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Review Article

Sulcus nervi dorsalis penis/clitoridis: anatomical and clinical implications

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ABSTRACT

Sulcus nervi dorsalis penis/clitoridis is a distinct groove located on the inferior ramus of pubis and ventral surface of the body of pubis. In male, it accomodates the dorsal nerve of penis whereas in female the dorsal nerve and artery of clitoris. Close relation of dorsal nerve of penis/clitoris and pubis, represented by the course of sulcus nervi dorsalis penis/clitoridis has a major impact in surgical disciplines. Exact preparation of the dorsal nerve of penis is crucial in correct performance of conversion of genitalia in patients with transsexualism, in reconstruction of posterior urethra, in hypospadia, during performance of penile blocade during circumcision and in revascularization surgery of erectile dysfunction.

The role of sulcus nervi dorsalis penis in the Alcock's syndrome is discussed. Similarly, it is advisable to take care of the dorsal nerve of clitoris inside sulcus nervi dorsalis clitoridis during reduction clitoridoplasty in patients with adrenogenital syndrome and during the insertion of transobturator vaginal tape. Injury of dorsal nerve of penis/clitoris leads to hypestesia or anestesia of glans penis/clitoridis. The injury of dorsal artery of clitoris leads to hematoma.

It is possible to use sulcus nervi dorsalis penis/clitoridis for sexing of isolated pubis for antropological or forensic purposes. Lateral border of sulcus nervi dorsalis penis corresponds to vertical ridge and lateral border of sulcus nervi dorsalis clitoridis to ventral arc – two parameters, which are parts of the Phenice's method for sexing of isolated pubic bones. ***Neuroanatomy; 2007; 6: 58–62.***

Key words [dorsal nerve of penis] [dorsal nerve of clitoris] [pubis] [ventral arc] [vertical ridge] [sex determination] [Alcock's syndrome]

Introduction

Sulcus nervi dorsalis penis/clitoridis is a distinct groove located on the inferior ramus of pubis and ventral surface of the body of pubis. In male, it accomodates the dorsal nerve of penis whereas in female the dorsal nerve and artery of clitoris. Close relation of dorsal nerve of penis/clitoris and pubis, represented by the course of sulcus nervi dorsalis penis/clitoridis has a major impact in surgical disciplines. Exact preparation of the dorsal nerve of penis is crucial in correct performance of conversion of genitalia in patients with transsexualism, in reconstruction of posterior urethra, in hypospadia, during performance of penile blocade during circumcision and in revascularization surgery of erectile dysfunction.

Dorsal nerve of penis

Dorsal nerve of penis is crucial for normal erectile and ejaculatory function. In addition, it serves as an afferent branch of the bulbocavernous reflex [1,2]. It originates from the pudendal nerve at the inferior part of greater sciatic foramen and accompanies the internal pudendal artery, vein and other branches of pudendal nerve into the pudendal canal on the lateral wall of the ischiorectal fossa [3]. It courses anteriorly along ischial ramus and medial margin of inferior pubic ramus, deep to inferior fascia of urogenital diaphragm. First, it runs in a close proximity to inferior ramus of pubis, then adjacent to inferior margin and anterior surface of the pubic body. At the apex of urogenital diaphragm, the dorsal nerve of penis courses via the subpubic space into the hiatus between diaphragm and inferior pubic ligament [4,5]. At the ventrocaudal margin of pubis, dorsal nerve runs in close proximity to the insertion of the crus of penis and further between crus and ventral surface of the pubic body to the penile dorsum. Here the dorsal nerve branches to supply the body and glans of penis [1].

Dorsal nerve of clitoris

The female counterpart of the dorsal nerve of penis, the dorsal nerve of clitoris, is crucial for normal function of clitoris [6]. It takes similar course but is thinner and shorter. In addition, the relation of the dorsal artery of clitoris and the caudal half of the ventral surface of pubic body differs from male – the dorsal artery of clitoris runs in a close proximity to the bone. In ischirectal fossa and close to inferior ramus of pubis, the artery is located similarly as in male; at the inferior margin of pubic body it but crosses the dorsal nerve of clitoris and gets medially to the nerve. On the ventral surface of the pubic body, both dorsal nerve and artery run adjacent to each other, in a close proximity to the bone [7,8].

