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Cadaveric Penile Microdissection and its Impact on Live Donor Penile Transplantation: an Experimental Case Series Study

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ABSTRACT

Purpose: We evaluated the possibility of using remaining penile tissue such as preserved corpora cavernosa, the remaining glans tissue with neurovascular components and the anterior urethra, after femininizing gender affirmation surgery for live donor penile transplantation.

Materials and Methods: Between January 2022 and January 2024, penile dissection was performed in 31 male cadavers, aged 20-59 years (mean 42 years). The dissection with tissue preservation was based on penile disassembly principles: penile skin, part of the glans with neurovascular elements, and proximal urethra were prepared for feminizing genitoplasty while remaining penile tissue such as full corpora cavernosa, glans and anterior urethra were micro dissected and properly measured.

Results: Mean penile length was 10.24 cm in the flaccid and 14.6 cm in the stretched state. The mean diameters of the deep dorsal vein and the right and left arteries were measured at 2.8 mm, 1.9 mm and 1.8 mm, respectively. Penile nerves with an anatomical distribution were found in all cases. The mean length and girth of cavernosum bodies were 19.24 cm, and 7.29 cm, respectively. The mean length of the distal urethra was 15.73 cm (range 11-21 cm), without registered anomalies. The mean volume of the glans after neoclitoris creation was 89% of total. All dissections were completed successfully, and all entities were joined again in all cadavers.

Conclusions: The cadaveric study has confirmed the technical feasibility and possibilities of using all remaining penile tissue for possible live donor penile transplantation.

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INTRODUCTION

Gender affirming vaginoplasty is the last step in transfemale surgical transition. Surgery includes several procedures such as bilateral orchiectomy, penectomy, clitoroplasty, labioplasty and vaginoplasty. Dissection of the penile entities represents a basis for the construction of the new female genitalia: penile and scrotal skin are used for vaginoplasty and labioplasty, a small part of the glans with neurovascular bundle for clitoroplasty and proximal part of the urethra for neovaginal vestibulum and female urethral orifice. All other parts, completely preserved corpora cavernosa, most of the volume of the remaining glans and distal penile urethra, are not necessary and are usually removed (1).

Penile transplantation represents an ideal substitute in cases with aphallia, penile trauma or penile cancer as well as for gender affirming phalloplasty. Recently, five allogenic human penile transplantations were performed in cis-men from deceased donors (2-6). The main goal of this cadaveric study was to demonstrate anatomical dissection of penile entities as a standard part for penile inversion vaginoplasty, and complete preservation of all available penile tissue as a possible material for live donor penile transplantation. We hypothesized that these remaining penile tissue with associated blood vessels and nerves, could be successfully transferred to a recipient. This could be the largest cadaveric study on genital organ dissection in the literature (7-9).

MATERIALS AND METHODS

Between January 2022 and January 2024, we performed anatomical dissection of the genitalia of 31 male human fresh-frozen cadavers, aged 20-59 years (mean 42 years). The study protocol was provided by the University Forensic Institute as a part of 2020 Project. The study was conducted according to the guidelines of the Declaration of Helsinki and approved by the Institutional Ethics Committee (1322/X-16, 2020). Informed consent was not required because the study did not include live human subjects. Exclusion criteria were cadavers older than 62 years, malignancy or trauma to the genitalia and medical comorbidities that may result in dissection difficulties. The identification of cadavers was confidential and protected according to the ethical principles.

The approach is based on vast experience in penile disassembly, which was introduced for the treatment of congenital and acquired penile anomalies (10, 11). Cadaveric dissection was separated in two stages: dissection of the penile entities that would be used for standard penile inversion vaginoplasty, and microdissection of the remaining tissue of the penis with preservation of all blood vessels and nerves. Clinically, penile inversion vaginoplasty includes several sub-procedures and the technique has already been described (12). Usually, the penis is separated into its anatomical components, i.e. the corpora cavernosa, the glans cap with neurovascular bundle, urethra and the vascularized penile skin. Distal part of the glans is dissected with the neurovascular bundle and used to create the clitoris. Urethra is mobilized at the prebulbar level and divided. The distal part remains attached to the corpora cavernosa, whereas the proximal part is spatulated up to the bulbus for creation of female-type urethra. The corpora cavernosa with remaining glans tissue at the top and part of anterior urethra are removed up to their attachments to the pubic bones, preventing postoperative erections (Figures 1A and B). Finally, penile skin is inverted and joined with scrotal skin grafts, forming the neovagina. Vulvoplasty involves the creation of the labia minora and majora. The remaining part of the base of the penile skin is used to form the labia minora, whereas the scrotal skin is dissected and used for labia majora.

