Sling surgery for stress urinary incontinence; the perfect solution?

Hogewoning, C.R.C.

Author: Hogewoning, C.R.C.
Title: Sling surgery for stress urinary incontinence: the perfect solution?
Issue Date: 2017-05-10

The somatic and autonomic innervation of the clitoris; preliminary evidence of sexual dysfunction after minimally invasive slings

Cornelis R. C. Hogewoning[1]*
Milou D. Bekker[1]*
Chris Wallner[2,3]
Henk W. Elzevier[1]
Marco C. De Ruiter[4]

** Both authors attributed equally to the manuscript*

1. *Department of Urology, Leiden University Medical Center*
2. *Department of Anatomy, Embryology and Physiology, Academic Medical Center*
3. *Nursing, Academy of Health, The Hague University of Applied Sciences*
4. *Department of Anatomy and Embryology, Leiden University Medical Center*

(Journal of Sexual Medicine (2012 Jun);9(6):1566–1578)

7

Introduction

Within a decade, the mid-urethral (vaginal) slings (MUS) became the most popular surgical treatment for stress urinary incontinence (SUI), with more than one million women treated (1). Despite the numerous studies on objective and subjective outcomes of this minimally invasive procedure, very few studies have addressed the impact of vaginal sling procedures on sexuality. Small series evaluating the sexual wellbeing before and after the tension-free vaginal tape (TVT), the in-out trans-obturator (tension-free vaginal tape-obturator (TVT-O)), and/or the out-in trans-obturator (trans-obturator tape (TOT)) procedures show conflicting results. Of these studies, some suggest deterioration (2-7) of sexual function, some improvement (2-4;8-11), whereas others were equivocal (12-16). A prognostic factor in the improvement of the sexual functioning of these patients is the cure of incontinence during intercourse (17;18). Negative effect on sexuality is hypothesized to be related to the implanted material because of the damage to important vascular and/or neural genital structures (2-7). Another interesting theory is that through movement of the clitoris during intercourse, incontinence tapes could also lead to an altered sexual function without initial nerve damage (19).

The clitoris plays an important role in achieving female orgasm by sexual stimuli (20). It is innervated by the dorsal nerves of the clitoris (DNC). These peripheral sensory afferents of the clitoris originate from the pudendal nerve (PN). The clitoris is also innervated with fibers coming from the autonomic pelvic plexus (also known as the inferior hypogastric plexus (IHP)): the cavernous nerves of the clitoris (CN). Clitoral and labial swelling during sexual arousal is associated with parasympathetic vasodilator mechanisms, among which nitric oxide (NO) appears to be a primary neurotransmitter contributing to the mediation of this function (21-23). NO control of vasodilatation and neuronal signalling between the cavernous nerves and the DNC contribute to the engorgement and subsidence of clitoral tissue. This supports the initiation of sexual arousal by tactile stimuli of the clitoris (24;25). Therefore, in theory, injury to the clitoris and/or its innervation, both somatic and autonomic, could lead to altered sexual function.

To investigate the anatomical relation of vaginal slings to important neurogenital structures, basic knowledge about and detailed descriptions of the neuroanatomy of the clitoris are needed. Research has demonstrated the integral relationship between the clitoris, distal urethra, and vagina (23;26-28). O'Connell et al. provided a major contribution to the research on the anatomy of the clitoris (26;29). They found the erectile tissue of the clitoris to be intimately related to the distal urethra, which leads them to suggest a role of the urethra in sexual function (26). The DNC was described in detail; the autonomic nerves, however, were poorly addressed.

In the research conducted by Moszkowicz et al. (23), the autonomic neural pathway as well as the DNC were described in detail in female fetuses. Although this research

did not link its results directly to medical practice, it is still very illustrative for a deeper understanding of the clitoral neural anatomy.
Disruption of the somatic innervation of the clitoris can lead to a diminished sensibility of the clitoris, thereby affecting sexual arousal due to the absence of tactile stimuli. The DNC is located along the medial aspect of the inferior pubic ramus (IPR) where it runs along the pubic bone in a sulcus; described as the sulcus nervi dorsalis clitoridis (30).
Risk of injury to the DNC along the IPR has been suggested by Delorme with the medial to lateral passage of the needle which is used for placing vaginal slings. This injury could then alter postoperative sexual function such as arousal, orgasmic function, or pain (31). This possible risk has been illustrated by Lowenstein, showing the topographic relation of MUS for SUI to critical female genital structures (32). In a cadaveric study, performed by Achtari et al., the potential risks of three vaginal slings to the DNC were evaluated. Distances of a TVT, in-out trans-obturator (TVT-O), and out-in trans-obturator (Monarc) to the DNC were similar (11–12 mm) (33). Given the outside-inside course, the Monarc was claimed to (theoretically) be the safest device. Another cadaveric study found similar results, although they only documented the course of the DNC from the piercing of the perineal membrane to its terminal branching and not its course along the IPR (34).
The CN are involved in the neural control of vasocongestion and, consequently, the lubrication swelling response. Disruption of these nerves could lead to altered vascular function during sexual arousal and possibly disordered orgasm. However, although important for normal sexual function, in aforementioned studies, no attention was paid to the possible effects of disruption of the CN (23;32-34).
The aim of this study was to reinvestigate the neuroanatomy of the clitoris by performing dissection in 14 adult female hemipelves and by using (immuno)histochemical and three-dimensional (3-D) reconstruction techniques on sectioned female fetuses. In this study, we focus on: (i) the autonomic innervation of the clitoris; (ii) the course of the DNC; and (iii) the investigation of the anatomical sites of potential nerve damage during vaginal sling surgery for SUI.

Methods

Fetal 3-D Reconstruction

Fetal pelves from the collections in the departments of Anatomy and Embryology at the Leiden University Medical Center and at the Amsterdam Medical Center were studied. Eleven paraffin-embedded fetuses (all female), ranging from 10 to 27 weeks of gestation, 6–26 mm crown-rump length, were serially sectioned. Six were stained with hematoxylin and eosin, three with hematoxylin-azophloxine, and two with both hematoxylin and neurofilament (35). The fetal tissue was fixed in 4% paraformaldehyde embedded in paraffin, and transversely sectioned into serial sections of 10 mm. Analysis of the transverse sections was performed from the superior part of the pubic arch to just below Alcock's canal. Digital images were taken from the serial sections, photographing every second section. These images were used to prepare 3-D reconstructions with the Amira software package (v3.0, Visage Imaging GmbH, Fürth, Germany). The perineal membrane (or urogenital diaphragm) was not detectable in these fetal series and therefore not reconstructed.

