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Three anatomical levels: possibilities to decrease invasiveness of reconstructive surgery for congenital penile curvature

Wojciech Perdzyński, Marek Adamek

Centre for Reconstructive Surgery of the Male Genito-Urinary Tract, Damian`s Hospital, Warsaw, Poland

Introduction The aim of the study was to report methods – based on penile anatomy – leading to the minimization in the invasiveness of reconstructive surgery for congenital penile curvature (CPC).
Material and methods From 2006 to 2016 authors operated on 186 adult men with CPC.
To avoid degloving, the authors used the longitudinal skin and tunica dartos incision. For decreasing invasiveness to the dorsal neurovascular bundle (NVB), the authors separated it only locally in the shape of a triangle or a trapezium, elevating it only over the place of the tunical reconstruction. To decrease the invasiveness for the tunica albuginea (TA) and cavernous vessels, a new operative technique based on the stratified structure of the TA was developed in which the corpora cavernosa were not opened. During reconstruction, only the elliptical fragment of the external layer of the tunica was excised (internal layer was left intact) and both layers of the tunica were sutured over the invaginated internal layer.
Results Follow-up ranged from 6 months to 10 years. In all the patients, the penis was straightened during operation. Follow-up examinations were done 6 months and 1 year postoperatively. Disorders of superficial sensation on the glans, erectile dysfunction or chronic postoperative edema were not detected in any of the 186 patients. The penis remained straight in 180 patients (96.7%). In 4 patients (2.2%) in whom the primary curvature was 80–90 degrees and the postoperative curvature was about 30 degrees, reoperation was done. In two patients (1.1%) with the remaining postoperative curvature up to 20 degrees and good functional result (patient's opinion), there was no need for further treatment.
Conclusions Longitudinal skin and tunica dartos incision on the convex surface of the penis allows for the ability to avoid penile degloving and to preserve the foreskin. Elevation of the dorsal NVB from the TA was done on a very limited surface in the shape of triangle or trapezium, in order to decrease the possibility of dorsal nerves/vessels damage. Excision of elliptical fragments of the external layer of the TA with subsequent invagination of the internal layer, excluded the need for opening of the corpora cavernosa as well as for the use of a tourniquet during reconstruction. This diminished the potential risk of complications, especially intra- and postoperative bleeding.

Corresponding author
Wojciech Perdzyński
Centre for Reconstructive
Surgery of the Male
Genito-Urinary Tract
Damian`s Hospital
46, Wałbrzyska Street
02–739 Warsaw, Poland
mobile phone
+48 601 28 59 17
perdzynski@perdzynski.pl

INTRODUCTION

Congenital penile curvature (CPC) causes not only sexual dysfunction (difficulty in intromission, discomfort during sexual intercourse), but also severe psychological problems leading to the avoidance of sexual contacts [1, 2]. Isolated curvature (not associated with hypospadias, epispadias or other anomalies) is caused by dysplasia of the tunica albuginea (TA) which results in asymmetrical development of the TA, disproportion of the corpora cavernosa and subsequent penile curvature in erection [3–7]. The most common type is ventral curvature, followed by lateral and rarely dorsal.
Penis is prone to intraoperative mechanical injury (especially nerves, blood and lymphatic vessels) which,

if damaged, may have great influence on its future function (lack of superficial sensation, chronic penile edema due to lymphatic or venous stasis, erectile dysfunction). That is why precise and minimally-invasive techniques are preferred during reconstructive operations on that field [8, 9, 10]. To avoid degloving authors use the longitudinal skin and tunica dartos incision [8]. For decreasing invasiveness to the dorsal neurovascular bundle (NVB), authors separate it only locally in the shape of a triangle or a trapezium, elevating it only over the place of tunical reconstruction. This attitude precludes the separation of the NVB from the entire dorsal surface of the penis [8, 9]. To decrease the invasiveness for the TA and the cavernous vessels, new operative techniques based on the stratified structure of the TA was developed in which the corpora cavernosa were not opened [10].

