Vascular Surgery for Erectile Dysfunction

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Glossary

Angioplasty An endovascular treatment specific to artery while balloon tamponade and arterial stent are always used in one setting.
Deep dorsal vein arterialization A hybrid surgery for erection restoration by increasing penile arterial supply using donor artery and meanwhile the circumflex veins were ligated to limit the venous drainage.
Electrocautery A device can deliver electrical energy to coagulate vascular lumen and prevent the blood vessels from bleeding.
Erectile dysfunction A newer term to replace the older one impotence which is defined as inability either to attain or maintain a rigid erection for satisfactory coitus.
Penile arterial insufficiency A situation that penile supply artery is dysfunctional. The supplying artery fails to adequately feed the sinusoidal tissue, in turn, unable to attain a full erection.
Penile arterial reconstruction A kind of reconstruction surgery to restore the penile arterial supply to meet the sinusoidal demands. The surgery purpose is to restore blood supply, therefore no destruction is allowed.
Penile veno-occlusive Dysfunction Penile sinusoidal tissues sustain blood perfusion from 2 to 3 to 60–80 mL/min to flaccid and erection status respectively. It is, therefore, understandable that abundant blood drains back to systemic circulation. Inability either to attain or maintain a rigid erection occurs if a penile veno-occlusive dysfunction occurs.
Penile vascular surgery Surgery method involves penile vascular system including penile arterial or venous surgery.
Penile vascular intervention A general term of penile endovascular treatment managed by the physician including methods used by the surgeon, interventional radiologist.
Penile venous embolization A measurement in an attempt to block the penile venous drainage by hindering the vessel from vascular endothelium by implanting coil, band ligation or scleronizing agent injection.
Penile venous ligation A ligation of penile erection related veins.
Penile venous sclerotherapy Any method in an attempt to reduce the penile venous drainage speed by using sclerosing agents.
Penile venous stripping A term to describe a thorough removal of erection related veins while the exits of emissary veins are firmly ligated.
Suction apparatus A device to suck bleeding blood away in order to clearly see the operative field during surgery.

Penile Arterial Surgery for Patient with Erectile Dysfunction

Innovative Penile Vascular Anatomy and Erection Physiology

The human beings have been in its current penile anatomy for some three thousand centuries. In traditional medical literature, it is consistently depicted that a single circular tunica layer and one deep dorsal vein flanked by paired dorsal arteries between Buck's fascia and the tunica albuginea of the corpora cavernosa. We may question how the veno-occlusive mechanism elucidates if no outer tunic layer exists? Thus it is likely that we may still not thoroughly understand its anatomy and erection mechanism and so does the reconstructive surgery derived from this anatomical knowledge.

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Recent studies substantiate a model of the tunica albuginea of the corpora cavernosa as a bi-layered structure with a 360° complete inner circular layer and a 300° incomplete outer longitudinal coat spanning from the bulbospongiosus and ischiocavernosus proximally and extending continuously into the distal ligament within the glans penis. The entire outer layer of the penis and the above two muscles could be collectively categorized as skeletal components. The inner layer contains and supports the intracavernous sinusoids, the erection-related veins, and artery which could collectively be allocated as the smooth muscle components. Human beings are peculiar within the erect animal family in that we possess an os analog associated with some proportionally large and extraordinarily extensible corpora cavernosa and however, man does not possess an os penis which is present in all quadriceps; the actual bony portion that provides penile rigidity. The erectile capability of the human penis largely depends on sinusoids in the glans penis, the corpus spongiosum, and the corpora cavernosa which are also exclusively responsible for erection rigidity.

Thus, human penis evolves from a rigid body into a hydraulic system. Albeit human may be proud of this penile hydraulic design at no expense of awkward locomotion for an erect animal. It seems that the human corpora cavernosa are vulnerable to encounter erectile dysfunction (ED) which is defined as inability either to attain or maintain a rigid erection for satisfactory coitus.

The importance of a functional penile artery is the prerequisite for rigid erection. A rigid erection of the corpora cavernosa is initiated by either local stimulation or central drive if there are healthy corpora cavernosa in which a unique dual circulatory route is characteristic. In addition to the regular vascular system for nutrition via the capillaries, there is a system for erectile function in which sinusoids shunt directly from arterial to sinusoidal space and then venous channels bypassing the capillaries. In human corpora cavernosa, therefore, it accounts for 2–3 mL/min to 60–80 mL/min in accordance with flaccid and erection status respectively. The main source of blood supply to the penile sinusoids originates from the internal pudendal artery which is the end branch of the internal iliac artery, although accessory contributions may arise from the external iliac, obturator, vesical, and femoral arteries. The internal pudendal artery gives off branches of bulbourethral, cavernosal and dorsal artery along exiting from the pudendal canal. The sinusoids of the corpora cavernosa are primarily supplied by the cavernosal artery and secondary by the dorsal artery (Fig. 1). Two types of branches arise from the cavernosal artery. Firstly, the outer capillaries which are responsible for penile nutrition supply the smooth component, skeletal component and nerve fibers. This system signifies that the corpora cavernosa are also susceptible to long hours in the erectile state. Secondly, and for fulfilling erection function, the inner helicine arteries open directly into cavernous spaces without entering capillaries, which are then emptied into the post cavernous venules. These inner arteries are shaped like corkscrews and allow the penis to elongate and enlarge without compromising flow.

The sinusoidal blood drains directly to sub-tunical venous plexus, subsequently passing through the tunica albuginea to the emissary veins, and then to the deep dorsal veins (DDV), cavernosal veins (CVs) and para-arterial veins (PAVs) separately. DDV, CVs and PAVs are collectively called erection related veins (ERVs) because they drain the sinusoidal blood independently. Thus DDV, CVs and PAVs own their specific emissary veins. This new understanding of penile venous anatomy is highly significant. Not only do we consider the traditional deep dorsal vein significant, but also the cavernosal vein, which distributes through the entire penile length and the para-arterial veins. The deep dorsal vein that lies consistently in the median position receives blood from the circumflex veins of the corpus spongiosum and from the emissary veins of the corpora cavernosa. Emissary veins run between the inner and outer layers of the tunica for a short distance, often piercing the outer layer bundles in an oblique manner. Therefore, and significantly, these emissary veins can be easily occluded by the shearing action elicited by the inner circular and outer longitudinal layers of the tunica albuginea.

