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Review article

Penile venous surgery for treating erectile dysfunction: Past, present, and future perspectives with regard to new insights in venous anatomy☆

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ABSTRACT

In the physiologic model of normal erectile function, a healthy veno-occlusive mechanism is essential to initiate and maintain a rigid erection. The surgical treatment of patients with venous leakage, which is synonymous with corporoveno-occlusive dysfunction (CVOD), was based on the decreased venous outflow during the erection process. The initial reports of short-term results were promising, but the long-term benefits of penile venous ligation surgery were limited. Most clinical guideline panels concluded that surgeries performed in an attempt to limit the venous outflow of the penis were not recommended. Consequently, this surgery was nearly abandoned in most medical societies worldwide. These unfavorable postoperative outcomes seemed attributable to the indispensable usage of electrocautery and insufficient venous management, based on conventional penile venous anatomy. Advances in better understanding of human penile venous anatomy has enabled the development of refined penile venous stripping surgery. The thorough stripping surgery is an even more radical procedure, which is an even more radical procedure, and seems to be a viable option for the treatment of CVOD, however, there is still a need for further study with well-defined diagnostic criteria, and standardized patient and partner outcome assessment.
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1. Introduction

Erectile dysfunction (ED) is the persistent inability to attain and maintain an erection sufficient to permit satisfactory sexual performance. It is a common disorder worldwide and affects a high percentage of the male population. It remains a challenging medical problem, even after the introduction of phosphodiesterase 5 (PDE5) inhibitors, which became the first-line drugs for ED management in 1998.

Erectile dysfunction affects physical and psychosocial health and significantly impacts the quality of life of men and their partners. It is uncommon in young men, but more common in middle age, and is highly prevalent in men aged > 60 years. Thus, to some extent, ED is a natural expression of aging. Epidemiologic studies of ED suggest that approximately 5–20% of men have moderate to severe ED.[1]

Most patients with ED were previously believed to be psychogenic. This belief has given way to the realization that ED etiologically has an organic basis in most patients. Erectile dysfunction can be caused by vasculogenic, neurogenic, hormonal and/or psychogenic factors, and alterations in the nitric oxide/cyclic guanosine monophosphate pathway or other regulatory mechanisms, which result in an imbalance in corporal smooth muscle contraction and relaxation.[2]

Vascular abnormalities are the most common factors in patients with an organic etiology. There is no doubt that arterial inflow and sinusoidal relaxation are important in the erectile phenomenon; however, failure to trap cavernosal blood within the corpora cavernosa is a common cause of ED.[3] Penile corporoveno-occlusive dysfunction (CVOD), which is synonymous with venous leakage and venogenic ED, represents the most common vascular dysfunction,[4,5] and can be identified in up to 85% of men evaluated for ED, regardless of the age of the patient.[6,7] Most patients with vascular ED are in this group, however, a minority of especially

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younger patients may develop ED because of circumscribed acquired or congenital vascular abnormalities.

2. Physiology of penile erection, pathophysiology of CVOD, and diagnostic investigations

Human penile erection is likely a mechanical phenomenon in a peculiar vascular system, which is involved in three phases of the erectile phenomenon: (1) an increase in arterial inflow into the penis via paired cavernosal arteries; (2) sinusoidal relaxation and filling of the corporeal bodies from this increased arterial inflow: and (3) a decrease in the outflow from or trapping of blood within the corpora, thereby causing tumescence and ultimate rigidity. If all three of these vascular events work normally, an erection ensues. The venous closure mechanism has been described in anatomical dissections and physiological studies.[3] By contrast, if there is a defect in one or all three of these events, ED may occur.

