*Czarnecki P. Secondary and salvage procedures in nerve injuries. Issue Rehabil. Orthop. Neurophysiol. Sport Promot. 2017; 19: 41–49. DOI: 10.19271/IRONS-00036–2017–19*

**SECONDARY AND SALVAGE PROCEDURES IN NERVE INJURIES**

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SUMMARY

**Introduction**

Nerve injuries often result in severe impairments despite proper initial treatment. Secondary and salvage procedures can be used to improve hand function in cases of medial, ulnar and radial nerves palsy.

**Aim**

To present and describe possibilities of treatment in late or irreparable nerve injuries.

**Material and methods**

Material included patients with severe nerve injuries. Clinical examination, case history and imaging studies were used to assess specific functional impairments. Surgical procedures were selected to improve function lost due to nerve injury.

**Results**

Clinical examination and additional studies are described to assess hand function and particular impairments. Possibilities of surgical treatment including: tendon transfers, nerve transfers, joint fusions and other are presented and explained according to the level of injury and nerve.

**Conclusion**

Despite unsatisfactory results of nerve injury treatment, selected procedures are applicable to improve hand function and patient's quality of life.

**OPERACJE WTÓRNE W USZKODZENIACH NERWÓW**

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STRESZCZENIE

**Wstęp**

Bardzo często pomimo odpowiedniego leczenia, uszkodzenia nerwów powodują poważne ograniczenia funkcji ręki. W takich sytuacjach można ją poprawić poprzez wykonanie wtórnych procedur.

**Cel**

Przedstawienie możliwości leczenia w sytuacjach nienaprawialnych lub zastarzałych uszkodzeń nerwów.

**Materiał i metody**

Oceniono historię choroby, badanie kliniczne oraz badania dodatkowe pacjentów z uszkodzeniami nerwów, aby określić poszczególne problemy i ograniczenia funkcji. Przedstawiono odpowiednie opcje chirurgiczne, mające na celu poprawę funkcji ręki.

**Wyniki**

Procedury zostały pogrupowane na transfery ścięgien, transfery nerwów, artrodezy i inne oraz omówione w kontekście uszkodzenia poszczególnych nerwów: pośrodkowego, łokciowego i promieniowego z uwzględnieniem poziomu uszkodzenia.

**Wnioski**

Pomimo nieodwracalnych skutków uszkodzenia nerwówo i wynikających z nich problemów z funkcją, istnieje wiele procedur mogących zminimalizować powyższe problemy i poprawić jakość życia pacjenta.

**Keywords:** late nerve injury, joint fusion, tendon transfer, nerve transfer

*Date received: 14th February 2017*
*Date accepted: 5th May 2017*

**Słowa kluczowe:** uszkodzenia nerwów, artrodeza, transfery nerwów, transfery ścięgien

*Data otrzymania: 14 luty 2017*
*Data zaakceptowania: 5 maja 2017*

## Introduction

Nerve injury occurs when trauma cause interruption of nerve's structure. According to severity, classifications are used to assess the problem and suggest possible solutions.

These injuries occur in 2–3% of all traumatic incidents, appearing to be significant clinical and social problem. Often many surgeries are needed to restore some function and unsatisfactory results of initial nerve repair are frequent. Upper extremity is mostly involved and injury pattern include sharp cuts or crushing, often in young active and working patients (Kotwal and Gupta, 2005).

Despite many salvage techniques described, it's unclear which should be selected to achieve best function. For some cases a combination of static techniques as joint fusion with active as tendon transfers can be necessary to regain grip, eg. in manual workers (Makarewich and Hutchinson, 2016). In other situations surgeon needs to focus on regaining sense by nerve transfers which can be combined with tendon transfers as in median nerve palsy (Chadderdon and Gaston, 2016).

## Aim

To present possibilities of treatment in late, irreparable nerve injuries or in situations of failed primary or secondary nerve repair.

## Material and methods

Case studies of patients with old, irreparable nerve injuries or after failed reconstruction in the upper extremity, whose clinical and social status was evaluated with routine examination methods and case history. Surgical procedures of treatment in different cases are presented with emphasis on reconstructive procedures used for restoring sensory and motor function.

## Results

Patients have to be carefully clinically evaluated. Other imaging and tests can only help the diagnosis and rarely decide about the treatment.

