F. Schreiter

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Urethral Reconstructive Surgery

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With 224 Figures

Springer

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Library of Congress Control Number: 2005929875

ISBN-10 3-540-41226-3 Springer Medizin Verlag Heidelberg
ISBN-13 978-3-540-41226-7 Springer Medizin Verlag Heidelberg

Cataloging-in-Publication Data applied for
A catalog record for this book is available from the Library of Congress.

Bibliographic information published by Die Deutsche Bibliothek
Die Deutsche Bibliothek lists this publication in the Deutsche Nationalbibliografie;
detailed bibliographic data is available in the Internet at <http://dnb.ddb.de>.

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springer.de
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Printed in Germany

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SPIN 10786983
Cover Design: deblik Berlin, Germany
Typesetting: TypoStudio Tobias Schaedla, Heidelberg, Germany
Printing: Stürtz, Würzburg, Germany

Printed on acid free paper 2111 – 5 4 3 2 1 0

Preface

This textbook seeks to determine the current state-of-the-art of reconstructive urethral surgery and to identify new trends in this subspecialty of reconstructive urology. To this end, internationally known experts and opinion leaders in the field were invited to Hamburg, Germany to discuss and demonstrate today's commonly used surgical techniques.

Dialogues that took place during this convention, held in the spring of 2001 at the General Hospital in Hamburg-Harburg, are presented in book chapter format in this volume. The text is rounded out by live recordings of the most important of the surgical procedures. (DVD included with this compendium.)

Our desire was to publish, in close collaboration with Springer, a surgical textbook that presents the most important basic and modern techniques in urethral surgery. These techniques are underscored with simple and instructive drawings and »live surgery« video clips. We consciously chose not to make the text an all-inclusive surgical text. Thus the techniques included reflect a deliberate subjective selection on the part of the editors. We focused on the »renaissance« of graft techniques. Much of the material is concentrated on buccal mucosal and preputial grafts Two-stage surgical techniques, particularly for complex cases or patients who have undergone multiple previous operations, are also included.

This book is written for all urologists. It is intended to be an easily understandable and useful tool for their daily work, by giving them practical, clear, and reproducible accounts of the surgical techniques shown. In doing so, we hope it becomes an important part of reconstructive urology surgeons' libraries.

Prof. F. Schreiter
G.H Jordan, M.D.

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Introduction

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The treatment of urethral stricture is among one of the oldest medical activities practiced by humankind. In approximately 600 BC, Egyptians and Indians used bougies made of wood, papyrus, feathers, and metal to widen constricted urethras. Early attempts at external urethrotomy (Aretheus, 80 AD) and internal urethral incision (Heliodorus, 90 AD, Opera chirurgica) are also described in the literature. In 1561, Ambroise Paré developed a lead bougie with a file-like tip for internal urethrotomy. The popularity of internal urethrotomy rose exponentially in 1971 with Sachse's description of visual internal urethrotomy. His work paralleled the development of the modern optical urethrotome. However, Riba in 1936, Fischer in 1937, and Ravasisni had already applied the technique of visual internal urethrotomy. Nonetheless, the status of optics at the time of their work did not favor wide application of the procedure.

Open single-stage surgical reconstructive procedures for urethral stricture, regardless of etiology, date back to the latter part of the 19th century. Heusner (1883), Guyon (1892), Rochet (1899), and Hamilton Russell (1914) described results of stricture resection with either partial or in some cases true end-to-end anastomosis. The results, however, were unsatisfactory because of the lack of understanding concerning the need for spatulated anastomosis and the need for efficient mobilization of the urethra so that the anastomosis was sutured tension-free. Likewise, their work was hindered by the poor availability of quality absorbable suture material. Additionally, they were unable to protect the repair by diversion because only hard rubber-based catheters existed at the time. Consequently, procedures were fraught with problems of infection due to lack of antibiotics, and thus single-stage primary reconstructive techniques were abandoned in favor of two-stage surgical techniques. The two-stage operations, as described by Bengt-Johanson, became the commonly applied technique. However, this operation, truly the first one suitable for all strictures regardless of etiology, was encumbered by poor long-term results. Much of the urethra was reconstructed with hair-bearing scrotal skin, giving rise to pseudo-diverticula, infections, abscess, urethral bezoar, and ultimately long-term failure. In 1970, Schreiter described a two-stage mesh graft operation. Many of the disadvantages of the Johanson technique were eliminated when this procedure was adopted. This procedure was also used for long and complex recurrent strictures.

In 1957, the full-thickness skin graft patch urethroplasty technique was described by Pressman and Greenberg. Devine later published a large series and improved and expanded the technique. From the time of its description to the early 1980s, full-thickness skin patch graft urethral reconstruction became the standard for single-stage urethral reconstruction for stricture. However, the early results never exceeded the mid 80% range, and long-term results showed deterioration and left much to be desired. Other surgeons such as Memmelar (bladder mucosa), Bürger and Hohenfellner (buccal mucosa), and Quartey (genital skin island flap techniques) explored new approaches in reconstructive surgery for urethral stricture. Today there has been a resurgence of interest in graft techniques, particularly with the advent of the use of the buccal mucosal graft. Island flap techniques are still applicable, but their use has drastically diminished.

Currently, the buccal mucosal graft prevails in the treatment of stricture associated with lichen sclerosus and is considered the method of choice. Whether the graft techniques employing buccal grafts will enjoy better success than flap techniques or skin graft techniques remains to be seen. The staged mesh graft operation remains for very complex situations in which there is a shortage of penile skin, the buccal mucosa donor site is not sufficient for the degree of stricture, etc. One chapter of this textbook is devoted to tissue engineering, and certainly while those techniques are in their infancy, the insights gained from today's work are felt to be the future of urethral reconstruction.

As already mentioned, this textbook is not intended to cover the entire spectrum of urethral reconstructive procedures. However, those techniques considered applicable to most surgeons' practices have been covered in this book.

We, as the editors, along with the publishers, thank the international forum of authors who have contributed to both the meeting and this volume. Without their cooperation, this textbook could not have come to press. We thank Springer for designing and publishing the book and for their assistance in its preparation.

Hamburg/Norfolk, August 2005
Prof. Dr. med. F. Schreiter
G. H. Jordan, M.D.

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Historical Highlights in the Development of Urethral Surgery

K. Bandhauer

»On the shoulders of the giants«: this should be the motto for the following short and of course incomplete survey of the historical highlights of urethral surgery as well as the topic of this meeting on reconstructive urethral surgery.