The DDV is sandwiched by cavernosal veins that are coalesced to one at the penile base. Bilaterally each dorsal artery is sandwiched by the medial and lateral para-arterial vein respectively. Veins from the glans penis form a retrocoronal plexus that drains predominantly into the deep dorsal vein, the urethral veins, and the corpus spongiosum. The deep dorsal vein courses proximally in the midline between the two corpora cavernosa and empties into the periprostatic plexus. The superficial dorsal vein drains the skin and the subcutaneous tissue superficial to Buck's fascia and may have direct shunts to the corpora cavernosa. This, in turn, drains into the superficial external pudendal vein and is frequently seen in young male with ED. If and only if the erectile function of corpora cavernosa is healthy, the penis not only expands in its girth but also increases in its length, resulting in sufficient rigidity with sexual arousal.

Multiple layers of smooth muscle surround the helicine branches. This muscle is contracted while flaccid, allowing only small amounts of blood into the lacunar spaces. After the appropriate stimulus, muscle relaxation occurs and the arteries dilate and straighten, increasing blood flow and dilating the lacunar spaces, in turn, applying pressure against the outer longitudinal layer of the tunica albuginea to reduce the blood drainage, which eventually results in a rigid erection. Application of real world physics would assume that the corpora cavernosa is an ideal vessel to apply Pascal's Law which states that pressure applied to any part of an enclosed fluid at rest is transmitted undiminished to all walls of the containing vessel.

Pathophysiology of Erectile Dysfunction

There is a current consensus of erectile dysfunction pathophysiology which includes psychological disturbance, hormonal imbalance, vascular insufficiency, neurological deficit, sinusoidal fibrosis, pharmacological adverse's effect and metabolism disease. In other words, healthy male with normal sexual function must be under psychological health, an intact neurological system, a normal hormonal profile, an absence of adverse drug influence, a lack of systemic diseases, a functional artery and healthy intracavernous tissues. However, the end-organ penis just requires arterial sufficiency, normal sinusoidal tissue, and functional veins. Although there is no agreement on what would be the major contributor, there is a bias towards endothelial function due to the dramatic effects demonstrated by phosphodiesterase-5-inhibitors (PDE5↓) on erectile dysfunction.