MATERIAL AND METHODS

From 2006 to 2016 authors operated on 186 adult men (mean age 23, ranging from 18 to 34 years) with congenital penile curvature (CPC). Before operation all patients were evaluated with medical and sexual history and physical examination. Patients were asked to supply a photo of the penis in the state of erection (Figure 1). The degree of curvature which qualified for correction was from 30 to 90 degrees (mean 60 degrees). Anesthesia: injection into subarachnoidal space (lumbar part of spinal column) with 0.5% bupivacaine solution and intravenous sedation with 1% propofol emulsion. In 168 patients, penile skin was incised longitudinally, directly over the convex surface of the penis (in 10 patients with hypospadias, in 5 with epispadias and in 3 after circumcision, the penis was degloved). Longitudinal skin incison can be moved in all directions which enables good access to the operative field. If necessary, the incision can be prolonged. Dorsal skin incision done over the penis shaft (prepuce was held in position covering glans) was used to repair ventral curvature in 99 patients (Figure 2), ventral incision was used to repair dorsal curvature (in 13 out of 18 patients), while lateral skin incision was used in all 53 patients with lateral curvature. In 2 patients with ventral curvature situated distally, the penis skin incision began just behind the subcoronal groove (after pulling the prepuce proximally), which enabled us to cover the suture line by the prepuce after operation. After producing an artificial erection (saline injection with compression of the penile base with a tourniquet) (Figure 3), the top of the maximum curvature was marked. After releasing of the tourniquet, there was flaccid state in which reconstruction was then performed.
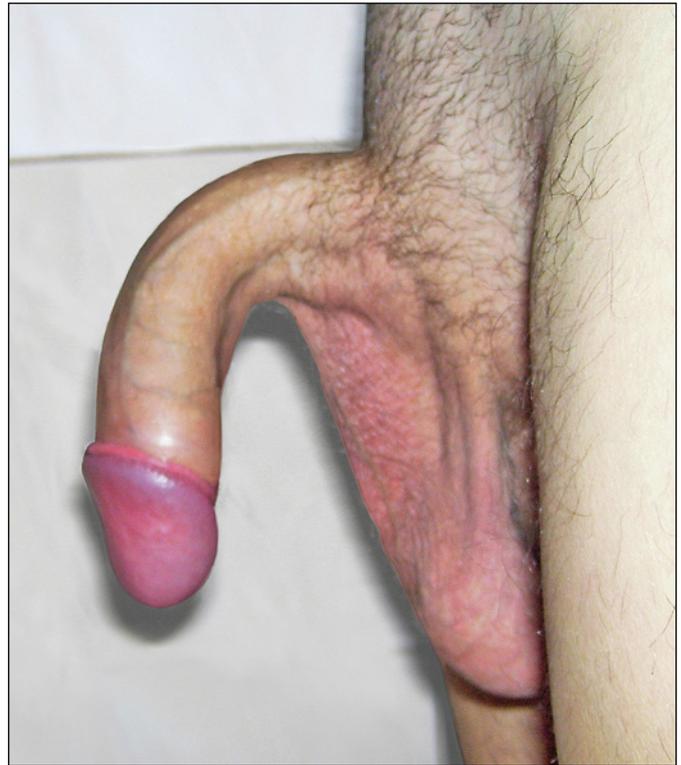
Figure 1. *Photo of penis in erection provided by the patient. Ventral curvature (90 degrees).*

Figure 2. *Longitudinal skin incision on dorsal penile surface.*

Figure 3. *Intraoperative artificial erection. Ventral curvature (90 degrees).*

Figure 4. *Partial penile protrusion through the operative wound.*

Figure 5. *Mobilization and elevation of the neurovascular bundle from the tunica albuginea in the shape of a triangle on the dorsal penile surface. Upper marking suture is 1–2 mm below the lateral groove of the deep dorsal vein (vein is seen above this suture). Lower marking suture is situated on a borderline between upper and lateral penile surfaces.*