Venogenic ED may result from an improperly functioning occlusion mechanism. Investigations stress the role of the tunica albuginea in the venous occlusion mechanism of the penis during an erection.[2,7,8] The location and degree of venous leak is variable and can occur anywhere along the tunica albuginea of the corpus cavernosum, which has been demonstrated in a canine model[8] and in ED patients.[9]

Recent studies suggest that, in most patients, CVOD results from endothelial dysfunction and damage to the trabecular smooth muscle content because of multifactorial degenerative processes.[10] Structurally based CVOD occurs in patients with ED who have a history of vascular risk factors and/or exposure to disorders that induce trabecular structural alterations such as veno-occlusive priapism, penile irradiation, and connective tissue disorders. Other investigators have reported patients with vasculogenic impotence who exhibit degeneration and atrophy of trabecular smooth muscle cells with increased fibrous connective tissue.[11,12] The possible causes of CVOD include: congenital vascular anomalies; trauma; arterial disease (e.g., hypercholesterolemia, arteriosclerosis); alterations in the cavernosal smooth muscle, trabeculae, or tunica albuginea; psychogenic factors; postpriapism; and unknown origin. It is a common belief that CVOD is an effect rather than a cause of ED.[11,12]

Objective vascular testing that provides a physiologic diagnosis may help direct appropriate therapy because not all patients respond adequately to oral ED therapy. Erectile hemodynamics is evaluated by duplex Doppler ultrasound or dynamic infusion cavernosometry. Diagnostic dynamic penile color-duplex ultrasound can assess arterial function and significant cavernosal venous leakage by measuring peak arterial flow and the calculated resistive index.[13,14] Localization and severity of veno-occlusive dysfunction may be determined by invasive dynamic intracavernosal cavernosometry and cavernosography.[15]

3. A historical overview: penile venous ligation surgery

In 1873, the Italian Francesco Parona injected the varicosity dorsal penile vein of an impotent young patient with hypertonic saline to cause sclerosis and thereby reduce excessive venous outflow. The concept that erectile disorders may be treated surgically by occluding venous channels from the penis was promoted as early as the turn of the 20th century.[16] Surgical ligation or resection of the dorsal vein was practiced by several American doctors [e.g., James Duncan (1895); Joe Wooten (1902); and particularly, Frank Lydston (1908), who reported 100 resections].[16] Beginning in the 1930s, Oswald Swinney Lowsley combined simple dorsal vein plication with a surgically more advanced perineal crural technique in which he plicated the bulbocavernosus and ischiocavernosus muscles with several mattress sutures.[16] After his initial report in 1935, he followed 273 patients from more than 1000 patients that he operated on in his later publication in 1953. After these techniques disappeared from the medical literature, the rebirth of COVD surgery began in the 1980s as a result of the new area of investigation of erectile physiology.[17]

3.1. Surgical technique

Using a parapenile inguinal incision, the shaft of the penis is delivered into the operative field in a gooseneck fashion. Buck's fascia is incised over the dorsum of the penis, the deep dorsal vein is identified and isolated. Care must be taken to avoid injuring the paired dorsal arteries and nerves. The deep dorsal vein is stripped from the symphysis pubis to 1 cm proximal to the corona, while its tributaries are transected and ligated. The suspensory ligaments are not divided and no attempt is made to ligate the cavernosal or crural veins.[18]

There has been some debate as to whether a standard surgical approach should be used, which involves ligating and excising the deep dorsal vein and its tributaries,[17,19,20] or whether the procedure should be directed specifically to the site of the leakage demonstrated on cavernosography.[21] Other investigators have routinely performed an even more extensive procedure by ligating the cavernosal and crural veins and the deep dorsal vein and its tributaries.

The technical goal of therapy addresses the identified malfunctioning or ectopic deep dorsal, crural, or cavernosal veins. The surgical procedure has, over time, been expanded from simple deep dorsal vein ligation to extensive surgical exposure and vein ligation, excision, crural placation, and spongiolysis performed alone or in combination.[22]

3.2. Outcomes of penile vein ligation surgery

Most studies have been retrospective analyses, and rely on the patient's report of his sexual functioning. No study has reported the use of standardized questionnaires for subjective improvement or has reported improvement in the quality of life as a result of the surgical intervention. There are generally no postoperative quantitative vascular assessments, except in patients with a poor response to the intervention.