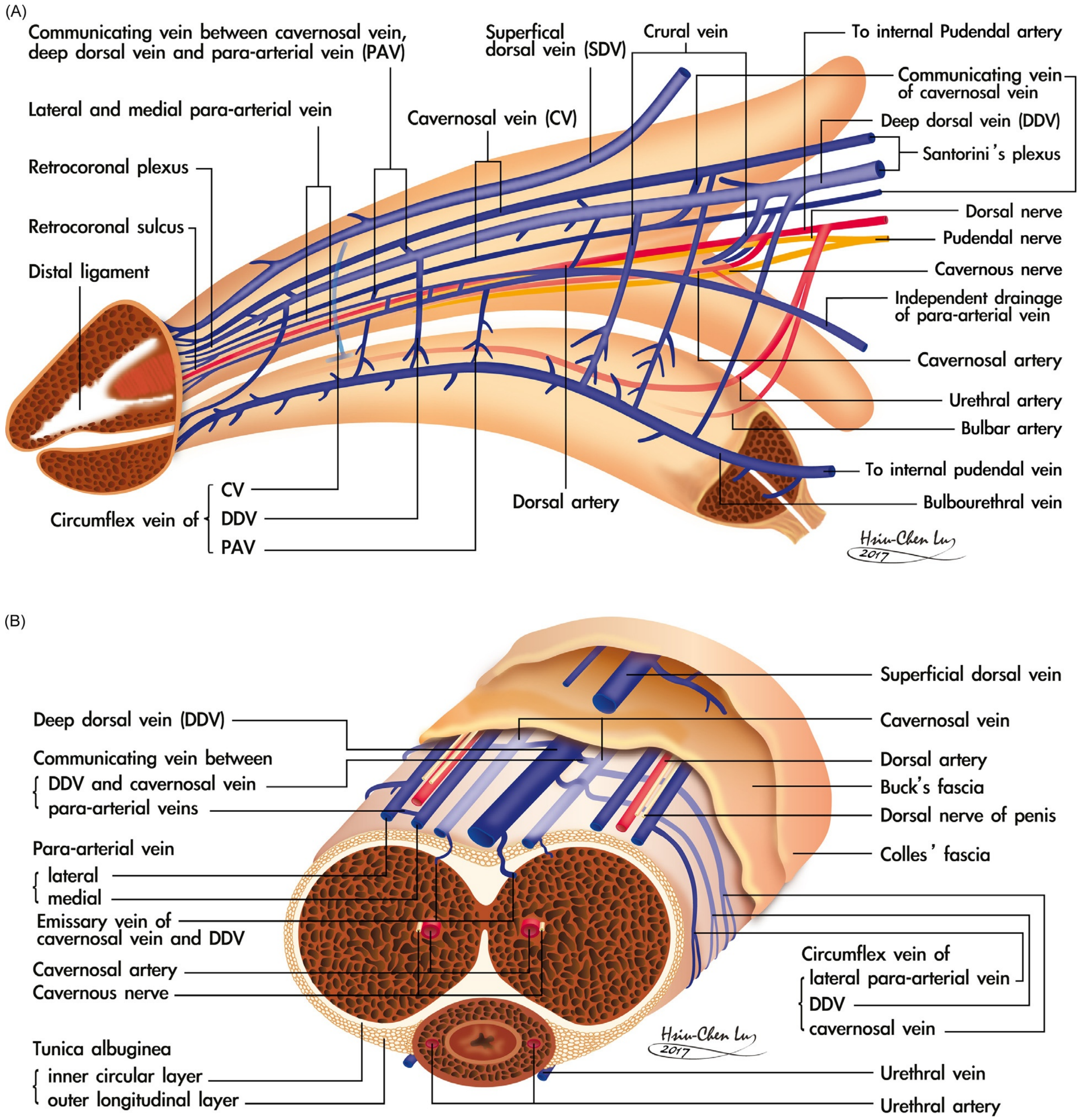

Fig. 1 Schematic illustration showing vascular system in the human penis. (A) Upper Lateral view: The deep dorsal vein consistently in the median position, receives the blood of the emissary veins from the corpora cavernosa and of the circumflex vein from the corpus spongiosum. It is sandwiched by cavernosal veins, although these lie in a deeper position. Bilaterally each dorsal artery is sandwiched by its corresponding medial and lateral para-arterial veins respectively. Note that the lateral para-arterial vein merges with the medial one proximally. The deeper color of the veins indicates the deepest group of the vasculature. The internal pudendal artery gives branch to bulbo-urethral artery and then the cavernosal artery which is the major supplier of the CC as well as dorsal artery supplying the glans penis. (B) Cross-section of the mid-portion: Note that the number of veins is seven rather than that of the traditionally described one, although it becomes four at the level of penile hilum because a mergence takes place in each pair of the nomenclature veins. The erection-related veins are arrayed in an imaginary arc on the dorsal aspect of the tunica albuginea. The penile artery does not always accompany fellow veins.

There are, however, recent hemodynamic studies on fresh and defrosted human cadavers whereby rigid erections were unexceptionally reproducible despite the lack of endothelial activity. Constant low-pressure perfusion was used to mimic arterial inflow, and the staged removal of ERVs produced increasingly more rigid erections. Could it be that ERVs may, in fact, be the predominant factor that underlies erectile rigidity? Certainly, and in the light of our increased understanding of the penile vasculature, it would at least warrant re-evaluation of the role and even a viable option of venous surgery for erectile dysfunction in addition to rudimentary penile artery reconstruction. In summary, the corpora cavernosa, skeletal muscle components unite smooth muscle components to meet the requirements for an erection and only allow vascular and nervous tissue to communicate with the systemic circulation. Their anatomical relation is seemingly like a cluster of the grape when the emissary vein is regarded as the grape trunk and each sinusoid as a fruit. The rigid erection of the corpora cavernosa overall depends on cooperation among healthy sinusoids, a normal tunica, functional arteries, and competent veins. Thereafter vascular dysfunction is an important cause of male erectile dysfunction. It can be classified as veno-occlusive dysfunction, arterial insufficiency, or mixed. Accordingly, the best resort may be penile venous surgery, arterial reconstruction, and venous/arterial reconstruction respectively.

Penile Artery Surgery

In general, arterial vasculogenic causes of ED increase with age and is most prevalent in those with risk factors for atherosclerosis such as diabetes, hypertension, cigarette smoking, hyperlipidemia and obesity. Traumatic events, which occur more often in younger men, are due to pelvic trauma, straddle injury or even perinea insult such as long time bicycling. Albeit it is not above controversy, documentation of arterial insufficiency can be noted via color Doppler ultrasonography, if peak systolic velocity is <25 cm/s or simple prostaglandin E1 test if the response fails to reach rigid erection.

Angiography, the benchmark for all arterial investigations, is reserved for those males who may resort their ED to penile arterial reconstructive surgery, concurrent embolization or angioplasty for treatment of arterio-venous fistula or stenosis respectively.

In 1973, Michal published firstly an article of penile arterial reconstruction in an attempt to enhance arterial flow to corpora cavernosa. He debuts revascularization surgery by the anastomosis of the inferior epigastric artery (IEA) to the corpora cavernosa. Subsequently, the deep dorsal vein arterializations, either without extensive ligation of the circumflex veins or with venous ligation, were introduced by Virag and Haudi in 1981 and 1986 respectively. In an effort to achieve more favorable outcomes varied modifications were performed, such as Furlow–Fisher procedure in which IEA was made in an end-to-side anastomosis to the DDV while several ligations were undertaken at the lateral circumflex veins, proximal and distal location (Fig. 2). It aims at increasing penile arterial inflow and limiting the venous drainage. Postoperative outcomes of arterial revascularization surgery are varied due to multifaceted causes, patient selection, surgical instruments and surgical technique. In general, its merit is limited, without long term benefits (Table 1). Furthermore, complication rate occurs in about 25% of patients who undergo penile revascularization surgery. Immediate postoperative arterial hemorrhage may result from disruption of the microvascular anastomosis with