Speaking about the historical development of the surgical treatment of different urethral diseases, whether urethral strictures, hypospadias, or epispadias, it should always be kept in mind that most of the surgical techniques we discuss in our meetings have already been performed by excellent and creative surgeons and urologists over a certain period of time, some even for decades.

With this in mind, the question can be asked why the results of urethral surgery, with some exceptions, were rather unsuccessful until about 50 years ago. The answer is simple: not only the surgical technique is crucial for the success of urethral surgery, but also perioperative measures such as correct temporary urinary diversion using the best catheters, the use of reabsorbable sutures without the risk of calcification caused by urine, and the use of antibiotics to prevent postoperative infections. Urethral surgery had a real chance to be successful irrespective of the operative technique used only after these tools became available. Besides these important achievements of modern medicine, a better understanding of the anatomy and the function of the urethra with its adjacent glands contributes to the immense success of urethral surgery, something our urological generation can rightfully be proud of. It was the knowledge of the different functions of the corpora cavernosa and the corpus spongiosum urethrae in erection, the practical experience showing that the urethra is flexible enough to replace at least 2–3 cm of resected urethra just by stretching the remaining parts, and finally the recognition of the enormous elasticity of the penile and preputial skin, which enabled creative urologists to conceive different methods for successful surgical treatment of urethral disorders.

Despite the indication of the importance of different perioperative measures for the outcome of urethral surgery, the following historical remarks are limited only to the development of urethral reconstruction. It was the German surgeon K. Thiersch in 1869 who designed an operation for epispadias using longitudinal flaps raised on either side of the urethral furrow, one for the floor of the urethra with the other used to cover it, overlapping it in double layer fashion. With this operative technique, he recorded the first use of buried skin to create a new urethra. Five years later in 1874, this procedure was used by the Frenchman Th. Anger to reconstruct the urethra in the hypospadias. But it was the Frenchman S. Duplay who published the first important paper on the subject of hypospadias in the *Archives Générales de Médecine* in 1874. He gave credit to Anger for presenting the first successful case of hypospadias repair to the Société de Chirurgie in 1874. S. Duplay himself converted ventral penile skin into a tube using a catheter as a splint to create a new urethra. His first successful operation required five stages and in 1880 he reported further successful operations. In the same year (1880), he declared in the description of his modified operation that it is not necessary to cover the splint completely by the inner edges of the skin flaps to develop a tube by itself: »Although the catheter is not actually covered entirely by skin, I am convinced that this has no ill effect on the formation of the new urethra.« With this statement he already anticipated the idea of Denis Browne's buried-skin technique. But the differences in techniques between Denis Browne's repair and Duplay's are obvious. Duplay created a new urethra by wrapping a penile skin flap around a catheter, while Browne buried only a strip of penile skin. It is beyond doubt that Duplay was the most important promotor of the French School of Urology, creating useful procedures to correct different forms of hypospadia. Even numerous modifications of Duplay's original methods are still in use, with reasonable results.

The next achievement was set in 1949 by the English plastic surgeon Denis Browne when he introduced his buried-skin technique using the tube forming capacity of penile skin to construct a new urethra (◘ Fig. 2.1). Although Hamilton Russell (1915) and Erich Lexer (1929) had already used buried urethral epithelium to construct a tube, it was the genius of Denis Browne to use this natural capacity of a buried skin flap to become a tube within about 10 days for creating an operation that that has been widely performed ever since, with remarkable success.

Even though Denis Browne's original method, with its numerous modifications by J. Blandy, D. Zoedler, R. Turner-Warwick, and Hans Marberger et al., are not the only methods available for creating a new urethra, it was the basis of modern urethral surgery. This is particularly so after the Swedish plastic surgeon Bengt Johanson adopted Denis Browne's idea for correction of posterior urethral strictures (◘ Fig. 2.2). Until this time, posterior urethral strictures were the fear of all urologists dealing with urethral surgery; they now became within the range of possibility for successful reconstruction. It was Johanson's idea to use the enormous elasticity of the scrotal skin to operate on posterior urethral strictures up to the membranous part. Even complex posttraumatic strictures of the posterior part of the urethra with extended scar production could be treated with this brilliant concept.

Bengt Johanson's achievement is no less important because Hans Marberger and his co-workers from Innsbruck, Austria introduced the Johanson-procedure into urology and made this method known throughout Western Europe and the United States. The Johanson procedure for the repair of posterior urethral strictures was so effective that it also gained access for the primary treatment of traumatic ruptures even when connected with pelvic fractures. This possibility was especially shown by H. Marberger and his co-workers in a long series of

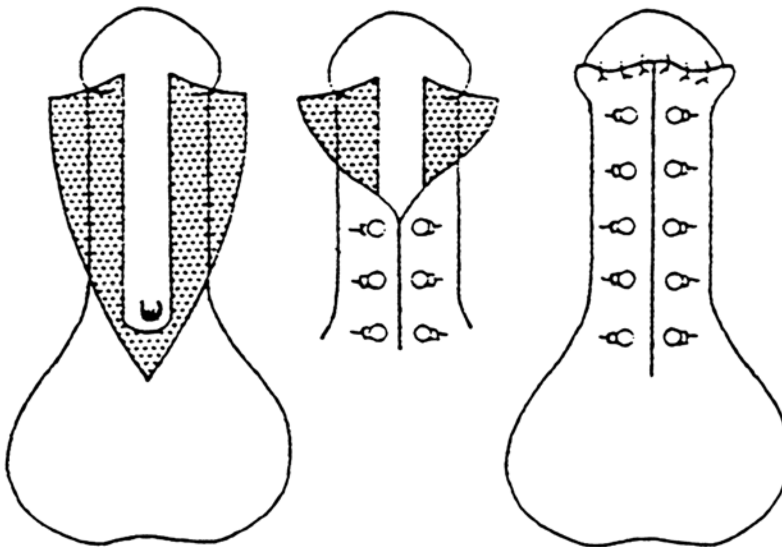


Fig. 2.1. Buried-skin technique by Denis Browne. (Courtesy of The History of Urology, by LJT Murphy, Charles C. Thomas, Springfield, IL, USA)