The initial reports with short-term results were promising,[17,19,20,23] however, the long-term benefits of venous ligation surgery have been limited. Success rates within the 1st year range from 23% to 80%, but consistently decline on longer follow up.[18,24,25] There is a time-related decline in successful function, presumably through incomplete ligation, recanalization, cavernosa-spongiosum leak, inadequate selection of patients, or the unrecognized presence or progression of arterial pathology, and/or smooth muscle dysfunction.[17,19,20,26,27] Perioperative complications include wound infection, penile curvature, skin necrosis, painful erections, postoperative shortening of the penis, penile deformity, transient or irreversible numbness, lymphedema, and ligation of the penile artery by error.[26,28] Berardinucci et al[18] report complication rates of 15%, which include temporary paresthesia of the penis (12%), and adhesions between the skin and the penis, which result in variable degrees of penile deviation during erectile episodes. Freedman et al[21] described complications such as excessive penile edema (33%), hematoma (15%), excessive pain (17%), scarring requiring revision (2%), penile shortening (43%), and hypoesthesias (20%).

4. Important guideline publications

The diagnosis and treatment of venous insufficiency is increasingly questioned because it appears that “leakage” is a misnomer and represents an erroneous interpretation of a more fundamental problem related to alterations in the cavernosal tissue and the

tunica albuginea rather than a primary venous disease.[29] The hemodynamics of CVOD is recognized; however, it is difficult to distinguish functional abnormalities (e.g., smooth muscle dysfunction) from anatomical defects (e.g., tunical abnormality). It is also difficult to determine what percentage of ED results from CVOD, independent of general arterial hypofunction; how to accurately diagnose this condition; how often arterial insufficiency coexists; and whether there exists a subset of patients with this disorder who would benefit from surgical intervention.

The National Institutes of Health Consensus Development Conference Statement and the Clinical Guidelines Panel on ED of the American Urological Association (AUA) previously concluded that penile ligation and penile revascularization should be performed in a research setting with long-term follow up available.[30,31] The ED guidelines update panel of the AUA further proclaimed that sufficient evidence to support a routine surgical approach in the management of veno-occlusive ED has not been published. Surgeries performed with the intent to limit the venous outflow of the penis are not recommended.[32] The first European Association of Urology Guidelines on Erectile Dysfunction were published in 2000 with subsequent updates. The latest update, renamed "Guidelines on Male Sexual Dysfunction: ED and Premature Ejaculation," also disclaimed using venous ligation procedures of the penis as an option for managing ED because of the poor overall outcomes.[33]

5. Discovery of penile venous anatomy

The venous system of the human penis has been widely studied, and was considered to consist of a single deep dorsal vein between Buck's fascia and the tunica albuginea (Figure 1).[34,35] However, in tandem with surgical assessment, clinical imaging, and a human cadaveric study, penile erection-related veins have been discovered,[36] which consist of a deep dorsal vein (DDV), a pair of cavernosal veins (CVs), and two pairs of para-arterial veins (PAVs) in between the tunica albuginea and Buck's fascia instead (Figure 2). The DDV serves as a common vessel that receives blood drained from the corpora cavernosa through numerous emissary veins, and from the corpus spongiosum via several circumflex veins. The CVs course along each corpus cavernosum and extend distally to the glans and between the dorsal artery and the DDV (but deeper to the latter) and, within a different perivascular sheath, lies intimately on the tunica albuginea and receives direct emissary venous drainage. The CVs are asymmetrical bilaterally in their size and course, and constitute independent drainage directly into the Santorini's plexus. Two sets of PAVs accompany the dorsal arteries. These veins are quite prominent distally with the medial PAV receiving emissary drainage from the corresponding corpus cavernosum and the lateral PAV occasionally having its own circumflex vein from the corpus spongiosum. The PAVs drain into the DDV close to the infrapubic angle or enter the pelvis independently. To negate psychogenic influence on the human erection, studies have been conducted on fresh and defrosted human cadavers and investigators concluded that penile veins have a pivotal role in determining a rigid erection.[37–39]