Cadaver Study

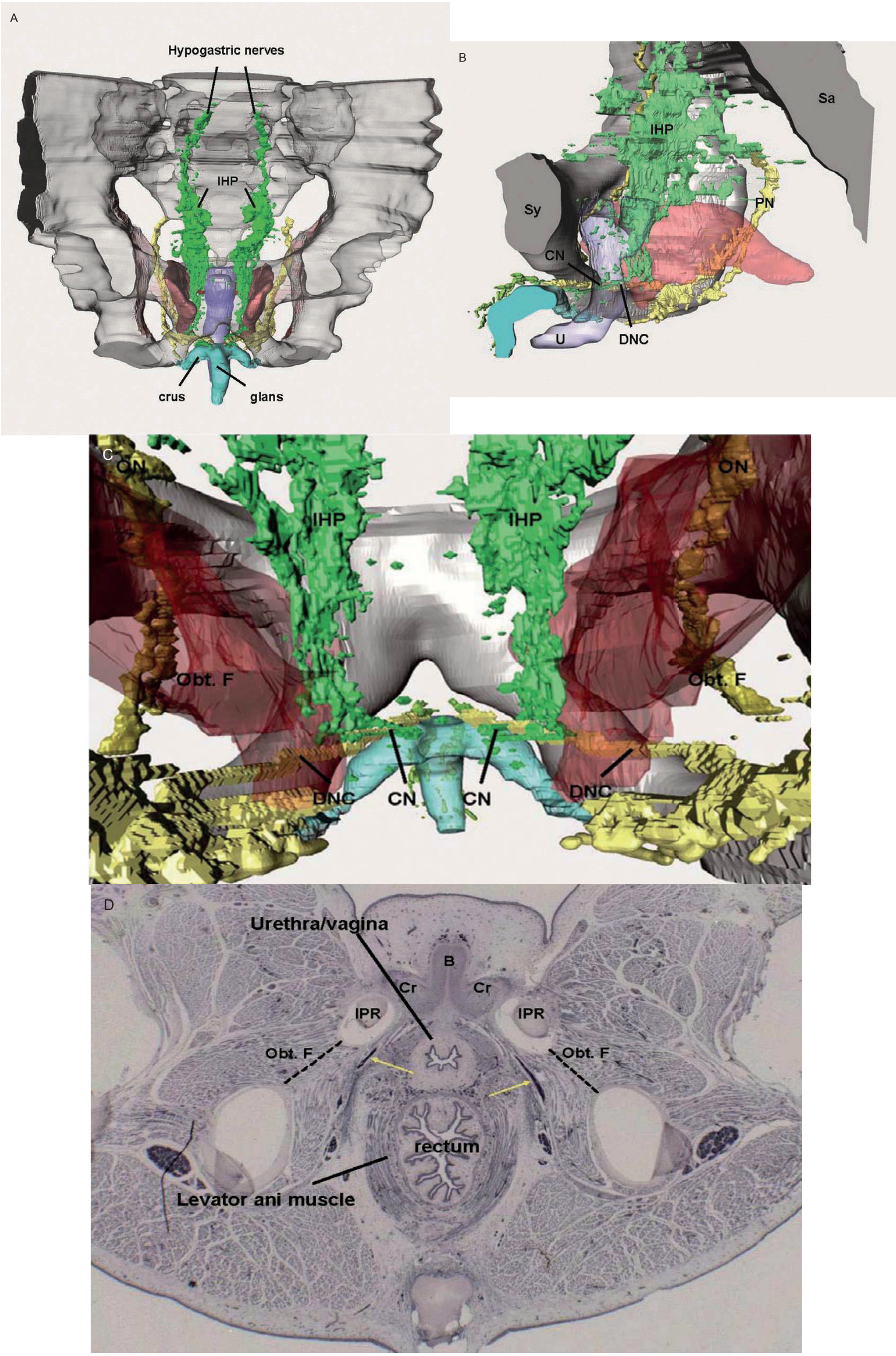
The pelves of female cadavers without signs of any pelvic surgery were used for this study. Usually, the age of death of these women is over 70 years of age. Preservation of all used bodies was performed by injection of AnubiFIX™ into the femoral artery followed by the embalming fluid, consisting of 36% formaldehyde with a mixture of ethanol, glycerin, phenol, K2SO4, Na 2SO4, NaHCO3, NaNO3,andNa2SO3. Due to this fixation process, the pelvic structures remained flexible which enabled natural dissection and allowed surgical procedures. The cadavers were donated to the university for medical research and, hence, did not require separate ethics approval for dissection. A trained urologist (HWE) performed both procedures (TVT and TVT-O) on the first cadaver, one on each side. After this test, three more TVT-O, and three more TVT procedures were performed on the female cadavers. All procedures were performed exactly similar as they would have been on normal patients.

The pelves were sectioned through the midline from the pubic symphysis anteriorly to the sacrum posteriorly. The urethra was sectioned along its full length in the midline. The clitoris and its somatic and autonomic nerves were dissected, and the shortest distance between the sling and the nerves was documented. All the stages of the dissection were recorded photographically. One hemipelvis with a TVT placed could not be properly dissected due to a large hematoma and was therefore excluded.

Results

Anatomy of the Clitoris

The clitoris is a multiplanar structure medial inferior to the pubic arch and symphysis. It is positioned deep to the labia minora, labial fat and vasculature, the musculus bulbospongiosus, and the musculus ischiocavernosus. It has a broad attachment to the pubic arch, and via extensive supporting tissue to the mons pubis (the adipose tissue lying above the pubic bone of adult females, anterior to the pubic symphysis) and labia. The clitoris consists of a tip, also known as the glans of the clitoris, the erectile body, and the crura (or corpora cavernosa) (Figure 1A). The clitoris has a close relationship to the distal urethra and vagina (Figure 1B). Because this study involved human fetuses, aged 10–27 weeks of gestation, these two structures are still partly merged.


A
Hypogastric nerves
IHP
crus
glans
B
Sa
IHP
Sy
PN
CN
U
DNC
C
ON
IHP
IHP
ON
Obt. F
Obt. F
DNC
CN
CN
DNC
D
Urethra/vagina
B
Cr
Cr
IPR
IPR
Obt. F
Obt. F
rectum
Levator ani muscle

