to be a prostate gland homologue, and often express prostate-specific antigen and prostatic acid phosphatase. The transitional cell (urothelial) lining of the urethral orifice (meatus urinarius) urethra is in continuity with squamous epithelium of the vestibule. The vulvar aspect of the hymen is lined by a glycogen-rich nonkeratinizing stratified squamous epithelium, underneath which lies a fibrovascular stroma with some touch and pain receptors ***(1)***.

Lymphatic drainage from the vulva is to femoral and inguinal lymph nodes, with a notable exception being the existence of a second lymphatic pathway from the glans clitoris ***(1,5,6)***. In this latter route, the lymphatic channels join the lymphatics of the urethra, traverse the urogenital diagram, and merge with the lymphatic plexus on the anterior surface of the urinary bladder, with subsequent drainage to interiliac, obturator, and external iliac nodes.

Arterial blood supply to the vulva is from the femoral artery to superficial and deep external pudendal arteries and internal iliac arteries to internal pudendal arteries. There are separate blood supplies to the clitoris, from the deep arteries of the

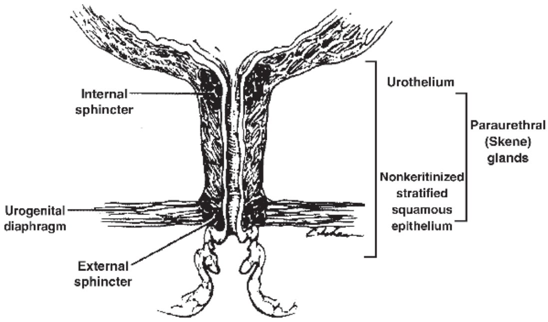

FIG. 1.3. Anatomy of the female urethra (From: Carroll PR, Dixon CN (1997) Surgical management of urethral carcinomas. In Current Genitourinary Cancer Surgery. Crawford D and Das S (eds.), Williams & Wilkins, Baltimore)

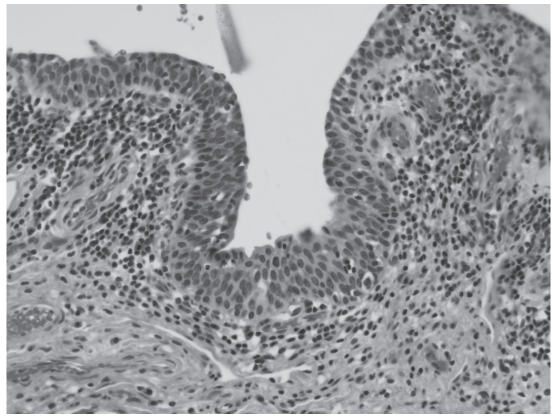

FIG. 1.4. Lining of the proximal female urethra: urotherlium, shown with chronic inflammation

clitoris, and vestibule and Bartholin's gland areas via the anterior vaginal artery. Venous blood drainage is mainly via the bilateral internal iliac veins, which drains into the external iliac venous system ***(1)***.

Innervation of the vulva is mostly via the anterior and posterior labial nerves, which are branches of the ilioinguinal nerve and pudendal nerve, respectively ***(1,7)***. The clitoris and vestibule receive nerve supply from the dorsal nerve of the clitoris and the cavernous nerves of the clitoris ***(1,7)***.

2. Female Urethra

The female urethra is about 4 cm in length (**Fig. 1.3**) in its course from the urinary bladder neck to the vaginal vestibule ***(8–10)***. Paraurethral glands are found along the periphery. Distally, the ducts from the glands (Skene's glands) empty near the external urethral meatus (**Fig. 1.4**). The proximal one-third of the female urethra is lined by urothelium and the distal two-thirds by nonkeratinized stratified squamous epithelium. There is a richly vascular underlying submucosa. The mucosa and submucosa are surrounded by a thick layer of inner longitudinal smooth muscle that runs from the urinary bladder to the external meatus. A thin layer of circular smooth muscle is outside the longitudinal layer. The striated urethral sphincter is found along the distal two-thirds of the female urethra ***(9–11)***. The skeletal muscle fibers are embedded in connective tissue and admixed with smooth muscle. The urethra is suspended beneath the pubis by a pubourethral ligament composed of an anterior suspensory ligament of the clitoris, a posterior pubourethral ligament of endopelvic fascia and an intermediate ligament representing a fusion of those two ***(12)***. Somatic innervation to the urethral sphincter muscle is from pudendal and pelvic somatic nerves. Branches of the pudendal artery supply the urethra (and perineum). Lymphatic drainage of the anterior (distal third) of the female urethra drains preferentially into the superficial inguinal lymph nodes, while drainage from the posterior urethra (the proximal two-thirds) is into a combination of three pelvic lymphatic channels ***(10)***. These flow underneath the clitoris to the external iliac nodes, along the internal pudendal artery to the obturator lymph nodes, and to the presacral lymph nodes ***(10)***.

3. Male Genital Skin

Male genital skin includes the cutaneous lining of the penis and scrotum. The skin of the penis includes epithelium and lamina propria, which overlay the corpora cavernosa, corpus spongiosum, and pendulous urethra (**Fig. 1.5**). The microanatomy of the penile skin can be discussed based upon consideration of distal anatomy, including glans, coronal sulcus and foreskin and of a proximal portion, the corpus or shaft (**Figs. 1.6, 1.7**) ***(13,14)***. The glans and coronal sulcus are covered by a thin, partially keratinized squamous epithelium. The glans and coronal sulcus surface is actually a mucosa, rather than skin, since no adnexal or glandular structures are present. The glans lamina propria separates the corpus spongiosum from the epithelium. Its thickness varies from 1 mm(at the corona) to 2.5 mm (near the meatus). Histologically, the lamina propria is comprised of fibrous and

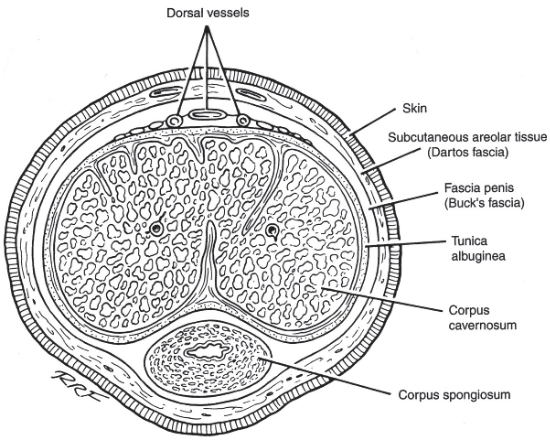

FIG. 1.5. Cross section of the penis (From Quartey JFM (1997) Microcirculation of Penile Scrotal Skin. Atlas of Urologic Clinics of NA 5(1), pg 2.)

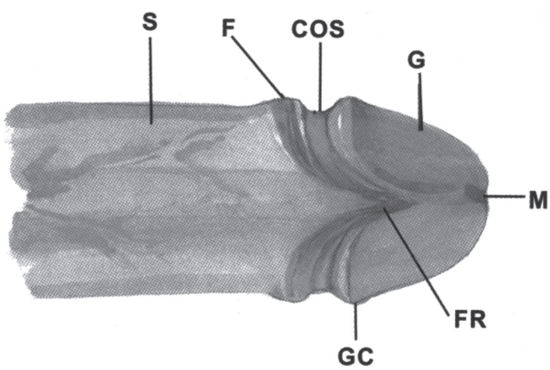

FIG. 1.6. Penile anatomy: Distal portion includes glans (G), coronal sulcus (COS), and foreskin, whereas proximal portion includes corpus or shaft (S), (M) urethral meatus, (GC) glans corona, and (FR) frenulum). (From Stacey E. Mills (ed) (2007) Histology for Pathologists, 3rd, Lippincott, Williams and Williams, Philadelphia, chapter 38)

vascular tissue, with the vascularity being less prominent compared to the underlying corpus spongiosum. The coronal sulcus lamina propria is essentially a prolongation of the foreskin and glans lamina propria.

