Early and late reconstruction in brachial plexus palsy: 
a preliminary report

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Key words: brachial plexus, neurolysis, nerve transfer, tendon transfer.

Summary. Objective. To evaluate the most effective surgical procedures in the early and late 
reconstruction of brachial plexus after its traumatic injury.

Material and methods. A total of 14 consecutive patients with brachial plexus injuries were 
examined and operated on at the Department of Plastic and Reconstructive Surgery and Burns 
at Kaunas University of Medicine Hospital. Less than half of them (43%) came for surgery in the 
éarly stage of disease – within 12 months after injury – and 57% in the late stage – 1–15 years 
after trauma. Altogether, 23 operations – neurolysis, nerve transfer, tendon transfer, and arthro-
desis – were performed. Patients were followed up for an average of 12.5 months (range 4 to 19 
months) after surgery. Postoperative motor assessment of hand function was based on the motor 
classification $M_0$–$M_5$ of Mallet and British Medical Research Council Muscle grading system. 
Results were considered positive if the range of active movements increased no less than 5– 
10° dependently from the level of injury and motor strength – no less than 1–2 grades ($M_0$→$M_1$ 
or $M_2$→$M_3$).

Results. Of the eight investigated, six patients from early group showed positive results. The 
most effective surgical procedures were neurolysis and nerve transfer. A significant improvement 
in the patients of late group was observed after tendon transfer procedure. Nevertheless, the 
recovery process of motor function was too slow or even minimal in 31% of patients to satisfy the 
patient and the surgeon.

Conclusions. Neurolysis or nerve transfer in the early stage or tendon transfer in the late 
stage after brachial plexus injury may result in a significant improvement of motor function of 
the hand. Sharing the information concerning brachial plexus reconstruction with neonatologists, 
neuropathologists, traumatologists, and hand therapists would be helpful in operating such 
patients timely and treating them adequately after surgery.

Introduction

The treatment of brachial plexus (BP) palsy is still 
one of the most difficult problems among the traumatic 
injuries of peripheral nerves. The first conclusion of 
SICOT Congress in Paris in 1960 was that traction 
and concomitant injuries of BP could not be surgical 
treated. More optimistic opinion was declared follow-
ing 42 years during the International Symposium 
on Brachial Plexus Surgery (Club A. Narakas) in Paris 
in 2002. But it was clear that there were still more 
questions than answers. Complicated anatomy and 
function of BP, multilevel injuries, symptomatic multi-
plicity after trauma, severity of dysfunction, unpred-
table course of disease, very slow recovery (2–3 years), 
and still often poor final neurological outcome dimin-
ished the enthusiasm of surgeons.

Nevertheless, H. Millesi and A. Narakas introd-
ced the microsurgical techniques and presented the 
first series of successful microsurgical reconstruction 
of damaged BP (1, 2). Subsequently outstanding plastic 
surgeons like A. C. Berger, D. Ch-Ch. Chuang, A. 
Gilbert, J. Terzis, Y. D. Gu, D. H. Kim, working in 
close contacts with anatomists, neurologists, electrophys-
ologists, orthopedists, occupational and physical 
therapists gained the experience by operating 1,000 
and more of such patients (3–8). Unfortunately, there 
are lots of patients in our country who come for recon-
structive surgery only in the late stages of disease.

The aim of this report is to estimate our possibilities 
in multidisciplinary clinic, preliminary achievements

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and disappointments in the first series of patients with BP operated at different posttraumatic periods.

Materials and methods

Patients. A total of 14 consecutive patients with BP injuries admitted to the Department of Plastic and Reconstructive Surgery and Burns at Kaunas University of Medicine Hospital between 2002 and 2005 were included in the study. The patients were divided into two groups: early group consisted of eight patients who were operated on during the first 12 months after trauma (five patients within the period of 0–6 months and three – within 6–12 months) and late group consisted of six patients who were operated on 12 and more months after trauma, according to Samii et al. (9).

Most of the injuries were due to motorcycle or other motor vehicles crashes (Table). There were 11 males and 3 females with a mean age of 32.1 years (range from 5 months to 57 years) (Table).

