Male Perineogenital Anatomy and Clinical Applications in Genital Reconstructions and Male-to-Female Sex Reassignment Surgery

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To determine the possibility of providing alternative surgical techniques for male genital reconstruction and for male-to-female sex reassignment surgery, the authors undertook an anatomic investigation of the perineogenital region in male cadavers. Anatomic dissection was performed on 14 male adult human cadavers (fresh and formalin-preserved) studying the main afferent vessels to the anterior perineal region and their mean internal diameters: deep external pudendal artery (0.60 mm), superficial perineal artery (0.50 mm), and funicular artery (0.37 mm). We established their exact topography, together with vascular anatomic variations, main vascular anastomosis circuits (base of the penis, scrotal septum, and perineal fat and lateral spermatic-scrotal fascia), angiomes, anatomy of the rectovesical septum cavity, and their “critical” key points of dissection. The authors discuss the clinical possibility of elevation of a “tree” of previously described paragenital-genital flaps including mainly those based on the terminal branches of the internal pudendal vascular system, the erectile tissue pedicled flaps, and finally, flaps of the external pudendal system. The authors indicate the concrete vascularization system for each flap. (*Plast. Reconstr. Surg.* 109: 1301, 2002.)

Although gross anatomy is well known through classic treatises, most scientific advances in the field of plastic surgery have come about as a result of investigation in the area of cutaneous vascularization patterns in both human cadavers and clinical practice. This research has resulted in impressive progress and development over the past 100 years, and probably no other surgical specialty has achieved such evolution, creativeness, and perfectionism in so short a period of time as has plastic and reconstructive surgery.

Either as a consequence of the lack of availability of human cadavers for scientific investigation or difficulties secondary to technical approaches in the zones concerned, the genitals and the perineum remain two neglected areas of anatomic study, with a relatively limited number of publications to date, so that further work in this area is necessary.

In 1991, we initiated an anatomic investigation in female cadavers of perineogenital soft tissues. The findings of these studies enabled us to successfully apply new techniques and approaches in vaginal reconstructive surgery,1–4 We have since undertaken a similar investigation in male cadavers, to determine the possibility of providing alternative surgical techniques to those already described for genital reconstruction and for sex reassignment surgery.

The main afferent vessels to the skin of the genitals and the anterior perineal region in the male anatomy are the anterior scrotal arteries, which are direct branches from the femoral vascular system; and the posterior scrotal arteries, which are terminal branches of the superficial perineal vessels from the internal iliac vascular system. In addition, there is another vascular structure which we consider to be relevant in this field, the funicular artery, a pro-
FIG. 1. (Above, left) Deep external pudendal system. (1) Deep external pudendal artery, (2) internal anterior scrotal arteries, (3) external anterior scrotal arteries, (4) superficial cutaneous arteries of the penis, (5) great saphenous vein, (6) superficial external pudendal artery, (7) superficial vein draining the penile shaft, (8) deep dorsal neurovascular pedicles of the penis, (9) aponeurosis of the adductor longus muscle, (10) adductor longus muscle, (11) gracilis muscle, and (12) spermatic cord. (Above, right) Deep external pudendal system with the deep external pudendal arteries crossing over the saphenous hiatus. (1) Deep
imal branch of the inferior deep epigastric artery from the external iliac system.

In this work, we report our experience in a series of human dissections of the perineogenital region in male cadavers. We describe the main vascular trunks arriving at this region, its exact topography and anatomic variations, and the principal anastomotic vascular circuits and their relation with spermatic-scrotal fascias. The internal diameters of these arteries measured by means of image analysis suggested the possibility of elevation of a “tree” of genital flaps based on these vascular axes and their terminal branches for applications in genital reconstructions and male-to-female sex reassignment surgery.

MATERIALS AND METHODS

Anatomic dissection was performed on 14 male adult human cadavers (12 formalin-preserved and two fresh), useful for teaching and investigation, from the Normal and Pathologic Morphology Department, Faculty of Medicine, Málaga University, Spain. External examination of the cadavers revealed no scars or anomalies in the perineal, genital, and inguinal regions. By means of macro-micro dissection, the main afferent and efferent vascular structures to the skin of the genitals and anterior perineal region were identified. We analyzed 16 vascular pedicles (eight right, eight left) of the superficial perineal, deep external pudendal, and funicular arteries, and determined their relation to certain anatomic landmarks, their main vascular anastomosis circuits, and the internal diameters of each artery. In addition, in six cadavers, angiosomes of the main cutaneous arteries of the anterior perineal region were studied, and neurovascular structures of the dorsum of the penis, the vascularization system of the scrotal septum, and the anatomy of the rectovesical septum, with identification of the “critical” key points of dissection of the rectovesical virtual space. Neurovascular structures were dissected bilaterally using magnifying glasses (×3.5), and high-resolution photographs of the origin, distribution, and topography of the vascular structures were taken.