The foreskin, or prepuce, is a mixture of skin and mucosa that is basically an extension of the skin of the shaft and normally covers most of the glans, with an inner mucosal surface of the foreskin covering the coronal sulcus and glans surface ***(13,14)***. Grossly, the skin surface is dark and wrinkled while the opposite mucosal lining exhibits a pink to tan coloration.

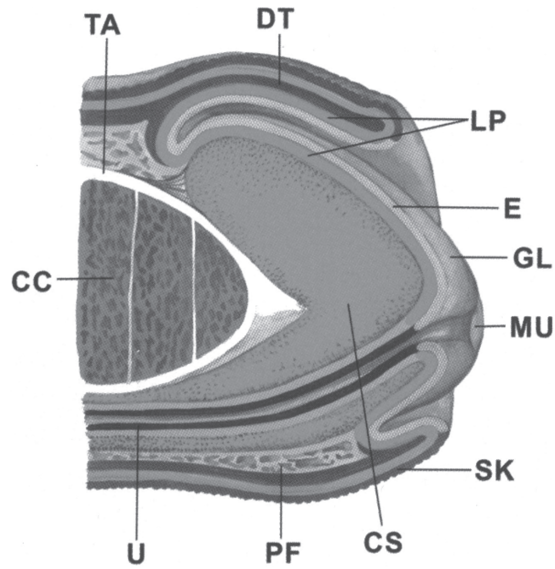

FIG. 1.7. Distal portion of penis including glans (GL), coronal sulcus, and foreskin. (E, epithelium; LP, lamina propria; CS, corpus spongiosum; TA, tunica albuginea; CC, corpus cavernosum; DT, dartos; SK, skin; U, urethra; MU, meatus urethralis; PF, penile or Buck's fascia) (From Stacey E. Mills (ed) (2007) Histology for Pathologists, 3rd, Lippincott, Williams and Williams, Philadelphia, chapter 38)

Histologically, there are five layers to the foreskin: the epidermis, dermis, Dartos, lamina propria, and epithelium. The skin is made up of epidermis with keratinized stratified squamous epithelium and dermis with connective tissue containing blood vessels, nerve endings, Meissner (touch), and Vater-Panini (deep pressure and vibration) corpuscles, with a few hair structures and sebaceous and sweat glands. The Dartos is the middle component of the foreskin and has smooth muscle fibers surrounded by elastic fibers, with numerous nerve endings. The lamina propria is a loose fibrovascular and connective tissue with free nerve endings and genital corpuscles. The squamous epithelium of the mucosa surface of the foreskin is in continuity with the glands and coronal sulcus mucosal epithelium and is the same structurally. The skin of the penile shaft overlies the Dartos, Buck's fascia, tunica albuginea, corpora cavernosa, and corpus spongiosum (**Fig. 1.5**). It is rugged and elastic and comprises an epidermis and dermis. The epidermis is thin, with slight keratinization and basal layer pigmentation. Hair follicles are present and are more frequent in the proximal shaft. Only a few sebaceous and sweat glands can be found.

Lymphatics of the glans drain into superficial and deep inguinal lymph nodes, whereas lymphatics of the foreskin and skin of the shaft drain into superficial inguinal nodes ***(14)***. The blood supply of the skin is supplied by external pudendal blood vessels ***(15)***. Venous blood of penile skin flows into a subdermal venous plexus, which drains into several veins at the base of the penis ***(15)***. Innervations of the glans and foreskin are by terminal branches of the dorsal nerve of the penis ***(13)***.

Skin of the scrotum is pigmented, hair-bearing, and loose with numerous sebaceous and sweat glands. Depending on patient age and tone of the underlying smooth muscle, the surface is smooth to highly folded and wrinkled, with transverse rugae. The epidermis is thin, and along with the dermis, overlies the Dartos layer of smooth muscle. A subcutaneous fat (adipose) layer is lacking. The anterior scrotum is supplied by the external pudendal blood vessels and the posterior scrotum is supplied by the internal pudendal blood vessels ***(15)***. Venous drainage for anterior scrotum is via the anterior scrotal subdermal venous plexus that converges at the neck of the scrotum to join the external pudendal vein. The subdermal venous plexus of the posterior scrotal wall drains into the perineal vein to join the internal pudendal vein ***(15)***. Lymphatic drainage is to the superficial inguinal lymph nodes. The scrotum has a complex pattern of innervation ***(16)***. The main supply is via scrotal branches of the perineal nerve, a branch of the pudendal nerve. Other contributions come from the inferior pudendal branch of the femoral cutaneous nerve and the genital branch of genitofemoral nerve and anterior cutaneous branches of the iliohypogastric and ilioinguinal nerves ***(16)***.

4. Male Urethra

The male urethra may be divided into proximal (posterior) and distal (anterior) segments. The proximal segment comprises prostatic and membranous portions, whereas the distal segment is made up of bulbous and penile (pendulous) segments (**Fig. 1.8**). The prostatic urethra is 3–4 cm in length, is formed at the bladder neck, turns anteriorly 35 degrees at its midpoint (the urethral angle), and exits the prostate at the apex, where it is continuous with the membranous urethra. The urethral angle divides the prostatic

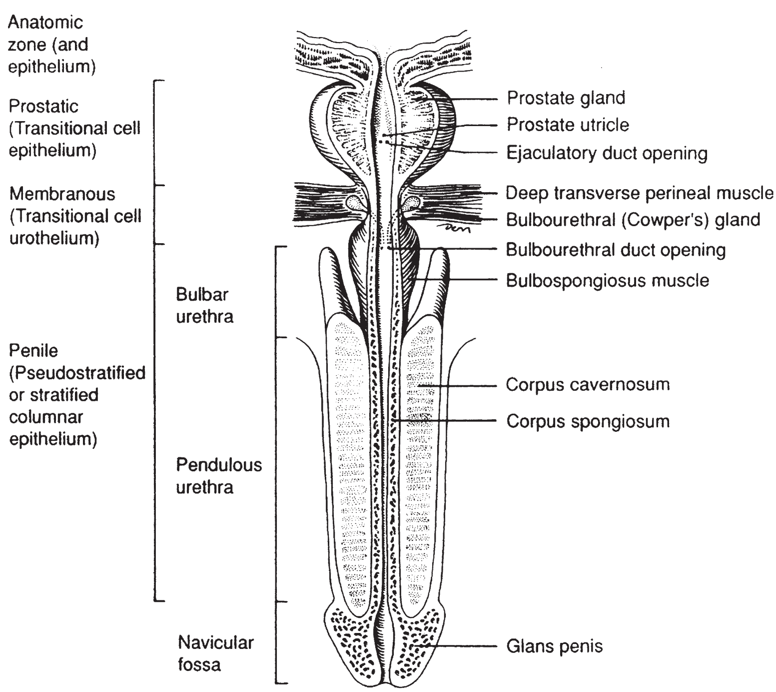

Fig. 1.8. Anatomy of male urethra (From Carroll PR, Dixon CN (1997) Surgical management of urethral carcinomas in Current Genitourinary Cancer Surgery. Crawford and Das S (ed); Williams & Wilkins, Baltimore)

