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Combined use of biomaterials and revascularisation in autoplasty of ulnar nerve

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ABSTRACT

Surgical treatment of peripheral nerve injuries is effective in only 50% of cases. This is primarily due to the significant extent of the diastasis between the fragments of the damaged nerve, in which autoplasty has to be performed. The drawbacks of this technique are the formation of scar tissue, possible necrotisation of the autograft, mismatch of the donor and recipient nerve diameters. In order to overcome these drawbacks and improve the efficiency of surgical intervention, the study presents a clinical case of successful multifascicular ulnar nerve autoplasty with the use of domestic biodegradable biomaterials SpheroGel and ElastoPob, revascularization of the autograft with a connective tissue flap on a vascular pedicle. A persistent regression of local pain syndrome was observed in the early postoperative period. The effectiveness of the performed surgical intervention was confirmed by ultrasound examination: there was no evidence of neuroma in the area of the operation, regeneration of nerve bundles was noted at the site of stitching. Positive dynamics was observed in the results of VAS, DN4, DASH questionnaires.

Keywords: *peripheral nerve damage, autoplasty, biomaterials, nerve regeneration, graft revascularization.*

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Introduction

Peripheral nerve injuries lead to significant impairment in the quality of life and disability mainly in young previously healthy people of working age [1]. The incidence of peripheral nerve injuries is significantly higher in men with male-to-female ratio 5:1 [2].

Most patients with upper extremity injuries (93%) have lesions of certain nerves (median nerve 66%, ulnar nerve 24%, radial nerve 10%). Concomitant nerve injuries are usually characterized by lesions of median and ulnar nerves (94%). Most often, only one arm is injured (left arm — 60%, right arm — 40% of cases) [1]. Annual incidence of nerve injury among patients with upper extremity injuries is 43.8 per 1 million. Mean age of patients was 38.1±0.05 years, and 74.3% of patients were men [3].

The cost per a patient with peripheral nerve injuries was $47,004±185 with average increment $4,623 per year and compound annual growth rate 9.59% [3]. The costs of nerve injuries are either comparable or higher compared to other common hand injuries such as distal radius fracture [4].

Peripheral nerve injuries can result from direct soft tissue trauma or bone fractures [5]. The most common causes of upper extremity nerve injuries are motorcycle and car accidents (59.4%) [6, 7]. Other common causes include stab wounds, glass cuts, and other similar soft tissue injuries [8—10]. In addition, ulnar nerve is exposed to high risk of injury during surgical interventions for distal humerus fractures, postoperative cicatricial and adhesive changes [11, 12]. According to the literature, the incidence of postoperative ulnar neuropathy ranges from 0 to 51% (mean 13%) [13, 14].

Ulnar nerve injuries significantly impair daily and professional activities [15]. Many patients with severe ulnar nerve injuries change profession, and some ones have to cope with constant household restrictions that significantly reduces the quality of life. This is due to severe impairment of motor function of the hand following simultaneous damage to hypothenar, lumbrical, interosseous muscles, adductor pollicis muscle and deep head of flexor pollicis brevis muscle [16]. Dysfunction of these muscles leads to "claw paw" contracture. In addition, ulnar nerve injuries are accompanied by hypo-, anesthesia of the little finger and ulnar surface of the ring finger. Prognosis for functional recovery in case of ulnar nerve injury, regardless of the level of injury, is usually less favorable compared to lesion of median or radial nerve [16, 17].

The most severe nerve lesion is complete anatomical disconnection (Sunderland grade V) corresponding to neurotmesis (Seddon classification, 1943). Depending on dimensions of diastasis between proximal and distal ends of the damaged nerve, such damages are divided into 3 groups: <1 cm, <5 cm and >5 cm [18]. Direct neurorrhaphy is preferable for diastasis <1 cm. This intervention is the gold standard for restoring nerve integrity and leads to good functional results [19, 20]. In case of diastasis >1 cm, approximation of nerve ends leads to their ischemia, terminal neuromas and no functional recovery. Peripheral nerve stretching by more than 10% at rest reduces blood flow by 50% [21]. Thus, nerve autotransplantation is preferable for diastasis up to 5 cm. Alternative options include artificial conduits (nerve conductors, artificial nerve grafts), i.e. products designed for directed axon growth and promoting nerve regeneration. However, there are currently no products approved for clinical application [22, 23]. According to some authors, artificial nerve conductors are considered for diastasis <3 cm [24, 25]. Vascularized nerve autografts are indicated for extended diastases (>5 cm) [26]. If proximal stump is inaccessible, nerve transfer and end-to-side neurorrhaphy are alternative options [5, 18, 27]. According to the literature, autoplasty with mean graft length of 4 cm is necessary to restore nerve integrity during repeated interventions in case of unsuccessful primary neurorrhaphy [27]. In addition to size of diastasis, the level of damage is important for choosing surgical tactic for ulnar nerve injury. Ghoraba S. et al. [28] proposed an algorithm for choosing surgical interventions in case of complete anatomical damage to the ulnar nerve depending on level of injury.