Cadaveric dissection

Cadaver is placed in proper supine position with good exposure of genitalia. Dissection is started with a circumcision incision, 2.5 cm under the glans corona, followed by proper degloving of the penile skin. A midline incision of the scrotum is used for penile body transposition and possible removal of both

Figure-1A. Feminizing gender affirming surgery. Penile disassembly includes separation of all penile entities, corpora cavernosa and glans with dissected neurovascular bundle (dorsally) and urethra (ventrally). Corpora cavernosa are completely detached from the glans.

Figure-1B. New clitoris is created, with preserved vascularization and innervation. Urethra is divided at prebulbar level and prepared for creation of vulvo-vestibular complex. Penile skin is prepared for inversion and creation of the new vagina. All penile remnants are prepared for removal: corpora cavernosa with both crura, distal urethra and glans remnant.

Figure -1C. Cadaveric dissection of the penis. Penile entities are separated and parts for feminizing genital reconstruction are properly prepared: neoclitoris with neurovascular bundle, penile skin and proximal part of the urethra. Complete dissection of the remaining entities (cavernosal bodies, crura, distal urethra and glans remnant) is done for potential graft preparation.

Figure-1D. Dissection of the neurovascular bundle. Dorsal nerve and penile artery with the deep dorsal vein are micro dissected along with the neoclitoris, leaving the other penile artery and nerve preserved and attached to the tunica albuginea with cavernosal bodies. In this way, arterial and nerve supply to the glans remnant is preserved without compromising vascularization and innervation of the neoclitoris.

testes. The penis is invaginated through the incision to provide an excellent access to the entire length of the penis. Ventrally, the urethra is mobilized at prebulbar level and divided. This way, the proximal part of the urethra is prepared for reconstruction of the vestibulo-vaginal complex and the new female orifice. Neurovascular bundle is evaluated, and all neurovascular structures, deep dorsal vein, two penile arteries and two penile nerves, are confirmed. The dissection includes mobilization of one penile nerve, one penile artery, and deep dorsal vein. Neurovascular elements are very precisely lifted from the tunica albuginea and all perforant and communicant branches are divided, leaving the other artery and nerve attached to the corpora cavernosa. Distally, the dissection is continued to the dorsal surface of the glans. The glans is lifted to a level determined by the appropriate size of the new clitoris. Further dissection includes removal of the glans tissue. Approximately 1-1.5 cm on either side of midline on the coronal ridge are divided from the glans and coned to shape the new clitoris. The remaining part of the glans is left in place and attached to the tips of the corpora cavernosa. Based on the experience in epispadias repair, the dorsal defect is closed directly giving a good shape of the glans (13).

This meticulous microdissection results in preservation of the remaining nerve and penile artery that remain attached to the cavernosal body. This way, all small branches are preserved and in contact with nerve and artery, as well as with ipsilateral cavernosum body. Finally, our primary dissection defined two groups of the tissues. The first group included completely preserved penile skin, coronal ridge of the glans with the deep dorsal vein, penile artery and nerve and proximal urethra, which could be used to create the neovagina, clitoris and vestibulo-vaginal complex (Figure-1C).

All the remaining parts are micro-dissected, offering good tissue for possible donation. Their dissection is continued toward the pubic bones. The crura are separated ventrally from bulbar urethra. The fundiform and suspensory ligaments are divided at the level of their attachment to the pubic bone. Both crura of the corpora cavernosa are mobilized together with ischio-cavernosal muscles. Partial neurovascular bundle (one-side penile artery and nerve) is left attached to the tunica albuginea during dissection. Both cavernosum arteries are precisely identified and dissected (Figure-1D).