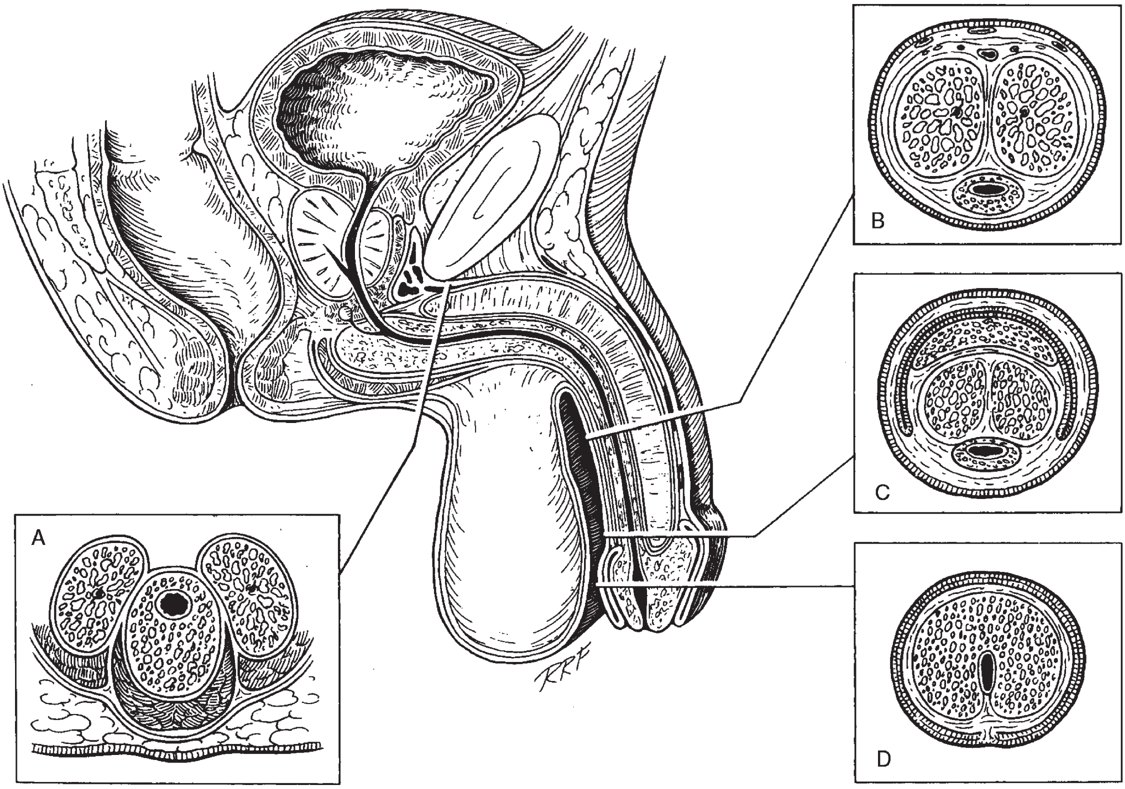

FIG. 1.9. Cross sections of the anterior urethra. (A) The bulbous urethra. (B) Penile shaft. (C) Coronal margin. (D) Glans (From Complications of interventional techniques for urethral stricture. In Complications of Interventional Techniques. (1996) Carson CC (ed), Igaku-Shoim, New York, pg 89)

urethra into proximal (so-called preprostatic) and distal (so-called prostatic) segments. The transition zone of the prostate wraps around the proximal urethra. The main prostatic ducts from this zone drain into posterolateral recesses of the urethra at a point just proximal to the urethral angle. Beyond the angle, ejaculatory ducts and ducts from the central prostatic zone empty at the posterior urethral protuberance known as the verumontanum. At the apex of the verumontanum, the slit-like orifice of the prostatic utricle, a 6-mm mullerian remnant, which is a sac-like structure, may be found. Ducts from the peripheral zone of the prostate empty into posterior urethral recesses in grooves in a double row from the verumontanum to the prostatic apex. Histologically, the surface epithelial lining of the prostatic urethra is predominately urothelial (transitional cell), although prostatic epithelium also may be found.

The membranous urethra, at 2 to 2.5 cm in length, is the shortest segment of the male urethra. It is lined by stratified/pseudostratified columnar epithelium and surrounded by skeletal muscle fibers of the urogenital diaphragm (external urethral sphincter).

The bulbous urethra is 3 to 4 cm in length, has a larger luminal caliber than the prostatic or membranous urethra, and extends in the root of the penis within the bulb of the corpus spongiosum from the distal margin of urogenital diagram to the penile urethra (**Fig. 1.9**). The lining epithelium is identical to that of the membranous urethra, being of a stratified/pseudostratified type. The ducts of Cowper's (bulbourethral) glands, which are embedded in the urogenital diagram, open into the posterior aspect of the bulbous urethra. Mucin-secreting Littre's glands can also be found in the walls of the bulbous urethra (**Fig. 1.10**).

The penile urethra is of about 15 cm in length and extends to the tip of the glans penis at the urethral meatus. It is surrounded in its entire length by the corpus spongiosum (**Fig. 1.2**). The distal 4

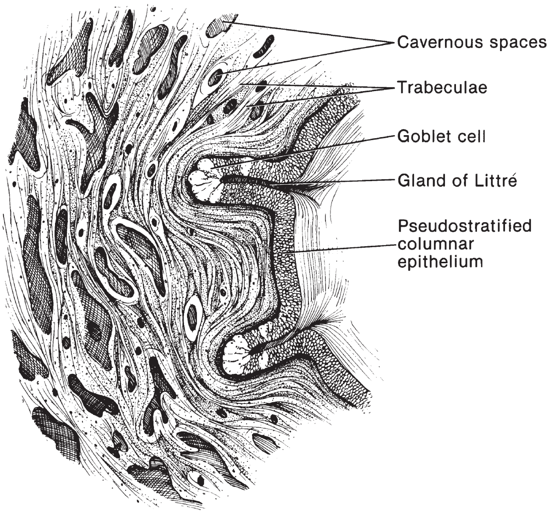

FIG. 1.10. Anatomy of the epithelium and glands of the penile urethra (From: Hinman F, Jr. (1993) Atlas of Urosurgical Anatomy, Philadelphia. WB Saunders, pg 447)

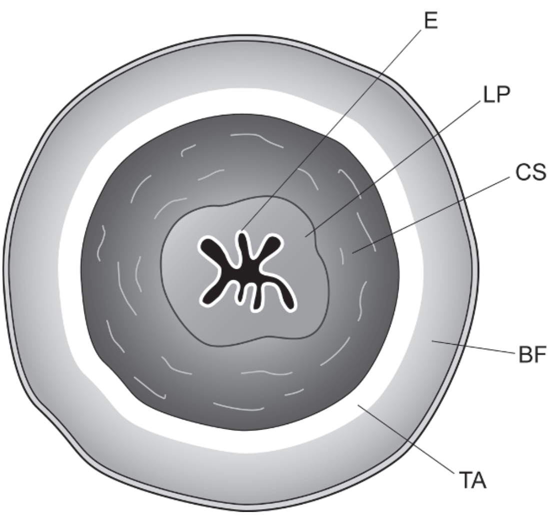

FIG. 1.11. Cross section of penile urethra and periurethral tissues. Diagrammatic cross section. E, epithelium; LP, lamina propria; CS, corpus spongiosum; TA, tunica albuginea; BF, Buck's fascia

to 6 cm of the prostatic urethra is a saccular dilation, termed the fossa navicularis, that terminates at the urethral meatus. Recesses called lacunae of Morgagni, which extend into Littre's glands, are found in the lateral walls of the penile urethra.

There are five anatomical levels of the distal (anterior) urethra (**Fig. 1.11**): urethral epithelium, lamina propria, corpus spongiosum, tunica albuginea, and Buck's fascia ***(13,17)***. Most of the penile urethral lining is a stratified/pseudostratified columnar epithelium, whereas the distal penile urethra, including the fossa navicularis, is lined by ciliated stratified columnar epithelium or stratified nonkeratinizing squamous epithelium. The lamina propria of the penile urethra is fibroconnective tissue with elastic fibers and scattered, longitudinally oriented smooth muscle.

Lymphatic drainage of the prostate and bulbomembranous urethra is into obturator and external iliac nodes, whereas the drainage from the penile urethra is into the superficial inguinal nodes. Urethral innervation is mainly by the dorsal nerve of the penis. Branches of the perineal nerve can supply the periurethral area in some men ***(13)***.