According to the literature, approximately 3—5% of all patients with traumatic or iatrogenic peripheral nerve injuries develop terminal neuromas accompanied by severe pain syndrome [29]. Excision of neuroma and scar tissue until visualization of clear nerve bundles is mandatory before direct neurorrhaphy or nerve autoplasty. Dimensions of neuroma of proximal nerve end and analysis of length of further diastasis are important factors in preoperative planning.

The purpose of the study was to demonstrate the effectiveness of biodegradable materials and autograft revascularization in surgical treatment of post-traumatic neuropathy of the left ulnar nerve at the level of the lower third of the forearm after failed primary neurorrhaphy.

A 48-year-old patient admitted to the neurosurgical department with complaints of severe impairment of active movements in fingers IV—V and fine motor skills, numbness in fingers of the left hand, severe local pain proximal to postoperative scar on the forearm (VAS score 9, DN4 score 8, DASH score 75, HADS scores of anxiety and depression 2 and 1, respectively).

There was previous injury of the left forearm by circular saw. On the first day after injury, neurorrhaphy of the ulnar and median nerves was performed at the level of the lower third of the forearm. There was partial postoperative restoration of motor skills in fingers I—III of the left hand with severe paresis of fingers IV—V and "claw paw" contracture **(Fig. 1)**.

Ultrasound examination of the left ulnar nerve revealed signs intra-truncal neuroma, reduced echogenicity, no differentiation of nerve fibers and signs of regeneration. Loose scar tissue about 3—4 cm long is visualized around the nerve **(Fig. 2)**. Electroneuromyography re-



Fig. 1. **Hand and preoperative markings.**
"Claw paw" contracture. Projection of the ulnar nerve and pisiform bone is indicated.

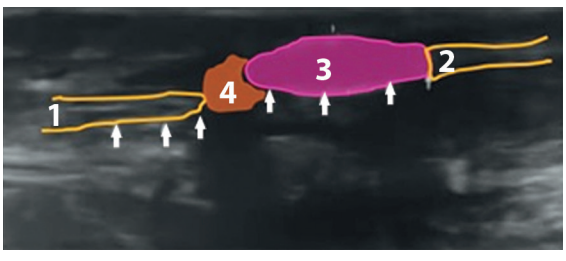


Fig. 2. **Ultrasound examination of the left ulnar nerve one month after primary neurorrhaphy.**
a — ultrasound scan; b — explanation: 1 — distal stump of the damaged ulnar nerve, 2 — proximal stump, 3 — terminal neuroma, 4 — scar tissue in the area of neurorraphy.

vealed signs of complete axonal damage to the left ulnar nerve at the level of the forearm.

Considering complaints, anamnestic, neurological and diagnostic data, we established the need for neurosurgical intervention: revision, decompression, neurolysis, dissection in Guyon canal, microsurgical neurorrhaphy of the left ulnar nerve using multi-fascicle autograft of the left sural nerve and biodegradable materials, revascularization of autograft by pedicled connective tissue flap **(Fig. 3)**.

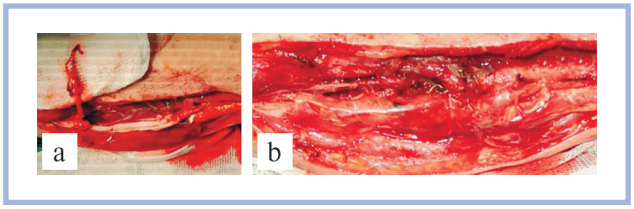


Fig. 3. **Intraoperative images: anastomosis between multi-fascicle autograft, proximal and distal ends of the damaged ulnar nerve and artery mobilized from surrounding soft tissues (a); final view of anastomosis with revascularization surrounded by "SpheroGel" and "ElastoPOB" (b).**

The need for autograft was due to large diastasis (5 cm) between proximal and distal ends of the ulnar nerve after excision of intra-truncal neuroma. The ElastoPOB material was used as a membrane between anastomosis and surrounding tissues, as well as an external frame. The SpheroGel biomaterial was used to maintain homeostasis, improve reparative processes and prevent scarring within anastomosis area. We used microsurgical instruments, operating microscope and non-absorbable polypropylene suture 6—0. A 15 cm long sural nerve harvested from the lower leg was used as an autograft.

Scheme of surgery is presented in **Fig. 4**.

Results

Local pain syndrome regressed in early postoperative period.

After 3 months, ultrasound found no evidence of neuroma (adequate anastomosis), compression or deformation of the ulnar nerve. There was regeneration of nerve bundles at the site of suturing of autoneural grafts **(Fig. 5)**.

