



Global Advanced Research Journal of Medicine and Medical Science (GARJMMS) (ISSN: 2315-5159) Vol. 3(12) pp. 400-407, December, 2014 Special Issue
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Review

Human penile tunica albuginea: Anatomy discovery, functional evidence and role in reconstructive and implant surgery

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Accepted 09 December, 2014

In the human penis the corpora cavernosa (CC) is a hydraulic system which can anatomically be assorted into the smooth muscle and skeletal muscle components. The former includes CC sinusoids and vasculature while the latter are bulbocavernosus, bulbospongiosus, tunica albuginea (TA) and distal ligament. Rigid erection is a result of interplaying two components via healthy supplying arteries and draining veins. Clinicians believed TA to be a single layer before 1991 when a model of a bi-layered structure was discovered as a 360° complete inner circular layer and a 300° incomplete outer longitudinal layer which is absent bordering the CC and corpus spongiosum. In the erection process the outer longitudinal layer plays a pivotal role in closing the emissary veins, which ascertain veno-occlusive mechanism. Although this peculiar design is considerable for allowing ejaculate passing, it is vulnerable to dilator trauma during penile implantation on the TA without outer longitudinal layer which is responsible for penile morphology and thereafter is the targeted tissue for corporoplasty and sustainable layer for penile prosthesis. Overall this new TA anatomy is prerequisite to surgeon whom is going to carry out penile implant or penile morphologic reconstruction regardless attempting surgery is for patching the shortage side of TA or excising the excessive side of TA.

Keywords: Corporoplasty, distal ligament, penile implantation, penile tunica albuginea

INTRODUCTION

The human penis may be the organ attracting most attentions in the entire human body owing to its magic

extensibility resulting from hydraulic mechanism. It has been in its current anatomical form for the last 2000 centuries. its anatomy has not fully depicted despite extensive studies had been made (Putz and Pabsteds 2001; Eardley and Sethia, 2003; Dean and Lue, 2005; Gratzke et al., 2010). It is likely that its anatomy and the erection process are still not thoroughly understood and consequently varied reconstructive surgeries might not

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be anatomically oriented. Humans are peculiar within the group of erect animals (Hsu et al., 2005), in that the males possess an os analogue associated with a proportionally large and extraordinarily extensible corpora cavernosa (CC) which is the most ideal milieu to apply Pascal's law in the entire human body if no venous leakage exists (Hsu 2006). The law depicts that pressure applied to any part of the enclosed fluid transmitted undiminished to every portion of the fluid and to the walls of the containing vessel (Halliday 1997). However man does not have an os penis, which is present in all quadrupeds but horse and cattle, i.e. the bony portion that provides penile rigidity externally. The erectile capability of the human penis largely depends on sinusoids in the corpus spongiosum, the glans penis within which a distal ligament, and the CC, which are also responsible for erectile rigidity (Simons and Jones, 2007). Therefore it seems that the human CC are destined to be prone to erectile dysfunction (ED), defined as inability either to attain or maintain a rigid erection for satisfactory intercourse (Kaminetsky 2008). The tunica albuginea (TA) plays a determinant role in penile rigidity and morphology. Herein this article is a review on TA about its three-dimensional structure, functional evidence and role in reconstructive and implant surgery.

Discovery of the human penile tunica albuginea

In 1985, I was asked by a 32-year-old impotent patient whether it was a cancerous growth that he had palpated a hard ridge inside his glans penis from the urethral tip (Hsieh et al., 2012). The glans penis was exclusively composed of sinusoids in all medical literature however. There was a paucity of a scientific depiction despite a long yarn inquiring on correct answer from professional colleagues. This inspired the conviction that medical literatures might not be so sustainable that further research on the glans structure was warranted. Using dissecting, light, scanning and transmission electron microscopy the fibro-skeleton structure, Tunica albuginea (Figure 1), was discovered (Hsu et al., 1992; Brock et al., 1997). Instead of single circular TA, all studies substantiate a model of the TA 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 (DL) within the glans penis (Hsu et al., 2004). Interestingly the outer longitudinal layer varies much either the strength or thickness at specific anatomical locations, in particular, there is an exclusive inner layer in between the 5 and 7 O'clock positions of the CC, which is the

borders between the CC and the corpus spongiosum (Hsu et al., 1994). Thus the DL, a continuation of the outer longitudinal layer of the tunica, is arranged centrally and acts as a trunk of the glans penis. Without this DL, the glans would be too weak to bear the buckling pressure generated during coitus. It is located at the 12 o'clock position of the distal urethra. This unique anatomical arrangement may explain why the glans penis is strong enough to bear the buckling pressure of coitus, and how an erect penis is sufficiently rigid but never compresses the corpus spongiosum, which otherwise would present an obstacle to ejaculation. The anatomical location and histology of the distal ligament invites convincing parallels with the quadruped os penis and therefore constitutes potential evidence of the evolutionary process. In the CC, a chamber design is seamless attained.