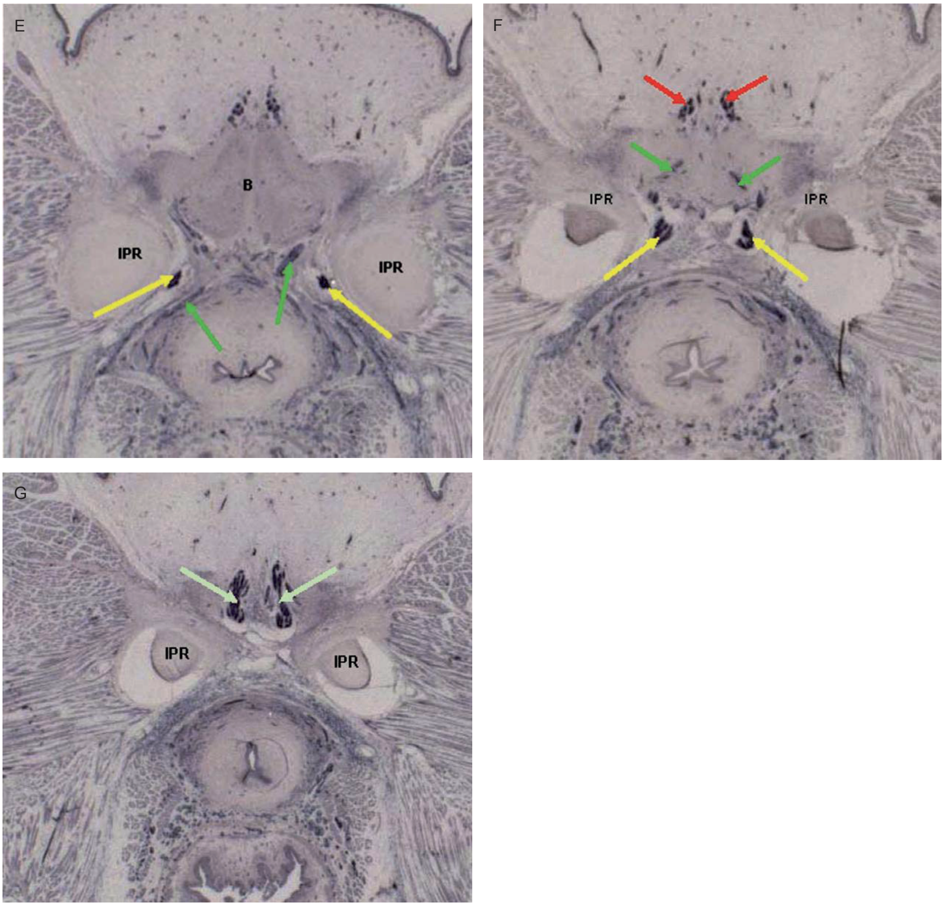


Figure 1 (A) Anterior view (3D) of the clitoris (blue), the pelvis (grey), the pudendal nerves (yellow), the hypogastric (autonomic) nerves (green) traveling into the pelvis and forming the inferior hypogastric plexus (IHP), and the merged autonomic and dorsal nerves (light green). (B) Lateral view (3D) of the midsaggital cut pelvis with the symphysis (Sy) centered (grey) the levator ani muscle (red), the clitoris (blue), the autonomic (green) and somatic (yellow) nerves, and the distal urethra/vagina (U, purple). (C) Anterior and slightly lateral view (3D) of the pelvis (grey) the obturator foramen (Obt. F), the obturator nerve (ON), the clitoris (purple), the dorsal nerve of the clitoris (DNC, yellow), and the cavernous nerves (green, CN) coming from the IHP. (D) Stained section showing the body of the clitoris (B) with its crura (Cr) close to the inferior ramus of the pubic bone (IPR), and the dorsal clitoral nerves (yellow arrows) passing along the Obt. F. (E) Stained section, the close relationship of the IPR to the clitoral dorsal nerve (yellow arrows), is notable and it shows that the branches of the cavernous nerves of the clitoris pass medial to the dorsal nerves (green arrows). (F) Stained section, showing both cavernous nerves (green arrows) and the dorsal nerves of the clitoris (yellow arrows) hooking over the clitoral body and traveling further caudally alongside and into the clitoral body and glans (red arrows). (G) Stained section, the autonomic nerves merge with the branches of the dorsal nerves as they pass over the clitoral body (light green arrows). B = clitoral body; PN = pudendal nerve; CN = cavernous nerve; Sa = sacrum

DNC

The 3-D reconstruction illustrates the course of the dorsal clitoral nerves. They originate from the PN in the Alcock's canal immediately medial to the pubic bone and lateral to the rectum, forming a bundle that fans out laterally, passing the levator ani muscle and ascending to the clitoral bodies (Figure 1A–C). The 3-D images also revealed that both DNC run medial and close to the ischiopubic ramus (Figure 1C). Furthermore, the close relationship of the clitoral crura to the clitoral dorsal nerve was notable. They traverse distally alongside the clitoral crura and run posterior to the body of the small pelvis, to be joined by the pelvic splanchnic nerves coming from sacral roots S2 to S4, to form the pelvic plexus, also known as the IHP on both sides of pelvic organs (Figure 1A). The IHP showed to be a triangularly shaped plexus in a sagittal plane. It is in close contact with its target organs as a flat meshed plaque of nerve tissue, stretching from anterolateral to the rectum, passing the cervix and vagina laterally, and extending from the lateral vaginal wall, to the base of the bladder and lateral to the urethra with branches to the clitoris.

The branches extend onto the lateral walls of the proximal and mid-vagina, where they form a dense network. These nerves travel superior to cover the proximal anterior vaginal wall, where they form the cavernous nerves at the 2 and 10 o'clock positions alongside the urethra (Figure 1C, E). There, they travel further caudal to the clitoral bodies crossing the dorsal clitoral nerve medially. The nerve bundles then travel alongside the branches of the dorsal nerve passing over the clitoral body. After passing over the clitoral body, these autonomic nerves merge with the branches of the dorsal nerve and travel further caudally alongside and into the clitoral body and glans (Figure 1B, F, G).

Dissection

Anatomy of the Clitoris

The initially almost straight clitoral crura run proximally along the ischiopubic ramus and join distally under the pubic symphysis as a single clitoral body that projects anteriorly into the glans and the fat of the mons pubis. Dissection shows that the apex of this triangular structure is the most superior point of the clitoral body, where it attaches to the under surface of the pubic symphysis by the deep suspensory ligament (Figure 2). As the clitoral body projects from the bone into the mons pubic fat, it descends and folds back on itself in a boomerang-like shape in a dorsal caudal direction forming the glans of the clitoris. The glans of the clitoris is a relatively small nodular structure that becomes partially covered by the glandopreputial lamella and prepuce (or clitoral hood).

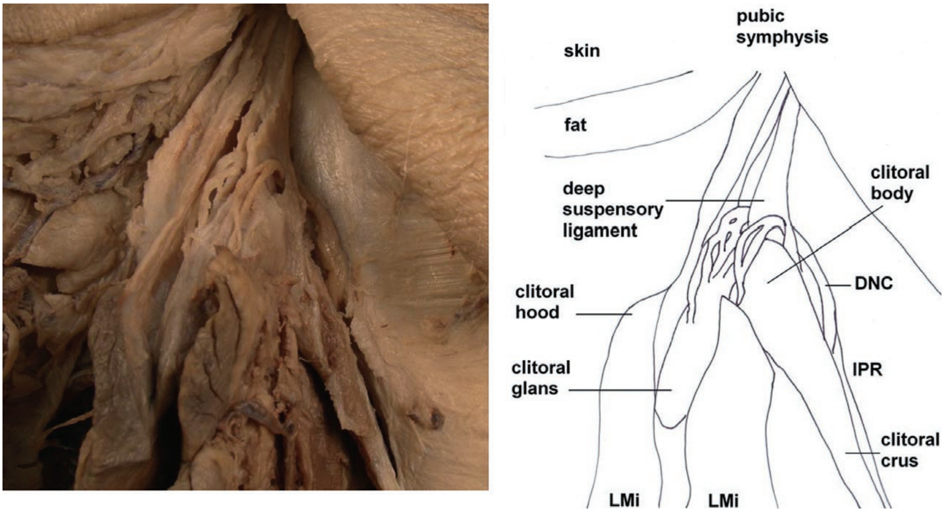


Figure 2 Anterior view of the dissection clitoris. The mons pubis has been opened to show the deep suspensory ligament. Furthermore, the clitoral crus, body, and glans are shown with the dorsal nerve of the clitoris (DNC) ascending along the inferior ramus of the pubic bone (IPR), hooking over the clitoral body while passing through the suspensor ligament and branching into the clitoris. LMi = labia minora