BP injury was related to a difficult childbirth in three patients: one from the early group and two from the late group with deformity. Nine patients (64.3%) sustained 21 associated injuries (Table). Of the nine with associated injuries, five patients (62.5%) had comminuted syndrome of various severity. Seven patients of 14 before admission to our department had been investigated and operated elsewhere (in other departments or other hospitals, or other countries). The surgery was performed at different periods following traumatic injury.

Clinical assessment. On admission to the department patients were examined by taking comprehensive history and physical examination. Motor assessment was based on the motor classification M1–M6 of Mallet and Medical Research Council Muscle Grading System (10, 11). Grip strength was measured by manometer “Hand on” and range of movements – by goniometer (12, 13). Additional information was gathered by using electromyography and occasionally (eight patients) magnetic resonance imaging or computed tomography. The preliminary results of motor activity of 13 BP patients operated on were evaluated on average after 12.5 months (range 4 to 19 months) during follow-up examination (Table). One patient did not arrive for examination (patient 11). The results were considered positive if the range of movements measured by goniometer increased in 5–10° and motor strength – by 1–2 grades (M1→M2 or M2→M4). If grip strength measured by manometer increased by 5 kg or more, it was also assessed as positive result. The results were considered negative if no recovery was observed in patients. Complete recovery of function was considered an excellent result.

Indications for surgery. An indication for the surgery in 12 patients was a significant disability after conservative treatment and only partial effect in 2 patients following the operations of our predecessors. The main aim of the surgery in the early group (3–12 months after trauma) of our patients with C5, C6, C7 palsy was to restore active shoulder movements and motor function of biceps and brachialis muscles (active elbow flexion) and in the late group with injury of the same level – the reconstruction of shoulder stability and improvement of movements. In case if C7, C8, T1 were affected, the main task in the late group was to restore the active movements in wrist and fingers. The most common procedure indicated in the early group for such patients was nerve transfer by using the donor nerves. Tendon transfer was an operation of choice in the late group (in case of incomplete brachial palsy or presence of active neighbor muscles innervated by extrabrachial plexus nerves). In case of long-standing paralysis with contracture of fingers, arthrodesis was preferential.

Surgery. A total of 23 surgical procedures were carried out in 14 patients (Table). Careful dissection was performed to isolate roots, trunks, and cords from posttraumatic scars and simultaneously to preserve donor nerves if nerve transfer was planned (Fig. 1) (14). Neurolysis of BP as a single procedure was carried out in one patient, and in three patients it was combined with other operations on BP. Nerve transfer (six procedures) was performed in four patients and included the connection of accessory nerve with suprascapular nerve and or some motor fibers of ulnar nerve with musculocutaneous nerve. Tendon transfer procedure was performed in nine patients; tendon was transferred predominantly from m. trapezius to humerus in order to regain arm abduction and from m. pronator teres to extensor carpi radialis brevis – to restore the active extension of the wrist.