Sulcus nervi dorsalis penis

On the inferior ramus of pubis and ventrocaudal surface of pubic body, the dorsal nerve of penis runs in a distinct groove which we previously termed 'sulcus nervi dorsalis penis' [7,9–11]. Dorsal artery of penis and veins of the subpubic space run ventrolateral to sulcus [7,10]. Mean length of the sulcus nervi dorsalis penis on the inferior ramus of the pubis is 15.8 mm, mean length on the

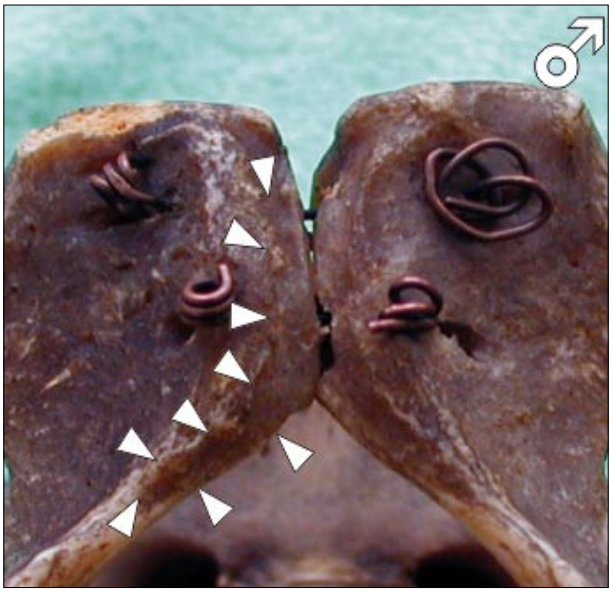

Figure 1. Sulcus nervi dorsalis penis from the anterior view. Its borders are outlined by arrowheads. Color version of figure is available online.

Figure 2. Sulcus nervi dorsalis clitoridis from the anterior view. Its borders are outlined by arrowheads. Note that the vertical (medial) part is much wider than in the sulcus nervi dorsalis penis. Color version of figure is available online.

anterior surface of pubis is 21.3 mm. Thus, the part of the dorsal nerve which runs in a close proximity to the pubic bone is approximately 37 mm long. The depth of the sulcus varies between 0 and 2 mm. It is present in 72% of male pubic bones. The superior end of the sulcus on the pubic body corresponds to the site where the dorsal nerve of penis curves anteriorly and enter the dorsum of the penis [7,9–11].

Sulcus nervi dorsalis clitoridis

Dorsal artery of clitoris runs medially to the dorsal nerve of clitoris and accompany it along the anterior surface the pubic body, which is the main reason for significantly wider sulcus nervi dorsalis clitoridis in comparison with sulcus nervi dorsalis penis. The crossing site of the dorsal artery and nerve of clitoris is close to the inferior border of pubic body [7,9]. Sulcus nervi dorsalis clitoridis is present on 83% of female pubic bones. It runs similarly as the sulcus nervi dorsalis penis in male. Its mean length on the inferior ramus of pubis is of 0.8 mm longer than in male. The part of sulcus on the anterior surface of the pubic body is significantly wider; mean mediolateral width is 2.4 mm, which corresponds to 132% of its male counterpart, due to the course of dorsal artery of clitoris. The length of sulcus, expressed as a percentage of the symphyseal length (57%) is comparable with the male counterpart [7,9,12].

Sulcus nervi dorsalis penis and Alcock's syndrome

Pudendal nerve compression syndrome, also known as "Alcock's syndrome", has been described in bicycle riders as prolonged irritation of pudendal nerve resulting in decreased glandular and penile sensitivity, and in erectile dysfunction [13–16]. Direct pressure of the nose of the saddle against the perineum and the symphysis, further provoked by the forward leaning of the cyclist, pinches the pudendal nerves at the point where they emerge below the pubis [17,18]. Although it has been characterized as resulting from a compression of pudendal nerve in pudendal canal, several authors [19–21] speculated that the source of one subtype of this syndrome might also be a compression of the nerve on the inferior border of pubis. Recently Hruby et al [5] speculated that the site of origin of Alcock's syndrome might be the lower margin of pubic body and additionally described a performed osteofibrotic tunnel, demarked by inferior ramus of pubis, suspensory ligament and crus of penis. Our studies of the sulcus nervi dorsalis penis/clitoridis supported this assertion [7,9,10], so we had consequently formulated a hypothesis of compression of dorsal nerve of penis in sulcus nervi dorsalis penis on the inferior margin of pubic body as a causation of Alcock's syndrome [22].

The pudendal canal is covered by a thicker mass of fat than the inferior border of body of pubis, which would protect the nerve. In addition, if compression occurs in the pudendal canal, irritation/damage of pudendal artery and vein might be expected. However, hematoma or other signs of vessel damage are not symptoms of Alcock's syndrome. Whereas hypesthesia or anesthesia are major signs of Alcock's syndrome, there are no reports of paresis of the bulbocavernosus muscle. It is innervated by another branch of pudendal nerve, the perineal nerve, that passes through Alcock's canal. Immediately after leaving the canal, the perineal nerve enters the bulbocavernosus muscle, where it passes between ischiocavernosus and bulbocavernosus muscle [2]. Thus, dorsal nerve of penis in sulcus nervi dorsalis penis is clearly sensory [1,2]. This observation further supports the hypothesis that Alcock's syndrome is caused by irritation of dorsal nerve of penis in sulcus nervi dorsalis penis on the inferior border of body of pubis [22].