*Clinical examination*

Clinical evaluation is the most essential part of presurgical preparation. It has to include testing of the nerve that is injured and wasted and evaluation of possible donors (tendons and nerves). Additionally joints have to be checked for passive range of motion to asses possible result of tendon transfer. In some severe cases of stiffness arthrolysis can be done as a first stage or joint fusion has to be decided as the only choice.

Patient's social status and expectations have to be evaluated and the procedure carefully explained. In cases of staged surgeries and taking rehabilitation protocols and nerve regeneration time under consideration, patient has to be familiar with long period from surgery to clinical effects.

*Imaging and nerve conduction studies*

Imaging and nerve conduction studies are not frequently used in these cases because the nerves are accepted to be irreparable. Ultrasonography can be helpful in some cases to asses possible tendon donors and muscle condition before the surgery in cases of severe trauma that can hinder clinical evaluation.

*Nerve transfers to restore sensory function*

Less important nerve branches can be transferred to restore sensory function of the hand (Schenck *et al.,* 2016).

Most favorable donors are: sensory branch of radial nerve, branches of ulnar nerve to the little and annular finger.

The donor nerves are usually transferred to sensory nerves for thumb and index finger (most important in daily life activities). The technique includes microsurgical end-to-end coaptation of the nerves under microscope magnification. Selected nerves are similar in size and function (almost pure sensory nerves), care has to be taken to make coaptation as distal as possible to decrease regeneration time (Moore *et al.*, 2014).

2. similar excursion
3. possible less morbidity
4. good patient cooperation and rehabilitation program

In typical injuries some known and confirmed protocols can be followed but still there are cases when the surgery has to be customized.

*Common examples of transfers are (Riordan, 1983):*

1. EIP for opposition transfer in median nerve palsy

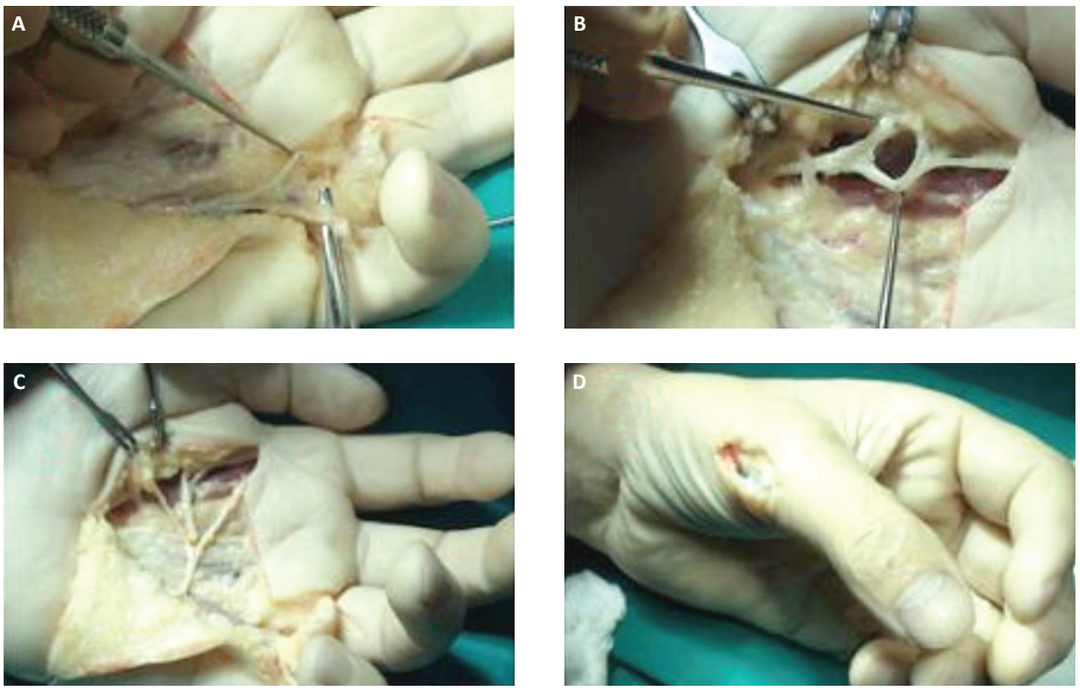


**Figure 1.** Transfer from ulnar nerve to sensory branches for thumb and index (A – donor site, B – recipient site, C – after transfer). In the same case EIP was simultaneously transferred for opposition – D.