Functional evidence of the fibro-skeleton

Rupture of the CC is not uncommon in medical practice. It is caused by rapid blunt force to an erect penis, usually during coitus or aggressive masturbation (Orvis and McAninch, 1989). It sometimes also involves partial or complete rupture of the corpus spongiosum including urethra or even injury to the veins, arteries and nerves (Haas et al., 1999; Jump and Zargooshi, 2000). An already penile deformity is plausibly responsible (Hsu et al., 2002). Coital ability can be ruined if the penis loses its intact distal ligament in spite of its erectile function being normal (Hsu et al., 2001). A penile veno-occlusive mechanism (Figure 2) was exploded via defrosted cadaveric research (Hsu et al., 2015). Therefore both erectile and morphology function integrity depends on an integral TA.

Role of tunica albuginea in penile implantation

Penile implantation remains a golden standard for providing a sufficiently rigid penis with which to fulfill intromission in the era of medical treatment (Montague 2011; Wilson et al., 2007). The tunica albuginea (TA) is the envelope of the cylinders in modern intracavernous prosthesis which had successfully developed in 1950 (Goodman 1952). Both cylinders are the major component regardless prosthesis types such as inflatable, semirigid and mechanical ones. The bi-layered structure of the TA was not elucidated as late as 1991 (Figure 3). Interesting a transitional membrane (Figure 2A) was found to encircle the CC sinusoids and there was a paucity of strong outer longitudinal layer in between the CC and corpus spongiosum (Figure 2B) where is vulnerable to prosthesis extrusion. Thus the