Cadaveric dissection includes precise measurement of penile entities: length of the penis in flaccid and stretched position; length and girth of the corpora cavernosa, length of the penile and bulbar urethra and its remaining part after division, as well as glans volume, total and after the removal of the part that is to be used for creation of the new clitoris. Cadavers are classified in 3 groups according to age, and comparison of all parameters between groups is performed using Kruskal-Wallis test, with $p<0.05$ presenting statistical significance. In addition, we verified the presence of the neurovascular elements, deep dorsal vein, penile arteries, penile nerves, crural arteries and veins as well all other elements such as perforant and circumflex branches and nerve endings. All dissection stages were photographed in situ and documented.

RESULTS

Macro-dissection was straightforward and revealed the usual penile anatomy without penile deformities in all cadavers. The penises consisted of non-deformed corpora cavernosa, well developed skin, good volume of the glans and urethra without any deformities, either congenital (hypospadias) or acquired (stricture). All penile structures were separated without complications and prepared for creation of the female genitalia according to standard feminizing gender affirming surgery.

Penile entities were measured, as shown in Table 1. The mean penile length was 10.24 cm (ranging 6-14 cm) in the flaccid and 14.6 cm (11.5-18 cm) in the stretched state, while the penile circumference in the middle part ranged from 7 to 9 cm (mean 8 cm). Next, the distribution of the neurovascular bundle was determined, and regular anatomy was found in all cases: two penile nerves, two penile arteries

Table 1 - Measurement of penile entities during cadaveric micro-dissection.

No.	Age	Penile length(cm): flaccid/stretched	Corpora (cm): Length/girth	Urethral length (cm): Total/distal	Glans volume (mL) (total)	Glans volume (mL) (resected)	Glans volume (mL) (remnant)
1	38	10.5/14	22/7	23/16	3.5	0.5	3
2	32	13/16	24/8	25/21	5.3	0.56	4.74
3	48	8.5/14	20.5/8.5	21/16	4.1	0.4	3.7
4	29	6/12	19/7.5	20/14	3	0.28	2.72
5	38	12/18	19/8	20/16	4.7	0.45	4.25
6	47	11/16	18/7	23/19	4.2	0.4	3.8
7	51	11/14	17.5/6.5	19/16	3.5	0.5	3
8	41	11/16	18/7.5	18.5/13.5	3.5	0.4	3.1
9	43	11/15	18/6.5	19/15.5	4	0.45	3.55
10	34	9.5/13.5	17.5/6	18.5/15	3.8	0.42	3.38
11	43	14/17	20/11	23/19.5	4.1	0.34	3.76
12	58	13/15	22/7	23/16	4	0.4	3.6
13	20	10/13	23/7.5	23/15	3.5	0.5	3
14	41	12/15	19/5.5	22/16	4.2	0.3	3.9
15	59	7/12	20/6	22/15	3.4	0.32	3.08
16	45	8/15	19.5/6.5	19/15	3	0.43	2.57
17	48	9/14	20/9	22/15	3.2	0.35	2.85
18	53	9/15	15/7	18.5/14	4	0.36	3.64
19	26	8.5/11.5	15.5/6.5	13/11	3.1	0.44	2.66
20	33	11/14.5	20.5/8	20/16	3.5	0.5	3
21	50	10.5/14.5	19/7	19/15	3.4	0.32	3.08
22	42	12/17	21/9	22/16.5	4.4	0.4	4
23	49	9/14.5	17/6.6	20/15	3.8	0.42	3.38
24	38	9.5/15	17.5/6	20/16	3.4	0.34	3.06
25	56	8/14	17/6	19/15	3.2	0.36	2.84
26	58	11/15	19/7.5	22/16	4	0.4	3.6
27	40	10/14	20/7.5	22/16.5	3.5	0.4	3.1
28	27	10/14	19.5/7	21/15	3.5	0.4	3.1
29	30	12.5/16	21.5/9	23/17	4.2	0.3	3.9
30	37	11.5/15	19/7	22/16	4	0.44	3.56
31	46	8.5/13	18/7	19/15	3.8	0.4	3.4
Mean	42	10.24/14.60	19.24/7.29	20.69/15.73	3.77	0.40	3.37
SD	-	2.12/1.70	2.35/1.26	2.72/2.22	0.59	0.07	0.59