*Tendon transfers*

Tendon transfers may be indicated to improve hand function and regain hand balance in irreparable late nerve lesions or reconstructions (Seiler *et al.*, 2013).

Before surgery, appropriate planning should be performed to select best tendon to transfer. Few issues and attributes should be considered (Prommersberger and van Schoonhoven, 2013):

1. synergistic way of function
2. PT for ECRB, PL for EPL and FDS IV for EDC in radial nerve palsy
3. FDS transfer – active tenodesis for claw hand in ulnar palsy

During surgery location of several cuts and tendon passage and trajectory has to be properly planned to fit biomechanic expectations. It is crucial to set proper tension and use tendon suture with high resistance to early load (mostly weave suture). Usually

**Table 1** Exemplary comparison of muscle attributes used for selection the best donor for the transfer. Usually these parameters are evaluated to be as close as possible to non-working muscle

| | ECRB | ECRL | FCU |
|---|---|---|---|
| weight | 5.1 | 6.5 | 5.6 |
| length (cm) | 6.1 | 9.3 | 4.2 |
| strength | 3.5 | 3.5 | 6.7 |

tendon-weave technique is used to join tendons and 3 weeks of immobilization in a splint is advocated followed by active exercises.

*Radial nerve palsy*

In radial nerve palsy, wrist, thumb and fingers extension have to be restored. Many ways of transfers have been described focusing on this three lost movements (Seiler *et al.,* 2013). Some authors promote simple transfers of FCU to cover fingers and thumb extension and keep wrist in neutral positions along with fingers motion (Sankaran *et al.,* 2015). Other option to consider is to make wrist fusion (described later) to provide full wrist stability (very reliable, especially in manual workers) and then transfer wrist flexors (FCR to EPL and FCU to EDC, EDMI and EIP). From my experience this is reliable procedure if patient accepts wrist fusion. The procedure can be staged (first fusion then transfer) or simultaneous.

In triple transfer PT is usually used for ECRB transfer but from my perspective PT with its short excursion is rather wrist tenodesis than real working muscle effect. PL for EPL works very well, especially in rerouting (for simultaneous palmar abduction and extension), I have never expected bad result with this procedure (Colantoni Woodside and Bindra, 2015). For fingers FDS IV, FCU or FCR can be used. First (FDS IV) is arguable due to its antagonistic nature but the muscle has very nice excursion. FCU and FCR have good power to run all four fingers and they are really worth considering in these cases.

*Median nerve palsy*

In this type there are different possibilities depending on the level of injury. In proximal lesions finger flexion deficit can be restored by tendon transfer from other flexors. Lack of thumb opposition and palmar abduction is usually treated by EIP, EDMI, PL or abductor digit minimi muscle transfer. I mostly use EIP which is really reliable in tramua cases and gives natural and with abduction of the thumb with some opposition (Seiler *et al.,* 2013). PL transfer is valuable in advanced median neuropathy bur rarely in traumatic cases because of frequent injury to PL accompanying median nerve lesion (Chadderdon and Gaston, 2016).

*Ulnar nerve palsy*

Low and high palsies have to be recognized and differentiated in the treatment. Mostly claw deformity is to be corrected by passive or active techniques (Diaz-Garcia and Chung, 2016). When clawing is eliminated, IP joints extension is much more efficient and possible even in non-working intrinsic muscles.

Capsulodesis of MP joints or transfer of FDS to pulleys or even lateral bands are proposed to prevent MP hyper extension along with improving PIP extension (Cook *et al.,* 2016).

Secondly power pinch grip can be restored by transfer of ECRB or FDS to adductor pollicis tendons.

*Joint fusion*

Fusion is solid but irreversible option for patients with irreparable nerve injury, mostly used when in radial nerve palsy. It stabilizes the wrist in neutral position thus enabling efficient load of flexors and possibility for tendon transfer for fingers and thumb extension. After wrist fusion FCU and FCR are redundant and can be used for the transfer.

Many techniques can be used to achieve good bone healing and stability including: K-wire, plate and allo-or auto bone grafts.