Figure 6. *Elliptical incision of the external (longitudinal) layer of tunica albuginea on the dorsal penile surface. Penis is stretched by assistant`s index finger situated against concave surface, while his thumb is pressing on convex penile side.*

Partial protrusion of the penile shaft through the skin incision was used especially during reconstruction of the ventral curvature (Figure 4) and sometimes in the dorsal curvature. In patients with ventral curvature in which one tunical excision was necessary, the dorsal neurovascular bundle (NVB) had been separated bilaterally from the TA into the shape of a triangle with its apex (marked by stay suture which held the NVB elevated) situated 1–2 mm laterally from ipsilateral margin of the deep dorsal vein groove (Figure 5). To achieve support for incisions on the TA, the penis was stretched by an assistant's index finger situated against the concave surface while his thumb was pressing on the convex penile side (Figure 6). Below the elevated NVB, the external layer of the TA was incised into the shape of an ellipse (Figure 6) and that elliptic fragment was excised (Figure 7) bilaterally, leaving the internal layer of the tunica intact. Margins of excision were sutured with resorbable 3/0 stitches, which went through both layers of the tunica (Figure 8) followed by invagination of the internal layer (Figure 9). If more tunical excisions were necessary for penile straightening, the NVB elevation may have the shape of a trapezium (when excisions of TA have to be close to each other) (Figures 10, 11) or of several triangles (when excisions of tunica have to be performed with greater distance from each other, with the possibility to save the circumflex veins) (Figure 12). Artificial erection was always produced to assess the shape of penis. If curvature still needed reconstruction, the new point of maximum curvature was marked and the next excisions of the tunica and their sewing was done until the penis was straight (Figure 13). Among 18 patients with dorsal curvature excision of the elliptical fragment of the external tunical layer and plication of the internal layer were done symmetrically on both sides of urethra. In 53 patients with lateral penile curvature, the same principle (longitudinal skin incision and tunical reconstruction on convex penile side) was applied and good access was achieved without the need of producing partial penile protrusion through window-like operative wound.

To prevent erections, authors of that study introduced anti-androgen therapy (cyproterone citrate, daily doses usually 50 mg in the morning, 150 mg in the evening) starting 3–5 days before operation and continued it for 3 weeks postoperatively (the higher level of testosterone and stronger nocturnal erections in anamnesis, the longer period of preoperative treatment).

Two weeks after operation, the patients were asked to start to move the skin with the postoperative scar along the penile axis to prevent adhesions between tunica dartos and Buck's fascia.

Figure 7. *Incised fragment of external layer of tunica albuginea is excised, internal (transversal) layer is preserved. Clear color difference between internal (white) and external (pink) layers is seen.*
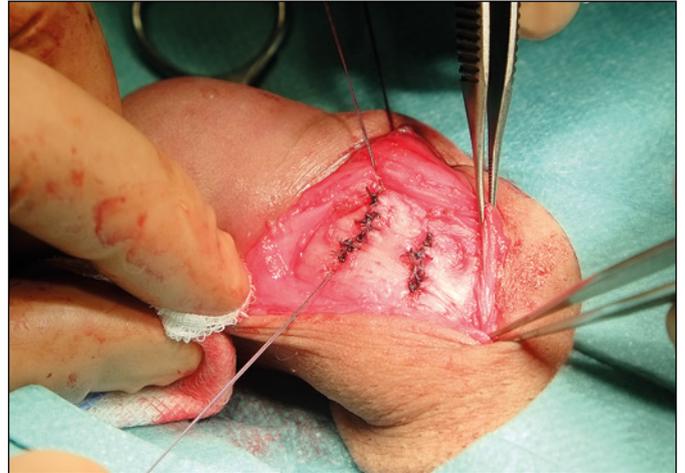
Figure 10. *Trapezium-shaped elevation of neurovascular bundle with margins of external layer of tunica albuginea sutured over the invaginated internal layer on the left side of the dorsal surface (two rows of sutures) .*