DNC

The course of the PN around the ischial spine was approached posteriorly by removal of the skin and superficial fascia between the anterior inferior iliac spine, the ischial tuberosity, and the posterior superior iliac spine. The gluteus maximus muscle was dissected from its origin to expose underlying structures. The sacrotuberous ligament was identified and transected to identify the PN subjacent to the sacrotuberous ligament and around the ischial spine of the pelvis. The entrance of PN into Alcock's canal was identified. Alcock's canal was then unroofed which revealed the three main branches of the PN, namely the inferior rectal nerve, the perineal nerve, and the DNC. The DNC was then followed until its termination in the clitoris. The DNC travels along the perineal membrane (or urogenital diaphragm) and runs inferiorly to the inferior pubic ramus (IPR). By opening the perineal membrane, the TVT-O tape was exposed (Figure 3A, B). The distance of the TVT-O to the DNC is shown in Table 1and has a mean of 9 mm. It is further important to report that the TVT-O and the DNC were separated by the perineal membrane in all pelves. See Figure 3C for a schematic overview of the DNC in relation to the TVT-O.

Table 1 Distance between the TVT, TVT-O, and the clitoral nerves

Distance to tape (mm)*	**Cadaver 1‡**		**Cadaver 2**		**Cadaver 3**		**Cadaver 4**	
Dorsal nerve of clitoris	L	R	L	R	L	R	L	R
TVT-O Mean: 9 mm	—	6	12	19	9	6	6	5
Distance to tape (mm)†	Cadaver 1‡		Cadaver 5§		Cadaver 6		Cadaver 7	
Cavernous nerves	L	R	L	R	L	R	L	R
TVT	0	—	—	0	0	0	0	0

*Distance from dorsal nerve of clitoris

†Distance from cavernous nerves of clitoris

‡Left TVT, Right TVT-O

§Left side excluded due to hematoma

Autonomic Nerves

The superior hypogastric plexus was identified inferiorly to the bifurcation of the aorta in all pelves. The proximal hypogastric nerves were identified in the subperitoneal layer (between the peritoneum and the endopelvic fascia) and followed alongside the ureter into the small pelvis to the IHP. Figure 4 is a lateral view of a midsagittal sectioned right pelvis showing the course of the autonomic nerves from the hypogastric nerve to the target organs. The IHP is a flat meshed plaque of nerves. Its branches, which follow the connective tissue plane within the small pelvis that supports the uterine cervix, vagina, and bladder, were identified and dissected into their target organs. Special attention was paid to the branches passing alongside the urethra and innervating the clitoris. The autonomic nerves, running from the IHP, were found to be pierced by the TVT needle in all pelves (Figure 4). See Figure 4C for a schematic overview of the autonomic nerves in relation to the TVT.

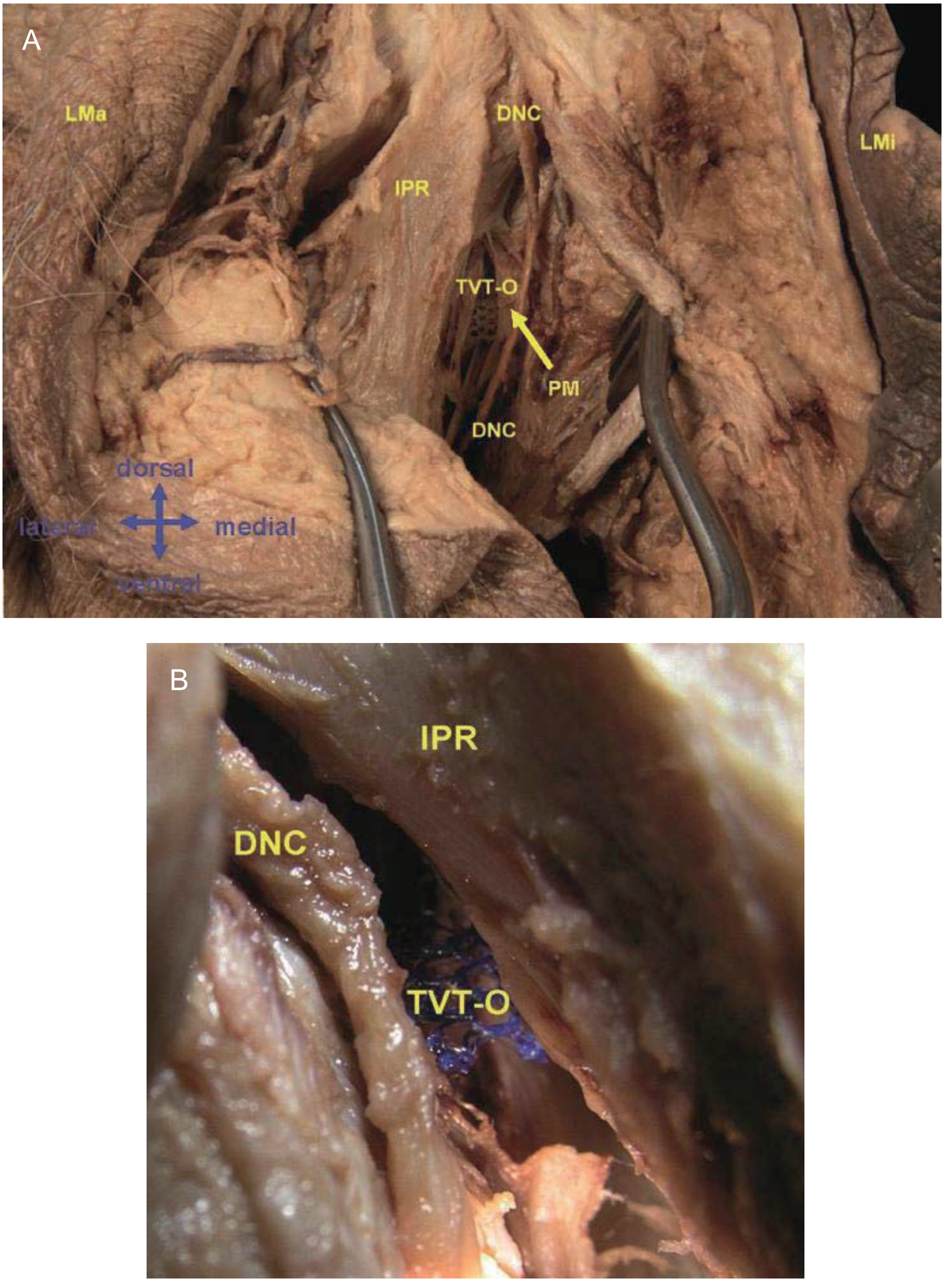
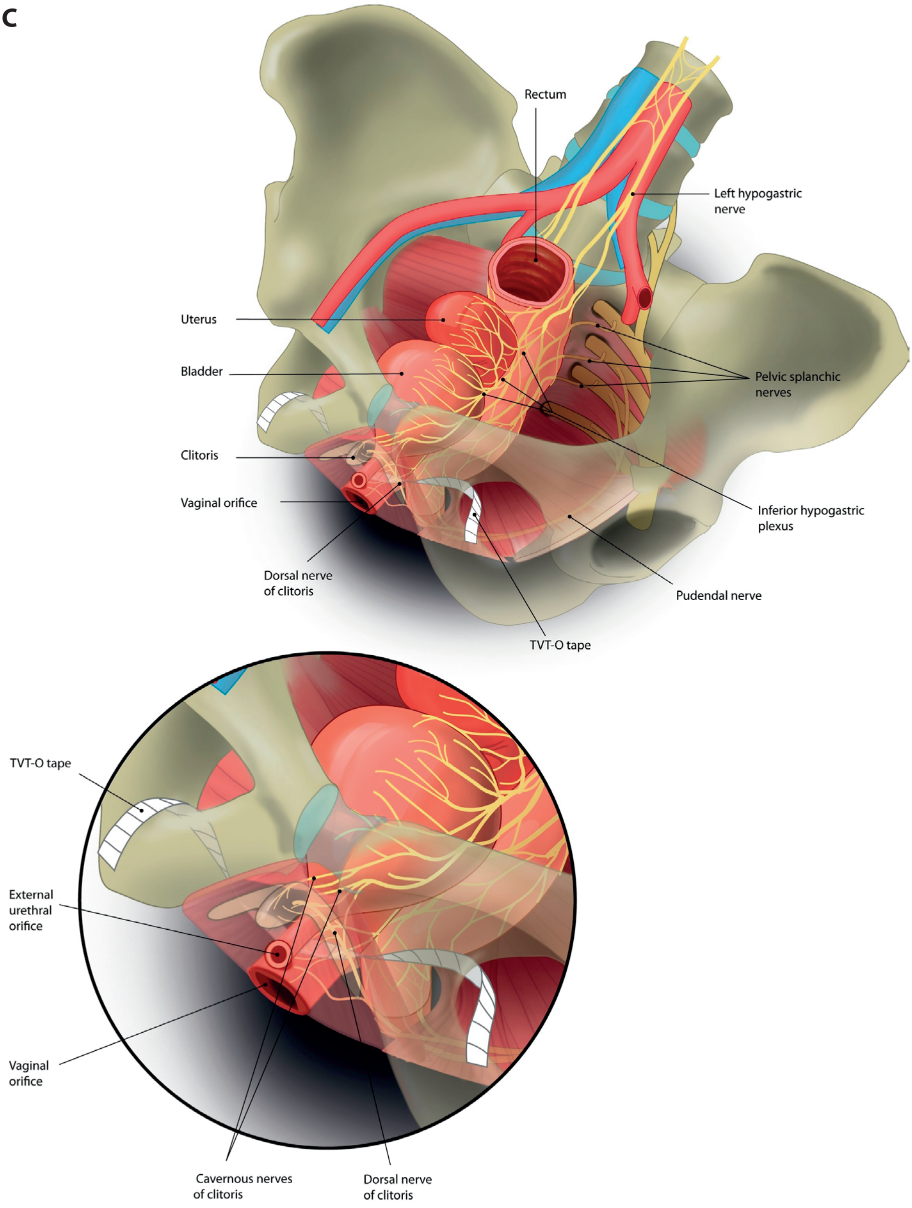