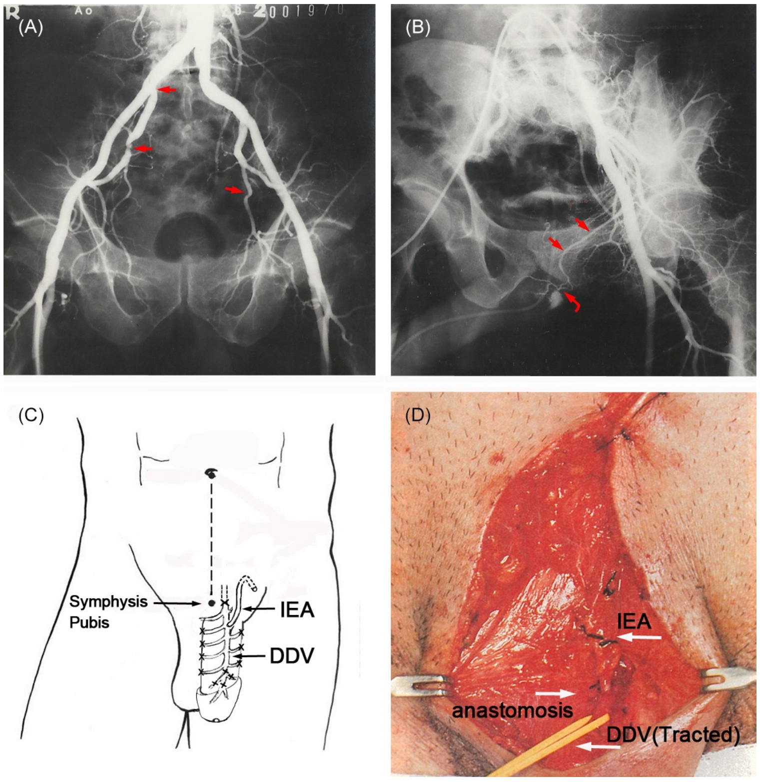

Fig. 2 Selective internal iliac arteriography. (A) An aortogram disclosed marked stenosis *(arrows)* of internal iliac artery bilaterally. It should not be prognostic for arterial revascularization. (B) A similar phase arteriogram showed a blockage of penile dorsal and cavernosal artery, whereas the spongiosal artery appeared diffusely profuse to the corpus spongiosum after a straddle injury in a 32-year-old man. Is it similar to an arterio-venous malformation? The Foley catheter *(arrow)* was clamped. The pudendal artery was well demonstrated *(arrows)*, therefore, was this male a good candidate for arterial reconstruction? (C) Illustration of Furlow–Fisher procedure. The inferior epigastric artery is fashioned to the deep dorsal vein which is ligated distally, proximally and lateral locations of the circumflex veins. (D) Photo of an already DDV (*yellow* traction) arterializations with IEA. The microvascular anastomosis was performed.

Table 1 Outcomes from penile revascularization surgery in recent two decades

Author/publication	*Patient No/age(y)*	*Procedure*	*Follow-up (months)*	*Intercourse success rate*
Jarow/1996	11	DDVAA[a]	50	92
Lukkarinen/1997	24	Hauri/F–F[b]	N/A[c]	77
Manning/1998	62	Virag/Hauri	41	54
Sarramon/1997	114	DDVAA	17	63
Kawanishi/2004	51	Hauri/F–F[b]	36–60	85.9
Vardi et al./2004	52/28.5	N/A	70.8	48
Kayigil et al./2008		F–F[b]	22.1	
Munarriz et al./2009	71/30.5		34.5	
Kayigil et al./2012	125/43.2	F–F[b]	73.2	63.6- $>$ 92.8

[a]DDVAA denotes deep dorsal vein arterilization and arterial reconstruction.
[b]F—F is an abbreviation of Furlow–Fisher procedure.
[c]N/A stands for non-applicable.

hematoma formation. The potential risks of these techniques, such as spongy necrosis and hyperesthesia of the glans, cannot be ignored. In addition, a complication rate of wound infection, inguinal hernias, loss of penile length, and decreased penile sensitivity cannot be avoided. Particularly, the major complications are priapism and glans hyperemia which deter continuing existence. Not surprisingly, it has been regarded as experimental among most urological surgeons. Although it is not beyond controversy, penile arterial revascularization surgery has been studied by several teams and supports its utility in young males suffered from arterial trauma, and in the older male with localized arterial occlusive disease (Fig. 2A). Endovascular angioplasty with stenting is also recommended as a minimally invasive option for this disease entity.

Penile Venous Surgery for Patient with Erectile Dysfunction

Conventional Penile Venous Ligation Surgery

In 1873, the Italian Francesco Parona injected varicosity dorsal penile vein of an impotent young patient with hypertonic saline in order to cause sclerosis and reduce the excessive venous outflow by this. Subsequently, surgical dorsal vein ligation or resection was practiced by several American doctors, e.g. Henry Raymond and James Duncan each in 1895, Joe Wooten in 1902 and mainly Frank Lydston in 1908, who reported on 100 resections. Beginning in the 1930′s Oswald Swinney Lowsley combined simple dorsal vein plication with a surgically more advanced perineal crural technique in which he plicated the bulbocavernous and ischiocavernous muscles with several mattress sutures. Penile venous surgery (PVS), however, remained unpopular until 1980′s when the majority of patients with organic erectile dysfunction were subject to veno-occlusive dysfunction (VOD), the procedure took place and prevailed accordingly. The approach was expanded from initial procedures involving single vessel ligation of the deep dorsal vein to more elaborate techniques in which excision of the deep dorsal vein, cavernous vein, as well as the crural vein were described. It appears that the offending veins of VOD are merely a single DDV with tributes, additionally crural veins and cavernous veins which drain the penile hilum.

Importantly, though anatomically the penis is in the realms of urology, the delicate microsurgery is beyond the traditional urology training, which may result in an inadequate skill level leading to just a single ligation at the expense of electrocautery influence. Not surprisingly penile venous ligation has been almost abandoned because the consensus on this type of treatment for erectile dysfunction (ED) is short term success of 1 to 2 years, without a sustainable long-term outcome. In addition to the lack of sustained functional improvement, irreversible deformity and permanent numbness of the penis after surgery were frequently noted and considered to be unacceptable complications. Failure to achieve a long-term merit for ED and the seemly, unavoidable, adverse side effects have discouraged many surgeons from applying venous surgery for patients with ED. However, irreversible numbness results from nerve damage, and penile deformity is a result of either fibro-skeleton alteration or loss of extensibility and sliding capability of layered tissues from electrocoagulation-induced fibrosis. Should then neither nervous nor fibrous tissues not be innocent if PVS is exclusively targeting on venous structures? Should the venous removal be sufficient if all conventional penile venous anatomy has exclusively depicted a single DDV and tribute veins nearby the penile hilum?