Figure 8. *Margins of external layer of tunica albuginea are sutured over invaginated internal layer (sutures go through both layers of tunia albuginea).*
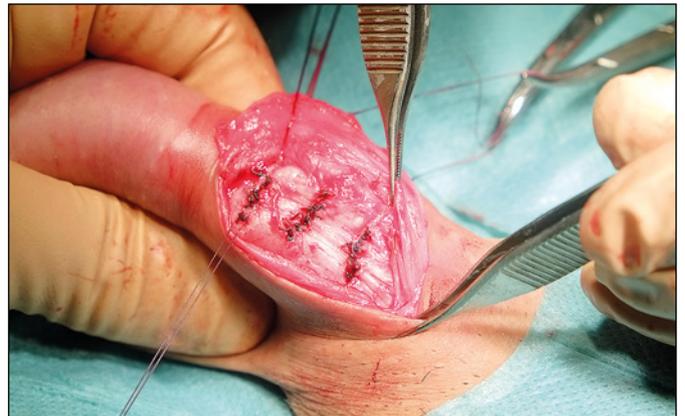
Figure 11. *Trapezium-shaped elevation of neurovascular bundle with margins of external layer of tunica albuginea sutured over the invaginated internal layer on the left side of the dorsal surface (three rows of sutures).*

Figure 9. *Triangle-shaped elevation of neurovascular bundle with margins of external layer of tunica albuginea sutured over the invaginated internal layer on both sides of the dorsal surface.*
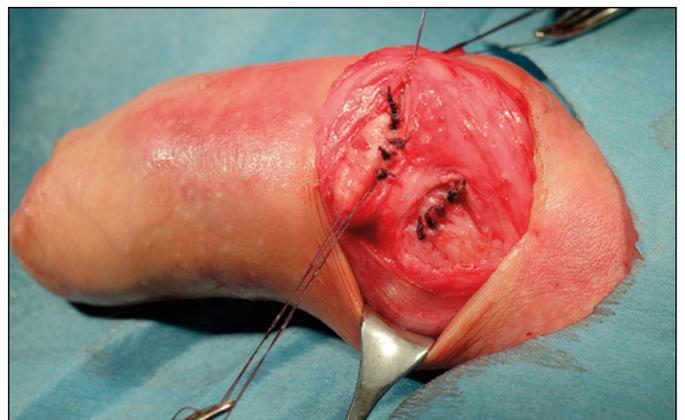
Figure 12. *Neurovascular bundle elevation may have shape of several triangles (two triangles are seen, with the circumflex vein within Buck`s fascia, between them).*

Figure 13. *Intraoperative artificial erection. Penis is straight.*

Follow-up examinations were done (with photography of penis in full erection) at 6 and 12 months after the operation. Afterwards, patients were asked to report if any change of penis shape during erection had been observed.

Before operation and 6 months after the operation, the stretched penile length (in cm) was measured.

RESULTS

Follow-up ranged from 6 months to 10 years (mean 72 months). In all patients the penis was straightened during operation. Postoperative edema showed decrease quickly, usually in 5–7 days. Follow-up examinations were done 6 months and 1 year postoperatively and the photo of the penis in state of erection was also assessed.

Disorders of superficial sensation on the glans, erectile dysfunction or chronic postoperative edema were not detected in any of the 186 patients. Penis was straight in 180 patients (96.7%). In 4 patients (2.2%) in whom primary curvature was 80–90 degrees, postoperative curvature about 30 degrees was detected and reoperation was done. In two patients (1.1%) with a remaining curvature up to 20 degrees and good functional re-

sult (patient's opinion) there was no need for further treatment. None of the patients observed perceptible penile shortening. Penile length before and after the operation was not changed in most of the patients, while it was slightly changed in 8 patients with the primary curvature of 80–90 degrees (up to 0.5 cm). All of the patients reported to feel great satisfaction from sexual life and their self-confidence connected with this important part of life much improved.