Arteriectomy specimens 1 cm long were harvested from the proximal segment of the main arteries (superficial perineal, deep external pudendal, and funicular) to determine their internal diameters. These arterial specimens were processed and image-system analyzed following the same systematic procedure used previously. The deep external pudendal artery was isolated and cannulated unilaterally in two cadavers, and its corresponding angiosomes were visualized by means of the intraarterial injection of 20 ml of methylene blue, and the stained cutaneous territories were photographed.

RESULTS

Afferent Vessels to the Anterior Perineal Region and their Distribution

In eight anatomic dissections, the unvarying presence of three main vascular axes was determined (Fig. 1) as follows:

1. Deep external pudendal artery, a direct branch of the femoral artery arriving at the anterior perineal region, crossing under the great saphenous hiatus in seven of eight dissections (87.5 percent), and over this venous structure in one case (12.5 percent) in our series. At the spermatic cord the deep external pudendal artery gives off the following:
   a. Internal anterior scrotal arteries crossing...
medially over the spermatic cord and arriving at the base of the penis in a horizontal path from the origin of the deep external pudendal artery to the penile-pubic angle (the terminal branches toward the base and dorsum of the penis, ventral scrotal septum, perineal fat located between the penis and spermatic cord, and the anteromedial spermatic-scrotal fascia).

b. External anterior scrotal arteries extending along the lateral scrotum (the terminal branches nourish the anterolateral spermatic-scrotal fascia and the soft tissues of the inguinocrural regions).

2. Superficial perineal artery, a terminal branch of the internal pudendal artery which superficially to the perineal superficial transverse muscle and the superficial perineal aponeurosis, lateral to the bulbocavernous muscle and 1 to 1.5 cm distant from the middle perineal raphe, gives off branches at the scrotal space between the external spermatic fascia and the tunica dartos. These terminal vessels are as follows:

a. Internal posterior scrotal arteries that course along each side of the middle scrotal raphe (the terminal branches nourishing the dorsal scrotal septum, posteromedial spermatic-scrotal fascia, and the perineal fat).

b. External posterior scrotal arteries (the distal branches nourishing the postero-lateral spermatic-scrotal fascia).

c. Transperineal arteries, originating from the internal posterior scrotal arteries or directly from the superficial perineal artery, crossing transversally over the dorsal surface of the bulbocavernous muscle, establishing vascular interconnections between both superficial perineal pedicles.

3. Funicular artery, a proximal branch of the deep inferior epigastric artery that, crossing below the inguinal ligament, comes to the anterior perineum joined to the surface of the spermatic cord giving off terminal branches to the cord, the base of the penis, perineal fat, and the posteromedial spermatic-scrotal fascia.

Venous Drainage of the Anterior Perineal Region

There are venae comitantes to the three main arterial axes as previously described, although superficial cutaneous venous drainage of the penile shaft may basically either go laterally toward the deep external pudendal venous system or ventrally toward the infraumbilical venous plexus and both superficial inferior epigastric and external pudendal venous systems just over the abdominal Scarpa fascia (Fig. 1).

Vascular Anastomotic Circuits

In all eight specimens studied, three terminal vascular anastomotic zones were identified (Fig. 1) as follows:

1. Base of the penis. This vascular circuit is basically formed by the bilateral confluence of the terminal branches of the internal anterior scrotal arteries, funicular arteries, and internal posterior scrotal arteries. In addition, fine terminal branches of the superficial external pudendal artery often descend toward the penopubic skin fold.

2. Scrotal septum and perineal fat. This circuit is composed of afferent vessels, basically from the internal posterior scrotal arteries, and also by additional blood supply from distal branches of the internal anterior scrotal, transperineal, and funicular arteries.

