

# Reconstructive Surgery for High-voltage Injury of Genitoperineal Area and Upper Extremities: The Uromanual Trauma Concept

Ruben T. Adamyan, MD, PhD, DSci\*  
 Olga N. Aleshina, MD\*  
 Elina I. Abdeeva, MD†  
 Mikhail Y. Sinelnikov, MY, MD,  
 PhD\*,†

**Summary:** Reconstruction of tissue defects resulting from high-voltage injuries remains a serious issue in plastic surgery. For many years it has been solved by applying autologous reconstruction with rotated and revascularized flaps. We present a series outlining reconstructive practices in treatment of patients with high-voltage “uromanual” injuries. These types of injuries include a group of upper extremities and genitoperineal high-voltage trauma due to urination on an electrical source, which are rarely discussed in the literature. This study aimed to describe the algorithm of perioperative care and surgical treatment in patients with high-voltage uromanual trauma. Three male patients (mean age 26.3 years, range: 20–35 years) with traumatic injury of the genital area and the upper extremities due to high-voltage injury underwent reconstruction with a one-stage repair of defects. In one patient, the defect of the left upper extremity was eliminated by microsurgical auto-transplantation of musculocutaneous thoracodorsal artery perforator flap. The genitoperineal region was repaired using rotated scrotal flaps. In two other cases, phalloplasty with a revascularized myocutaneous thoracodorsal artery perforator flap was followed by urethroplasty with a prefabricated radial forearm free flap. Hand deformities were eliminated using split-thickness skin autografts. All flaps survived. No complications were observed in the autograft harvesting areas. All cases showed good aesthetic and functional postoperative outcomes. Management of uromanual injuries should include one-stage reconstruction of upper extremities and genitoperineal defects for restoration of satisfying functional and aesthetic components crucial for patient’s quality of life and socialization. (*Plast Reconstr Surg Glob Open* 2021;9:e3842; doi: [10.1097/GOX.0000000000003842](https://doi.org/10.1097/GOX.0000000000003842); Published online 4 October 2021.)

The first case of high-voltage injury was reported in 1879: a French carpenter suffered extensive soft tissue defects after contacting an alternator, which led to his death.<sup>1</sup> Injuries caused by high-voltage electrical currents are considered to be among the most devastating due to the high level of damage and mortality rate,

general severity, long rehabilitation period, and difficulties in perioperative planning.<sup>2</sup> Electrical traumas are divided into low-voltage (under 1000 volts) and high-voltage (over 1000 volts).<sup>3</sup>

High-voltage injuries are characterized by extensive destructive processes in both soft tissues and osseous structures with the involvement of blood vessels and nerves. The true extension and degree of injuries is often significantly greater than the visible defect. As a result, the subsequent boundaries of the defects may differ from the initial size and tend to be more extensive. To determine tissue viability in the preoperative period, Doppler ultrasound with pulse oximetry was used to assess the perfusion activity of soft tissues in the region of electric shock damage.

Most often, electrical traumas occur due to direct contact of body parts with high-voltage electric currents. The term “uromanual injury” is suggested to differentiate a specific type of high-voltage injury referring to electric

From the \*N.O. Milanov Reconstructive Surgery Department, Petrovsky National Research Centre of Surgery, Moscow, Russian Federation; and †Human Anatomy Department, First Moscow State Sechenov University, Moscow, Russian Federation.

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damage simultaneously affecting the upper limbs and genitoperineal area. All patients in our report experienced uromanual injuries as a result of urination on a source of high-voltage electricity. Extensive defects, including complete penile amputation, and postburn deformations were located in functionally significant areas of the body. Free revascularized tissue flap transfer was applied as the optimal technique of reconstructive surgery.<sup>4</sup>

## MATERIALS AND METHODS

### Patient Characteristics

Three male patients aged 20, 24, and 35 were included in this evaluation. All patients underwent reconstructive surgery due to uromanual trauma at Milanov Reconstructive Surgery Department.