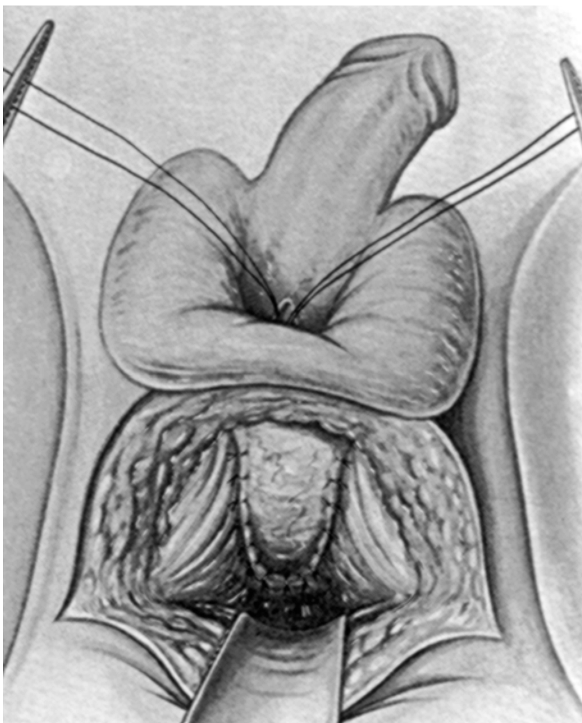


Fig. 2.2. Johanson procedure for surgical treatment of posterior urethral stricture using scrotal skin. (Courtesy of Urologische Operationen, G. Mayor and E. Zingg, 1973, Georg Thieme Verlag Stuttgart)

patients. Although the discussions on acute therapeutical measurements for traumatic ruptures of the posterior urethra continue between primary attempts to restore the continuity of the urethra or primary urinary diversion above the laceration, drainage of the intrapelvic hematoma and if necessary stabilization of the bony pelvis followed by secondary treatment of the posttraumatic strictures, the Johanson procedure provided a method that offered an excellent and safe basis for the acute treatment of urethral ruptures.

In spite of the many applications of the Johanson procedure and their numerous variations, there were some unpleasant disadvantages such as calcifications caused by remaining hair of the scrotal skin used for the reconstruction of the urethra or necrosis of the top of the skin flap used for the anastomosis with the membranous urethra. It was the idea of the German urologist Friedhelm Schreiter (1987) to eliminate this complication by using an inlay of mesh graft, which made it possible to create a wide neourethra without the risk of calcification (Fig. 2.3). The combination of Johanson's modification of Denis Browne's brilliant method with Schreiter's use of mesh graft is at the moment the safest operation for the repair of long and complex strictures in any area of the urethra.

These techniques require at least two sessions. Therefore various attempts have been made over the years to repair strictures with a one-stage operation. Probably it was the German surgeon Heusner (1883) who carried out the first excision of a stricture, restoring the urethra by sutures. Similar operations were performed by Mayo Robson (1884), Guyon (1892), and other French surgeons at the same time. The immediate outcome with one-stage operations, excising the strictured part of the urethra and re-establishing a wide urethra by anastomosis were mostly successful, but further stricture formation gave disappointing long-term results. In a review of 13 patients carried out by Watson and Cunningham (1908), only five patients showed satisfactory results more than 1 year after a one-stage operation (Fig. 2.4). In 1915, Hamilton Russel summarized the role of excision and primary anastomosis in the operative treatment of urethral strictures as follows:

»Excision of the strictures has never been very generally practised and is attempted only in a small number of cases; the reason is that the operation, as usually performed, is difficult and uncertain in its results, and surgeons are a little shy of it in the natural fear lest things should be made worse instead of better.«

An important step to improve the outcome of one-stage urethral plasties was done by Roche as early as 1895, who recommended temporary suprapubic urinary diversion after urethra surgery. But altogether the results of one-stage urethroplasties remained moderate, above all because of restrictures caused by calcification of nonreabsorbable suture material and severe local reactions produced by inappropriate catheters. For these reasons exceptional surgeons and urologists such as Marion (1929), Krois (1929), Watson (1935), and Solovov (1935) had to accept disappointing results in spite of excellent designs and operative techniques. Only when reabsorbable sutures, better catheter material, and especially effective antibiotics were available did the long-term results of one-stage urethroplasties improve. Resection of the stricture and primary end-to-end anastomosis became a routine procedure in many urological institutions all over the world. In 1975, Turner-Warwick reported excellent results of an oblique end-to-end anastomosis in the bulbous region of the urethra (Fig. 2.5). Based on these achievements, further developments were possible. Turner-Warwick (1976) made use of pediculated

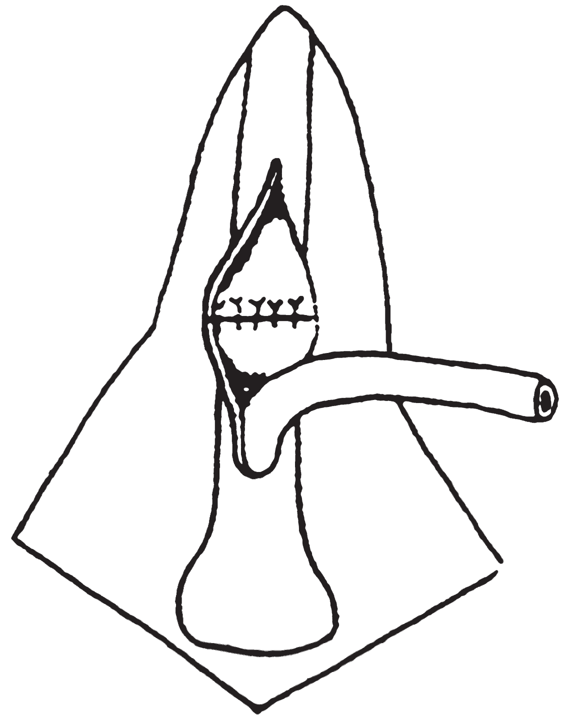


Fig. 2.4. H. Russell's technique for repair of hypospadia after excision of stricture and primary anastomosis of roof of urethra. (Courtesy of The History of Urology, by L.J.T.Murphy, Charles C. Thomas, Springfield, Illinois, USA)