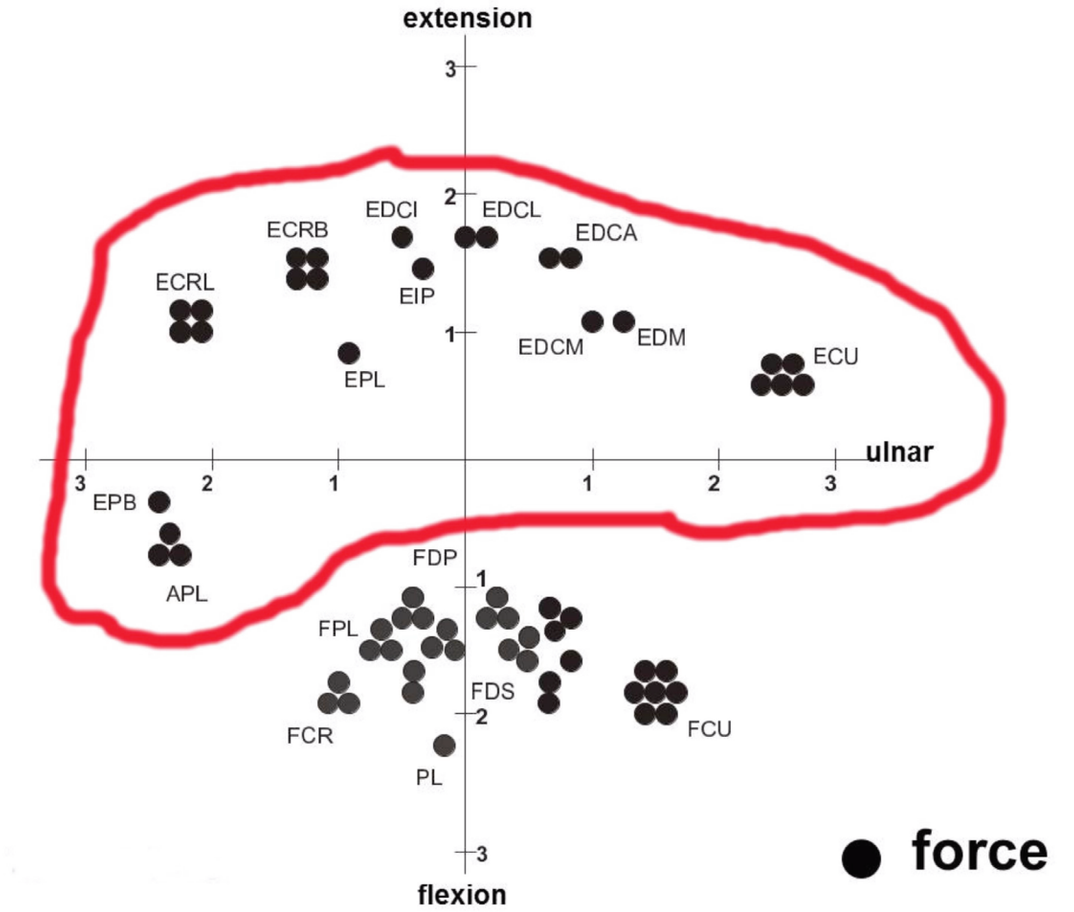


**Figure 2.** Tendon function and strength in healthy and injured hand (marked tendons are innervated in radial palsy) – modified original picture by Brand (Brand, 1988).