Figure 3
(A) Frontal view of the right female genital and perineal area. In order to expose the dorsal nerve of the clitoris (DNC), the skin was opened between the right labia majora and minora. To show the route of the tension-free vaginal tape-obturator (TVT-O) sling, the perineal membrane was opened subsequently. (B) Close-up of TVT-O and DNC. IPR = inferior pubic ramus; LMa = labia majora; LMi =labia minora; PM = perineal membrane.

C



(C) Relation between the DNC and the TVT-O.

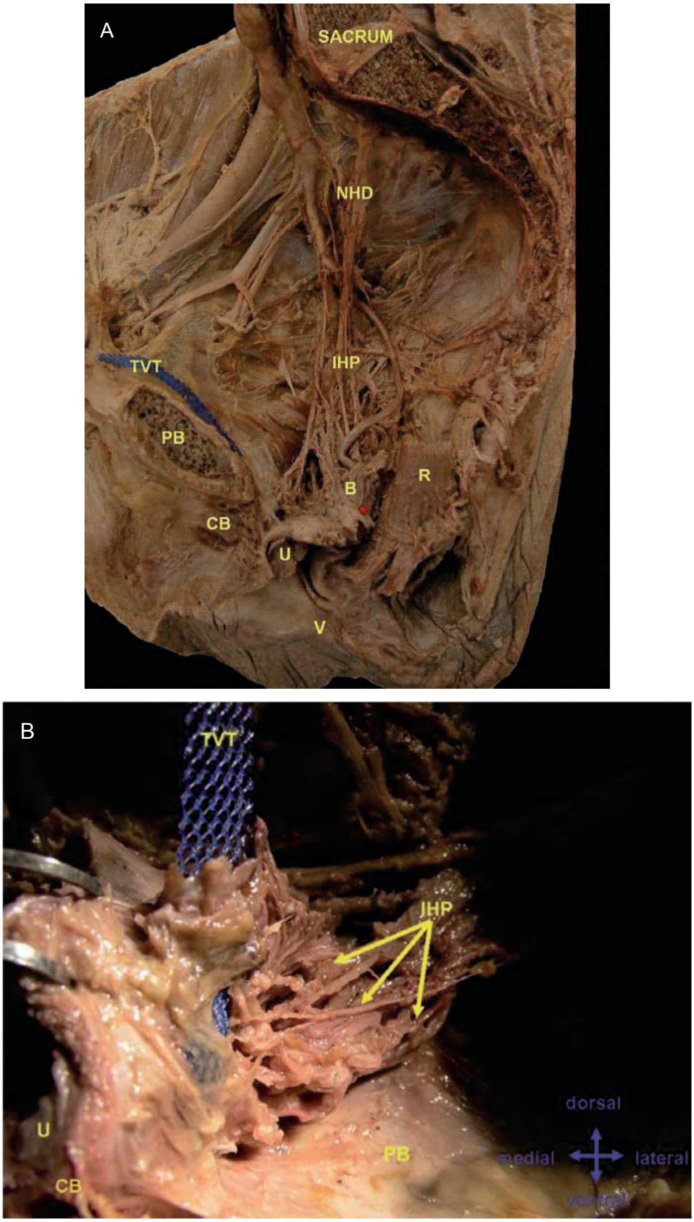


Figure 4 (A) Lateral view of a midsagittal-sectioned right pelvis showing the course of the autonomic nerves originating from the nervus hypogastricus dexter (NHD) through the inferior hypogastric plexus (IHP) to the clitoral body (CB) and the urethra (U). The uterus as well as the largest part of the bladder (B) were removed in order to get a clearer view of the course of the autonomic nerves. (B) The final branches of the IHP (close up). The dissected urethra (U) and surrounding tissue are withdrawn from the pubic bone (PB) to expose the final nerve branches originating from the IHP and finally reaching the urethra and CB. As seen the TVT pierces these cavernous nerves. PB = pubic bone; R = rectum; V = vagina