### Computed Tomographic Angiography

Computed tomographic angiography was the main diagnostic tool for selection of donor and recipient vessels. For additional preoperative evaluation of tissue perfusion in donor and recipient sites, patients underwent Doppler ultrasound examination of the following blood vessels: a. et v. epigastrica profunda, branches of a. et v. subscapularis, as well as arteries and veins of the upper extremities on both sides.

### Myocutaneous Thoracodorsal Artery Perforator Flap Neophalloplasty

This method is recommended in patients with total penile amputation along with prefabrication of a radial forearm free flap (RFFF) for urethral reconstruction. For this procedure, the patient is placed in a lateral decubitus position, with an abducted hand, and elbow bent at 90 degrees secured on an arm rest. The flap is then mobilized according to preoperative markup.

Following cutaneous incision, the pedicled myocutaneous flap (including the thoracodorsal arteries, nerve, veins) is isolated via careful dissection. The thoracodorsal nerve is then transected. The length of the vascular pedicle should be between 10 and 15 cm for ease in peritoneal revascularization. The flap is then mobilized. The large donor-site defect is closed using a lateral abdominal rotated pedicle flap.

The mobilized thoracodorsal artery perforator flap (TDAPF) is used to form a neophallus: according to the prior markup, the flap is rolled into a cylinder. Next, the neophallus is sutured with single stitches to regulate pressure during the recovery period.

The patient is then placed on the operating table in a supine position, with his arms abducted at 45 degrees. The pubic periosteum is exposed, and the neophallus is attached to the periosteum of the pubis with retention sutures (Fig. 1).

The skin of the neophallus and recipient zone skin are sutured with interrupted sutures. The inferior epigastric vessels are then exposed, clipped, transected, and rotated caudally. The vascular pedicle of the neophallus and the thoracodorsal nerve are drawn through a subcutaneous



**Fig. 1.** TDAPF neophallus is attached to the pubic periosteum with retention sutures. The epigastric vessel access is seen laterally to the neophallus.

tunnel toward the recipient vessels. Additionally, the nerve innervating the gracilis muscle is exposed and rotated cranially.

The thoracodorsal artery is then anastomosed to the inferior epigastric artery. The venae comitantes are attached to the inferior epigastric veins. After restoration of flap blood supply, the thoracodorsal nerve is anastomosed end-to-end to the nerve, innervating m. gracilis. The urethra is located, separated from damaged tissue, and a urostoma on the inferior scroto-perineal border is performed. This opening will be later used for urethroplasty. After stable flap perfusion is achieved, the wound is closed, drains are placed, and sterile dressing is applied. The dressing should not compress the neophallus. In case of venous stasis, midline and base sutures may be partially released to release tension.

### Radial Forearm Flap Prefabrication

Along with the phalloplasty, the radial forearm flap for urethral reconstruction is prefabricated. The prefabrication consists of a radial rectangular cutaneous flap mobilization along three borders, with one remaining intact. The hair follicles are removed, and the flap is reattached with a temporary sterile separator between the flap and the underlying tissue. This procedure allows for later mobilization of a flap without hair follicles and with stable perfusion.

### Urethral Reconstruction using the Fasciocutaneous RFFF

This method is applied following TDAPF phalloplasty for urethral reconstruction in cases of intact forearm tissues (unilateral uromanual trauma). This method cannot be applied in patients with bilateral trauma to the upper extremities.

The upper extremity with the prefabricated radial flap is abducted at 90 degrees. Within the neophallus, a tunnel is formed and dilated for radial flap insertion. The prefabricated RFFF is then mobilized with the deep fascia, and the radial artery is harvested up to its bifurcation. The flap should exceed the neophallus in length. The length of

the vascular pedicle should be 7–10 cm for proper revascularization in the recipient zone. The radial donor-site defect is closed with a split-thickness skin graft. The prefabricated RFFF is then wrapped around a Foley catheter with the cutaneous surface on the interior (Fig. 2).