Consensus of Penile Vascular Surgery

Penile arterial revascularization is considered to be unproven and controversial. In 1996, it was the first consensus reached when the AUA (American Urological Association) in its guidelines considered penile venous and arterial surgery in men with arteriosclerotic disease as investigational and should be performed only in a research setting with long-term follow-up available. The proceedings of the First Paris International Consultation on Erectile Dysfunction in 1999, the second in 2003 and the third in 2009 were in tandem with the AUA guidelines. Similarly, in 2005, the AUA Update on the Management of ED, and the ISSM's Standard Practice in Sexual Medicine textbook maintained the consensus. However, it may deserve reappraisal after a review of arterial reconstructions reported after 2004 (Table 1), including Kawanishi and Vardi in 2004, Kayigil in 2008, Munarriz in 2009 and Kayigil in 2012. Interestingly, researchers unexceptionally report positive long term outcomes when both penile arterial and venous reconstruction are incorporated, suggesting arterial reconstruction alone is not sufficient to long term restoration of ED.

For investigating the vascular contribution exclusively, hemodynamic studies have been performed on both fresh and defrosted human male cadavers since 2001 to 2013. In each case, a rigid erection was unexceptionally attainable under very low infusion rate following venous removal. This clearly has significant ramifications in relation to vascular reconstruction and its role in treating ED patients. Albeit there are no comparative prospective randomized studies assessing outcome of penile revascularization surgery for arteriogenic ED. Based on the evidence in the literature, this surgery may be offered to men below the age of 55 who are non-smokers, non-diabetic, show no evidence of venous leakage, and demonstrate an isolated stenosis of the internal pudendal artery in particularly to young patients who have sustained focal arterial injury due to trauma. Regarding penile venous surgery for patients with VOD, it is rejected by most medical community due to disappointing outcomes and unavoidable complication such as permanent penile numbness and penile deformity. Although, use of electrocautery is routine in surgery, it is a major avoidable hazardous in penile venous surgery while penile sinusoids are too delicate to sustain a back fire. The second reason for unsuccessful-conventional PVS is incomplete removal of offending veins for VOD if the PVS refers to the conventional penile venous anatomy. Both residual veins and electro-cautery effects are readily demonstrated in those patients whom underwent PVS somewhere internationally since 2001.

Chronological Development of a Refined Penile Venous Stripping

The advancements in our understanding of penile anatomy, in our surgical instruments and our surgical techniques have resulted in our performing on an ambulatory basis PVS on over 3000 men since 1986 (Table 2). After microsurgery drill on rat and human cadaveric dissection of the entire penile structure in 1985, neither a Bovie nor a sucker has been used with our penile venous stripping techniques. In 1986, we introduced penile venous ligation of the proximal DDV in an initial study of 8 males. This simple procedure was replaced by venectomy very soon thereafter and then by venous stripping which was based on the single DDV conventional penile venous anatomy until 1999. The rate of successful intercourse improved from 50% to 91% in the past decade.

During 1999, 35 patients underwent repeat cavernosography because of the gradual decrease in the erectile capability that occurred in a period of 6 months to 7 years postoperatively. Imaging demonstrated some excessive veins - cavernosal and para-arterial veins, which were further confirmed in cadaveric dissections. By then, the revolutionary edition of erection-related veins in the human penis was regarded as a blueprint for venous stripping surgery. The latest method of penile venous reconstructive surgery is based on a circumferential incision plus a median pubic longitudinal approach via a specific key instrument with an acupuncture assisted local anesthesia on an ambulatory basis. Since the penile venous surgery is exclusively directed at the veins, damage to non-venous soft tissues has been avoided. Tissues like nerve, artery, and lymphatic vessels are spared. Since June 1988, we have performed the penile venous stripping procedure as an outpatient surgery under local anesthesia. Neither a Bovie nor a suction apparatus has been required in the entire procedure, resulting in minimal or no injury to any tissue other than the veins. The incision is small and delicate.

Table 2 Chronological refinement in penile venous stripping surgery methods since 1986

Methods	*No.*	*Age (Year)*	*Time period*	*Op. time (hours)*	*IR* (%)*	*SR* (%)*	*Follow-up period (years)*	*Anatomy blueprint*
Ligation	8	22–58	Jun. 1986 Aug. 1987	0.5–2.0	<50.0	0.0	5.0–17.0	Multiple ligation of single DDV*
Stripping	23	19–68	Sep. 1986 May 1987	2.0–5.0	80.0	52.5	5.0–32.0	Venous stripping as much as possible
Stripping	245	19–83	Jun. 1987 April 1991	2.2–3.1	67.8	NA	6.0–32.0	Venous stripping under local anesthesia since 1988
Stripping	1207	22–82	May 1992 Aug. 1997	2–3	69.7	57.6	8.0–32.0	Single DDV* with its branches
Stripping	615	23–83	Sep. 1997 July 2000	2–5	85.0	64.6	8.0–32.0	IIEF* available since 1998 Suspected penile venous anatomy
Stripping	378	19–81	Aug. 2000 Nov. 2003	2.1–5.0	90.4	76.6	5.1–8.2	*Newfound penile venous anatomy*
Stripping	235	20–91	Jan. 2004 Jan. 2009	2.1–6.2	90.8	77.8		DDV*, CV* & PAV*
Stripping	103		Feb. 2009 Jan. 2011	4.2–8.0	88.7	68.7		Without well-trained assistant
Ultimate	283	20–75	Feb. 2011 Aug. 2016	2.1–7.5	95.7	85.3		Unpublished data, ultimate method of USPTO* patent
Total	3097	19–91	1986–2015	0.5–8.0	<50–95.7	0–85.3	5–32.0	

*The DDV, CV, PAV, IIEF, USPTO, IR & SR are an abbreviation for the deep dorsal vein, cavernosal veins, para-arterial veins, international index of erectile function, The United States Patent and Trademark Office, improvement rate and satisfaction rate respectively.