3. Lateral spermatic-scrotal fascia. Adhered intimally to the external and internal spermatic-scrotal fascias, the internal and external pudendal arterial systems branch off forming, respectively, a dorsal and ventral arborization pattern or a vascular mesh from the proximal to the distal scrotal sac. This anastomotic circuit is well defined and particularly important at the lateral portion of the scrotal sac, and it is basically formed by the anterior and lateral branches of the deep external pudendal artery and the lateral and posterior branches of the superficial perineal artery. This represents an anastomotic circuit between the lateral terminal branches of both pudendal systems, the internal and the external. Secondary musculocutaneous perforants from the medial adductor muscle (lateral femoral circumflex artery) and gracilis muscle (obturator artery) complete this vascular circuit. Both anterior and posterior scrotal arteries are located between the spermatic-scrotal fascias and the dartos muscle of the scrotum (the so-called scrotal space).

Arterial Diameters

Accurate measurement of the internal arterial diameters was accomplished by means of
image-system analysis, obtaining the following average calibers: deep external pudendal artery, 0.60 mm; superficial perineal artery, 0.50 mm; and funicular artery, 0.37 mm. In all eight specimens, the results on both right and left sides were homogeneous.

Vascular Injection Studies

Cannulation of the deep external pudendal artery at its origin from the femoral artery was carried out in two fresh cadavers, and 20 ml of methylene blue was injected to visualize the stained cutaneous pattern and the potential extension of its angiosome (Fig. 2).

Penile Shaft Cutaneous Blood Supply

The previously described vascular circuit around the base of the penis was identified and dissected in eight cadavers (Figs. 1 and 2). This circuit is basically responsible for the nourishing system of the penile cutaneous coverage, with additional fine dorsal afferent vessels from the terminal branches of the superficial external pudendal artery. The vessels coming from proximally (base) to distally (foreskin), are located in the areolar connective tissue (superficial penile fascia) under the dartos and the penile skin; the venous system is located superficially with respect to the superficial cutaneous arteries of the penis (terminal branches of the internal anterior scrotal arteries), basically paired on the dorsal skin with further fine branches coming to the lateral and ventral cutaneous coverage of the penis.

Lateral Scrotal-Perineal Paired Flaps

The wall of the scrotum is composed of the following layers, starting at the surface: skin, dartos, external spermatic fascia, cremaster, internal spermatic fascia, and vaginal (Fig. 2). The vascular and topographic study of the soft tissues of the anterior perineal region in the male cadavers suggested the possibility of elevation of lateral scrotal-perineal paired flaps, posteriorly pedicled and connected to the superficial perineal neurovascular pedicle—running along the penis beneath Buck’s fascia and over the albuginea of the corpora cavernosa. The deep dorsal venous system is composed of a unique vein in the middle of the penile dorsum between both corpora cavernosa bodies, although this vessel may divide proximally at the decussation of the crura and also give off one or two perforants with the superficial suprapubic venous plexus. In most specimens, the neurovascular structures on the dorsum of the penis are located according to the palindrome “NAVAN” (nerve-artery-vein-artery-nerve).

Finally, the deep dorsal arteries of the penis give off short perforants that pierce the albuginea and bilateral lateral branches, which form a deep vascular circuit around the penis. The dorsal nerves run over these circumflex vessels from proximal to distal.
FIG. 2. (Above, left) Intraarterial injection (methylene blue) of the deep external pudendal artery showing the angiosome that can potentially be captured by flaps based on the terminal branches of the internal pudendal vessels. (Above, right) The skin of lateral scrotal-perineal fasciocutaneous flaps has been removed, showing the lateral scrotal-spermatic fascias, the lateral anastomotic circuit, and the anterior extension of these flaps. (Center, left) In a fresh cadaver, the deep dorsal neurovascular pedicles of the penis have been dissected, opening Buck’s fascia to show the anatomic disposition following the palindrome “NAVAN” (nerve-artery-vein-artery-nerve). (Center, right) A neurovascular island flap of the glans penis has been elevated, skeletonizing the
Rectovesical Space

Midline sagittal sections of the whole pelvis in two male cadavers were carried out to study the length of this virtual cavity, and the “critical” key points of dissection of the rectovesical space (Fig. 2). The mean distance from the perineal skin to the peritoneal inferior reflection (Douglas pouch) was 11.5 cm, addition of further length by means of blunt digital dissection being difficult. The key point for adequate opening of this space, without risking perforation of the urethra and/or the rectum, is careful sharp dissection of the rectourethral muscle. This structure is formed of dense fibromuscular tissue closely adhering the membranous urethra to the anterior convexity of the rectum ampule, and it is found behind the corpus spongiosum 4 to 5 cm deep with respect to the perineal skin. Surgical division of this fibromuscular structure requires sharp dissection with fine scissors once the two lateral rectal spaces have been dissected easily by means of blunt digital dissection.