Other pudendal nerve entrapment syndromes

Pudendal nerve entrapments before the entrance or inside the pudendal canal are sources of intractable perineal pain and variety of motor perineal disturbances [3,23–26]. Their causes differ from the typical ones of Alcock's syndrome; their origin is related to other causes like previous surgeries, deliveries, chronical obstipation, extreme sports activities or trauma [24–26]. Desensitization of penile dorsum and erectile dysfunction have not been described in these cases; thus, we hypothesize that the perineal and inferior rectal nerves are affected during their course in the inferior half of the pudendal canal and not by compression of the dorsal nerve in the sulcus of the pubic bone [22].

Sulcus nervi dorsalis penis in transsexuals

Preservation of the innervation to the glans tailored to neoclitoris and correct surgical fixation of dorsal nerve of penis are crucial in male-to-female gender reassignment in transsexuals. Meticulous dissection of the dorsal neurovascular bundle is required to gently liberate the bundle from the glans proximally. The dissection may be more difficult in cases with a deep intercrural groove in its proximal end. Surgical resection of crura of cavernous bodies must be complete because remnants can form a barrier that causes problems during intercourse. Hemostatic sutures are then located in close vicinity to inferior ramus of pubis, proximal to the course of pudendal nerve and care must be taken not to put a suture around or through the nerve. Damage of the nerves and vessels can lead to necrosis or numbing of the neoclitoris thereby blocking orgasm, a condition typical in male to female transsexuals. To prevent an uncontrolled course of the neurovascular bundle, it is suitable to fix it into the soft tissues above the symphysis [27–29].

Other clinical aspects of sulcus nervi dorsalis penis

Detailed kowledge of the course of dorsal nerve and artery of penis is crucial for planning and correct performance of number of surgical approaches. During the reconstruction of posterior urethra, the surgeon operates near the dorsal nerve, which can thus be damaged or cut [30]. During the hypospadia correction, the dorsal plication and mobilization of neurovascular bundle is performed [4,31]. The course of the dorsal nerve of penis should be considered during the penile nerve block before the performance of circumcision [32]. Unsuccessful performance of this type of anesthesia might cause a sensorial disturbances and complicate the future sexual life of the patient [33,34]. During the revascularization surgery of erectile dysfunction, the surgeon also operates in the region of sulcus nervi dorsalis penis and can thus damage the nerve [35]. During radical prostatic or urinary bladder surgery, the neurovascular supply can also be directly or indirectly damaged and immediate or delayed clinically significant erectile dysfunction might develop [36].

Clinical aspects of sulcus nervi dorsalis clitoridis

The knowledge of topographical relations of dorsal nerve of clitoris is crucial in reconstructive surgery of lower parts of female genitourinary system. For example, the reduction clitoridoplasty in girls with adrenogenital syndrome where mobilization and sparing of neurovascular bundle is performed, requires the ligation of cavernous bodies in a close proximity to the dorsal nerve of clitoridis running in the sulcus nervi dorsalis clitoridis [6,8,34]. Other examples include the insertion of transobturator suburethral vaginal tape for surgical treatment of female stress incontinence [37–39] or mobilization and separation of common sinus into the urethra and vagina in the surgical treatment of congenital urogenital sinus anomalies [4]. The damage of the dorsal nerve of clitoris during these surgical approaches might cause complete insensitivity of clitoris, which leads to lower satisfaction during intercourse, whereas damage of dorsal artery of clitoris might cause peropeative bleeding and/or postoperative hematoma.

Clinical aspects of sulcus nervi dorsalis penis/clitoridis in both sexes

It is important to avoid the damage of dorsal nerve and artery of penis/clitoridis during the reposition of pelvic fractures, surgical treatment of urethral distraction defects originating from lower pubectomy or the re-routing of urethra [40].

Sexual dimorphism of sulcus nervi dorsalis penis/clitoridis

Analysis of mineralized tissues is a cornerstone of anthropology and forensics. In this context, the pelvis is generally accepted as the region of skeleton that best allows determination of sex [41–45]. The rate of accuracy of sex determination using the entire pelvis is reported to range between 88-97% [41,46,47]. However, the entire pelvis may not always be preserved for analysis of skeletal remains. Consequently, several studies have focused on the pubic bone for gender determination [48–50].

For the sexing of isolated pubic bone for the forensic and antropological purposes, the Phenice's method, named after its founder, TW Phenice, is most frequently used since the year 1969 [41,48,49]. This method includes analysis of the ventral arc in female and the vertical ridge in male, two characteristics, which are considered as the fundamental parts of the method [48,49,51]. The accuracy of sex determination by this technique is estimated to range between 59-96 % [48,49,51–54] or even greater when used in combination with other methods [55].