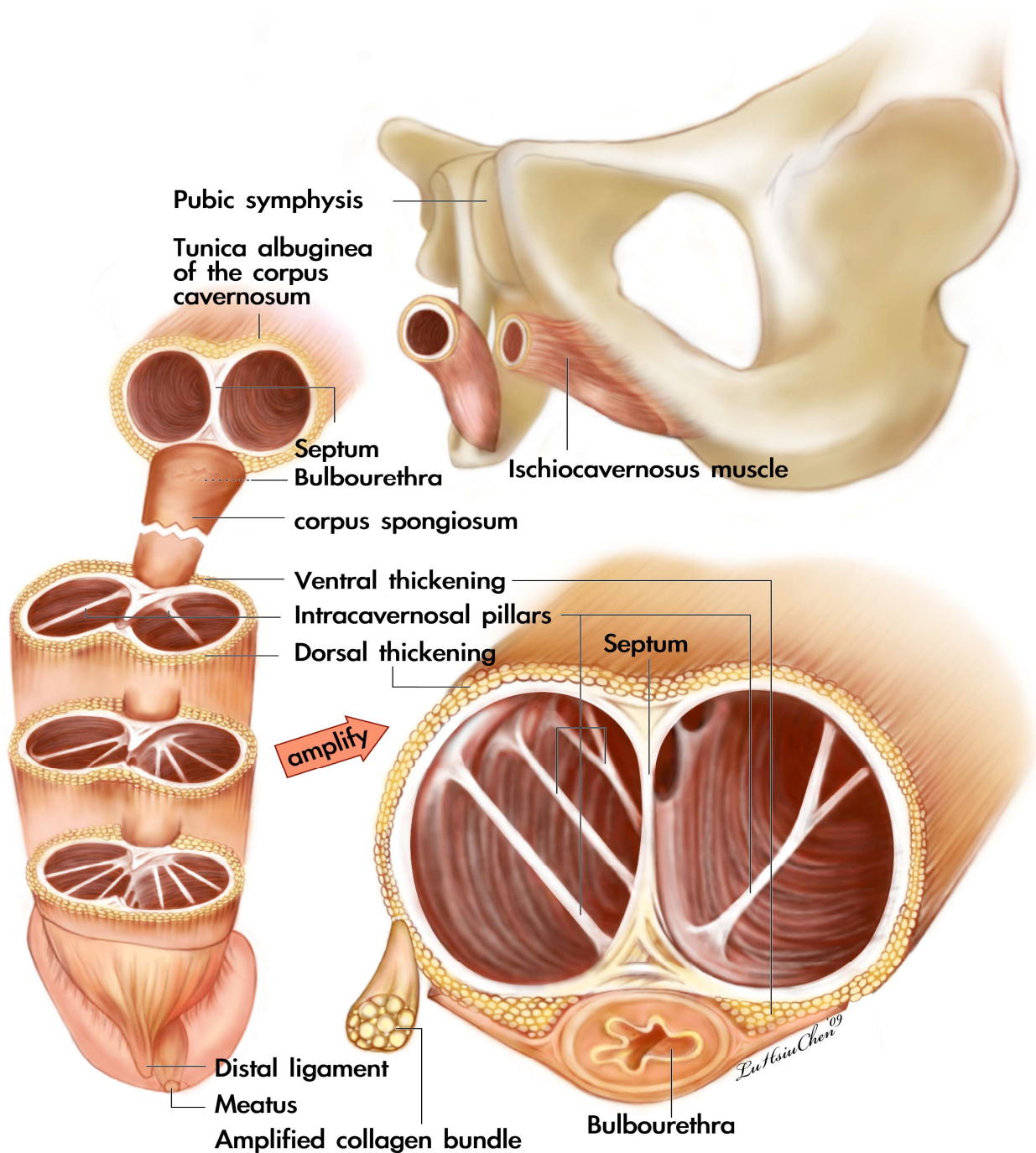


Figure 1. Schematic illustration of the fibroskeleton, Tunica albuginea (TA), in the human penis. The tunica albuginea (TA) of the corpora cavernosa (CC) is a bilayered structure in which a 360° complete inner circular layer, together with the intracavernosal pillars, contains and supports the sinusoids which are removed in this illustration. Both layers are composed collagen bundles with longitudinal and circular orientation respectively. There is an absence of outer layer bundles at the region between the 5 and 7 o'clock positions where CC are close contact with the corpus spongiosum. Distally, they are grouped into the glans penis forming the distal ligament, located at the 12 o'clock position of the distal urethra. This structure is indispensable for supporting the glans penis. The median septum is incomplete with dorsal fenestration at the pendulous portion of the penis and is complete where the penile crura are formed.