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2
Vascular Anatomy of Genital Skin and the Urethra: Implications for Urethral Reconstruction

Steven B. Brandes

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Summary An intimate knowledge of the penile skin blood supply is essential to successfully mobilize and construct a fasciocutaneous onlay flap for "substitution" urethral reconstruction. For successful anastomotic urethroplasty, an intact and adequate dual urethral arterial blood supply is essential. The key vascular feature of the urethra and the reason that it can be mobilized extensively and divided is its unique bipedal blood supply. The proximal and distal ends of the urethra are supplied by two arterial blood supplies, the proximal urethra in an antegrade fashion, and the distal, retrograde. The common penile artery, a branch of the internal pudendal, first branches into the bulbar and circumflex cavernosal arteries (supplying the proximal corpus spongiosum), and then bifurcates into the central cavernosal arteries and into the dorsal artery of the penis. The dorsal artery arborizes and penetrates into the glans penis, and then flows retrograde into the spongiosum. Thus, the corpus spongiosum has two blood supplies, proximally the bulbar and circumflex arteries, and distally, arborizations of the dorsal penile artery.

Keywords External pudendal artery, internal pudendal artery, bipedal blood supply, circumflex vessels, arterial plexus.

1. Penile Anatomy: Gross

The penis is covered with an elastic layer of skin that has no subcuticular adipose layer. Beneath the penile skin is the Dartos fascia, a layer of loose areolar subcutaneous tissue. The Dartos is devoid of fat and slides freely over the underlying Buck's fascia. The Dartos of the penis is contiguous with Scarpa's fascia of the abdominal wall, in which run the superficial nerves, lymphatics, and blood vessels. Beneath the Dartos fascia lies the superficial lamina (or lamella) of Buck's fascia. Buck's fascia covers in one envelope the tunica albuginea (outer longitudinal fibers) of the two corpora cavernosa, and the tunica of the corpus spongiosum. In the scrotum, the embryologic equivalent of Buck's fascia is the external spermatic fascia.

When one develops a fasciocutaneous penile skin island flap of genital skin, as one does with an Orandi (vertical flap) or a McAninch/Quartey (circular transverse) flap, we take advantage of the natural anatomical cleavage planes of the superficial layers of the penis. The main two distinct cleavage (relatively avascular) planes are between the skin and the Dartos fascia, whereas the other is between the Dartos fascia and Buck's fascia. Buck's fascia is fairly adherent to the underlying longitudinal fibers of the tunica albuginea and much more difficult to separate. In Peyronie's disease surgery, tunica plaque incision and grafting demands developing that difficult plane between the outer longitudinal layer of tunica albuginea and the overlying Buck's fascia.

2. Penile Skin Arterial Blood Supply

The blood supply to the skin of the penis and the anterior scrotal wall are from the external pudendal arteries. The blood supply to the posterior aspects of the scrotum is from posterior scrotal arteries, which is a branch of the perineal artery, which is a further branch of the internal pudendal arteries *(5)* (**Fig. 2.1**).

Branching off the medial aspect of the femoral artery are the superficial/ superior branches and the deep/inferior branches of the external pudendal artery. These superficial external pudendal branches pass from lateral to medial, in a variable pattern, across the femoral triangle, and within Scarpa's fascia (a loose membrane of superficial fascia; **Fig. 2.2**).

After giving off scrotal branches to the anterior scrotum, the superficial external pudendal artery cross the spermatic cord and enter the base of the penis as posterolateral and anterolateral axial branches. Together with interconnecting, perforating branches, they form an arterial network within the Dartos fascia. The Dartos fascia is not really the blood supply; it is more accurate to visualize the fascia as a trellis and the blood supply as the vine entwined on the trellis. At the base of the penis, branches from the axial penile arteries form a subdermal plexus which supplies the distal penile skin and prepuce (**Fig. 2.3**). There are perforating connections between the subcutaneous and subdermal arterial plexuses. These connections typically are minimal and very fine and, thus, a relatively avascular plane can be developed between the Dartos and Buck's fascia. Because the fascial plexus is the true blood supply to the penile skin flaps that we use in urethral reconstruction, the flaps are considered axial, penile skin island flaps that therefore can be mobilized widely and transposed aggressively. When developing a penile skin island flaps, it is often important to preserve the lateral and base aspects of the flap pedicle, because the arborizations of the superficial external pudendal arteries pass onto the penile shaft from lateral to medial. The pedicles can be kept large and mobilized extensively and reliably, enough so to even reach the perineum and proximal urethra. Occasionally, between the two layers, there is a large communication or perforating branch that needs to be ligated and divided. At the subcorona, the axial penile arteries continue onto the foreskin as preputial arteries, as well as send perforating arterial branches which pierce Buck's fascia to anastomose with the dorsal arteries *(5)* (**Fig. 2.4**).

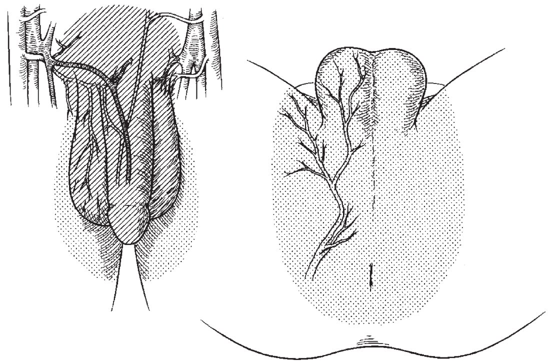

Fig. 2.1. The relative areas of arborization of the superficial external pudendal artery and the perineal/labial scrotal arborization. Cross-hatched area is based predominantly on the superficial external pudendal artery. The dotted area is based primarily on the perineal/labial scrotal arterial blood supply. There are areas of overlap on the scrotum. (From Jordan GH (ed) (1997) Reconstruction for urethral stricture, Atlas of Urol Clin NA 5(1))

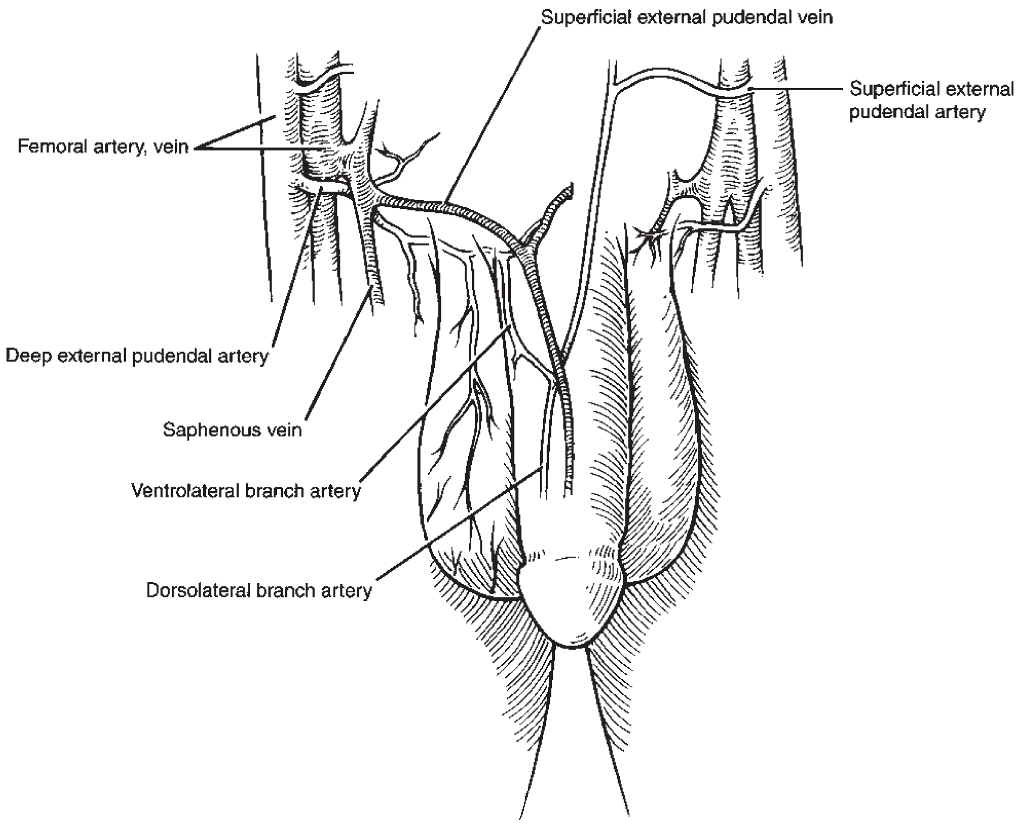

Fig. 2.2. The superficial external pudendal blood supply (to penile and anterior scrotal skin). (From Jordan GH (ed) (1997) Reconstruction for urethral stricture, Atlas of Urol Clin NA 5(1))