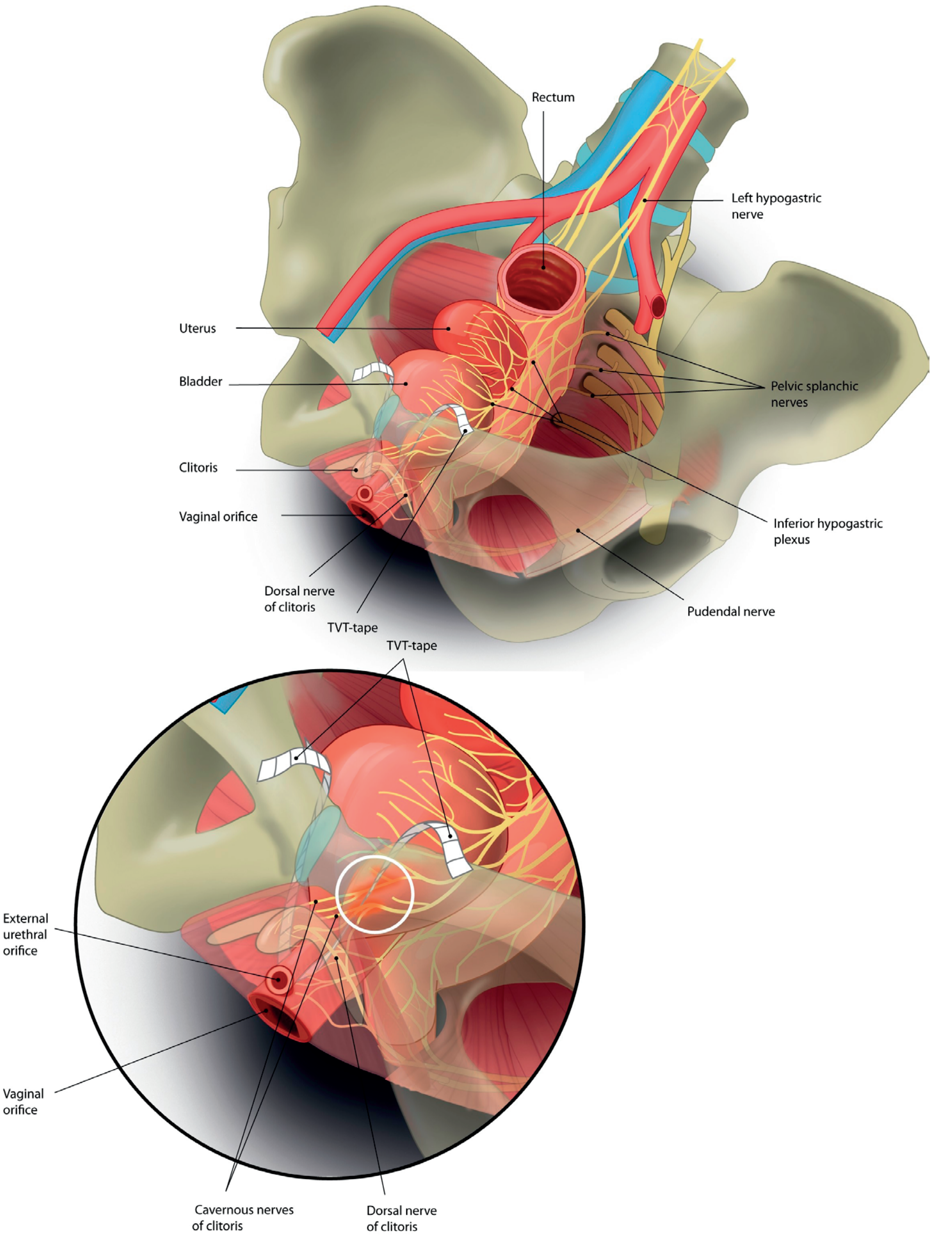


Figure 4 (C) The relation between the autonomic nerves and the TVT.

Discussion

This study describes the somatic and autonomic anatomy of the clitoris. Most of the previous studies on the innervation of the clitoris were mainly focused on the DNC, paying no attention to the cavernous nerves coming from the pelvic plexus, which play an important role in female sexual function (26;28-30;34;36-38). The cavernous nerves are involved in the neural control of vasocongestion and, consequently, in the lubrication-swelling response and were described by Moszkowicz et al. (23).
Disruption of these nerves could lead to altered vascular function during sexual arousal and possibly disordered orgasm. In 1982, Walsh and Donker described the anatomic location of the pelvic plexus (or IHP) in men and the nerves innervating the corpora cavernosa (39). These pioneering observations and descriptions of the anatomical basis for radical prostatectomy fostered resurgence of surgery as treatment for localized prostate cancer and led urologic surgeons to refine a nerve-sparing technique within the following two decades. Only in the recent years, attention is paid to the IHP in females and nerve-sparing techniques are being developed in surgery for cervical cancer (40-42). Although the IHP has been described in females, little attention has been paid to the cavernous nerves coming from the IHP and their anatomical relation to other pelvic structures (29). Yucel et al. and Moszkowicz et al. both reported that the cavernous nerves supply the female urethral sphincter complex and clitoris (23;28). The branches of the cavernous nerves were described and, as in our study, noted to join the clitoral dorsal nerves. The cavernous nerves have also been described in mice and guinea pigs, using immunostaining to show communicating nerves between the cavernous nerve and the DNC which supports the initiation of sexual arousal by tactile stimuli and following clitoral swelling (24;25). This study underlines the importance of both somatic and autonomic innervation of the clitoris in normal female sexual function.
Vaginal sling procedures for SUI have been developed in the 1990s by Ulmsten et al. (43). After research, the procedure showed to be safe and effective, and the TVT and derived procedures became well-established surgical procedures for the treatment of female SUI. Especially in these early years, no attention was paid to the topographic relation to important genital structures. Only in recent years, the possible risk of nerve damage during vaginal sling procedures, especially the obturator procedures, has been suggested (32).
The aim of this study was to describe not only the neuroanatomy of the clitoris but also its relation to surrounding structures which are anatomical landmarks in vaginal tape procedures for SUI.
When performing vaginal sling surgery, a sagittal incision is made within the anterior vaginal wall mucosa about 1 cm from the urethral meatus and the vaginal wall is dis-