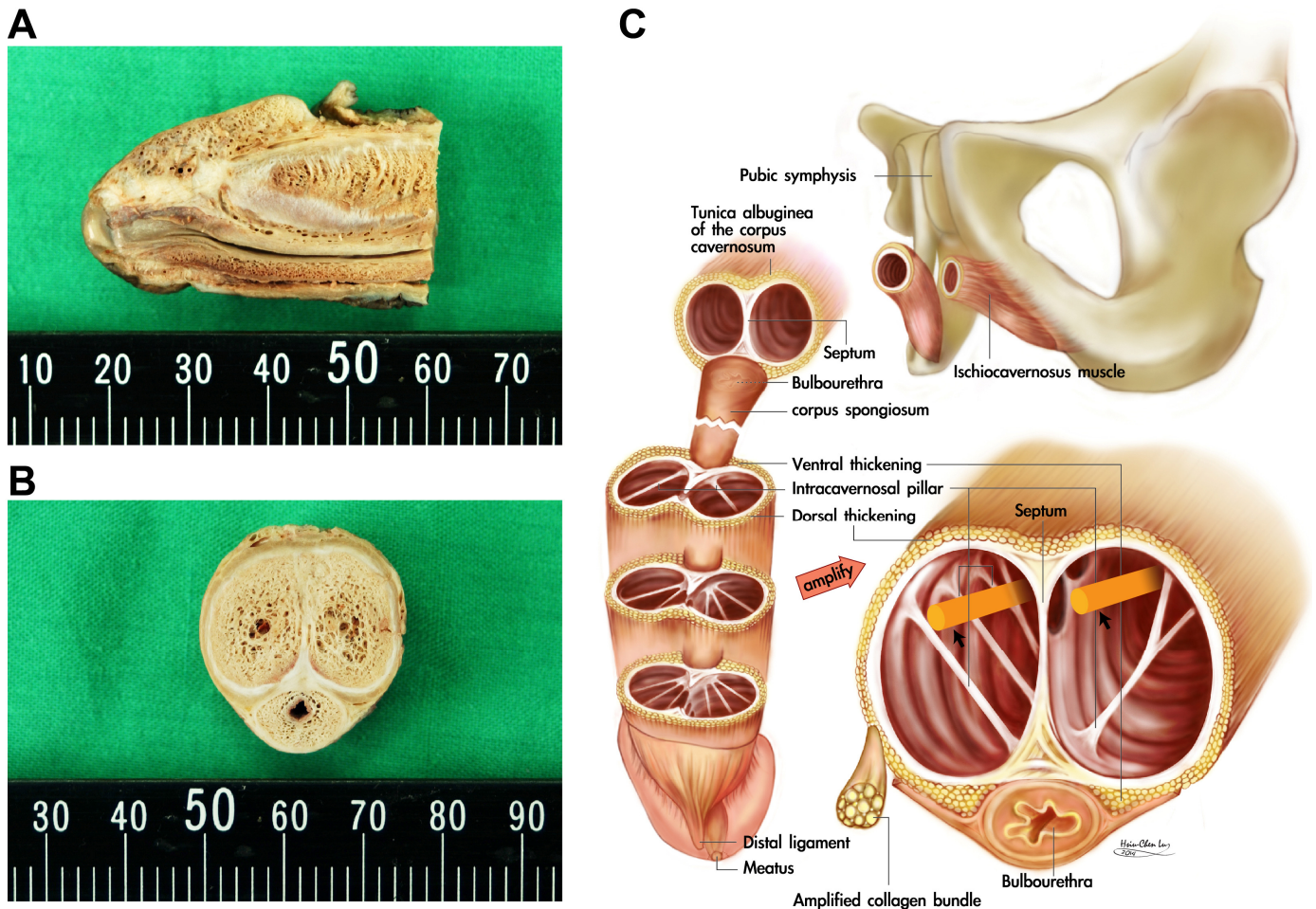


Figure 3. Illustration and photos of the related architecture for penile implant. A. Cross section of the distal penis showed the thickness of the tunica albuginea varied markedly while its dorsal aspect was more thicker than that of ventral one. In between a transitional membrane was clearly demonstrated outward to the intracavernosal pillars. Note a stout distal ligament which was categorically overlooked before 1992. B. An median section of the distal penis discloses the relation of the tunica and CC. Note the deeper-colored 300° incomplete outer longitudinal layer which was a continuation of ischiocavernosus and bulbosongiosus muscles. C. The CC could be divided into four spaces by intracavernosal pillars. The cylinders of penile prosthesis was advised to house in the medial two rooms.

attending surgeon may have no idea of this concern before then. We subsequently regarded this new found TA (Figure 2C) as a blueprint and derived a manual dexterity of handling the Hegar’s dilator medial-dorsally toward the distal ligament of glans penis during corporal dilatation in penile implant surgery.

Role of tunica albuginea in penile corporoplasty

Penile morphology is paramount in performing genital coitus. It is not uncommon to encounter tortured minds in many patients who had suffered from penile deformity resulting from Peyronie’s disease, congenial penile deviation and a variety of injury. Although the traditional anatomical paradigm of the TA of CC has consistently

overlooked the outer longitudinal layer, varied surgical methods have been introduced in an attempt to establish an ideal penile shape in addition to erectile function. The first corporoplasty was debuted in 1965 (Nesbit, 1965). Subsequently tunical plication was popular owing to simplicity and reproducibility despite postoperative outcomes was not beyond controversy (Lee et al, 2004; Hsieh et al 2001; Paez et al., 2007).

Penile corporoplasty for mature Peyronie’s disease might be a good option for this complicated disease entity (Gholami and Lue, 2002). A postoperative penile shortage should be avoided by all means, which is a problem that can be solved through grafting. Therefore graft surgery may be recommendable although technically challenging. Many kinds of resources have been advised as graft materials for tunical patches