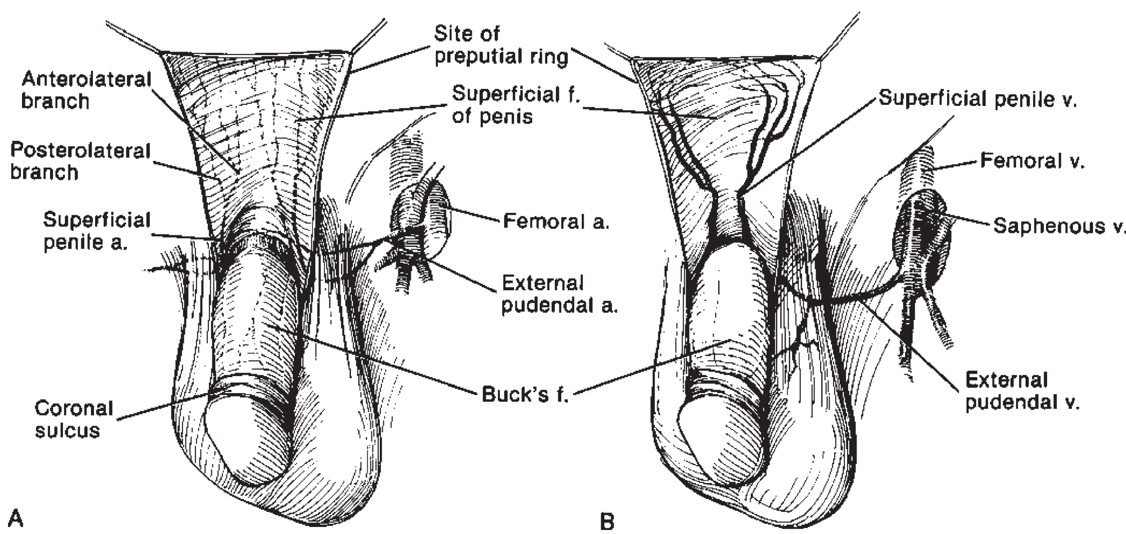

Fig. 2.3. Preputial blood supply. (A), Arterial supply. (B), Venous drainage (From Hinman F, Jr (1993) Atlas of Urosurgical Anatomy, Philadelphia, WB Saunders)

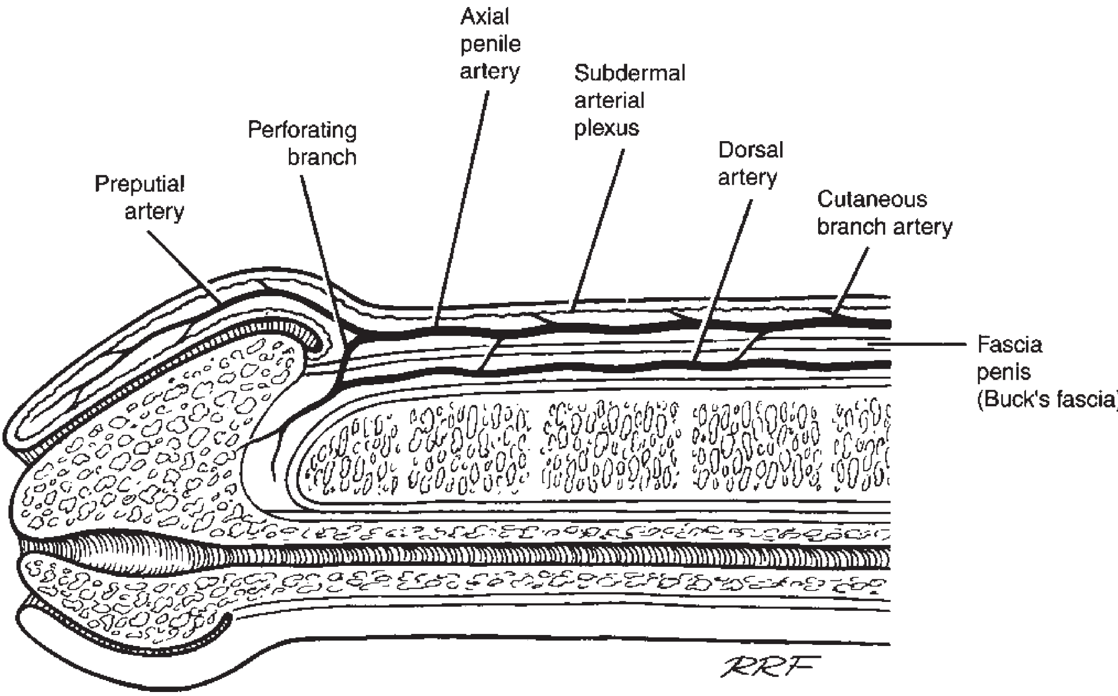

FIG. 2.4. Cross-sectional view of penile skin arterial plexuses; subdermal, subcutaneous, dorsal arterial. (From Jordan GH (ed) (1997) Reconstruction for urethral stricture, Atlas of Urol Clin of NA 5(1))

3. Scrotal Skin Blood Supply

The anterior aspect of the scrotum is supplied by anterior scrotal arteries, which are branches of the external pudendal artery. At the cephalad end (top) of the scrotum, they give off branches superficially to form a subdermal plexus that continue along the caudal aspect of the anterior scrotum to anastomose with the posterior scrotal arteries.

The blood supply to the posterior aspect of the scrotum is from several scrotal arteries, which are branches of the perineal artery, which is a superficial terminal branch of the internal pudendal artery (**Fig. 2.5**). The perineal artery emanates from Alcock's canal to pierce the posterolateral corner of the perineal membrane and then runs anteriorly, along the superficial fascia, in a groove between the bulbospongiosus and ischiocavernosus muscles. The scrotal arteries also give off branches to form a subdermal arterial plexus that anastomose at the apex of the scrotum with anterior scrotal arteries from the other side (**Fig. 2.1**). Furthermore, along the central scrotal septum, there are additional intercommunications between the anterior and posterior scrotal arteries.

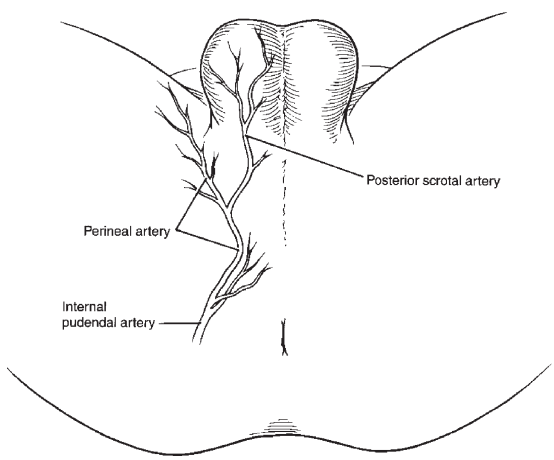

FIG. 2.5. The perineal artery/labial-scrotal blood supply. (From Jordan GH (ed) (1997) Reconstruction for urethral stricture, Atlas of Urol Clin of NA 5(1))

Scrotal skin island flaps, based on a fascial flap of tunica Dartos can be efficient for mobilizing skin island to the bulbar urethra, the pedicle is