sected from the mid-urethra. When performing the TVT procedure, a tape is placed (blindly) behind the pubic symphysis using trocars attached to the tape (43).
When performing the TOT, the "outside-in," procedure, a similar midline incision is made in the anterior vaginal wall between the mid-urethra and bladder neck. Dissection is carried out laterally to the level of the vaginal sulcus without penetration of endopelvic fascia. The IPR and the obturator foramen are located manually, and the medial edge of the ramus is pinched between the thumb and index finger. The skin puncture is made at the level of the clitoris right above the pinching thumb. The curved sling passer is guided from the thumb to the index finger, and then rotated and delivered to the vaginal incision with the tip on the index finger. The arm of the tape is hooked to the tip of the passer and brought out to the skin (31). When performing the TVT-O (inside-out), a similar midline incision is made and periurethral tunnels are developed bilaterally. Unlike the TOT, where the dissection stops at the IPR, with the TVT-O, the obturator membrane is perforated with the tip of the scissors. A winged metal trocar, which is designed to help guide the tape around the IPR, is inserted into the periurethral tunnel and the tip is pushed just beyond the perforated membrane. The trocar is then rotated around the IPR to exit out via the skin through stab incisions located 2 cm above a horizontal line at the level of the urethral meatus and 2 cm outside the thigh folds. The same procedure is performed on the other side, the sling is tensioned, and the procedure completed (44). As described, during these procedures, the part of the mid-urethra along the anterior vaginal wall is an important surgical site; here, the first incision is made. This study illustrates that the urethra is surrounded by autonomic nerves coming from the IHP. Not only do they travel to and innervate the urethra, the cavernous nerves travel from the vaginal nervous plexus occupying the 2 and 10 o'clock positions on the anterolateral vagina, and they travel at the 5 and 7 o'clock positions alongside the urethra. It is therefore possible that during the mid-urethral incision in all vaginal procedures and the para-urethral tunneling during the obturator procedures, the cavernous nerves are disrupted. The cadaveric part of this study showed that the cavernous nerves were indeed pierced during the TVT procedure. These results are further confirmed by the pilot study by Caruso et al. in 2007 (45) in which the clitoral blood flow significantly decreased after the TVT procedure. These findings further support our conclusion that the TVT procedure causes iatrogenic damage to the CN.
The IPR plays an important role in the obturator procedures; the tapes are placed around this bony structure. Furthermore, dissection is performed para-urethral to the IPR, and during the inside-out technique, the obturator membrane is perforated with scissors. Because the DNC travels along the medial side of the IPR, it could potentially be damaged during obturator procedures, both outside-in and inside-out. The results of the dissections did not confirm this, although the distance between the tape and the DNC was only 9 mm. Achtari et al. also dissected female cadavers and measured

the distance of the DNC to the TVT, TVT-O, and Monarc. Their results showed a distance varying from 19 mm to 40 mm, the TVT-O being the closest to the DNC (33). A similar study in fresh cadavers measured a distance between the DNC and the TOT of 3–14 mm. Despite this small distance, they concluded the TOT to be a safe procedure. This last study was however biased because straight needles were used to mimic the course of the TOT, instead of curving trocars (34). Our study showed a median distance of 9 mm. from the TVT-O to the DNC. The results found in dissection, in combination with the fetal anatomy, could indicate that when dissecting in the direction of the foramen, the DNC is potentially at risk for injury.

This study is one of the first to illustrate, in detail, both the somatic and autonomic pathways of the clitoris and link these results directly to medical practice. Significant progress has been made in the field of female sexual anatomy and its representation. This study facilitates further research in related fields of female sexual health and education, and can be used by surgeons in the field of urogynecology. Furthermore, the topographic relation of vaginal slings to the important critical female genital structure, the clitoris, has been illustrated and described for the first time. Limitations of this study were the unevaluated role of clitoral movement during intercourse (19) and post-surgery tissue reaction (fibrosis of the tape) (46). Future (clinical) research should be performed to confirm these results and to determine the consequences of injury to the clitoral nerves on the clitoral sexual response and female sexual functioning.

Conclusion

The DNC is located inferiorly to the pubic ramus and was in this research not disturbed during the placement of the TVT-O. However, the autonomic innervation of the vaginal wall and clitoris was disrupted by the TVT procedure. It is also shown that when the "inside–out" technique is used, the introducer could hypothetically come into contact with the DNC, although this did not show in our results. Summarizing, this study illustrates that the retropubic technique clearly disrupts the nervous system to the clitoris and that the obturator technique does not. Further evidence will be needed from clinical studies to decide which technique should be recommended for which patient, in order to achieve the highest possible quality of life.

Acknowledgements

We wish to thank , M.J. Aarents, A.H. Van Immerseel, and J.den Boeft from the Department of Anatomy and Embryology, Leiden University Medical Center for their assistance with the anatomical dissections and L.J. Wisse for his assistance with the 3-D reconstructions. And, lastly, we want to thank R.P. Slagter for the beautiful medical illustrations. Furthermore, we wish to thank the NutsOhra Fund for their financial support of this study.

Reference list

1. Hermieu JF. Suburethral bands in women urinary stress incontinence: A review of the various techniques. Ann Urol (Paris) 2005;39:124–36.
2. Berthier A, Sentilhes L, Taibi S, Loisel C, Grise P, Marpeau L. Sexual function in women following the transvaginal tension free tape procedure for incontinence. Int J Gynaecol Obstet 2008;102:105–9.
3. Elzevier HW, Venema PL, Nijeholt AA. Sexual function after tension-free vaginal tape (TVT) for stress incontinence: Results of a mailed questionnaire. Int Urogynecol J Pelvic Floor Dysfunct 2004;15:313–8.
4. Ghezzi F, Serati M, Cromi A, Uccella S, Triacca P, Bolis P. Impact of tension-free vaginal tape on sexual function: Results of a prospective study. Int Urogynecol J Pelvic Floor Dysfunct 2006;17:54–9.
5. Mazouni C, Karsenty G, Bretelle F, Bladou F, Gamerre M, Serment G. Urinary complications and sexual function after the tension-free vaginal tape procedure. Acta Obstet Gynecol Scand 2004;83:955–61.
6. Rogers RG, Kammerer-Doak D, Darrow A, Murray K, Olsen A, Barber M, Qualls C. Sexual function after surgery for stress urinary incontinence and / or pelvic organ prolapse:A multicenter prospective study. Am J Obstet Gynecol 2004;191:206–10.
7. Yeni E, Unal D, Verit A, Kafali H, Ciftci H, Gulum M. The effect of tension-free vaginal tape (TVT) procedure on sexual function in women with stress urinary incontinence. Int Urogynecol J Pelvic Floor Dysfunct 2003;14:390–4.
8. Jha S, Moran P, Greenham H, Ford C. Sexual function following surgery for urodynamic stress incontinence. Int Urogynecol J Pelvic Floor Dysfunct 2007;18:845–50.
9. Jha S, Radley S, Farkas A, Jones G. The impact of TVT on sexual function. Int Urogynecol J Pelvic Floor Dysfunct 2009;20:165–9.
10. Murphy M, Van Raalte H, Mercurio E, Haff R, Wiseman B, Lucente VR. Incontinence-related quality of life and sexual function following the tension-free vaginal tape versus the “inside-out” tension-free vaginal tape obturator. Int Urogynecol J Pelvic Floor Dysfunct 2008;19:481–7.
11. Pace G, Vicentini C. Female sexual function evaluation of the tension-free vaginal tape (TVT) and transobturator suburethral tape (TOT) incontinence surgery: Results of a prospective study. J Sex Med 2008;5:387–93.
12. Glavind K, Tetsche MS. Sexual function in women before and after suburethral sling operation for stress urinary incontinence: A retrospective questionnaire study. Acta Obstet Gynecol Scand 2004;83:965–8.
13. Maaita M, Bhaumik J, Davies AE. Sexual function after using tension-free vaginal tape for the surgical treatment of genuine stress incontinence. BJU Int 2002;90:540–3.
14. Marszalek M, Roehlich M, Racz U, Metzenbauer M, Ponholzer A, Rauchenwald M, Madersbacher S. Sexual function after tension-free vaginal tape procedure. Urol Int 2007;78:126–9.
15. Sentilhes L, Berthier A, Caremel R, Loisel C, Marpeau L, Grise P. Sexual function after transobturator tape procedure for stress urinary incontinence. Urology 2008;71:1074–9.
16. Shah SM, Bukkapatnam R, Rodriguez LV. Impact of vaginal surgery for stress urinary incontinence on female sexual function: Is the use of polypropylene mesh detrimental? Urology 2005;65:270–4.
17. Bekker M, Beck J, Putter H, Venema P, Nijeholt A, Pelger R, Elzevier H. Sexual function improvement following surgery for stress incontinence: The relevance of coital incontinence. J Sex Med 2009;6:3208–13.
18. Serati M, Cattoni E, Salvatore S. Coital incontinence: The tip of the iceberg? J Sex Med 2010;7:2287–8.