[a] SD - standard deviation

and deep dorsal vein. As lumen of the blood vessels could not be precisely measured, external diameter was measured at two points, distally and proximally. Average diameters of deep dorsal vein, right and left artery were 2.8 mm, 1.9 mm and 1.8 mm, respectively. Penile nerves with the usual anatomical distribution were found in all cases. Maximal volume of the glans was 5.30 mL and decreased down to 3 mL (mean 3.77 mL, SD – 0.593) Finally, the volume of the neoclitoris (resected part of the glans) was quantified and ranged from 0.28 mL to 0.56 mL (mean – 0.40 mL, SD – 0.074). Penile and scrotal skin were preserved in all cases and being sufficient for neovaginal reconstruction. The penile urethra length was sufficient in all cases and adequate for joining with female urethra of the potential recipient.

Remaining penile tissue were then precisely measured. The average volume of the remaining glans tissue after creation of the neoclitoris was 3.37 mL (89% of total volume) (ranged from 2.57 to 4.74 mL, SD – 0.591). Mean length and girth of cavernosum bodies were 19.24 cm (from 15 to 24cm) and 7.29cm (from 5.5 to 11cm), respectively. Both crural arteries were identified in all cases. The length of the distal urethra ranged from 11 to 21 cm (mean 15.73 cm), without registered anomalies or signs of spongiofibrosis or stricture. Circumflex branches and perforators of the blood vessels were detected in all cases. Mean values of all anatomical entities in three age groups are presented in Table 2. There is no statistically significant difference between groups in any parameter (p>0.05). (Table-2) All dissections were completed successfully, and all entities were assembled again in all cadavers.

DISCUSSION

In recent decades, there has been an intensive search for ideal phallic reconstruction. Neophalloplasty still represents the most used penile replacement method and includes the use of pedicled or free flaps. The success of these procedures is limited and associated with poor cosmetic result, complications (strictures and urethral fistulas) and poor erectile function (14, 15). Moreover, in severe trauma, genital injury is usually associated with limb injuries, making the use of reconstructive flaps problematic. Recently, the vascularized composite allotransplantation has become an option for the treatment of complex hand and face defects, offering the same idea as a viable alternative for genital reconstruction (16, 17). The first penile transplantation was reported in 2006, and four more have been performed since (2-6). The allograft was procured from a suitable deceased donor, with a cold ischemia time of 16 hours. The team had practiced the transplantation technique, including the microsurgical reconstruction, on cadaver-to-cadaver transplantation extensively before undertaking the operation in their landmark case. Despite the improvements in surgical techniques, many questions

Table 2 - Comparison of parameters between age groups.

Group No.	Age (years)	Penile length (mean, cm): flaccid/ stretched	Corpora (mean, cm): Length/girth	Urethral length (mean, cm): Total/distal	Glans volume (mL) (total, mean)	Glans volume (mL) (resected, mean)	Glans volume (mL) (remnant, mean)
1	<40	10.3/14.4	19.8/7.3	20.7/15.6	3.8	0.43	3.36
2	40-49	10.3/15	19/7,6	20.9/16	3.8	0.4	3.4
3	>50	10/14.2	18.5/6.7	20.4/15.3	3.6.	0.38	3.26
P values*		0.859/0.441	0.465/0.281	0.686/0.632	0.525	0.198	0.619

* Kruskal-Wallis Test

remain (18, 19). Procurement of the penis from a deceased donor is prolonged owing to additional multi-organ donor, highly complex procedure. Long cold ischemia, which is one of the main limitations, could be avoided by live donor transplantation. As the number of transgender surgeries continues to increase globally, in candidates who have elected feminizing gender affirmation procedures, the removed penile tissue (corpora cavernosa, remaining volume of the glans and anterior urethra) could be potentially suitable for live donor transplantation (12).