On the anterior surface of pubis, Phenice described the ventral arc in female as 'a slightly elevated ridge of bone that extends from the pubic crest and arcs inferiorly across the ventral surface to the lateral extension of the subpubic concavity where it blends with the medial border of the ischiopubic ramus' [48]. In our study, we assumed that this feature, often used in sexing of the isolated pubis [41,49] corresponds to the lateral border of the sulcus nervi dorsalis clitoridis [7,10,12]. Similarly, 'ventral ridge' in male, described by Phenice as 'similar ridge, but this should never be confused with the ventral arc fi proper observation is carried out… either it will extend from the pubic crest or pubic tubercle infero-medially to the inferior margin of the pubic symphysis, or it will extend to from the pubic crest inferiorly, parallel to the medial border of the pubis, to a point superior and lateral to the subpubic angle where it too forms an angle and extends

for some distance along the ischiopubic ramus parallel to its medial border.' corresponds to the lateral border of the sulcus nervi dorsalis penis [48]. Moreover, Phenice stated, that on the ishio-pubic ramus, there is a 'sharp ridge' in females, although it is 'flat' in males [48]. We assumed that this 'sharp ridge' is the ventrolateral border of the sulcus nervi dorsalis penis/clitoridis [7,10,12]. Morphological characteristics of ventral arc/vertical ridge are probably determined by different widths of the sulcus nervi dorsalis penis/clitoridis and the shape of the subpubic concavity as a consequence of different developmental bases of pubis in males and females [12].

Study of Budinoff and Tague hypothesized that ventral arc morphology coincides with the elongation of pubis in females and more 'lateral placement' of ventral arc in females [56]. They define 'lateral placement' as 'a minimum distance between the ventral arc/vertical ridge and the inferior border of the symphyseal face of the pubis' [56]. Our study supports these findings and concludes that different shape of the subpubic concavity and different 'lateral placement' of the ventral arc/vertical ridge result in different morphological characteristics of the sulcus in males and females [7,10,12].

Commentaries on the anatomical basis of the ventral arc have been few. Phenice, as well as his followers, focused on antropological and forensic aspects of the ventral arc and the vertical ridge and did no anatomical study [41,48,49]. Several speculations and partial descriptions have been made as reviewed in Introduction of paper by Budinoff and Tague [56]. In fact, only two studies systematically analyzed developmental and anatomical relations of the ventral arc/vertical ridge. Budinoff and Tague studied this problem extensively and found that the ventral arc/vertical ridge is an insertion site of tendons of the adductor brevis and the gracilis and fibers of the ventral pubic ligament [56], Anderson revealed developmental basis of these attachments [57]. These results are indirectly supported by study of Sutherland and Suchey [49], who found that precursor of the ventral arc appears in about 20 years of age and the definite modal ventral arc appears in about 23 years of age. Thus, in female, the definite modal ventral arc and its lateral placement present a consequences of changes of the site of osseous attachment of the adductor brevis and the gracilis during the hormone-dependent pubic elongation in puberty [56,57], while in male, the presence of the vertical ridge is probably associated with an entesopathic changes [56,57].

Different characteristics of sulcus nervi dorsalis penis and sulcus nervi dorsalis clitoridis enable their use in sexing of isolated pubic bones. Their sexual dimorphism is based on different course of nerves and vessels in sulci, different width of sulci and different shape of the subpubic concavity in male and female. Our results indicate it is possible to identify 88% of male and 83% of female pubic bones when using discriminant function analysis of seven parameters of pubis [7,10,12]. The most important parameters are the width of sulcus and craniocaudal length of symphysis [10,12]. Since the method for sexing of pubis using the sulcus nervi dorsalis penis/clitoridis is comparable with the Phenice's method, it would be interesting to merge both methods in future and develop a comprehensive system for sexing of isolated pubis.

Conclusions

Sulcus nervi dorsalis penis accomodates dorsal nerve of penis, sulcus nervi dorsalis clitoridis accomodates dorsal artery and nerve of penis. Sulcus nervi dorsalis penis might play a role in the development of Alcock's syndrome. Clinical anatomy of sulci is important in several situations in urologic surgery such as the conversion of genitalia in transsexuals, penile nerve block for the circumcision or insertion of transobturator suburethral vaginal tape for the treatment of female stress urinary incontinence. It is possible to use sulcus nervi dorsalis penis/clitoridis for sexing of isolated pubic bones for the forensic and antropological purposes, using the discriminant function analysis of seven parameters of pubis, where width of the sulcus and craniocaudal length of symphysis are the most important ones.

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