Results

Anatomical level of injuries. According to case history and clinical investigation in our department the most common type of injury was complete injury of PB. Rupture, avulsion of roots, or compression of C5, C6, C7, C8, and T1 were diagnosed in six patients. In four patients lesion affected C5, C6, and C7. In three patients it was not possible to evaluate the initial level of injury because of long-standing cases and partial effect of conservative treatment and surgical repair of BP by our predecessors (Table). In such cases the term “uncertain,” similar to A. Narakas term “probable but uncertain,” was used (2). In patients from
<table>
<thead>
<tr>
<th>Patient number</th>
<th>Sex/age</th>
<th>Cause of trauma</th>
<th>Level of BP injury</th>
<th>Associated injuries</th>
<th>Time of surgery after trauma</th>
<th>Surgery</th>
<th>Follow-up examination at months</th>
<th>Result</th>
<th>Remarks</th>
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<td>1</td>
<td>M/25</td>
<td>motorcycle accident</td>
<td>C5, C6, C7</td>
<td>comminutional syndrome</td>
<td>4 months</td>
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<td>2</td>
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<td>obstetrical BP palsy</td>
<td>C5, C6, C7, C8, T1</td>
<td></td>
<td>5 months</td>
<td>transfer U → MC</td>
<td>3</td>
<td>negative (still)</td>
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</tr>
<tr>
<td>3</td>
<td>M/22</td>
<td>motor vehicle accident</td>
<td>C5, C6, C7</td>
<td></td>
<td>5 months</td>
<td>transfer Acc → SS U → MC</td>
<td>22</td>
<td>positive</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>M/44</td>
<td>motor vehicle accident</td>
<td>C5, C6, C7, C8, T1</td>
<td>fracture of scapular, brachial and antebrachial bones</td>
<td>5 months</td>
<td>neurolysis of BP transfer ECRL → FDP BR → FPL</td>
<td>19</td>
<td>positive positive</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>M/44</td>
<td>horse vehicle trauma</td>
<td>C5, C6, C7, C8, T1</td>
<td>intracranial hematoma, rupture of lung, rupture of kidney. Comminutional syndrome</td>
<td>6 months</td>
<td>transfer Acc → SS</td>
<td>7</td>
<td>negative prolonged (2 months) comminutional syndrome after trauma</td>
<td></td>
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<tr>
<td>6</td>
<td>F/52</td>
<td>falling from stairs (fracture of clavicle)</td>
<td>C5, C6, C7, C8, T1</td>
<td>clavicular fracture</td>
<td>7 months</td>
<td>neurolysis of BP</td>
<td>13</td>
<td>excellent (complete recovery of function)</td>
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<td>19</td>
<td>positive</td>
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<td>transfer LD → B</td>
<td>16</td>
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<tr>
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<td>uncertain scapular fracture, comminutional syndrome</td>
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<td>transfer trapezius</td>
<td>17</td>
<td>positive</td>
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<tr>
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<td>motor vehicle accident</td>
<td>C5, C6, C7, C8, T1</td>
<td>hematoma intracranial, comminutional syndrome, fracture of scapular, clavicular and costal bones</td>
<td>3 years</td>
<td>arthrodese PIP I</td>
<td>5</td>
<td>positive neurolysis of BP, multiply nerves and tendons transfer procedures in Hannover clinic resulted in recovery of motor function of the limb in 70–80%</td>
<td></td>
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</table>

*Table. Patients, surgical procedures, and motor function recovery after surgery for brachial plexus (BP) palsy*
### Table continuation

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<td>transfer trapezius</td>
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<td>M/15</td>
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<td>C5, C6, C7, C8, T1</td>
<td>15 years</td>
<td>transfer PT → ECRB transfer trapezius</td>
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</tr>
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<td>M/17</td>
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<td>uncertain</td>
<td>17 years</td>
<td>arthrodesis carpi</td>
<td>6</td>
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</tbody>
</table>


![Image](2002_12_14.png)

**Fig. 1.** Brachial plexus after neurolysis (anterior view, right side) (14)
early group positive results were obtained in six out of eight investigated (Table). The most effective surgical procedure was neurolysis. Such decompression of BP from scarring after three consequent operations on clavicle for one patient produced excellent results (patient 6). Nerve transfer procedure in two patients (patients 1 and 3) resulted in a significant improvement (“hand to mouth”) after 13 and 15 months (Fig. 2 A, B). A baby (5 months old at the time of surgery) was examined only three months after surgery and there was still no recovery of elbow flexion (patient 2). A 44-year-old patient (patient 5) with complete BP palsy sustained severe associated injuries of head, thorax, and kidney. These injuries resulted in prolonged comatose syndrome, respiratory dysfunction, rupture of kidney, and decubitus ulcer. He underwent craniotomy, pulmorraphy, nephrectomy, and plastic surgery for decubitus ulcer. Five months after the accident neurolysis of BP and the connection of accessory nerve to suprascapular was performed. The patient was examined four months after surgery. No recovery of active movements in shoulder was observed.