DISCUSSION

The anatomy of the perineum and the genital has been well described in classic treatises, although recent studies of its cutaneous vascularization system have been decisive for enhancement of genital reconstructive surgery. However, there has been very little scientific investigation concerning the exact topographic anatomy of the main afferent and efferent vessels of the perineogenital skin, together with their corresponding clinical applications in the field of surgery.

Although many useful genital and paragenital flaps have been described over the years by authors who have focused their efforts on this interesting and challenging area, from time to time reconstructions are reported using new genital flaps based on different terminal vessels of the main vascular systems afferent to the genitoperineal region. During the past two decades, the internal pudendal artery and its terminal branches have possibly been the most frequent objects of investigation, and many different perineal axial flaps have been used for reconstruction of congenital malformations, for acquired genital defects, and for sex reassignment surgery.

In female patients, and as far as we are aware, Morton et al.⁵ in 1986 were the first to use labioscrotal fasciocutaneous flaps based on the superficial perineal artery for treatment of severe vaginal stenosis in two patients with adrenogenital syndrome. Hagerty et al.⁶,⁷ used similar triangular flaps for acquired vaginal defects. Wee and Joseph⁸ in 1989 described the “Singapore flap” or neurovascular pudendal-thigh flap for complete vaginal reconstruction, and Woods et al.⁹ in 1992 used the “modified Singapore flap” for complex postoncologic reconstructions. Giraldo et al.¹⁰ described the “Málaga flap” or vulvar perineal fasciocutaneous flap for reconstruction of neovaginas in the Mayer-Rokitansky-Kuster-Hauser syndrome. Further experience has been accumulated by others who have achieved satisfactory outcomes with flaps based on the superficial perineal artery.

In male patients, the terminal vessels of the internal pudendal vascular system have also been used for genital reconstructions, basically for coverage of acquired perineogenital defects and sex reassignment surgery in male-to-female transsexuals. Since the initial description of Jones et al.¹⁰ in 1968, many others have used the posterior scrotal flap for vaginoplasty in male-to-female transsexuals. Huang¹¹ in 1995 used two neurovascular inguinopudendal flaps combined with a penile skin flap for vaginopasty in male-to-female transsexuals. Karim et al.¹² and Hage¹³ reported a very large and successful series of vaginoplasties in male transsexuals, adding to the anteriorly based penile cutaneous flap a triangular perineoscrotal middle flap (5 × 10 cm) to complete the posterior neovaginal wall. Knol and Hage¹⁴ in 1997 published the infragluteal skin flap, based on the anterior perineum, for reconstruction of rec-

neurovascular structures. (1) Transversal section of the penis at the bifurcation of the corpora cavernosa, (2) corpora cavernosa, and (3) corpus spongiosum. (Below, left) Sagital section of a pelvis in a male cadaver. (1) Penis with corpora cavernosa and albuginea, (2) corpus spongiosum or bulb of penis, (3) scrotal septum, (4) anal canal, (5) rectum, (6) prostate, (7) urinary bladder, (8) pubic symphysis, (9) retropubic space with venous plexus, and (10) sigmoid colon. (Below, right) Close-up view of the key points of dissection of the rectovesical space. (1) Corpus spongiosum, (2) rectum, (3) urogenital diaphragm with membranous urethra, (4) rectourethral muscle, (5) anterior wall of the rectum, (6) Denovilliers aponeurosis, (7) rectovesical space, (8) Douglas pouch, (9) prostatic urethra, (10) urinary bladder, (11) interpubic disc, and (12) retropubic space showing section of the deep dorsal vein of the penis and the prostatic vascular plexus.
tovaginal fistulas in female patients and male-to-female transsexuals.