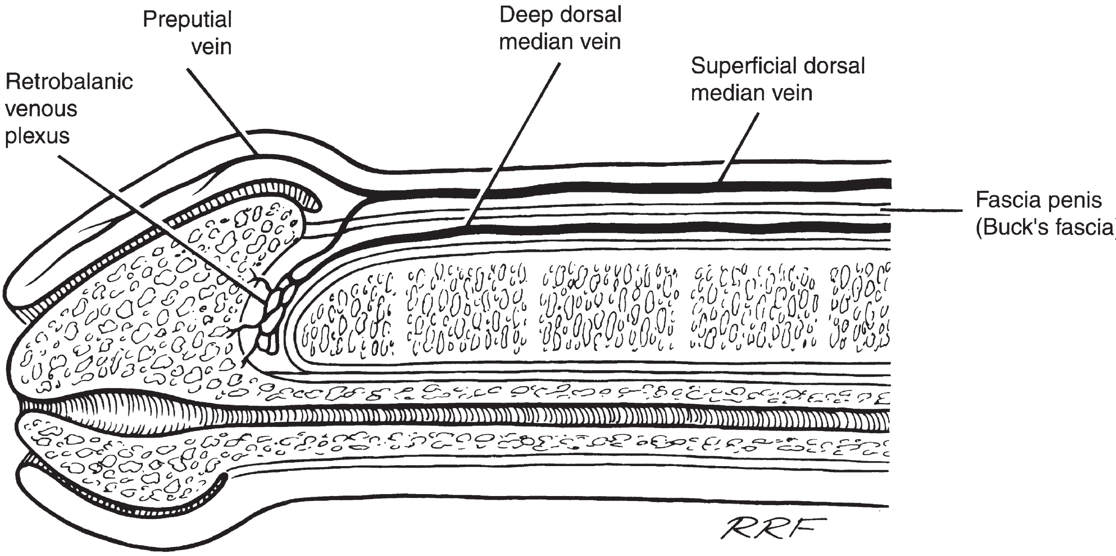

FIG. 2.6. Deep and superficial dorsal median veins arising from the retrobalanic venous plexus. (From Jordan GH (ed) (1997) Reconstruction for urethral stricture, Atlas of Urol Clin of NA 5(1))

often too short to reach anterior urethra. The facial pedicle can also be oriented posteriorly, by extending a "∩"-shaped incision onto the perineum (as in the Blandy flap for perineal urethrostomy).

4. Venous Drainage of the Penile Skin

Between the proximal–posterior aspects of the glans penis and the distal ends of the corpora cavernosal bodies is the retrobalanic venous plexus. From this venous plexus arise two branches of veins, the deep dorsal median and the superficial dorsal median (**Fig. 2.6**). The deep dorsal median vein runs posterior to Buck's fascia, while the superficial dorsal median vein pierces Buck's fascia subcoronally to run in the superficial layer of the Dartos fascia. Typically, there are no large connections between the deep (subdermal) venous plexus and the superficial (subcutaneous) veins (**Fig. 2.6**). However, occasionally the circumflex or deep dorsal median veins connect to the superficial veins in the subcutaneous tissue, or the superficial dorsal median vein branch off directly from the deep dorsal median vein, instead of the more typical origin in the retrobalanic venous plexus.

The superficial veins can also run dorsolateral, lateral, and/or ventrolateral. Running with the axial dorsal penile arteries are venae comitantes. The veins in the prepuce, however, are small and multiple and are distributed without particular orientation. These veins then join together to drain into one or two of the large superficial veins or continue independently, to the base of the penis, that drain through the inferior external pudendal vein into the saphenous vein (**Fig. 2.3B**). At the base of the penis, the large communicating veins, the venae comitantes, and the subdermal venous plexuses all combine in variable patterns to form the external pudendal veins, which further empty into the long saphenous veins or directly into the femoral vein.

5. Venous Drainage of the Scrotum

The anterior scrotal veins and the veins that drain the anterior scrotal subdermal venous plexus coalesce at the base of the scrotum to drain into the external pudendal vein. The posterior scrotal veins combine with the veins of the subdermal venous plexus of the posterior scrotal wall and drain into the perineal vein. The perineal vein then pierces the posterolateral corners of the perineal membrane to join the internal pudendal vein within Alcock's canal.

6. Genital Flap Selection

Genital skin island flaps are versatile for anterior urethral reconstruction. A thorough knowledge of the anatomy and specific tissue characteristics and adhering to the surgical principles of tissue transfer can result in long term success. The specific skin island flap that is selected should be based on specific physical characteristics. Sought after characteristics for such island flaps are: 1) skin for harvest is from an area of natural skin redundancy, 2) the skin at the donor site is elastic or redundant enough to be closed, 3) the skin island is thin and hairless, 4) the island of skin is long and wide enough to bridge the entire stricture, 5) the vascular pedicle to the skin island is reliable, long, and robust.

7. Blood Supply of the Urethra (Corpus Spongiosum)

A detailed knowledge of the arterial blood supply of the corpus spongiosum is essential to perform stricture excision and primary anastomosis urethral surgery.

7.1. Arterial Blood Supply

The key feature and the reason that the urethra can be mobilized extensively, divided, and then sewn back together is that it has a unique dual blood supply. The distal and proximal ends of the urethra are supplied by two arterial blood supplies, the proximal urethra in an antegrade fashion, and the distal urethra in a retrograde fashion. The internal pudendal artery branches into the perineal artery and posterior scrotal artery and then continues distally as the common penile artery (**Fig. 2.7**). The common penile artery branches into the bulbar arteries and circumflex cavernosal arteries (which both supply the proximal corpus spongiosum). The common penile artery then bifurcates into the central cavernosal arteries (also known as the deep artery of the corpus cavernosum) and into the dorsal artery of the penis (**Fig. 2.8**). The dorsal artery of the penis arborizes and penetrates into the spongy tissue of the glans penis. From the glans penis, the blood flows retrograde into the corpus spongiosum. The corpus spongiosum thus has two blood supplies, proximally by the bulbar and circumflex cavernosal arteries, and distally by arborizations of the dorsal penile artery. There are also perforators between the ventral corpora cavernosa and the corpus spongiosum. These perforators, however, are neither constant nor reliable in their distribution. When the urethra is mobilized and transected for anastomotic urethroplasty, adequate distal blood supply and retrograde flow is essential. Within the corpus spongiosum there are typically two or three urethral arteries. Based on recent ultrasonography studies, contrary to common belief, the urethral

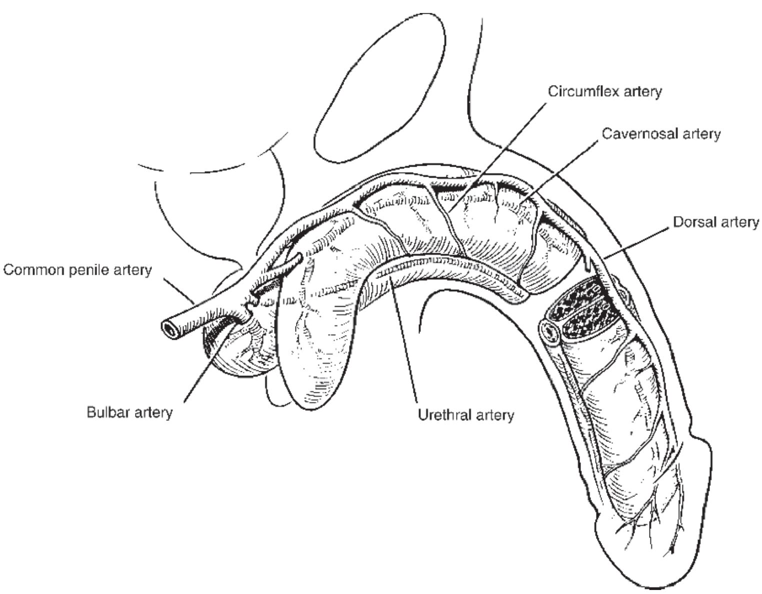

Fig. 2.7. Urethral and penile arterial blood supply. (From Jordan GH (ed) (1997) Reconstruction for urethral stricture, Atlas of Urol Clin of NA 5(1))

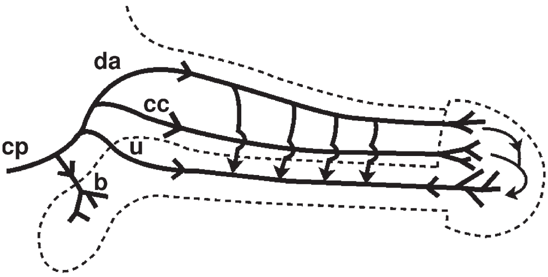

Fig. 2.8. Bipedal arterial blood supply of the urethra (cp, common penile; da, dorsal artery of the penis; cc, central cavernosal; u, urethral; b, bulbar artery)

arteries are not typically located at the 3- or 9-o'clock positions *(1)*. Urethral arteries, in contrast, have a variable position, and the location varies with near equal distribution around the clock, among patients (**Fig. 2.9**). The arteries can be close to the urethral lumen epithelium, especially in patients who have undergone prior urethral procedures. Although researchers suggest that urethral stricture patients who undergo urethrotomy, the direction for the incision can be determined by the preoperative ultrasound artery location, we have not found this to be particularly helpful. Rather, urethrotomy location probably does not matter so much as it is not too deep into the spongiosum, yet deep enough to allow the epithelium open up and re-scar in an open position.