6. Refined penile venous stripping surgery

The innovation of penile venous anatomy has enabled the refinement of penile venous stripping surgery, an even more radical procedure that is routinely performed under local anesthesia on an outpatient basis.[40,41] It has been patented by the United States Patent and Trademark Office.[42]

The patients were highly selected, compared with patients enrolled in series published in the literature. Enrollees received

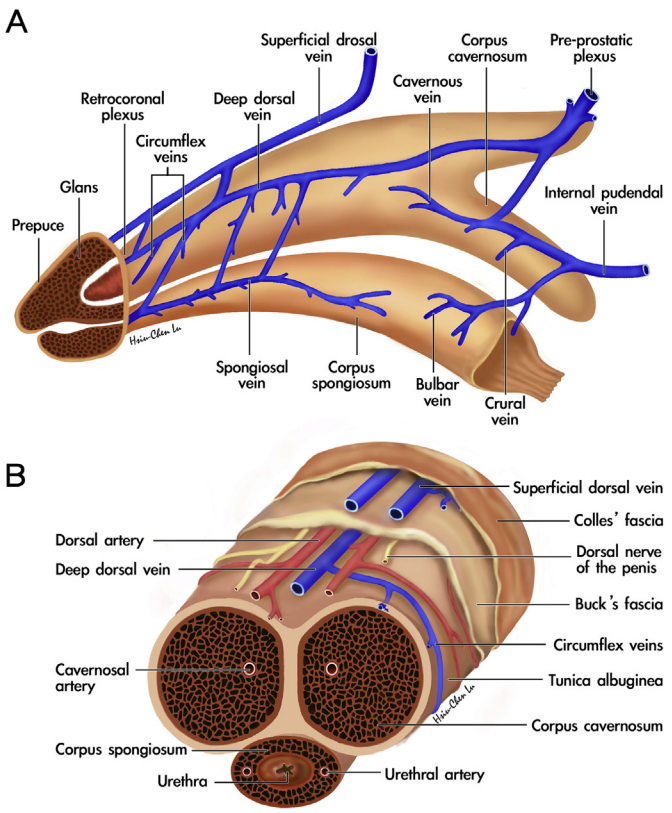

Figure 1. Schematic illustrations of the conventional penile tunical and venous anatomy. (A) Lateral aspect. The glans penis is exclusively composed of uniform sinusoids only. The deep dorsal vein (DDV) is flanked by a pair of dorsal arteries (DA). The 2:1 ratio of arteries to veins is the same as in the umbilicus vessel. (B) Cross-section of a pendulous portion of the human penis. The tunica albuginea of the corpora cavernosa is consistently described as a one-layered coat with uniform thickness and strength. The median septum is complete. There is one single DDV and two DAs between the Buck's fascia and tunica albuginea. Thus, the penile vascular system still complies with the general anatomical rule that veins number more than arteries in the entire body. Note. Figure 1 is from "Advances in our understanding of mammalian penile evolution, human penile anatomy and human erection physiology: clinical implications for physicians and surgeons," by C.H. Hsieh et al, 2012, *Medical Science Monitor*, 18(7), p. RA118–125. Copyright 2012, *ISL*. Reprinted with permission.

multidisciplinary diagnostic approaches. Patients who had an untreated chronic systemic disease (e.g., diabetes mellitus, chronic liver disease, renal failure, hormonal insufficiency, or psychoneurotic disorders) or other obvious etiologies such as prostate surgery, major pelvic surgery, and trauma were excluded from undertaking cavernosography. Patients were diagnosed with CVOD, based on dual pharmacocavernosography and dynamic penile color-duplex ultrasound.