As a result of our anatomic study of the cutaneous angiosomes of the anterior perineal region in human male cadavers, we consider the following clinical applications to be of interest:

**Flaps Based on the Internal Pudendal System**

1. Cutaneous and fasciocutaneous flaps.
   a. Scrotal flaps based on both superficial perineal arteries. Internal and external posterior scrotal arteries are final divisions of the superficial perineal artery and these terminal vessels nourish the internal pudendal cutaneous angiosome, which is integrated basically by the posterior half of the scrotum and the adjacent crural skin. A centrally pedicled or island scrotal sensate flap as large as 5 cm wide by 10 to 12 cm long includes the superficial perineal artery together with its internal and external posterior scrotal arteries and complementary vascularization from the superficial perineal transverse artery, which runs along the central perineum between the anus and the perineum-scrotum; this is the vascular anatomic basis of the biaxial scrotal flaps of Jones, Small, Eldh, and Van Noort and Nicolai. Finally, the cutaneous shaft of the penis can be included in continuity with the posteriorly pedicled scrotal sensate flap, as described by Edgerton and Bull for vaginoplasty in sex reassignment surgery, the vascular circuit at the base of the penis being responsible for its reliable distal perfusion.

   b. Scrotal-perineal flaps based on the internal posterior scrotal arteries. Anatomically and clinically, we have gathered evidence of the possibility of elevation of scrotal-perineal flaps including the scrotal skin, darts, and both spermatic and perineal fascias proximally, and the scrotal-inguinal skin and the aponeuroses of the gracilis and medial adductor muscles distally. The main vascular system is the external posterior scrotal and the perineal superficial transverse arteries. Thus, this is an axial flap, at least in its posterior two-thirds, whereas the circulation at its distal third is guaranteed by the “choke” anastomoses between the internal and external pudendal angiosomes. These flaps retain sensation at their proximal segments.

   c. Paraperineal flaps based on the external superficial transverse and inferior rectal arteries. Flaps mainly nourished by these lateral vessels branching off the internal pudendal artery have in common the fact that they include at their base the soft tissues of the central perineum. Examples include the “lowermost” lotus petal flap described by Yi and Niranjan in 1996, and the similar infragluteal skin flap described by Knol and Hage in 1997. Only the base of this flap is sensate.

2. Erectile tissue pedicled or island flaps.
   a. Dorsally pedicled sensory island flap of the glans penis. This is a sensate and erectile flap nourished and innervated by the terminal branches of the internal pudendal artery, the dorsal neurovascular pedicles of the penis. This is a well-known flap described initially by Hinderer in 1974 for neoclitoral reconstructions in the adrenogenital syndrome, and later used by Brown for neoclitoroplasty in male-to-female transsexuals. It is recognized today as the best choice for neoclitoroplasty and the “gold standard” against which other procedures are compared.

   b. Pedicled urethrobulbar flaps. These flaps include the whole urethra, with or without the glans, and are vascularized by the bulbar arteries, which are the first branches of the common penile artery at the penile hilum and penetrate the corpus spongio-
sum at the 2-o’clock and 10-o’clock positions, according to the fine anatomic study of Martinez-Pineiro et al. A tubular urethra and corpus spongiosum design with the glans anchored at its distal apex has been used for neoclotoroplasty and a dorsally spatulated ureterobulbar flap with the ventral glans anchored at its distal part for neovaginoplasty with a “pseudocervix” in male-to-female transsexuals.

Flaps of the External Pudendal System

Dorsally pedicled penile skin flap. This is an axial flap basically nourished by the internal anterior scrotal arteries, terminal branches of the deep external pudendal artery. Additional vascularization comes from the terminal vessels of the posterior scrotal arteries and fine terminal branches of the funicular artery. Therefore, this tubular cutaneous flap, either ventrally or dorsally pedicled, has a robust and secure vascularization formed by distal anastomoses (at the base of the penis) of three different vascular systems: deep and superficial external pudendal, internal pudendal, and deep inferior epigastric arteries.

When an abdominally pedicled penile shaft flap is used in transsexual surgery, to achieve maximum neovaginal depth we need a posterior advancement of this flap from the supra-pubic skin to the cavernosa stumps, anchored with two stitches, placed 2 cm ventrally of the penopubic angle, to prevent vascularization problems derived from trapping of the afferent vessels of the penile shaft flap. For many good reasons, this is the most frequently used flap and the gold standard for neovaginal reconstruction in male-to-female transsexuals. Our anatomic study of the anterior perineal region in male cadavers provides an approximation to the accurate knowledge of the vascular basis of the perineogenital skin that may allow easier understanding and reliable design and management of flaps in genital reconstructions and in sex reassignment surgery.

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REFERENCES