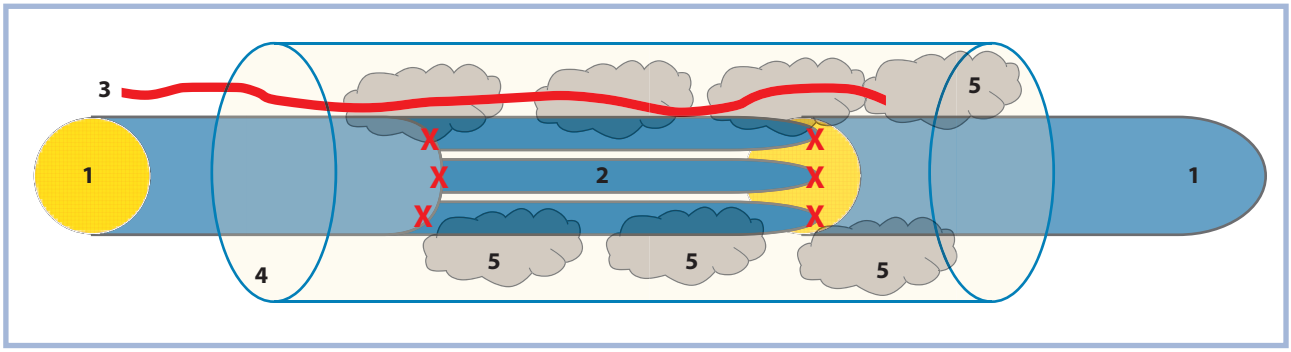


Fig. 4. **Combined use of biodegradable materials, multi-fascicle autograft and vascularized flap (scheme).**
1 — ulnar nerve; 2 — multi-fascicle autograft; 3 — artery; 4 — "ElastoPOB"; 5 — "SpheroGel".

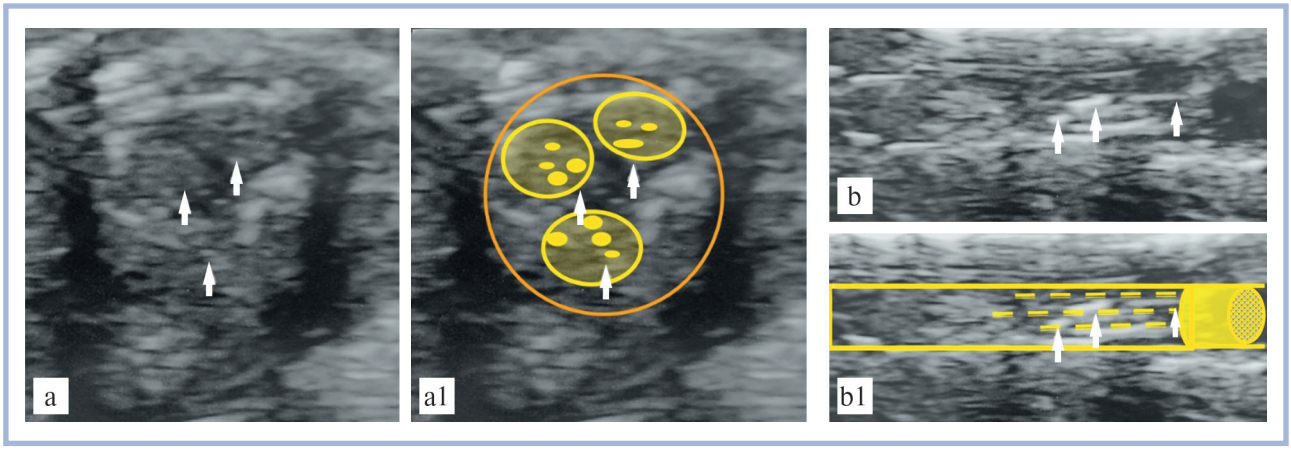


Fig. 5. **Ultrasound control of multi-fascicle graft with biodegradable materials and graft revascularization. Cross-section (a) and scheme (a1): all three trunks of the autograft are visualized with regenerating nerve bundles. Longitudinal section (b) and scheme (b1): regenerating nerve bundles along the autograft.**

The follow-up examination after 3 months revealed higher strength in fingers IV—V of the left hand. There was positive dynamics in various scores (VAS 0 point, DN4 1 point, DASH 32 points, HADS 2 and 1 point, respectively). The patient himself expressed high satisfaction with surgical intervention.

Conclusion

Autoplasty is the "gold standard" for nerve recovery in case of extended defect. The quality of anastomosis provided by biodegradable materials and autograft revascularization, no terminal neuroma and signs of nerve bundle regeneration indicate the effectiveness of this technique. Biodegradable materials maintain homeostasis, improve reparative processes and reduce pathological effect of cicatricial adhesive process preventing adhesion of scar tissue in the area of nerve bundle growth. Revascularization by connective tissue flap reduces the risk of graft ischemia. Minimally invasive autograft harvesting is preferable.

Author participation:
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Collection and analysis of data — Fedyakov A.G., Sidneva L.A., Razin M.A., Plieva Z.Kh.
Statistical analysis — Fedyakov A.G., Razin M.A.
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