6.1. Surgical technique

Using the revolutionary penile venous anatomy as a blueprint, penile venous stripping surgery was performed in sequence (Figure 3). A circumcision was first performed to identify the DDV, which was freed 2–3 cm proximal to the retrocoronal sulcus. It was then thoroughly stripped distally to the level of the glas penis where several dozen branched veins may reside. A step-by-step pull-through maneuver of the DDV system was performed proximal to the penile hilum, using the trunk of the DDV as a guide, and passed through the openings formed on the Buck fascia at the exits of the emissary veins. This maneuver minimizes tissue damage. The CVs were similarly managed. A longitudinal pubic incision was then formed to pass the DDV and CVs trunk

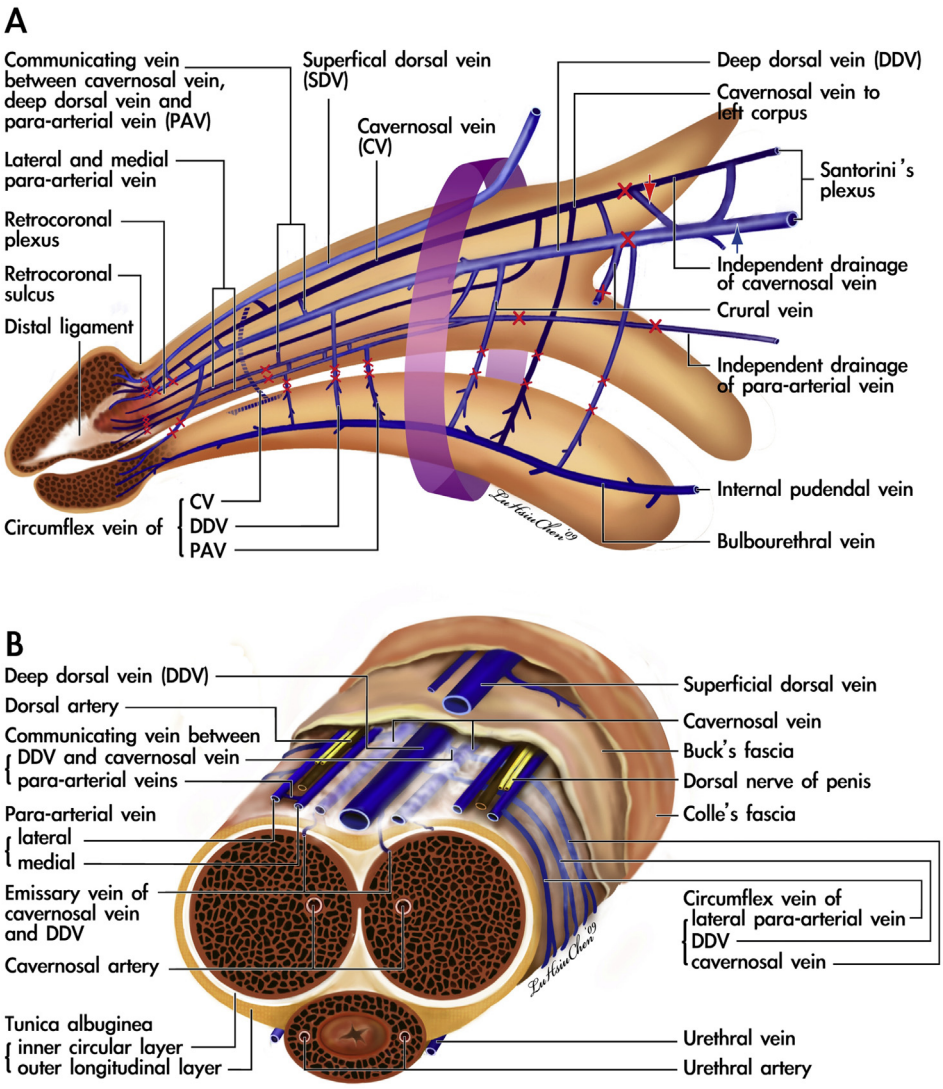

Figure 2. Schematic illustrations of the revolutionary penile venous anatomy in the human penis. (A) Lateral view. The deep dorsal vein is consistently presented in the median position and receives blood from the emissary veins draining the corpora cavernosa and of the circumflex vein communicating with the corpus spongiosum. It is flanked by bilateral cavernosal veins, although these lie at a deeper position in specific venous sheath. Bilaterally, each dorsal artery is respectively sandwiched by its corresponding medial and lateral para-arterial veins. Note that the lateral para-arterial vein merges with the medial vein proximally. (B) Cross section of the penis in middle pendulous portion. Note that the number of veins is seven, not one, as was traditionally believed, between the tunica albuginea and Buck's fascia. Note that the number of independent veins becomes four at the level of the penile hilum because each pair of the nomenclature veins merges. Erection-related veins are arrayed in an imaginary arc on the dorsal aspect of the tunica albuginea with connecting network. It is a blueprint for penile venous stripping and ligation sites (cross) are resorted to the tunical level.