A clear understanding of normal penile anatomy represents the foundation of our research. Our experience with penile reconstructive surgery for different congenital and acquired anomalies, allowed us to be confident that we could dissect all penile elements in an anatomical fashion, and preserve all penile tissues. Penile disassembly has been previously defined as an option in the treatment of very severe penile deformities, preserving all penile structures with their functional assembly after correcting the anomaly (10, 11). Based on our anatomical dissections, we propose that the corpora cavernosa with tunica albuginea could be completely separated during the feminizing gender affirming surgery. The standard technique involves dissection of a small piece of the glans for reconstruction of the clitoris, leaving the rest of the glans tissue attached to the tips of corpora cavernosa. Since the new clitoris is supported by dorsal penile artery, deep dorsal vein, and penile nerve, we left the other penile artery and nerve attached to the tunica albuginea together with all perforant and circumflex branches. The main question remaining open is venous drainage of the glans after harvesting and dissection of deep dorsal vein. We hypothesized that the distal part of the urethra, which is connected to the glans and anterior part of the corpora cavernosa, enables additional venous drainage from the glans. This is one of the main points in urethral dissection. The male urethra is very long, and only a short segment of anterior urethra is usually necessary for the creation of the new female orifice. Almost the entire anterior urethra, which is very rich in blood vessels due to its connection to the tunica albuginea, could be preserved and used for joining with the original urethra in the recipient.

We precisely measured all penile structures to estimate the quality and quantity of the tissue after using the parts necessary for the reconstruction of the female genitalia. The main ethical request was to enable a completely normal reconstruction of female genitalia according to more recent techniques in feminizing gender affirming surgery. Our results showed an excellent potential of the penile tissue remnants, encouraging us to continue with our project and improve ideas on how to transplant tissue after dissection. In all cases we found good anatomical relations for safe dissection of all corpora cavernosa, including crura and joints with the pubic bones. The length of the corpora cavernosa with associated crural arteries was sufficient for microvascular transfer to a potential recipient. Also, we found no evidence of potential hypotrophy of penile structures with aging, since all measurements do not show significant variations according to age. In contrast to reported cases of penile transplantation, there would be a lack of penile skin for transplantation since all penile skin is usually used for standard gender affirming vaginoplasty (18). Lack of penile skin for transplantation could be resolved with recipient's genital skin.

The possibility of living and healthy donors of organs represents a great improvement in transplant surgery with the best post transplantation results. We are certain that penile transplantation will be accepted by all surgeons and health professionals who believe that it will be an ideal option for organ replacement. One of the limitations – the lack of available donors will be resolved by the possibility to use tissues from live donors, i.e., transwomen, where the penis is planned to be removed. We confirmed in our research with 41 transwomen that completely preserved corporal bodies with a good volume of remaining glans tissue and anterior urethra present viable tissue for potential live donor penile transplantation (20).

Recently, the incidence of transgender population has changed, ever growing, with a pre-

dominance of transwomen candidates. It could be the biggest bank for male organs, mostly penises, in the world. The development of immunosuppressive therapy could improve our goals for live donor penile transplantation as an ideal solution for all candidates (e.g., transwomen, trauma, malignancy, absence, etc.).

CONCLUSIONS

The anatomical principles of penile disassembly in feminizing gender affirmation surgery have been precisely described. Cadaveric dissection of the penis was defined as a similar procedure with detailed recovery of the remaining penile tissues after creation of new female genitalia. This preserved tissues such as corpora cavernosa with anterior urethra, ventrally, and glans with nerves and blood supply, dorsally, could be used for safe and successful live donor penile transplantation. Preliminary results of our cadaveric study have confirmed the technical feasibility, but further research could improve technical possibilities and offer standardization of operative techniques that will lead to the final goal of achieving a male genital organ ideal in all aspects.

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Institutional Review Board Statement

The study was conducted according to the guidelines of the Declaration of Helsinki and approved by the Institutional Ethics Committee (1322/X-16, 2020). Informed consent was not required because the study did not include live human subjects.

CONFLICT OF INTEREST

None declared.

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