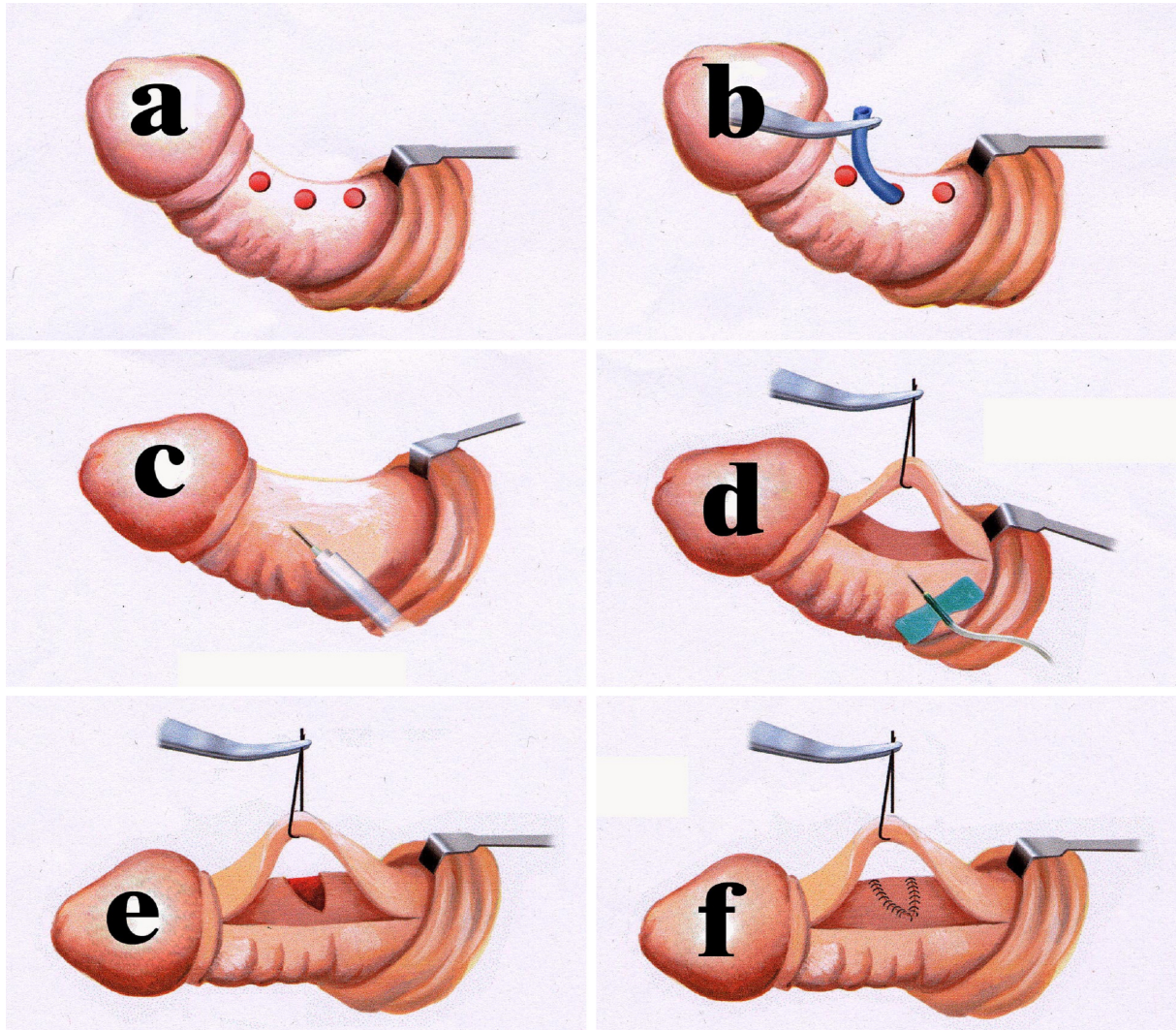


Figure 4. Schematic illustration of venous patching. A) A retrocoronal circumferential incision was made and the prepuce was carefully degloved. The major branch of the deep dorsal vein (DDV) was readily visible with a milking manipulation. Its trunk served as a guide to undergo the stripping of the DDV with double ligation of each emissary vein. Similarly the cavernosal vein was managed (not shown). B. It was performed step by step via opening the Buck's fascia at the exits of emissary veins. C. The hydropressure technique was used to expand the tissue layers in order to separate, isolate, and tag the neurovascular bundle. Subsequently an artificial erection was performed with normal saline, via a 19G scalp needle, in order to determine where was optimal for an incision. D. An adequate incision sector was performed using a new surgical scalpel meanwhile the neurovascular bundle was well protected. E. The length of corporotomy was determined by $2\pi r\theta_c/\theta$ where θ was the curvature degrees and θ_c was its corresponding incision sector. Thus the length of patched veins required was ascertained. F. Finally using 6-0 nylon suture the autologous venous grafting was fashioned after area difference was calculated with a scientific formula $\pi r^2\theta/45^\circ$ where r is the penile radius in centimeters, and θ is the deviation of the curvature in degrees.