DISCUSSION

It is important to perform penile operations as delicately and as precisely as possible as it may decrease intraoperative injury and its possible complications. To achieve these goals during operation for CPC authors concentrated on three main anatomical levels [8, 9, 10]:

a. the skin with tunica dartos (superficial fascia of penis),

b. Buck's fascia (deep fascia of penis) with NVB,

c. tunica albuginea.

According to the anatomy, penile skin is well-vascularized with a very flexible cutaneous blood supply of coiled vessels running along the shaft, having mostly longitudinal orientation [11]. That is why our preferred approach is through longitudinal skin incisions over the convex surface of the penis which give a chance to avoid harm to the greater arteries and veins by moving them laterally or medially, decreasing the number of coagulated or divided vessels [8, 9]. The skin over the penis is particularly moveable and expandable to accommodate erections [11]. This facilitates access to Buck's fascia and the TA by window-like longitudinal skin incisions which can be easily moved in all directions. Thanks to this, operations may be performed on the central (most of incisions are done on this part of penile shaft), as well as, on the proximal and distal parts of the penis. Partial protrusion of the penile shaft through the skin incision is possible and very useful during the reconstruction of the ventral curvature and in some patients with dorsal curvature. This attitude prevents from performing total penile degloving, which in our opinion, is much more invasive than longitudinal incision, especially if we compare the surface of penile denudation between this two approaches [1–6, 8, 9, 12, 13, 14]. Other advantages of longitudinal incision are the possibility to avoid circumcision and to preserve the foreskin [8, 9, 14], to decrease the dimensions of postoperative edema and to avoid chronic penile edema [2]. Most authors use circumferential subcoronal incision and perform circumcision as a part of the degloving [1, 2, 4, 5, 6, 14]. We use this approach only in patients with associated hypospadias, epispadias

or in those who want to be circumcised (or are circumcised already). Some authors after circumferential subcoronal incision make degloving by a very meticulous separation of the tunica dartos and Buck's fascia, which enables the preservation of blood supply into the distal part of the penile skin and in consequence preserves the foreskin [3, 13]. If penile curvature is situated at the base of the penile shaft, the same prepuce-saving effect can be achieved with the penoscrotal approach [3, 15], dorsal infrapubic approach [15] or the longitudinal incision at the proximal part of the penile shaft [8, 9] are used.

Anatomical studies on human fetal penile specimens proved that the perforating branches of dorsal penile nerves into erectile bodies were not documented along dorsal and lateral aspects of the NVB based on serial step sectioning and microscopic examination of the male genital specimens [16]. That is why it is possible to elevate safely the NVB , but the dissection needs to remain directly on top of the TA to prevent neuronal injury [16]. Delicate, precise surgical techniques and usage of optical magnification are mandatory during the elevation of NVB. It is obvious that the less surface of NVB mobilization, the less possibility for nerves and vessels injury. Some authors, including us, utilize this rule in clinical practice [2, 8, 9, 17, 18]. In our study with patients who had ventral penile curvature, we preferred to perform local (as narrow as possible) elevation of the NVB, just over the place of tunical reconstruction in the form of a triangle (when excision of one elliptic fragment of external layer of TA is necessary) with its apex (marked by stay suture which hold NVB elevated) situated near the ipsilateral margin of the deep dorsal vein groove. If more tunical excisions are necessary NVB elevation may have the shape of a trapezium (when excisions of tunica albuginea have to be close to each other) or of several triangles (when excisions of tunica have to be performed with greater distance from each other) creating the additional possibility to save the circumflex veins. Local incision of Buck's fascia and local elevation of NVB often enable us to avoid the division of the circumflex veins if they are situated nearby the point of maximal penile curvature (not possible if they are situated on this point). This is a part of our strategy of saving as much of the vessels as possible in the skin and in Buck's fascia levels, which decreases additional intraoperative injury. In our material we did not detect disorders of the superficial sensation on the glans in any of our patients [9, 10]. Extensive bilateral [6, 19] or unilateral [18] NVB mobilization done over all or almost all dorsolateral penile surface is still used by some authors.