If the urethra is overly mobilized distally or the patient has a known severe hypospadias, retrograde distal blood flow can be severely compromised. Here, anastomotic urethroplasty can result is proximal urethral ischemia and re-stricture. Such patients with compromised dual blood supply are thus often better served with substitution urethroplasty (**Fig. 2.10**). The other situation where the proximal urethra is at risk for ischemic necrosis with excision and primary anastomosis (EPA) surgery is the unusual situation where the bulbar arteries, as well as the common penile circulation have been disrupted and, thus, bipedal blood flow is inadequate (**Fig. 2.11**).

Urethral ischemic necrosis or ischemia refers to recurrence of stricture of the anterior and proximal urethra after Excision and primary anastomosis (EPA) urethral surgery. Such ischemic strictures are particularly difficult to manage because often they are very long and either have a very narrow caliber or completely obliterate the proximal anterior urethra. In contrast, technical error strictures are typically short, annular and easily amenable to internal urethrotomy. Jordan et al. *(2)*, upon reviewing all their failed posterior urethroplasties after pelvic fracture, observed that patients who developed the severe complication of proximal urethral necrosis all seemed to have one or more of the same characteristics; namely, previous histories of pelvic fracture associated with vascular injuries, were children, were elderly, had a cold or decreased sensate glans penis, decreased erections, or failed prior posterior urethroplasty. They further studied these patients with nocturnal penile tumescence studies and, if abnormal, with penile ultrasound and Doppler and of those, if abnormal, with pudendal angiography. They concluded

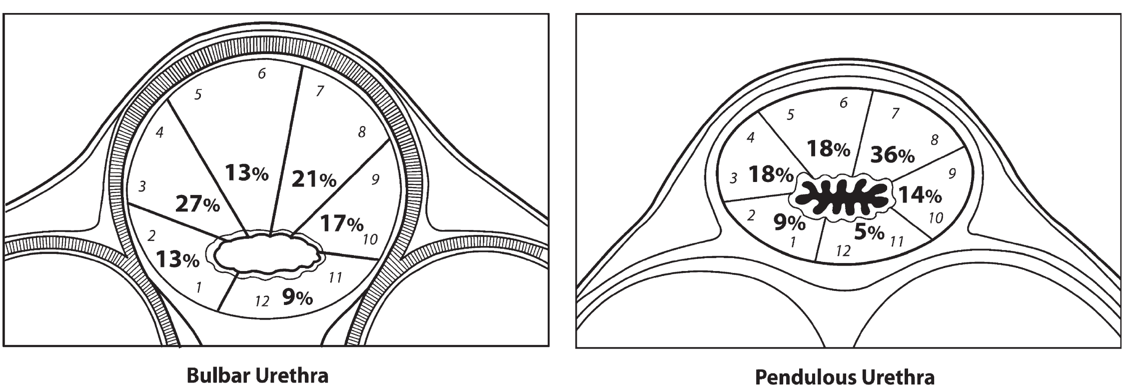

Fig. 2.9. Distribution of the location of the urethral arteries in the bulbar and pendulous urethra. (Redrawn after Ref. *[1]*)

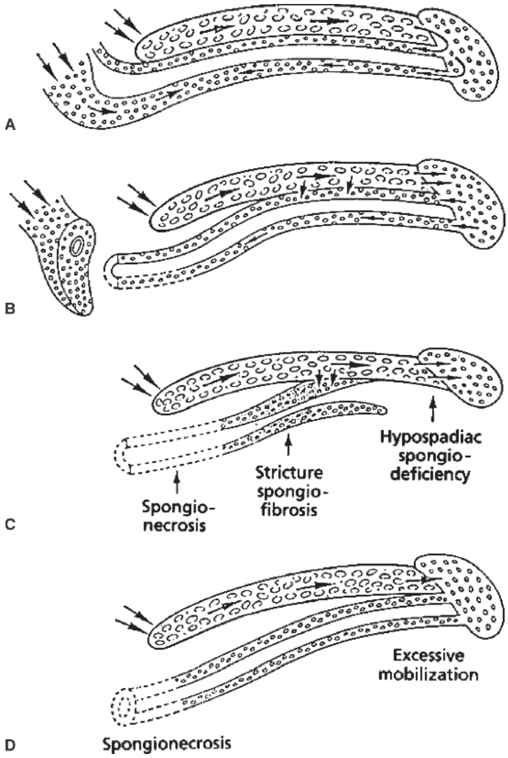

Fig. 2.10. Vascular principles of anastomotic urethroplasty. After division of the bulbar arteries, blood supply of the proximal bulbar urethra relies on the retrograde blood supply along its spongy tissue (A) and (B). Ischemic necrosis of the proximal mobilized urethra can result when the retrograde blood supply is compromised, such as occurs with hypospadias (C), incidental spongiofibrosis, or division of distal collateral vessels by excessive mobilization of the penile urethra (D). (From Yu G, Miller HC (2996) Critical operative maneuvers in urologic surgery. Mosby, St. Louis)

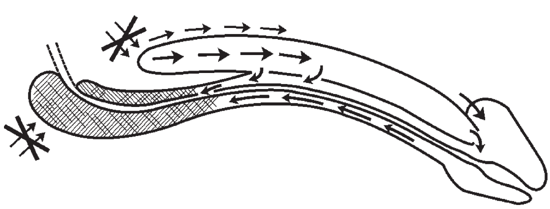

Fig. 2.11. The illustration shows that, in bilateral internal pudendal complex obliteration ("X" marks), there can be insufficient blood supply to the proximal urethra with an anastomotic urethroplasty. Hatched marks demonstrate "ischemic necrosis" of the proximal urethra after EPA surgery

that ischemic urethral necrosis was most likely, when on angiography, there was bilateral injury to the deep internal pudendal artery-common penile arterial system, without distal reconstitution. In other words, because the bulbar arteries and the common penile circulation are disrupted in this situation, there is inadequate retrograde and antegrade urethral blood flow for anastomotic urethroplasty. Such extreme vascular injuries after pelvic fracture are exceedingly rare ***(4)***.

Jordan et al. ***(2)*** suggest that patients who lack adequate bipedal blood supply of the urethra should be considered for penile revascularization before posterior urethroplasty. An algorithm for evaluating and managing patients at risk for ischemic necrosis is detailed in **Fig. 2.12**. When possible, a bilateral end to side anastomosis of inferior epigastric artery to dorsal penile artery should be performed (**Fig. 2.13**). Impotent patients with bilateral pudendal complex injury with distal reconstitution also may have insufficient blood flow not allowing for normal erections ***(4)***. In our experience with penile revascularization and refractory impotence after pelvic fracture, in young patients with few comorbidities, revascularization helps to resolve penile numbness and "coldness" and enables erection with intracavernosal injections or intraurethral alprostadil. In general, after pelvic fracture, aside from neurologic or venous problems, for normal erectile function or a normal response to pharmacotherapy, patients need at least one intact internal pudendal complex. According to Jordan et al. ***(2)***, all patients with risk factors for urethral ischemic necrosis who undergo successful penile revascularization before anastomotic urethroplasty have successful urethral reconstructions. Successful penile revascularization means here that at 3 to 6 months after revascularization, peak systolic arterial blood flows are in the normal range. In summary, all patients with ischemic urethral necrosis, when studied, have bilateral injuries to the pudendals without reconstitution. Lack of reconstitution, however, only predisposes, not guarantees, that the urethra will experience necrosis after EPA.