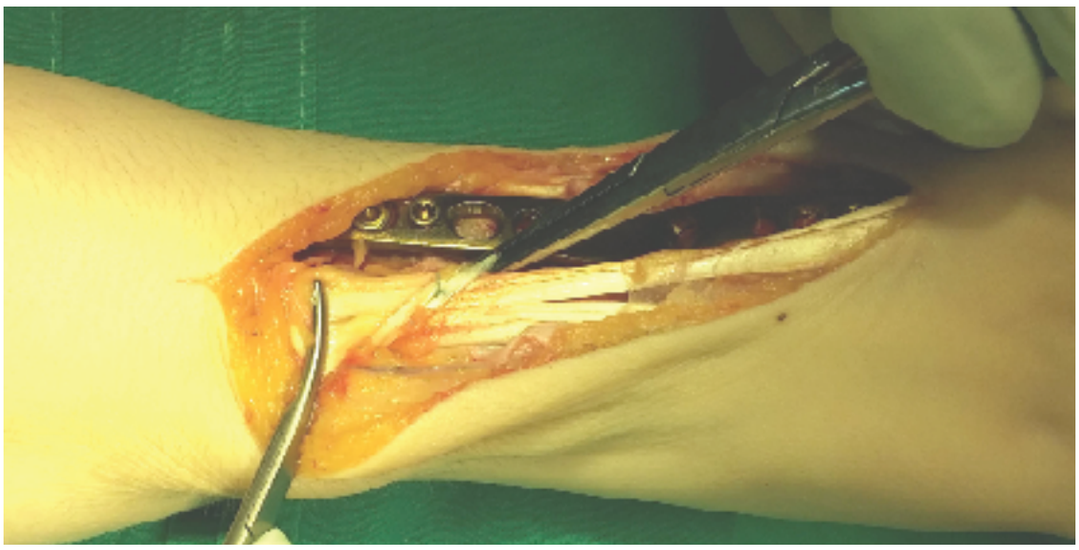

**Figure 3.** Simultaneous wrist fusion with plate and FCU to EDC tendon transfer, transfer site lies on the side an doesn't interfere with fusion area.

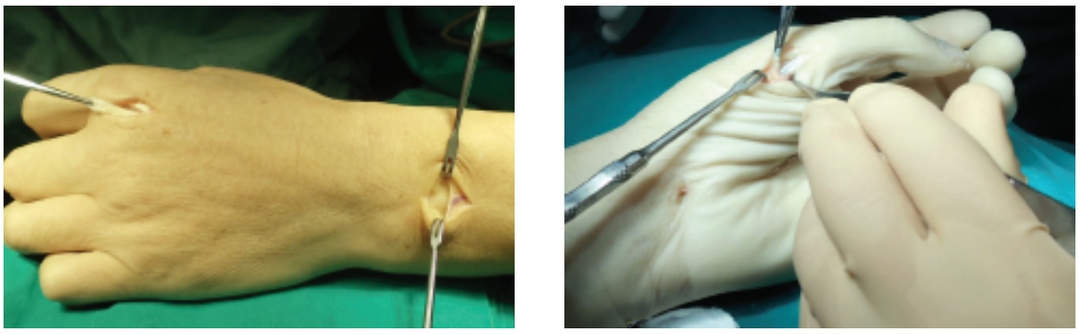

**Figure 4.** Harvesting and transferring EIP to APB insertion through multiple cuts and tunneling, the tendon is passed around ulnar side to the radio-dorsal point of insertion to achieve slight opposition along with full abduction.

Recently, dedicated plates are promoted to achieve perfect initial and long lasting stability, this fixation is precontured and low-profile and give an option of choosing most appropriate wrist position (Kalb and Prommersberger, 2009).

Dorsal approach is used and at least central column should be prepared for fusion with cartilage removal up to CMC III joint. The space is filled grafts and plate applied with possible compression. Splint can be used for short time but it is not necessary due to initial stability of fixation. Fusion is followed on X-rays and usually achieved between 3 to 6 months but bone remodeling can last up to 1 year. Some of the complications can be also expected, mostly delayed union or loss of fixation, rarely infection (Kalb and Prommersberger, 2009).

Fusion of other joints is used only in severe or failed cases as salvage procedures (MP, IP joints). Because of their irreversible limitation of motion they should be avoided and previously described transfers used instead.

*Other procedures*

Pain and hypersensitivity of injured area can be often found caused by post-traumatic neuroma formation (Domeshek *et al.*, 2017). In digital nerves, frequently seen after amputation, simple shortening and burring nerve end can be satisfactory. In recurrent cases or other techniques are proposed including end-to-side suture of injured nerve to the healthy one, introducing the nerve end into the bone or use of allografts (Sosin *et al.*, 2016).

Sensitive and prominent neuroma is frequently seen after median nerve injury treated with end-to-end repair. Usually, nerve is not adequately covered by injured tissue and neuroma-in-continuity is formed. Many techniques are suggested to solve this problem by means of coverage with