(Devine and Horton, 1974; Bruschini and Mitre, 1979; Dad and Amar, 1982; Lowe et al, 1982; Collins, 1988; Gelbard and Hayden, 1991; Schwarzer et al, 2003; Schultheiss et al, 2004), autologous venous material might be the material of choice for covering a corporotomy defect because its functional and histological compatibility (Fournier et al, 1993; Kim and McVary, 1995; Montorsi et al, 2000, Hsu et al., 2007). Likewise similar procedures are feasible to patients with congenital penile curvature undergoing penile

corporoplasty. For anatomical consideration the deep dorsal vein and cavernosal veins were recommended although a controversy was addressed on its sufficiency (Jordan et al, 1998; Hsu et al., 2003), it appeared unequivocally sufficient after a scientific formula was developed however (Hsu et al., 2006) (Figure 4). This surgical intervention has become a routine works in our practice since then (Figure 5). Further scientific research is warranted.

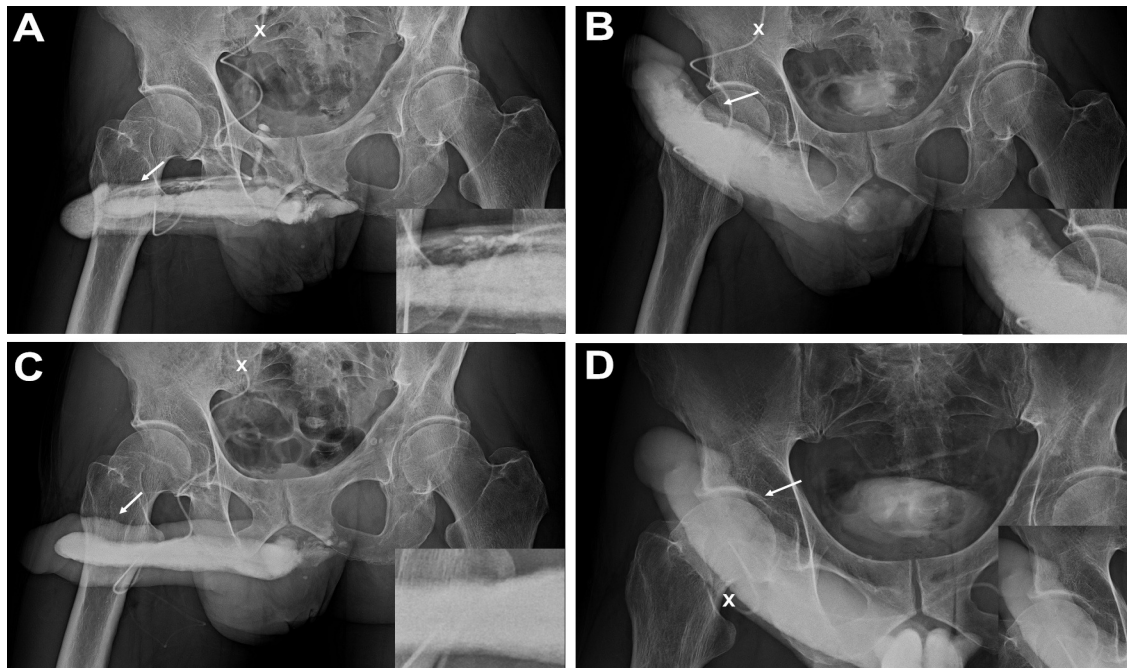


Figure 5. Dual pharmacocavernosography in an impotent 54-year-old man who underwent temporalis fascia graft elsewhere. A. The first cavernosogram was undertaken while a 10 mL dilute lohexol solution was intracavernously injected on an anterior-posterior (AP) view, which showed an immediate opacification of preprostatic plexus via the (Arrow and inserted) drainage from the erection related veins such as the deep dorsal vein and cavernosal veins. Note several indentations along the distal corpora cavernosa. B. A 30-degree oblique view Pharmaco-cavernosogram was made after further injection of 10 mL solution. In addition to the venous system, there was an indentation defect (arrow) resulting from prior temporalis fascia graft. C. A thorough penile venous stripping surgery was made for erection restoration. The intracavernous fluid retention was significantly enhanced. D. The dorsal penile dysmorphism was corrected via a tunical plication of 5 and 7 O'clock positions respectively. Note the sound penile morphology afterwards.

CONCLUSION

It appears that the discovery of the tunica albuginea benefits medical professionals who are intentional to carry out ED research, medical treatment and surgical reconstruction for either functional and morphological integrity.

ACKNOWLEDGEMENT

We would like to thank Benedict S A Murrell for his English editing, along with Ms Hsiu-Chen Lu, Margaret Su-Lan Tang and Venus Ying-Hui Chen their preparations of illustration and photos for this manuscript.

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