The latest refined penile venous stripping

In medical history, it is rare to encounter a surgical procedure like venous surgery for restoring erectile function that has sustained such an extended period of disrepute. For over a century, the merit for conducting penile venous surgery to treat ED has never been firmly established. It was believed to be indicated only for <1% of patients with ED secondary to veno-occlusive dysfunction (VOD). Recent studies, however, show that VOD may be more prevalent in patients with ED, and even in those with ED ascribed to penile arterial insufficiency. Thus, the prevalence of VOD may be greater than expected suggesting that a larger proportion of patients with ED may be suitable for venous surgery. In contrast to the feared potential recurrence of conventional penile venous surgery, <25% of our 3000 patients on whom the operation was performed have complained of a recurrence. The overall outcomes are commensurate with method refinement over several decades.

The most advanced method of penile venous stripping—as depicted on the United States Patent and Trademark Office (USPTO) website—for treating impotence resulting from veno-occlusive dysfunction. A circumferential incision was first made while a circumcision was completed if required (Fig. 3). A more extensive degloving of those tissue layers superficial to the Colles' fascia was then undertaken. A milking manipulation is helpful to enhance the visibility of the DDV which is stripped proximally with a pull through technique via an opening made on the buck's fascia from opening to opening on the Buck's fascia until the penile base using a 6-o nylon suture. Likewise the paired cavernosal veins (CVs) were stripped. For accessing the deep seated venous vessels a median longitudinal pubic incision skin was used to continue the venous stripping. The paired proximal stumps of the DDV and the CVs served as a guide, and the DDV was then firstly thoroughly stripped and then ligated with a help of 85° hemostat as far as the infra-pubic angle. Similarly, the deep-seated CVs are managed. The paired para-arterial veins (PAVs) which sandwich the dorsal arteries bilaterally were meticulously ligated rather than stripped. Smaller veins between the tunica albuginea and the Buck's fascia were identified by squeezing the sinusoids of the corpora cavernosa. The wound was closed with 5-0 chromic catgut and 6-0 nylon sutures. A compression dressing was placed such that it encircled the penile shaft. Follow-up cavernosograms is routinely undertaken immediately postoperatively or intraoperatively if required (Fig. 4). Postoperative cavernosograms categorically confirmed that the CCs are an ideal chamber for intracorporeal fluid retention in all patients, particularly, the penile crura was unexceptionally stronger radiopaque than that of femoral cortex (Fig. 4D, E & F vs. A & C).

Despite those drawbacks of conventional penile venous surgery, our penile venous stripping has been developed with the inspiration of patients' positive response in tandem with the advances of penile tunical and venous anatomy associated with the erection mechanism since 1986. We applied chronologically refined stripping techniques in a large patient population under acupuncture-assisted local anesthesia on an ambulatory basis. We consistently encounter patients seeking this treatment because of poor functional outcomes and unexpected adverse effects of prior penile vascular interventions internationally. Although currently we recommend this treatment only to patients who are nonresponders to phosphodiesterase-5 (PDE-5) inhibitors, we always fail to decline this sort of patient. Penile venous surgery has likely been innocently condemned; the abandonment would be more appropriate if its justification shifted from the surgery itself to the method of surgical manipulation. We heretofore suggest its ban should be lifted to help males that suffer from ED. Surely its efficacy and safety warrant well-structured, randomized, and controlled research by surgeons who know the anatomy well and are well-equipped with microvascular surgery skill without the necessity of electrocautery.

Varied Endovascular Intervention for Patient with Erectile Dysfunction

Penile endovascular interventions, both angioplasty and venous embolization, aim to treat VOD or arterial insufficiency via limiting the outflow of blood or increasing arterial inflow in the penis, respectively. It may be technically easy for physicians to implant, owing to simplicity and reproducibility, and it is a minor procedure for patient because of low morbidity. Consequently, pudendal stents and penile venous embolization with or without sclerotherapy have been repeatedly introduced for treating VOD and arterial insufficiency correspondingly. It is effective and safe in some vascular diseases. On the elusive ED issue, what great news to patients if endovascular treatment of vasculogenic erectile dysfunction works. Among options for venous treatment, penile venous embolization is an old paradigm newly revisited by the intervention radiologist. It is commonly believed to be minimally invasive and safe.

Refractory ED has prompted five international males to seeking our penile venous stripping since late 2012 despite coil venous embolization with sclerotherapy was performed elsewhere. Stunningly, uncontrolled coils not only lodged in pulmonary artery, but also made a right cardiac ventricle perforation (Fig. 5A) which is confirmed by a contrast computerized tomography. An acute chest pain occurred in a 25-year-old male resulting from the uncontrolled coils traveling to right pulmonary artery just in seven days after coils inserted (Fig. 5B). On limiting the VOD drainage, an insufficiently erectile rigidity resulting from blockage of the deep dorsal vein and cavernosal veins distal to the preprostatic plexus (Fig. 5C) and a consistently unacceptable erection quality resulting from failing venous blockage was noted (Fig. 5D). Therefore, the efficacy of endovascular therapy is not beyond controversy, and its safety may not be sustainable. This implies that a penile venous embolization coil is at risk of migrating throughout the body once it is inserted in the main common drainage channel of corpora cavernosa.

Accordingly, the efficacy of venous embolization warrants research because it just treats vascular channels outside the corpora cavernosa. Pulmonary migration of coils inserted for treatment of erectile dysfunction caused by venous leakage was reported in 1993. This can lead to symptoms such as acute chest pain and chronic cough. An uncontrolled coil is capable of traveling more than just the pulmonary arteries, and may also perforate the ventricular wall. The tension of embolization coils varies by manufacturer, as