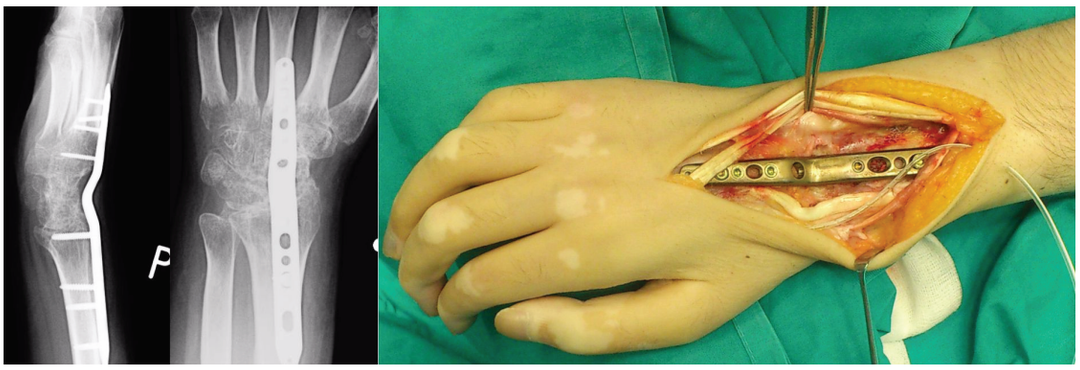

**Figure 5.** Total wrist fusion with use of dedicated plate.

local flaps including mostly adipofascial and muscle (Adani *et al.*, 2014).

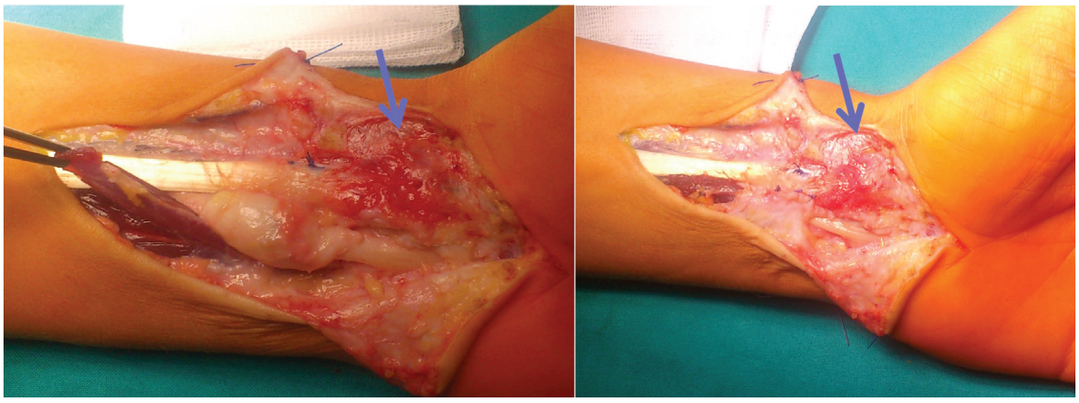

**Figure 6.** Painful neuroma-in-countinuity of median nerve covered with local muscle and adipofascial flap (arrows).

## Discussion

Due to many options presented, the selection of treatment methods is based on clinical situation, patients demands and surgeon experience. Use of methods with predicted results is better for the patients, who expect improvement in certain period of time. It is arguable which kind of tendon transfer is more applicable but variety of possibilities enables this kind of surgery in almost every case of nerve lesion.

The main advantage of these procedures is their timing and reliability (Seiler *et al.*, 2013). After initial treatment with nerve suture or reconstruction approximately one year is needed to assess motor and sensory regeneration and state that the situation will change no more. Then secondary and salvage procedures can be selected, despite the time from injury the same result can be expected. These procedures can be contraindicated in very old cases; in patients that adopted well to the impairment ant this kind of surgery can produce unimportant change with the risk of complications (Kalb and Prommersberger, 2009).

In my opinion and experience, most of patients don't know and are not informed about possibilities of hand function improvement after nerve injury. Most of them will risk next surgery or some minor loss to get more motion or sensibility in critical parts of the hand. Typically, they need opponensplasty in median nerve lesion – sensibility is usually efficient after nerve repair. In radial palsy triple tendon transfer is used, sensibility loss is acceptable, in manual heavy workers wrist fusion with transfer is better solution. Ulnar nerve palsy usually needs correction of claw hand deformity, it this exists and is not compensated.

## Conclusions

Even in irreparable nerve injuries or failed nerve repair there are many possibilities to improve sensory and motor function of the hand. Every case needs specific evaluation and selection of adequate methods.

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*Author reported no source of funding.*
*Author declared no conflict of interest.*

*Autor nie zgłosił źródła finansowania.*
*Autor nie deklarował konfliktu interesów.*

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