19. Foldes P, Buisson O. The clitoral complex: A dynamic sonographic study. J Sex Med 2009;6:1223–31.
20. Leff JJ, Israel M. The relationship between mode of female masturbation and achievement of orgasm in coitus. Arch Sex Behav 1983;12:227–36.
21. Burnett AL, Calvin DC, Silver RI, Peppas DS, Docimo SG. Immunohistochemical description of nitric oxide synthase isoforms in human clitoris. J Urol 1997;158:75–8.
22. Hoyle CH, Stones RW, Robson T, Whitley K, Burnstock G. Innervation of vasculature and microvasculature of the human vagina by NOS and neuropeptide-containing nerves. J Anat 1996;188(Pt 3):633–44.
23. Moszkowicz D, Alsaid B, Bessede T, Zaitouna M, Penna C, Benoit G, Peschaud F. Neural supply to the clitoris: Immunohistochemical study with three-dimensional reconstruction of cavernous nerve, spongious nerve, and dorsal clitoris nerve in human fetus. J Sex Med 2011;8:1112–22.
24. Martin-Alguacil N, Pfaff DW, Shelley DN, Schober JM. Clitoral sexual arousal: An immunocytochemical and innervation study of the clitoris. BJU Int 2008;101:1407–13.
25. Vilimas PI, Yuan SY, Haberberger RV, Gibbins IL. Sensory innervation of the external genital tract of female guinea pigs and mice. J Sex Med 2011;8:1985–95.
26. O'Connell HE, Hutson JM, Anderson CR, Plenter RJ. Anatomical relationship between urethra and clitoris. J Urol 1998;159:1892–7.
27. Suh DD, Yang CC, Cao Y, Garland PA, Maravilla KR. Magnetic resonance imaging anatomy of the female genitalia in premenopausal and postmenopausal women. J Urol 2003;170: 138–44.
28. Yucel S, De Souza JR A, Baskin LS. Neuroanatomy of the human female lower urogenital tract. J Urol 2004;172:191–5.
29. O'Connell HE, Sanjeevan KV, Hutson JM. Anatomy of the clitoris. J Urol 2005;174(4 Pt 1):1189–95.
30. Sedy J, Nanka O, Belisova M, Walro JM, Jarolim L. Sulcus nervi dorsalis penis/clitoridis: Anatomic structure and clinical significance. Eur Urol 2006;50:1079–85.
31. Delorme E, Droupy S, De Tayrac R, Delmas V. Transobturator tape (Uratape): A new minimally-invasive procedure to treat female urinary incontinence. Eur Urol 2004;45:203–7.
32. Lowenstein L. Topographic relation of mid-urethral sling for stress incontinence to critical female genital structures. J Sex Med 2009;6:2954–7.
33. Achtari C, McKenzie BJ, Hiscock R, Rosamilia A, Schierlitz L, Briggs CA, Dwyer PL. Anatomical study of the obturator foramen and dorsal nerve of the clitoris and their relationship to minimally invasive slings. Int Urogynecol J Pelvic Floor Dysfunct 2006;17:330–4.
34. Tate SB, Culligan PJ, Acland RD. Outside-in transobturator midurethral sling and the dorsal nerve of the clitoris. Int Urogynecol J Pelvic Floor Dysfunct 2009;20:1335–8.
35. Wallner C, Dabhoiwala NF, DeRuiter MC, Lamers WH. The anatomical components of urinary continence. Eur Urol 2009;55:932–43.
36. Baskin LS, Erol A, Li YW, Liu WH, Kurzrock E, Cunha GR. Anatomical studies of the human clitoris. J Urol 1999;162(3 Pt 2):1015–20.
37. O'Connell HE, DeLancey JO. Clitoral anatomy in nulliparous, healthy, premenopausal volunteers using unenhanced magnetic resonance imaging. J Urol 2005;173:2060–3.
38. Vaze A, Goldman H, Jones JS, Rackley R, Vasavada S, Gustafson KJ. Determining the course of the dorsal nerve of the clitoris. Urology 2008;72:1040–3.

39. Walsh PC, Donker PJ. Impotence following radical prostatectomy: Insight into etiology and prevention. J Urol 1982;128: 492–7.

40. Maas CP, Trimbos JB, DeRuiter MC, van de Velde CJ, Kenter GG. Nerve sparing radical hysterectomy: Latest developments and historical perspective. Crit Rev Oncol Hematol 2003;48: 271–9.

41. Maas CP, Kenter GG, Trimbos JB, DeRuiter MC. Anatomical basis for nerve-sparing radical hysterectomy: Immunohistochemical study of the pelvic autonomic nerves. Acta Obstet Gynecol Scand 2005;84:868–74.

42. Pieterse QD, Ter Kuile MM, DeRuiter MC, Trimbos JB, Kenter GG, Maas CP. Vaginal blood flow after radical hysterectomy with and without nerve sparing. A preliminary report. Int J Gynecol Cancer 2008;18:576–83.

43. Ulmsten U, Henriksson L, Johnson P, Varhos G. An ambulatory surgical procedure under local anesthesia for treatment of female urinary incontinence. Int Urogynecol J Pelvic Floor Dysfunct 1996;7:81–5.

44. De Leval J. Novel surgical technique for the treatment of female stress urinary incontinence: Transobturator vaginal tape inside-out. Eur Urol 2003;44:724–30.

45. Caruso S, Rugolo S, Bandiera S, Mirabella D, Cavallaro A, Cianci A. Clitoral blood flow changes after surgery for stress urinary incontinence: Pilot study on TVT versus TOT procedures. Urology 2007;70:554–7.

46. Yildirim A, Basok EK, Gulpinar T, Gurbuz C, Zemheri E, Tokuc R. Tissue reactions of 5 sling materials and tissue material detachment strength of 4 synthetic mesh materials in a rabbit model. J Urol 2005;174:2037–40.