The other place where antegrade and retrograde blood flow preservation with EPA urethroplasty is important is the postprostatectomy incontinent patient who also has a urethral stricture. When stress incontinence is severe, it often is treated with an artificial urinary sphincter, where a cuff is placed

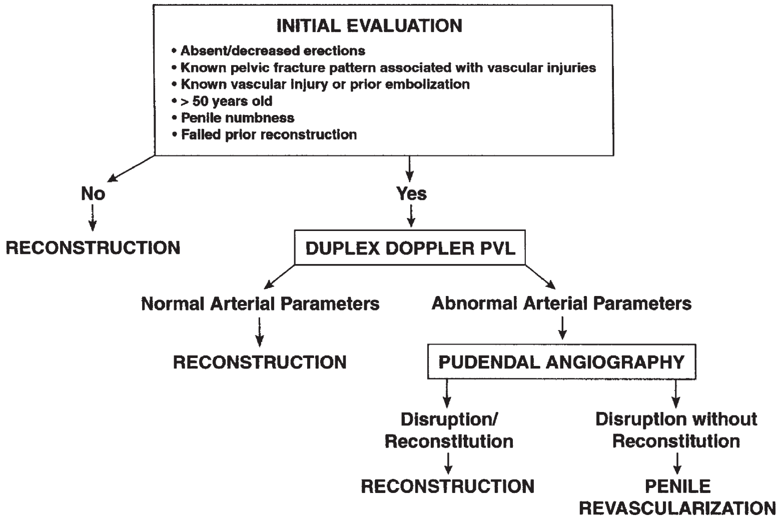

FIG. 2.12. Algorithm for identifying patients for potential urethral ischemic stenosis after posterior urethroplasty, and after urethral disruption injury. (From Jordan GH (ed) (1997) Reconstruction for urethral stricture, Atlas of Urol Clin of NA 5(1))

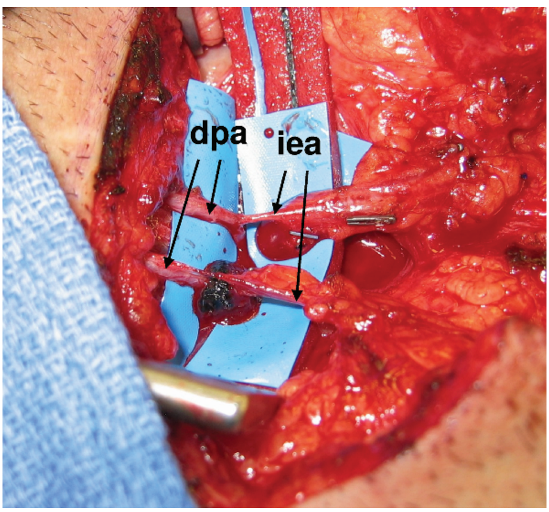

FIG. 2.13. Revascularization of the penis with bilateral end to side inferior epigastric artery (iea) to the dorsal penile artery (dpa)

around the urethra and compresses it circumferentially. In our experience, the cuff erosion rate is high after anastomotic urethroplasty. Perseveration of the bulbar arteries, however, can help maintain the blood supply of the urethra proximal to the cuff, which might otherwise be compromised by cuff compression and occlusion of retrograde urethral blood flow. In maintaining the bulbar arteries, there should be adequate antegrade blood flow to the urethra proximal to the cuff. It seems logical that a vessel sparing technique could improve spongiosal vascularity and bulk underneath the cuff, and thus possibly decrease the risk of cuff erosion. Jordan et al. ***(3)*** have described an elaborate technique for sparing these vessels.

The other place where maximizing the bipedal blood supply of the urethra is important is when a bulbar or membranous urethral stricture is associated with a distal urethra with compromised blood supply (such is the case with patients with hypospadias, distal urethral spongiofibrosis). Because the retrograde blood flow is compromised with such distal urethral conditions, it is important to try to isolate and preserve the antegrade blood flow of the bulbar arteries, and consider either a pedicle skin island flap for the distal urethral stricture or a staged approach.

7.2. Venous Drainage

The venous drainage of the corpus spongiosum is predominantly the venous drainage of the glans panis and the other deep structures, namely via the periurethral veins, circumflex veins and the deep and superficial dorsal veins (**Fig. 2.14**).

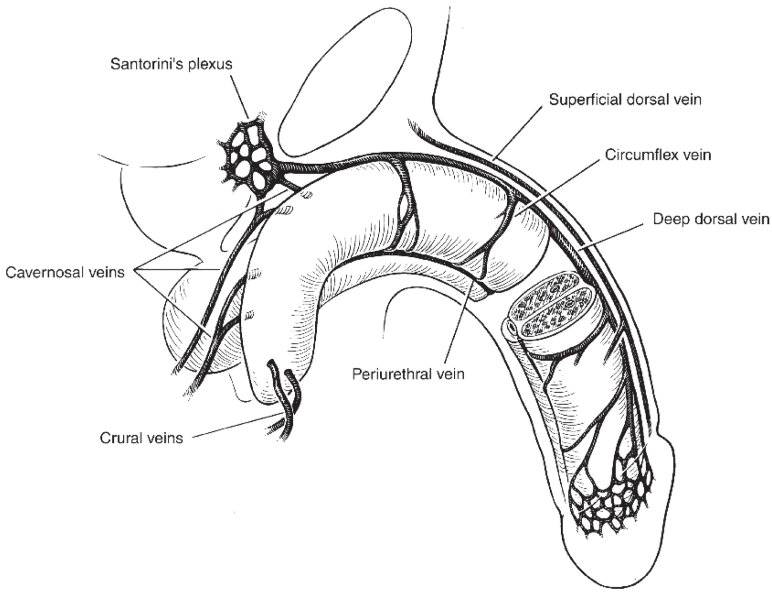

FIG. 2.14. The venous drainage of the urethra and penis. (From Jordan GH (ed) (1997) Reconstruction for urethral stricture, Atlas of Urol Clin of NA 5(1))

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3
Lichen Sclerosus

Ramón Virasoro and Gerald H. Jordan

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Summary Lichen Sclerosus is a chronic inflammatory disorder of the skin. Incidence in the western world is 1:300. In men, LS peaks between the 30 to 50 years. Both genders can be affected, although genital involvement is much more common in women. Possible etiologies for LS are the Koebner phenomenon, genetic susceptibility and autoimmunity, oxidative stress, and infection. Clinical presentation is usually white patches that seem to coalesce into "plaques" that can affect the prepuce and glans. It is not clear whether LS spreads by direct extension into the fossa navicularis and a portion of the anterior urethra, or if urethral involvement is secondary to LS induced meatal stenosis and subsequent "Littritis". The classic radiographic appearance of LS anterior urethral stricture is a saw-toothed pattern. Surgical management of LS is primarily by staged urethroplasty.

Keywords Skin disorder, Koebner phenomenon, urethral stricture, staged urethroplasty.

1. Introduction

Lichen sclerosus (LS) is a chronic inflammatory disorder of the skin of unknown origin. No specific mechanism of disease has been elucidated, although substantial advances in characterizing the immunological basis of other disease processes may eventually characterize the pathogenesis of LS. There are several acquired scarring disorders of the skin associated with pathology of the basement-membrane, such as mucous membrane pemphigoid, that may be shown to be related ***(1)***.

The reported incidence of LS in the western population is 1 in 300 ***(2)***; however, the worldwide prevalence