Penile length in patients with CPC is more than two standard deviations greater than the mean normal length for their age [20]. That is why most authors correct CPC by shortening of the longer, convex side of the penis and we used the same principle [1, 2, 4, 8, 9, 10, 12, 14, 18, 19].

There are many different surgical techniques of tunical reconstruction in the treatment of CPC and all of them are of different success rate. For example, recurrence rate after tunical plication technique described by Essed-Schroeder (E-ST) is from 10 to 20% [4, 19, 21, 22]. Six months after operations done by the 16-dot plication technique (16-dot PT), 93% of patients reported straight erections, 7% reported almost straight, but acceptable erections but recurrence rate is 15% at a mean of 2.6 years of follow-up [14].

Main reasons for presence of these complications are suture loosening and breakage caused by erections or cut through by the tied suture across the tunica. Postoperative problems arise because in the above mentioned methods smooth, intact surface of the TA is only approximated by non-absorbable sutures (lack of natural healing followed by producing a scar strong enough to prevent recurrence) and the final result is based solely on the sutures which hold the plicated tunica in the desired position [4, 9, 12, 14, 19, 22]. Another disadvantage of methods based on tunical plications is the creation of protruding the bulk because the entire thickness of the TA is invaginated inside the cavernous cavity, which decreases its volume and compresses cavernosal tissue [22]. Excessive folding may also lead to decreased distal rigidity [23]. In the original description of 16-dot PT dots are placed 0.5 cm apart that is why one suture (4 dots) invaginates 2 cm in the broad field of the tunica, which may be responsible for indentations and for irregular penile shape after operation [9, 14]. Also loss of penile length may be detected after that operation (ranged from 0,5 to 1.5 cm) and 7% of patients stated that this situation affected their sexual life [5, 14]. Discomfort or even pain from palpable knots of non-absorbable sutures, as well as, narrowing or indentations are felt by up to one third of patients operated by tunical plication techniques [14, 22]. On the other hand, the low invasiveness without the necessity of opening the cavernous cavity [4, 5, 14, 19, 21, 22], and additionally – in the 16-dot PT – without separation of the dorsal NVB from the TA and the short operative time are main advantages of these techniques [5, 14]. In the multiple parallel plication techniques (MPPT) or in 16-dot PT, sutures are placed between the deep dorsal vein and dorsal arteries in narrow spaces where there are no nerves [12, 14]. In spite of that, 6% of patients experienced decreased penile sensation and 11% of them had pain connected with erection [14]. Probably non-absorbable sutures tied

with 5 knots produce a kind of nodus (also granuloma formation – if present – around it) that may touch to some medially situated dorsal penile nerves which are the cause of these sensations.

Corporoplasty described by Nesbit (excision of the elliptical fragment of the TA and then sutured margins of the operative wound) [24] or Yachia (longitudinal incision of the TA and its transversal closing according to Heineke-Mikulicz method) [25] allow for much better results (due to permanent fusion of tunical margins by healing process) in terms of recurrence (5 to 15%), but their invasiveness is greater because corporal cavity is opened: underlying erectile tissue may be injured during tunical excision or incision and bleeding may occur. For this reasons a tourniquet is often used during these procedures [24, 25]. If circulation within the penis is stopped for a too long period (over 15 minutes?, over 30 minutes?) it may be harmful for erectile and sensory nerves, as well as, for erectile tissue [9]. Postoperative hematoma caused by leakage through the sutured TA is not rare after the Nesbit operation [1].