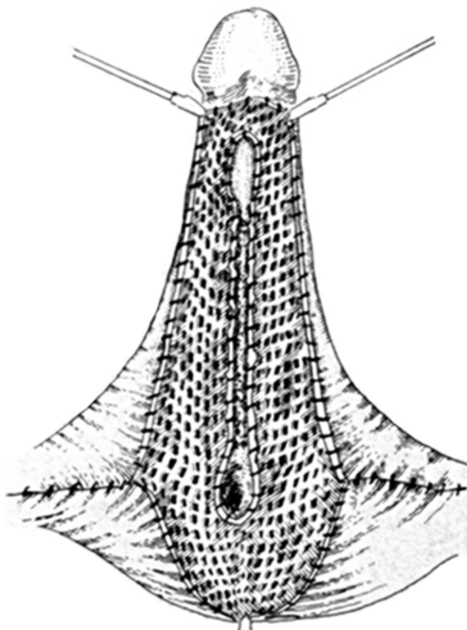


Fig. 2.3. Schreiter's method to create a new floor of urethra using an inlay of mesh graft. (Courtesy of Operative Therapie der Harnröhrenstriktur, von Klaus Bandhauer und Friedhelm Schreiter, 1991, Georg Thieme Verlag, Stuttgart, New York)

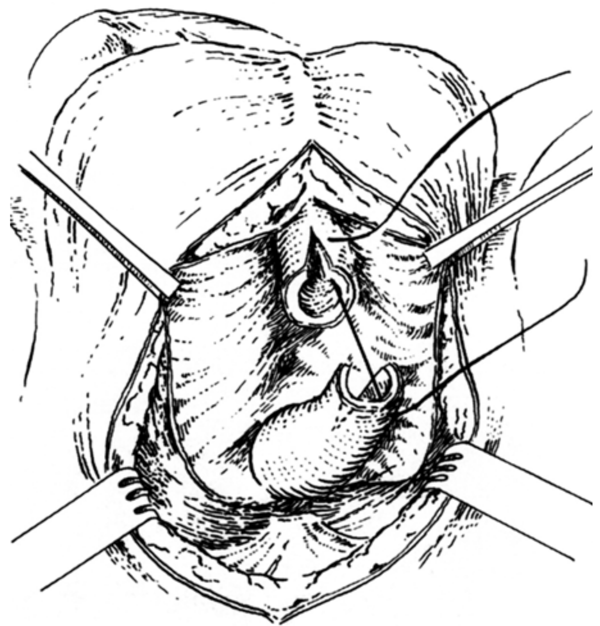


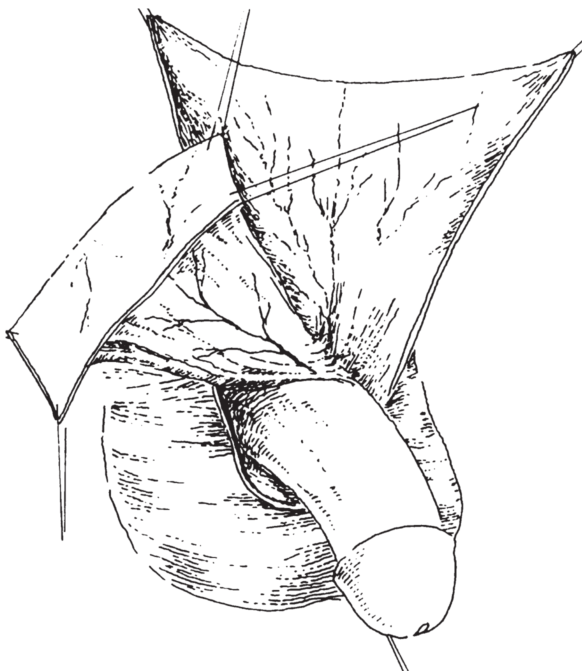
Fig. 2.5. Oblique end-to-end anastomosis in the bulbous part of urethra. (Courtesy of Operative Therapie der Harnröhrenstriktur, von Klaus Bandhauer und Friedhelm Schreiter, 1991, Georg Thieme Verlag, Stuttgart, New York)

flaps of omentum majus to cover the end-to-end anastomosis at the membranous urethra.

The elasticity of the preputial skin was already being used for pediculated grafts to make a tube to create a new urethra by Rochet in 1899 and C. H. Mayo in 1901. But it was Duckett who introduced his transverse preputial island flap technique in 1980, a method that enabled a repair of long parts of the urethra in one session (◘ Fig. 2.6).

In contrast to pediculated flaps, the use of free grafts, pioneered already by Nové-Josserand in 1897 and again described by Devine and Horton, DeSy and others showed mostly poor results because free grafts have a strong tendency to shrink. In addition, the use of veins as reported by Tanton (1909), Tuffier (1910), Cantas (1911), and Marion (1922), and of ureters by Schmieden (1909) and McGuire (1927) to replace urethral defects, showed disappointing results. On the contrary, free grafts of bladder mucosa used by Memmelar (1947) and Marshall and Spellman (1955) to build a new urethra produced promising results, without becoming a common method in urethral surgery.

After these disappointments with different forms of free grafts, it was the utilization of oral mucosa as a free graft for reconstructive urethral surgery that seems to be an important development and can be mentioned as a highlight in the trials to replace urethral defects in one session. Oral mucosa has variously been utilized for more than 100 years in reconstructive plastic surgery, especially in ophthalmology and maxillofacial surgery. But it was to the merit of the Mainz school of Urology that Buerger et al. reported in 1992 the first results of animal experiments, using oral mucosa for reconstruction of the urethra. Based on these findings, they applied oral mucosa grafts to replace the urethra in cases of hypospadia injuries. In the same year (1992), Dessant et al. reported eight patients in whom a combination of oral mucosa and bladder mucosa was successfully employed for urethral replacement. These encouraging findings led to increased use of grafts from buccal mucosa not only for hypospadias, but also for the operative treatment of urethral strictures. Many reports on the successful use of free oral mucosa grafts for complex hypospadias have been published since and today the use of buccal mucosa onlays is widely used in urethral reconstructive surgery.



◘ **Fig. 2.6.** Duckett's pediculated transversal preputial island flap to repair long parts of urethra. (Courtesy of Operative Therapie der Harnröhrenstriktur, von Klaus Bandhauer und Friedhelm Schreiter, 1991, Georg Thieme Verlag, Stuttgart, New York)

In conclusion, the historical development of reconstructive surgical treatment of urethral disorders, whether these are posttraumatic or postinflammatory strictures, hypospadias or epispadias, and even the primary treatment of urethral strictures, has known continuous improvement over the last decades. Different skillful techniques are used today as routine operations and the results of surgically treated complex urethral disorders are excellent compared to the results still 20–30 years ago. But with this short and of course incomplete historical review, I wanted to emphasize that our urological generation must remember, that we still depend on the ideas and the skill of surgeons and urologists who performed outstanding operations on the urethra already in the end of the nineteenth and the beginning of the twentieth century. Only a few of these historical highlights of urethral surgery could be presented. We were able to build on these ideas and although our operative results are much better, we must always keep in mind that this improvement stems more from the much better perioperative measures such as antibiotics, suture material, and catheters than from spectacular new operative ideas. We urethral surgeons can only remain very modest.