Note. Figure 2 is from "Advances in our understanding of mammalian penile evolution, human penile anatomy and human erection physiology: clinical implications for physicians and surgeons," by C.H. Hsieh et al, 2012, *Medical Science Monitor*, 18(7), p. RA118–125. Copyright 2012, *ISL*. Reprinted with permission.

underneath. The DDV and CV systems were subsequently ligated proximally for 7–10 branches and 4–9 branches, respectively, until the infrapubic angle was reached. Engorged circumflex veins and PAVs resulted from the rich drainage of the emissary veins and were simple ligated respectively. The bilateral crural veins were ultimately managed close to bulbocavernosus muscle.[41] Excessive application of the electrocautery outside the tunica can produce tissue destruction that extends far beyond the treated foci of interest.[43] With electrocautery spared, fine 6-0 nylon sutures were utilized for ligating the veins and hemostasis through the entire procedure.

6.2. Outcome of refined penile venous stripping surgery

During a follow up of 5.1–8.2 years, Hsu et al[41] reported an improvement rate of 90.4% in well-selected patients with CVOD. Hsu et al[44] also reported salvaging penile venous stripping surgery with a fair outcome in patients who had experienced poorer erectile capability or/and penile deformity from prior venous surgeries they had received elsewhere. There is controversy on whether the insufficient response to penile venous surgery in an attempt to restore erectile function results from the recurrent veins or residual veins. Hsu et al[45] propose that the clinical relapse of ED results from residual veins rather than recurrent veins.

The complication rate was low. Compared with complications reported in the literature, complications such as minor bruising, hematomas, and temporary edema seem minor and negligible. Application of refined venous surgery appears to augur well. However, it is impossible to compare the outcome among series because of the variable criteria used for the selection of patients, diverse surgical techniques, and different follow-up methods and periods.