Next, the neourethra is passed into the neophallus on the catheter, with the vascular pedicle in the proximal direction. The distal edge of the neourethra is fixed to the neophallus head skin with interrupted sutures, creating the neourethral external meatus. The urinary catheter remains within the neourethra. The proximal edge of the neourethra is anastomosed with the native urethra with interrupted sutures. The intact inferior epigastric artery and vein are accessed, clipped, transected, and rotated caudally. The neourethral vascular pedicle is transferred into the recipient vessel site. The radial artery is anastomosed with the inferior epigastric artery. The venae comitantes and the inferior epigastric vein are then anastomosed. Visual control of flap perfusion is assessed on the small skin island of the neourethra that was brought and fixed in the area of the neophallus head. After stable flap perfusion is achieved, the wound is closed, drains are placed and sterile dressing is applied. The urethral catheter remains in the neophallus until the wound has healed completely. This may take up to 4 weeks.

#### Upper Extremity Defect Closure

Depending on the severity of damage to the upper extremities, several methods can be applied for defect closure. In cases of superficial tissue damage, localized to one anatomical zone without loss of tissue viability, it is possible to close the wound with primary sutures. In cases of more extensive damage, local and free flaps can be applied. Severe damage often leads to amputation, or requires surgical amputation.

## RESULTS

#### Case 1

A 24-year-old male patient presented with a superficial penile cutaneous defect and traumatic amputation of the left upper extremity at the level of the middle third of the forearm with soft tissue defects of the inner surface of the left shoulder and elbow. The damage was a result of a high-voltage uromanual injury. Primarily, the upper



**Fig. 2.** Preparation of neourethra over a urinary catheter. The cutaneous surface of the prefabricated radial forearm flap is on the interior.

extremity defect was closed with a free myocutaneous thoracodorsal flap taken from the contralateral side of the defect, revascularized via the thoracodorsal and subscapular arteries and veins.

Next, a two-stage penile reconstruction with local scrotal flaps was performed. At the first stage, after removal of damaged tissues, the penile corpus was placed into the scrotum.

The secondary surgery was performed three months later. The penis was released, and scrotal flaps were attached along the midline.

#### Case 2

A 20-year-old patient presented with a 5-month-old uromanual high-voltage trauma. The patient had complete penile amputation with an intact scrotum and a left upper extremity tissue defect (Fig. 3). A two-stage TDAPF neophallus and RFFF urethral reconstruction were performed.

The upper extremity defect in this patient did not require flap coverage. Reconstruction of the upper extremity defect included surgical scaring release. The neophallus and urethral reconstruction were successful. Urinary catheter was removed 16 days after surgery. No complications occurred (Fig. 4).

#### Case 3

A 35-year-old patient presented with a uromanual trauma following high-voltage injury causing complete penile amputation and left upper extremity deformation. The patient underwent a two-stage reconstructive surgery to restore the penis and urethra. The first stage included microsurgical phalloplasty with a TDAPF and RFFF prefabrication. Three months later, microsurgical urethroplasty with a prefabricated fasciocutaneous radial flap was performed. Urinary catheter was removed 15 days after surgery. No complications occurred.



**Fig. 3.** Complete penile amputation due to uromanual high voltage trauma.





**Fig. 4.** Reconstruction result in a patient with TDAPF and RFFF reconstruction following high-voltage electrical uromanual trauma.

### Uromanual Injury: A Novel Concept

The main causative factor of the uromanual trauma is urination on a high-voltage electrical source. This causes damage to the urogenital area and upper extremities of varying extent. Importantly, simultaneous damage to these organs creates difficulties in clinical management, including reconstructive donor site damage, significant vascular perfusion deficiencies, and urination defects. Injury mechanism involves a high-voltage electrical current spreading through urine to the urogenital area and the hands, in cases of manual assistance during urination. The trauma causes severe disability and traumatic defects in these patients. Diagnosis is based on clinical evaluation and patient history. Treatment depends highly on severity of electrical damage, ranging from light (superficial localized defects) to severe (amputations and damage exceeding one anatomical zone).