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Anatomy and Blood Supply of the Urethra and Penis

J. K.M. Quartey

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3.1 Structure of the Penis

The penis is made up of three cylindrical erectile bodies. The pendulous anterior portion hangs from the lower anterior surface of the symphysis pubis. The two dorsolateral corpora cavernosa are fused together, with an incomplete septum dividing them. The third and smaller corpus spongiosum lies in the ventral groove between the corpora cavernosa, and is traversed by the centrally placed urethra. Its distal end is expanded into a conical glans, which is folded dorsally and proximally to cover the ends of the corpora cavernosa and ends in a prominent ridge, the corona. The corona passes laterally and then curves distally to meet in a V ventrally and anterior to the frenulum, a fold of skin just proximal to the external urethral meatus.

The erectile tissue of the corpora cavernosa is made up of blood spaces lined by endothelium enclosed in a tough fibroelastic covering, the tunica albuginea. The corpus spongiosum is smaller with a much thinner tunica albuginea, and its erectile tissue surrounds the urethra.

Proximally, at the base of the pendulous penis, the corpora cavernosa separate to become the crura, which are attached to the inferomedial margins of the pubic arch and adjoining inferior surface of the urogenital diaphragm. The corpus spongiosum becomes expanded into the bulb, which is adherent in the midline to the inferior surface of the urogenital diaphragm. This is the fixed part of the penis, and is known as the root of the penis. The urethra runs in the dorsal part of the bulb and makes an almost right-angled bend to pass superiorly through the urogenital diaphragm to become the membranous urethra.

3.2 Deep Fascia (Buck's)

The deep fascia penis (Buck's) binds the three bodies together in the pendulous portion of the penis, splitting ventrally to ensheathe the corpus spongiosum, and is closely adherent to the tunica albuginea. Distally, it is attached to the coronal groove. Proximally, it covers the crura and bulb with their overlying corpora cavernosus and corpus spongiosus muscles. At the junction of the pendulous and fixed parts of the penis, the suspensory ligament, a thickened sling of the deep fascia from the lower anterior and inferior margin of the symphysis pubis supports the penis. In the dorsal groove between the corpora cavernosa lie the deep dorsal median vein(s) and its tributaries, and on either side the dorsal artery and its branches and the dorsal nerve in that order mediolaterally between the tunica albuginea and Buck's fascia, although in cross-section they appear to be embedded in the deeper layers of Buck's fascia (Fig. 3.1).

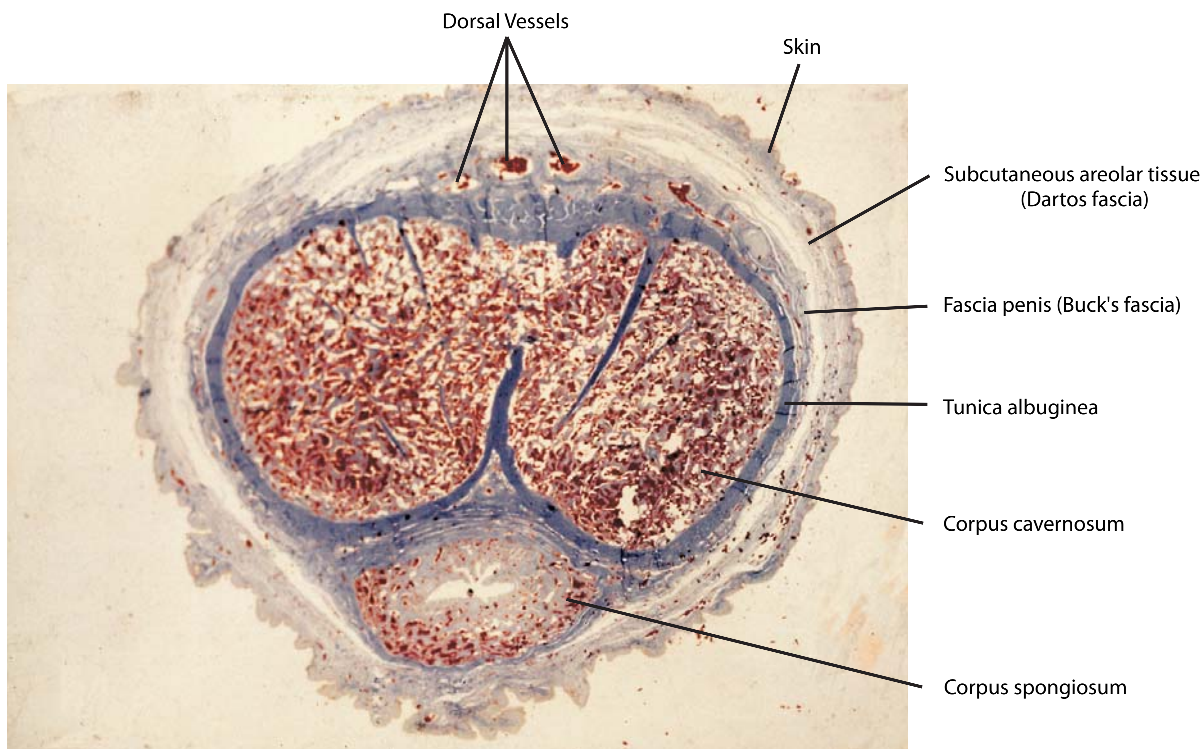

Fig. 3.1. Cross-section of the penis showing the layers

3.3 Subcutaneous Tissue (Dartos Fascia)

A loose areolar subcutaneous tissue, devoid of fat (dartos fascia) surrounds the deep fascia penis and contains the superficial blood vessels, nerves, and lymphatics. It is continuous with the membranous layer of the superficial fascia of the lower abdomen, femoral triangles and scrotum.