Giammuso et al. introduced a new surgical technique useful for ventral curvatures (Yachia procedure done in the bed of deep dorsal vein after the vein's resection) [26]. Akbulut et al. and Colpi et al. in ventral curvatures excised, in the same place of the penile midline, a diamond-shaped 4–5 mm deep fragments of the TA from the intercavernous septum [6, 27]. In both approaches good results according to penile straightening were assessed. There was no need to separate the NVB from the TA, which was great advantage in those methods. Giammuso et al. noticed postoperative penile shortening from 1 to 2.5 cm [26]. Colpi et al. detected penile shortening from 0.5 to 1.5 cm [27], although the other authors using the same method did not confirm that observation [6]. Another disadvantage is the development of the postoperative scar which may disturb the elasticity of the junction between the intercavernous septum and TA (elasticity of this junction play an important role in erection and during coital activity) [28, 29]. It would be interesting if authors of studies in which 4–5 mm deep fragments of TA were excised [6, 27] would follow-up their patients for long-term having in mind especially the danger of the development of acquired dorsal penile curvature. Probably superficial excision of the TA in the dorsal penile midline would not produce such consequences [18]. The following disadvantage of the above mentioned operations is the necessity of dividing the deep dorsal penile vein (together with major collecting trunks of lymphatic vessels associating this vein [11]) with possible complications of that maneuver [6, 18, 26, 27]. The last problem can be solved by performing the Yachia procedure slightly laterally from the deep dorsal vein and medially from the dorsal arteries and then placing sutures transversally [4] on a narrow surface where there are no dorsal nerves [12, 14].

Authors of this study were trying to make use of advantages and to avoid disadvantages of the most commonly used techniques with the goal to:

- avoid approximation of the intact and smooth TA by the sutures (E- ST, MPPT, 16-dot PT [12, 14, 21]).
- avoid opening of the cavernous cavity having in mind possibility of bleeding and local injury of erectile tissue (Nesbit and Yachia methods) [24, 25],
- avoid using of the tourniquet during tunical reconstruction with subsequent temporary hypoxia which may be harmful to sensory and erectile nerves and erectile tissues (Nesbit and Yachia methods) [24, 25],
- take advantage of good healing of the sutured margins of transected tunica (Nesbit and Yachia methods [24, 25] and in method based on stratified structure of TA [8, 9, 10, 18]),
- take advantage of the decreasing size of the invaginated bulk of TA into the cavernous cavity (method based on stratified structure of TA [8, 9, 10, 18] in contrast to utilize invagination of the entire thickness of tunical wall like in E-ST, MPPT, 16-dot PT [12, 14, 21]).

Taking into account all of these, we developed a new, minimally invasive technique, based on the stratified structure of the TA [11], in which the corpora cavernosa are not opened [10]. Our approach is based on surgical differentiation of both tunical layers, which allows for the precise excision of the elliptical fragment of the external layer of the tunica containing longitudinally oriented fibers and plication only of the internal layer with transversally oriented fibers localized at the bottom of the invaginated area [8, 9, 10]. Kuehhas and Egydio started to use similar techniques of excision of the superficial layer of TA [18].

Our method can be used to correct ventral, lateral, dorsal, as well as combined penile curvatures [9]. Precise excision of the elliptical fragments of the external layer of the tunica and plication (by absorbable sutures going through both layers of TA) only of the internal layer of tunica [8, 9, 10] diminish compression of cavernosal vessels and sinusoids compared to other plication techniques in which both tunical layers are invaginated by non-absorbable sutures [4, 14, 16, 21, 22]. Continuity of the internal layer of the TA are preserved during that kind of surgical procedure. That's why in our study there is no need to use the tourniquet during tunical reconstruction and there was no intra- and postoperative bleeding from the cavernous