## DISCUSSION

The concept of categorizing a uromanual trauma as an independent group of high-voltage injuries at first seemed comical. Yet given the similarities between tissue damage, treatment, and rehabilitation tactics, we believe this pathology should be categorized separately. In most cases, men use their hands to assist in urination. When urine comes in contact with an exposed high-voltage electrical source, an electric shock injury of the urogenital organs and upper extremities occurs, damaging functionally important body areas.<sup>5,6</sup> The similarities between patients with high-voltage injuries associated with urination on an electrical source are uniform. Such patients require reconstruction of the upper extremities and the genitals. Damage to both forearms limits the possibility of radial flap mobilization, though often patients with uromanual high voltage trauma have unilateral forearm damage.

Reconstruction of the penis and urethra is the most difficult problem requiring urgent surgical care.<sup>7,8</sup> Due to strong heating effects of electric currents on biological tissues, the superficial structures of the body are affected by thermal

burns.<sup>9</sup> Deeper tissues are subjected to ischemia, vascular thrombosis, and necrotic processes.<sup>10</sup> The use of revascularized flaps allows for restoration of both superficial and deep tissues, providing a new source of blood supply to the defect.<sup>11</sup> Injuries of the perineal region due to high-voltage electrical injury most commonly manifest as various defects of the external genitals, including penile amputation.<sup>12</sup>

Phalloplasty with various types of soft tissue flaps includes either one-stage reconstruction of both the penis and urethra or two consecutive operations. For one-stage phallo-urethroplasty, groin flaps, anterolateral thigh flaps, thoracodorsal artery perforator flaps and other myocutaneous and fasciocutaneous flaps in various combinations have been recommended.<sup>13-21</sup> The presence of axial blood supply, the constancy of the vascular anatomy, and the possibility of modeling the neophallus of a given size allow for evaluating the extent of tissue viability and availability of a thoracodorsal flap for reconstructive phalloplasty. The most optimal reconstruction method of the male urogenital region in cases of total penile amputation is the phalloplasty technique with a TDAPF followed by urethroplasty using a prefabricated RFFF.<sup>17</sup> These methods are associated with certain difficulties, due to the peculiarities of the urogenital system physiology and anatomy. The division of these stages into separate surgical interventions makes it possible to minimize the formation in the long-term post-operative period of urinary fistulas, urethral strictures, and marginal necrosis of the neophallus.

The most common complications of the neourethra, regardless of the reconstruction method, are urethral strictures, urinary fistulas, and suture dehiscence.<sup>22,23</sup> Prefabrication of the radial flap by removal of dermal layer containing hair follicles prevents hair growth within the urethra. The advantage of using the TDAPF for phalloplasty is the possibility of its intraoperative reinnervation with the subsequent development of muscular contractility of the flap. Strictures and fistulas occur as common complications of such surgical interventions, but were avoided in our series using prefabrication of the radial flap and minimally invasive surgical technique (with tunnelling and tissue release).

For penile reconstruction of superficial trauma, subtotal amputations and the local scrotal flaps are favored. Aesthetically, the presence of hair and the difference in cutaneous coloration are the main drawbacks of scrotal flaps. Despite this, scrotal tissues provide excellent elasticity and viability, unlike full-thickness or split-thickness skin autografts.<sup>24,25</sup>

Cutaneous defects of the hands as a result of postburn cicatricial deformities can be restored by means of skin grafts. Reconstructive surgery on the upper extremities restores lost and damaged tissues, prevents post-traumatic infectious complications, and creates a reliable support function for subsequent exo-prosthetic limbs in cases of limb amputations.<sup>26</sup>

## CONCLUSIONS

Uromanual injuries include conditions brought about by urination onto high voltage electrical sources and are associated with a combination of urogenital and upper extremity tissue defects ranging from superficial damage

to total amputation. Such conditions require restoration of functional, aesthetic, and psychological components. A combination of flaps for urogenital reconstruction (TDAPF and RFFF) is limited by upper extremity damage. In our experience, autologous reconstruction with stacked microsurgical flaps or local scrotal flaps provides the best results.

**Mikhail Y. Sinelnikov, MY, MD, PhD**  
 Abrikosovskiy 2  
 Moscow 119991  
 Russian Federation  
 E-mail: snlnkv15@gmail.com;  
 mikhaile.sinelnikov@gmail.com

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