3.4 Skin

The skin is the outer covering of the penis and scrotum. It is thin, and the dermis contains smooth muscle fibers, the dartos muscle, to accommodate the wide variation in size between the flaccid and erect penis, and between the shrunken and relaxed state of the scrotum [1, 2]. The dartos muscle is more prominent in the scrotum than in the penis. Distally, the skin is folded inwardly on itself as the prepuce to cover the glans; the inner layer passes proximally to be attached to the coronal groove and to become continuous with the skin of the glans, which is closely adherent directly to the spongy tissue. The loose areolar subcutaneous tissue extends in between the two skin layers of the prepuce. Proximally, at the base of the penis, the inferior part of the skin is expanded into a loose bag, the scrotum, which hangs down from the urogenital diaphragm, contains the testes, epididymes and spermatic cords, and covers the structures in the root of the penis.

3.5 Urethra

The urethra in the male can be divided into penile, bulbous, membranous, and prostatic.

The penile urethra runs through the center of the corpus spongiosum in the pendulous penis. It lies ventrally in the glans to open as a vertical slit just ventral to the tip of the glans.

At the base of the penis, the urethra bends posteriorly and inferiorly as the bulbous urethra, and the erectile tissue is expanded around it to form the bulb with the urethra running in the dorsal aspect. Posteriorly, it pierces the urogenital diaphragm at a right angle to become the membranous urethra.

The membranous urethra is 2–3 cm long, and extends from the upper surface of the urogenital diaphragm to the apex of the prostate. This can be appreciated in urethrograms, at urethroscopy, and at urethroplasty as the distance from the bend at the proximal end of the bulbous urethra to the apex of the prostate. It is surrounded by areolar tissue only. The external urethral sphincter is made up of voluntary muscle fibers, which descend from the outer layers of the bladder and prostate to blend with the outer longitudinal muscle layer of the membranous urethral wall [3] (Fig. 3.2).

The prostatic urethra runs through the prostate and its walls are intimately attached to the prostatic lobes.

3.6 Superficial Arterial Supply

The superficial (superior) and deep (inferior) external pudendal arteries, branches of the first part of the femoral, supply the skin and subcutaneous tissues of the penis and anterior scrotal wall. In most bodies, the deep external pudendal is the dominant artery, but in a small proportion the superficial external pudendal is dominant. They pierce the deep fascia to run in the membranous layer of the superficial fascia across the femoral triangle to the base of the penis. Here they divide into dorsolateral and ventrolateral axial penile branches, which run distally in the subcutaneous tissue to the glans. The axial arteries

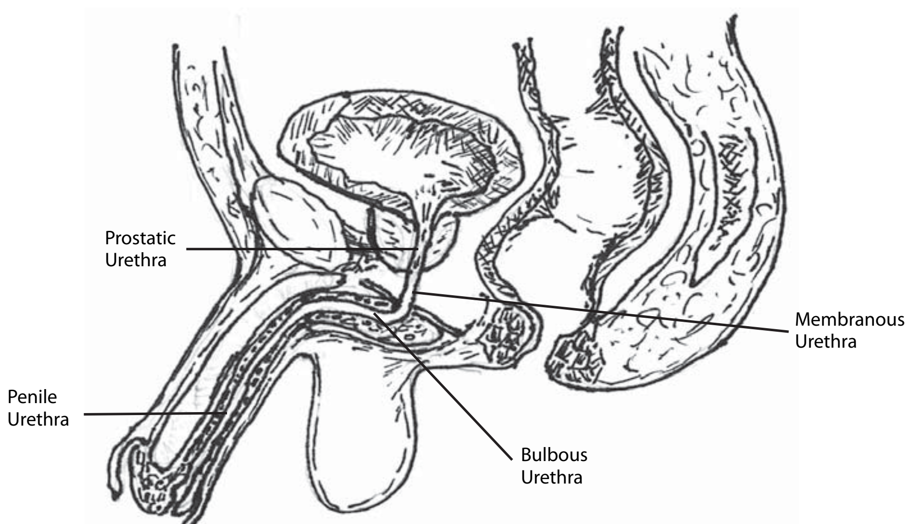

Fig. 3.2. Parts of the urethra

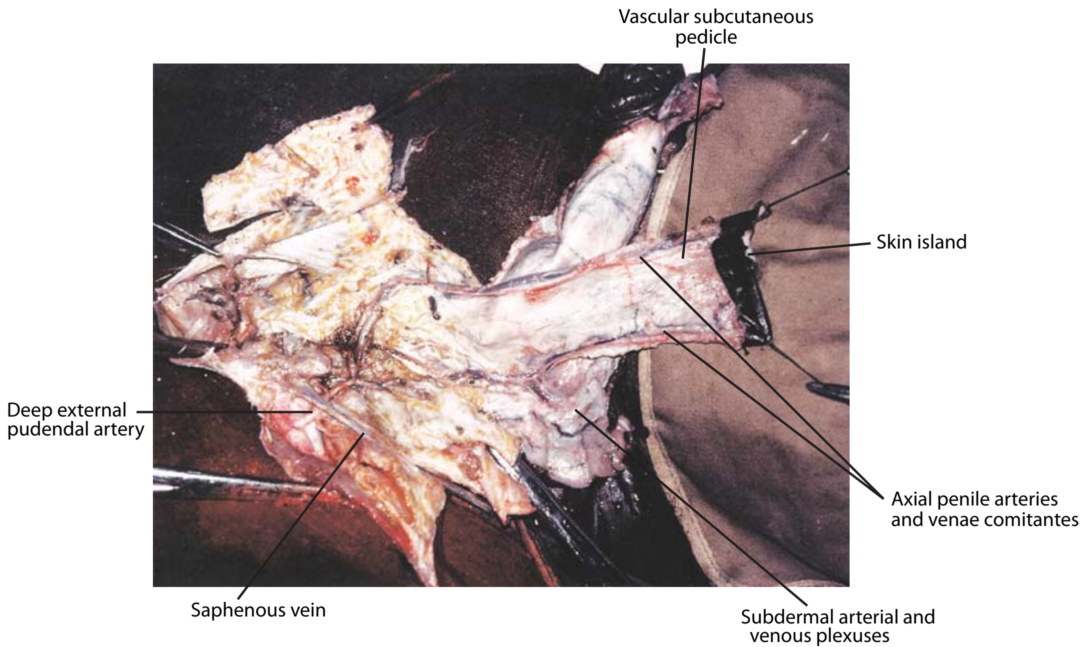

Fig. 3.3. Superficial arterial supply of the penis

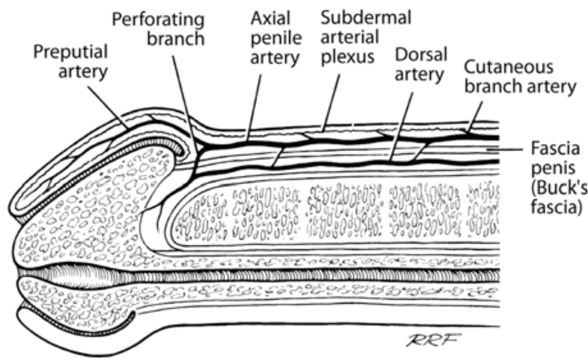

Fig. 3.4. Relationships of subdermal, subcutaneous, and dorsal arterial plexus. (From [7])

give off cutaneous branches at the base of the penis to form a subdermal arterial plexus, which extends distally to the prepuce. The axial arteries together with interconnecting branches form a rich subcutaneous arterial network, which passes distally to the prepuce (Fig. 3.3).