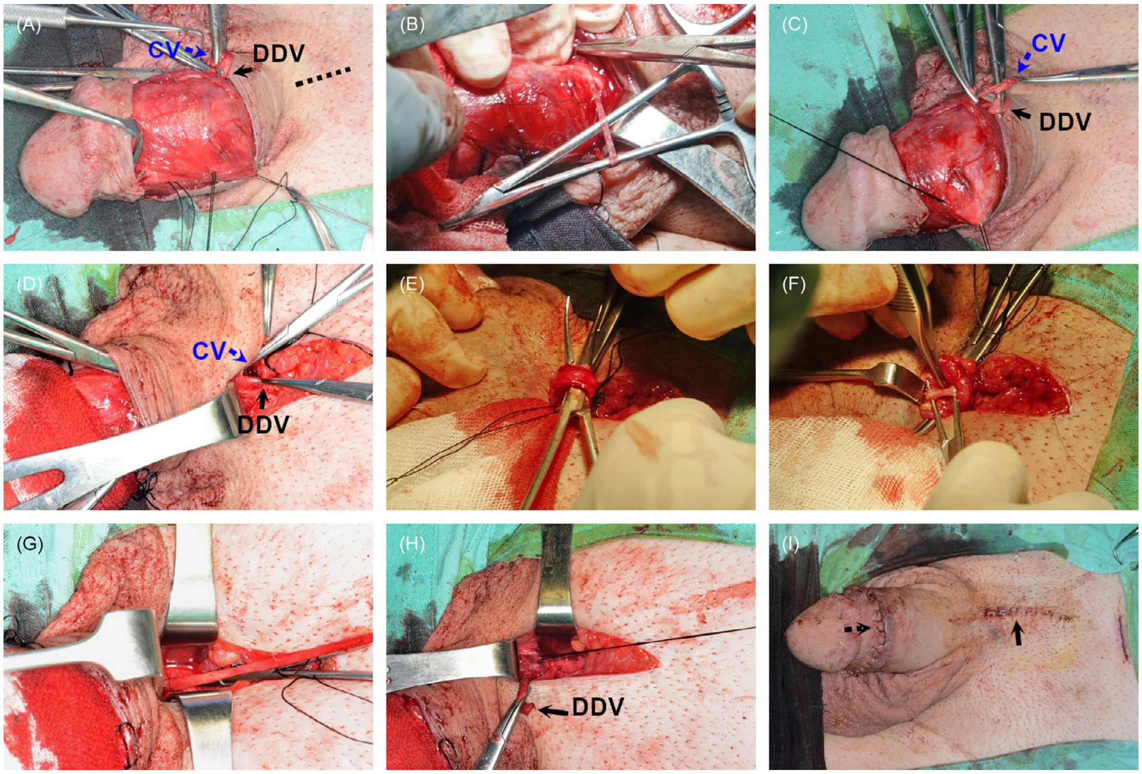

Fig. 3 Photos of the ongoing penile venous stripping process. (A) A longitudinal pubic incision was marked *(dotted line)* and preputial approach was performed to access the offensive veins, DDV *(arrow)* and CV *(dotted arrow)*, which were managed and clamped with hemostat respectively. Note that tag suture was made at the junction between the corpus spongiosum and corpora cavernosa for fixation of the circumflex veins. The visibility of the deep dorsal vein (DDV) was enhanced by employing a milking manipulation, mimicking a squeeze applied to a balloon, of the corpora cavernosa. (B) The circumflex vein was managed while each emissary vein was ligated with 6-0 nylon closest to the outer tunical layer. Eventually, the venous channel was free from blood. (C) The venous plexus of DDV *(arrow)* and CV *(dotted arrow)* was stripped by 4–5 pull-through maneuvers until the pubic level encountered. (D) The venous plexus was passed underneath via a public longitudinal approach to relay the penile venous stripping. (E) The venous stump was relayed smoothly. Note the DDV *(arrow in D)* and CV *(dotted arrow in D)* were managed in an entire group in this case. (F) The first branch of the DDV was managed. (G) 7–9 big branches of DDV were managed one by one until the infra-pubic angle was met. (H) The DDV *(arrow)* was managed completely, then the CV was likewise managed while 5–8 branches were firmly ligated with 6-0 nylon. (I) Finally, the preputial *(dotted arrow)* and longitudinal pubic *(arrow)* wounds were fashioned with 5-0 chromic sutures respectively. Note that neither an electrocautery nor a suction apparatus was required in the entire procedures.

does the coils' penetration ability. So potentially severe morbidity of coils, though rare, should be borne in mind, and patients should be informed of this possibility in choosing coil embolization for treating ED resulting from veno-occlusive dysfunction.

The past 3 decades have seen an explosion of new technologies, devices, gadgets and application of state-of-the-art tools to medicine and surgery professionals. Penile vascular reconstructive surgery and endovascular intervention are significantly beneficial from this trend. It ought to be promising in the near future if and only if the sound method is used via valid instruments and appropriate technology.

Summary

New insights into penile tunical and venous anatomy, and erection physiology have been made in recent decades. They have underpinned penile morphological reconstructive, penile endovascular intervention as well as penile vascular surgery. Although vascular reconstructive surgery is still regarded as experimental, anatomical-based techniques of vascular reconstruction should be reappraised. Arterial reconstruction has been shown to be beneficial to young healthy males who sustain trauma. Older healthy ED males are more likely to benefit if the vascular surgery includes both arterial revascularization and veno-arterilization. The reproducible refined penile venous stripping procedure which has been developed and refined over several decades is showing promise as a viable solution for veno-occlusive dysfunction across all ages.