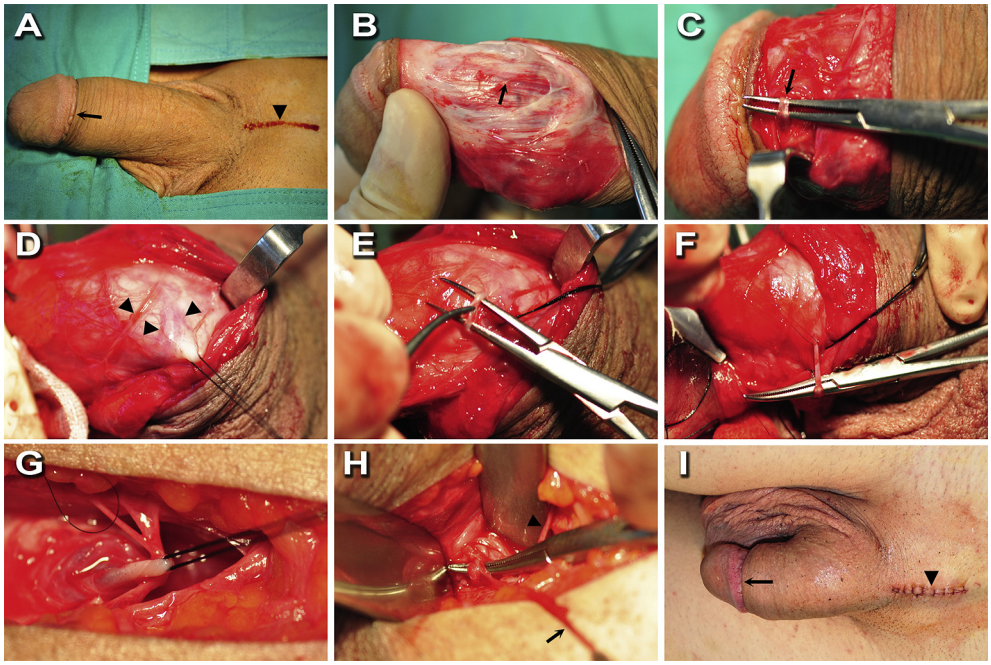

Figure 3. Photos of an ongoing surgical process. (A) A circumferential incision (arrow) and longitudinal wound (arrowhead) are used to access the offensive veins. (B) The deep dorsal vein (DDV, arrow) is readily visible if the corpora cavernosa is manually compressed. The DDV and cavernosal veins (CVs) are thoroughly stripped to the penile base. (C) An engorged circumflex vein is identified and managed in the left corpus cavernosum. (D) Several circumflex veins (arrowheads) are visible as the stripping procedure proceeds proximally; a tag suture is fixed at the 5 o'clock position of the tunica albuginea using 3-0 silk suture. (E) One vein of them is managed. (F) It is ligated as close as possible to the corpus spongiosum using 6-0 nylon sutures. The para-arterial veins are similarly meticulously ligated rather than being stripped. (G) A longitudinal pubic incision is formed to continue the stripping procedure proximally. The DDV trunk is tagged (black suture). (H) The DDV (arrow) and one CV (arrowhead, at least two) systems are ligated proximally for 7–10 branches and 4–9 branches, respectively, until the infrapubic angle is ensued. (I) The circumferential wound (arrow) and the median longitudinal pubic wound (arrowhead) are approximated layer by layer with a 5-0 chromic sutures.

7. The future

As mentioned previously, veno-occlusive mechanisms involve the corpus endothelium, smooth muscle, tunica albuginea, subtunical venous drainage system, and extracorporeal aberrant venous vessels in erectile function. Most investigators agree that CVOD is an effect rather than a cause of ED. Whatever the mechanism, CVOD represents a failure of normal veno-occlusion during the increased arterial inflow of an erection, and venous leak surgery is directed at increasing venous resistance. Thus, penile venous surgery may not be acting at the site of the causal veno-occlusive incompetence, but it achieves the desired physiological effect. However, the extensive collateral venous drainage of the penis is probably a major reason that most venous ligation procedures fail to have a consistent beneficial effect in most patients with venogenic ED.[46]

Venous leak surgery is an option that offers the possibility of obtaining spontaneous unaided erections. This is intuitively attractive to patients and to surgeons. Based on the new insight into the penile venous anatomy, a definitive surgical removal of offending veins appears promising and may augur well with better results in properly selected patients.[47] To some degree, refined penile venous surgery is envisaged to offer a beneficial effect in most patients with CVOD and comorbidities. It is interesting that numerous surgical failures can be rescued with the intracavernosal administration of vasoactive agents to which they were unresponsive before the operation.[27,48] Furthermore in conjunction with corporoplasty and penile venous stripping, combination surgeries may offer a viable option for the treatment of ED and dysmorphology.[48]

In rare cases of isolated venous leaks due to congenital or posttraumatic lesions, targeted ligation of these venous outflow channels may be practical.[49] All patients should be provided detailed information about the current uncertainties of this procedure, alternative therapies, possible complications, the probability for secondary corrective surgery, and the need for long-term follow up.

The efficacy of this surgery is controversial largely because patient selection and outcome criteria have not been objective and because a variety of surgical techniques has been used. It is paramount to document a standardized diagnostic approach and assessment of surgical efficacy, if feasible.

8. Conclusion

With the current review of evidence-based analysis, there are no additional outcome data of sufficient quality or quantity to supersede the recommendations proposed by the guideline panels. Refined penile vascular surgery seems promising for the treatment of CVOD. There is still a need for further study with well-defined diagnostic criteria and standardized patient and partner outcome assessment. Penile prosthesis implantation remains the last resort for treating ED.

Conflicts of interest

The authors declare that they have no financial or non-financial conflicts of interest related to the subject matter or materials discussed in the manuscript.

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