Behind the corona, the axial arteries send perforating branches through Buck's fascia to anastomose with the terminal branches of the dorsal arteries before they end in the glans. The attenuated continuation of the arteries pass into the prepuce. Connections between the subcutaneous arterial plexus and the subdermal arterial plexus are very fine, so that the skin can be dissected off the subcutaneous tissue with little bleeding. Occasional large connections need to be ligated and divided to raise the skin [4, 5] (Fig. 3.4).

3.7 Superficial Venous Drainage

The axial penile arteries are usually accompanied by venae comitantes.

Large communicating veins may originate from within the prepuce or from the retrobalanic venous plexus and then pierce the fascia penis to run in the subcutaneous tissues. They sometimes arise directly from the circumflex or deep dorsal median veins. They may be dorsal, dorsolateral, lateral, or ventrolateral, but converge to end in one or two dorsal median or dorsolateral trunks at the base of the penis.

A subdermal venous plexus extends from the prepuce to the base of the penis, where small venous trunks emerge to join either the communicating veins or the venae comitantes.

The communicating veins end in a variable manner. They may end in one saphenous vein, usually the left just before it enters the femoral, or they may divide and the branches join the corresponding long saphenous vein. The communicating veins or the venae comitantes may end directly in the femoral vein (Fig. 3.5).

3.8 Planes of Cleavage

There are definite planes of cleavage between the skin and loose areolar subcutaneous tissue, and between the subcutaneous tissue and fascia penis (Buck's). This makes it possible to easily dissect the skin off the subcutaneous tissue, and the subcutaneous tissue off Buck's fascia to form

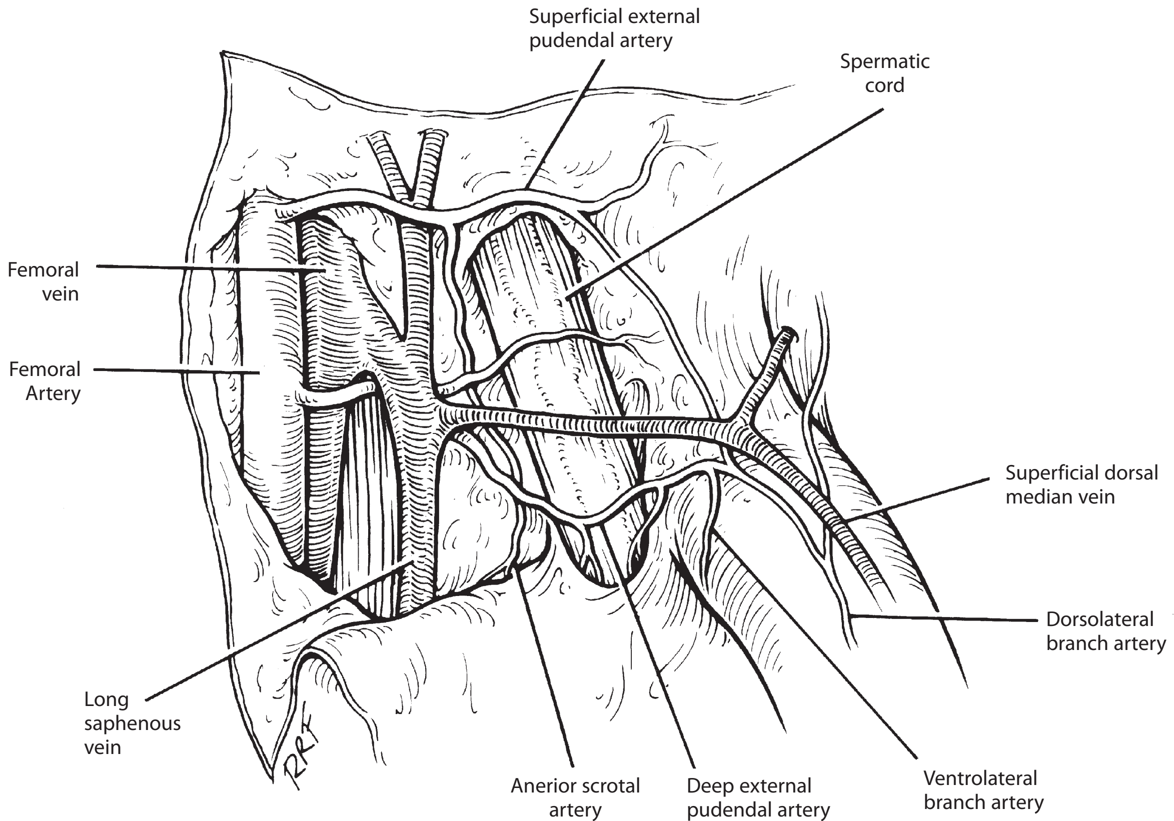

Fig. 3.5. Termination of the superficial dorsal median vein. (From [8])

a rich vascular subcutaneous pedicle nourishing a distal penile or preputial island of skin for urethral reconstruction [4, 5] (Figs. 3.1, 3.3).

There is no easy plane of cleavage between Buck's fascia and the tunica albuginea. Careful dissection is required to raise Buck's fascia off the tunica albuginea to avoid damage to the dorsal neurovascular bundle in operations for Peyronie's disease, venogenic impotence, and curvatures of the penis.

3.9 Deep Arterial System

The deeper structures of the penis and perineum get their arterial blood supply from the internal pudendal arteries. On each side, after exiting from Alcock's canal, the internal pudendal passes forward to the posterolateral corner of the urogenital diaphragm. Here it gives off the perineal artery, which pierces the urogenital diaphragm and deep fascia (Buck's), runs forward in the superficial fascia between the ischiocavernosus and bulbospongiosus muscles, and ends as the posterior scrotal artery (Fig. 3.6).