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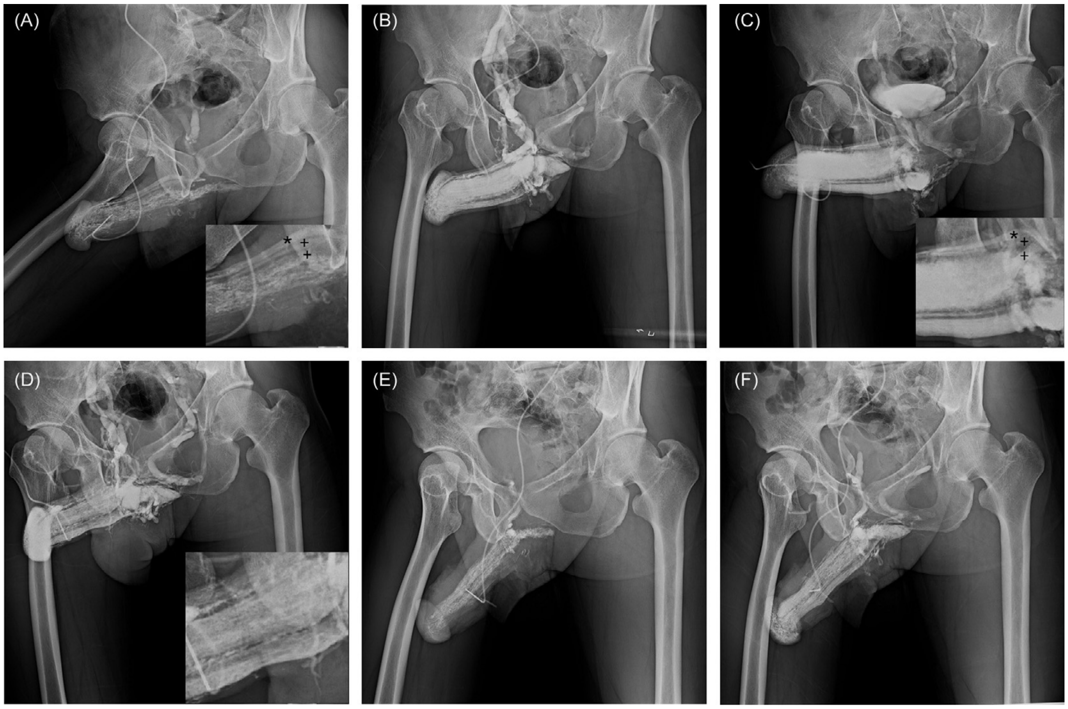

Fig. 4 Dural pharmaco-cavernosography of veno-occlusive dysfunction and cavernosographic evidence of erection restoration. (A) The first cavernosogram was obtained while a 10-mL diluted iohexol solution was intracavernously injected, resulting in the immediate opacification of the DDV *(asterisk)*, CV *(cross)* and then preprostatic plexus. Note the volcano-like eruption of emissary veins. (B) A cavernosogram was obtained after further injection of the 10-mL solution, while the drainage veins were remarkable at the penile hilum. (C) A pharmacocavernosograms was obtained 20–30 min after 20 μg of prostaglandin E1 (test) was intracavernously injected. The bulking of drainage veins were relatively prominent despite a rigid erection attained. Thus a veno-occlusive dysfunction was documented. (D) An intraoperative cavernosogram disclosed most offensive veins was stripped but an accessory cavernosal veins and several circumflex veins were left. (E) An immediate postoperative cavernosogram showed the penile venous stripping was complete. (F) Further intracavernous injection confirms an ideal milieu to apply intracavernosal fluid retention. Note D, E and F were postoperative ones in which the penile crura was unexceptionally stronger radiopaque than that of femoral cortex.

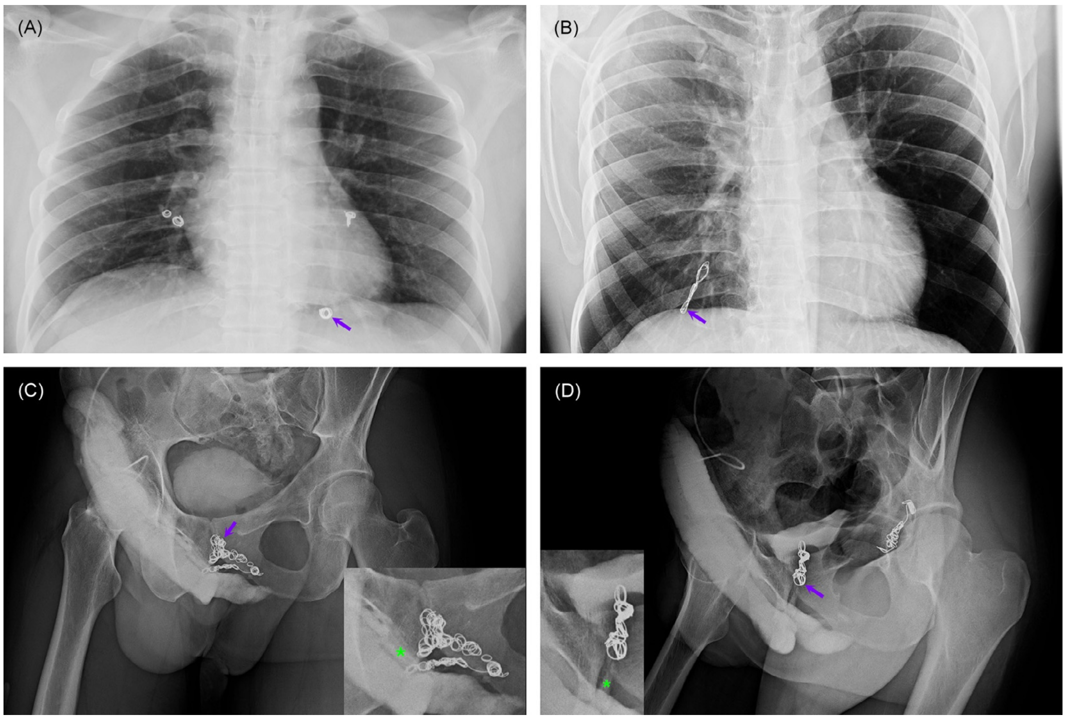

Fig. 5 Imaging of patients received prior coil embolization and sclerotherapy elsewhere internationally. (A) Coils migrated to lodge in left and right pulmonary artery respectively, and one coil perforated the right cardiac ventricle *(purple arrow)* which is further confirmed by a contrast computerized tomography. (B) The inserted coils *(purple arrow)* migrated to right lower pulmonary artery, which caused an acute chest pain. (C) An insufficient rigidity of erectile penis suffered a 25-year-old patient albeit dozens of coils *(purple arrow)* were inserted in an attempt to limit the penile venous drainage. Note the venous buckle *(green asterisk)* was remarked. (D) The preprostatic veins *(green asterisk)* were blocked and engorged despite many coils were inserted *(purple arrow)*.

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