cavity. The other advantage of excision of the external layer of TA is creation of a superficial wound in tunica, which starts the healing process necessary to keep the penis straight [9, 10, 18]. By increasing the number of elliptic incisions, while decreasing their width better and regular penile shape can be achieved. In this way, excessive penile indentation and formation of 'dog ears' during erections can be avoided [4, 9, 18]. Preservation of the internal layer of TA, use of absorbable sutures as well as the natural healing process of the TA, probably are the reasons that in our study penile length (measured as stretched penile length in cm) before and after the operation was not changed in most of the patients or changed slightly in those with 80–90 degrees curvature (up to 0.5 cm). Techniques proposed by us, enabled penile straightening in 180 patients (96.7%). In 4 patients (2.2%) in whom residual curvature up to 30 degrees was detected, reoperation was done. In two patients (1.1%) with remaining curvature up to 20 degrees and good functional result (patient's opinion), there was no need for further treatment. Other authors using similar tunical procedure for correction ventral and ventro-lateral curvatures also presented good results [18].

Many authors use vasoactive agents (prostaglandine E1 or papaverine) for obtaining artificial erection which is sustained during the time of corporoplasty [2, 4, 5, 12, 14, 18, 23]. Disadvantages of such kind of procedures is that sutures are tied on the erect penis, with necessity of approximating rims of tunical fold [2, 4, 12, 14, 23] or margins of excised tunica under tension [4, 18]. Authors of this study and some other authors produced artificial erection by saline injection into the cavernosal body only for assessing the degree of curvature and later for intraoperative control of the progress of penile straightening [1, 2, 8, 9, 10, 19]. Usually after releasing a tourniquet, flaccidity can be restored very quickly [9] and the next stages of our tunical repair were done on the penis in flaccid state. This is an important difference comparing to other techniques of penile reconstruction. To achieve the support necessary for making tunical incisions and excisions, the penis is stretched by an assistant's index finger against the concave surface of the penis while the distal part of the penile convex surface is pulled by a thumb. During placing and tying sutures, stretching on the penis is relieved. In such situations, sutures can be tied gently, with minimal tension in order to prevent them from cutting through the tunica intraoperatively [9, 12, 14].

We use 3/0 single absorbable sutures with the advantage of dividing tension among many sutures, but with the drawback of temporary knots palpation (usually for 2–3 months). It is also possible to place the continuous suture to avoid this, but in patients with strong erections higher risk of recurrence may be anticipated (if suture rupture will take place). Erections increase tension on the sutured TA and sexual intercourse adds some extra tension [2, 12]. That is why most of the authors advise 2 months of abstinence from sexual intercourse [9, 23, 25].

Younger patients, especially those <24 years have a higher possibility of suture failure (due to a greater force of erection) than elder ones [12].

Postoperative erections, which increase tension of the sutured margins of TA are potentially invasive for wound healing (suture loosening and breakage or cut through of tied suture across the tunica) and may be one of the main causes of curvature recurrence [5, 9, 18, 22]. In order to decrease the invasiveness of erections, we tried to diminish of their intensity in the postoperative period by introducing anti-androgen therapy [8, 9, 10] which was also used by other authors [18].

CONCLUSIONS

Longitudinal skin and tunica dartos incision on the convex surface of the penis enables good access to Buck's fascia and the tunica albuginea (TA), which avoids possible penile degloving and the many other complications. Another value of this access is the preservation of the foreskin. Elevation of the dorsal neurovascular bundle (NVB) from the TA is done on a very limited surface – necessary for reconstruction – in the shape of triangle or trapezium which decreases the possibility of dorsal nerves/vessels damage.

Excision of an elliptic fragment of the external layer of the TA with subsequent invagination of internal layer by the sutures, excludes the need for opening of the corpora cavernosa as well as for the use of a tourniquet during reconstruction. This diminishes the potential risk of complications, especially intra- and postoperative bleeding.

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