The internal pudendal next gives off the bulbar artery, which pierces the urogenital diaphragm and bulbospon-

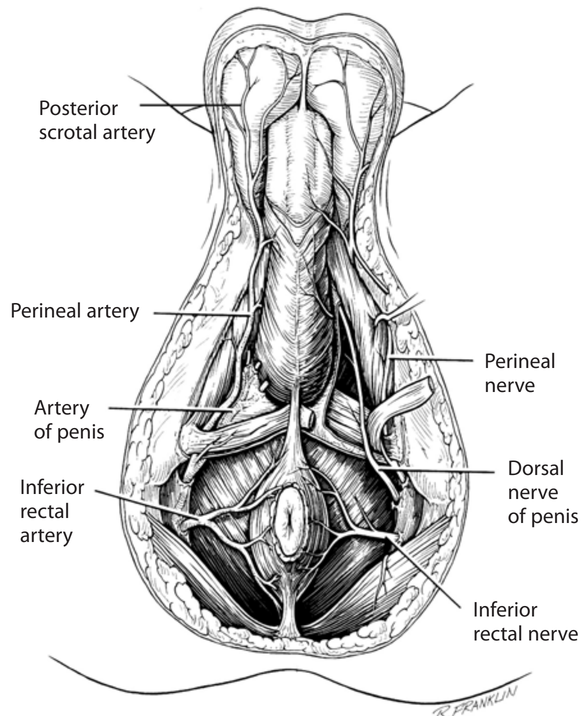

Fig. 3.6. Diagram of perineum illustrating on the left the arterial branches-perineal and posterior scrotal. (From [9])

giosus muscle to enter the base of the bulb, and slightly more distally the urethral artery to enter the bulb close to the bulbar. These two arteries anastomose or may share a common trunk, and continue along the side of the penile urethra to end by anastomosing in the glans with the branches of the dorsal artery (Fig. 3.7).

The internal pudendal artery finally divides into two terminal branches, the cavernosal and dorsal arteries. The cavernosal artery runs along the superomedial aspect of the crus, pierces the tunica albuginea in the hilum of the penis just before the two crura unite, and runs distally in the center of the corpus cavernosum. The dorsal artery continues dorsally in the hilum to gain the dorsum of the corpus cavernosum and runs distally lateral to the deep dorsal median vein and medial to the dorsal nerve. At intervals along the distal two-thirds of the penile shaft, it gives off four to eight circumflex branches, which pass coronally and ventrally round the sides of the penis, giving perforating branches to the tunica albuginea and terminal branches to anastomose with the urethral artery in the corpus spongiosum. The dorsal artery terminates in the glans.

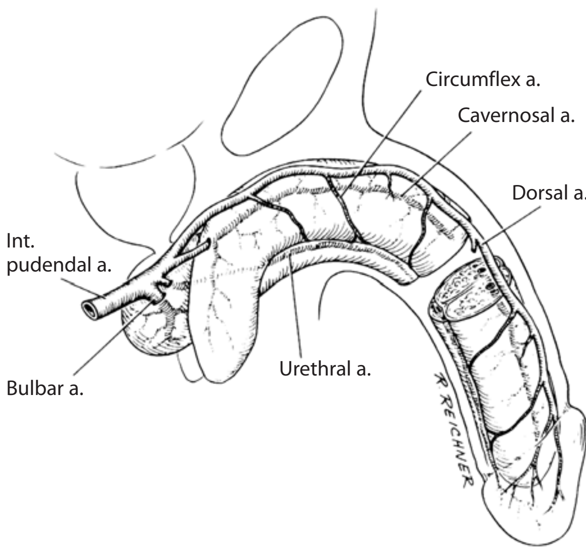

Fig. 3.7. A longitudinal view of the penis showing the deep arterial blood supply. (From [10])

3.10 Intermediate Venous System

Tributaries from the glans penis coalesce to form a retrobalanic venous plexus between the glans and the ends of the corpora cavernosa. From this plexus usually one and occasionally two or more deep dorsal median veins run proximally in the dorsal groove of the corpora cavernosa deep to Buck's fascia. At the base of the penis, where the corpora cavernosa separate into the crura, the vein(s) pass below the symphysis pubis to end in the periprostatic plexus of Santorini. Along the shaft of the penis, it receives the circumflex vein tributaries and direct emissary veins from the corpora cavernosa. Occasionally it receives tributaries from the superficial dorsal median or other superficial communicating veins, or these veins may arise de novo from it.

Emissary veins from the ventrolateral parts of the corpora cavernosa are joined by small tributary veins from the venae comitantes of the urethral arteries to form the circumflex veins, which usually accompany the circumflex arteries. The circumflex veins receive other emissary veins as they pass round the sides of the cavernosa, deep to the dorsal nerves and arteries and join the deep dorsal median vein(s) (Fig. 3.8).

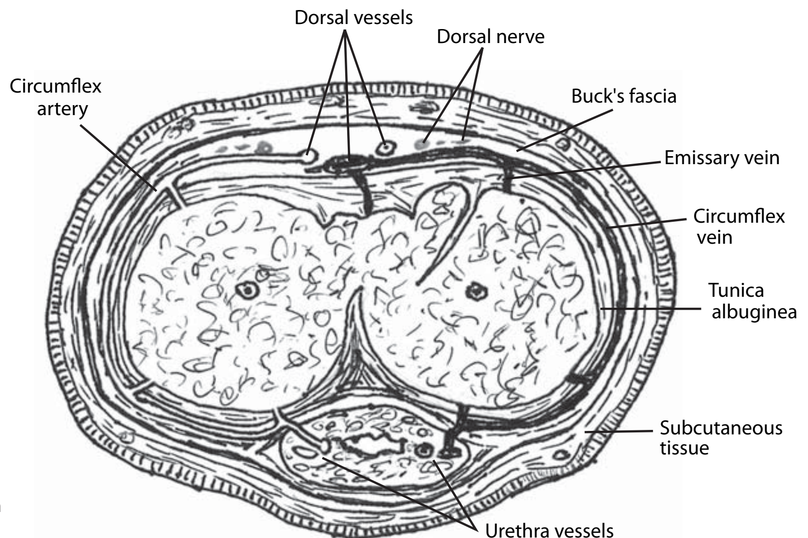

Fig. 3.8. Cross-section of penis showing the dorsal neurovascular structures and disposition of the circumflex artery and vein