In the late group a positive result was achieved in five patients out of five investigated. One patient did not arrive for follow-up examination. Three patients who had undergone trapezius muscle transfer showed a substantial improvement of up to 30° in shoulder abduction (patients 9, 12, 13). It was sufficient to reach actively the mouth with the hand during eating (in case if elbow flexion was not impaired). A 15-year-old patient with obstetrical brachial palsy (patient 13) was operated on in our department twice. The first surgical procedure – transfer of pronator teres tendon to extensor carpi radialis brevis and longus – restored active wrist extension to 180° (Fig. 3 A, B). The next procedure that was performed after six months – transfer of trapezius muscle – also provided positive results. Another 17-year-old patient with obstetrical brachial palsy (patient 14) who underwent carpal arthrodesis showed an improvement in the strength of grasp function following six months after the surgery.

**Discussion**

Predominant etiological factor in BP palsy like in atlantoaxial fractures was traumatic injury – fall or traffic accident (15). It is known that the best clinical outcome may be expected when the surgery is performed within 3–6 months following injury of BP structures (16–19). Other surgeons extend this early period and perform direct operations on nerves like nerve transfer within 12 months after trauma (9, 20–22).

Lack of any uniform system of evaluation and only early results of the surgery allowed us to assess the outcome of the treatment by using only the terms

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**Fig. 2. Patient with C5, C6, C7 injury**

A – before surgery; B – after surgery (nerve transfer).
“positive” or “negative,” similarly as in the study by A. Narakas (2). Altogether, 11 patients out of 13 from early and late groups, who have undergone follow-up examination after surgery, demonstrated an initial positive result. Neurolysis or decompression of BP provided the best results in the early group. A patient with complete paralysis of superior limb lasting for 7 months, who had a surgical procedure before, demonstrated a significant improvement after neurolysis. Restoration of the function by assistance of intensive rehabilitation took only one month. The rather small group of patients (patients 2, 8, 12, and 13) and short follow-up period after nerve transfer procedure did not provide us the ground to make conclusions about the final clinical outcome for these patients.

In the patients of late group the most effective surgical procedure was transfer of tendons (4, 6, 22–24). In case of incomplete paralysis of the limb the surgeon has a great choice to make decision dealing the strategy of surgical treatment. Transfer of pronator teres tendon to tendon of extensor carpi radialis brevis or longus provided the positive results in three patients but just in one of late group. Further carpal arthrodesis was very helpful for one psychologically unstable patient with obstetrical BP injury.

It was estimated that the final clinical outcome after surgical treatment of BP palsy might be evaluated only 2–3 years after operation (6, 20, 25, 26). Other authors presented on average more than a 4-year follow-up data (range from 9 months to 14.6 years) (9). So the results of our follow-up examinations after mean period of 12.5 months are still only preliminary. Naturally, the further follow-up of two years or more is needed to evaluate the degree of recovery.

Rehabilitation after surgery is a very important procedure during these 2–3 years. Unfortunately, only five patients had a possibility to attend hand therapist and get adequate procedures regularly. The procedures were not adequate for five patients and three patients did not receive them at all. Slow recovery, particularly in arm abduction following trapezius transfer, in our patients may be related to such inadequate rehabilitation. Too short tendon used for transfer in this surgical approach may be an additional reason for failure. In our opinion, it would be useful to make this tendon longer by using an interpositional graft. It would be helpful for the patient to use fewer attempts and to gain more abduction in shoulder.

**Conclusions**

1. Neurolysis or nerve transfer in the early stage and tendon transfer in the late stage of brachial plexus injury may result in significant improvement.

2. More close cooperation with neuropathologists, traumatologists, neonatologists, and hand therapists are necessary in order to operate patients with brachial plexus palsy timely and to treat them adequately after surgery.
Skubiai ir vėliau atlikta pažeisto peties rezginoi rekonstrukcija: preliminariniai duomenys

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Raktažodžiai: peties rezgins, neurolizė, nervų transpozicija, sąsugyslių transpozicija.

Santrauka. Tikslas. Įvertinti efektyviausias chirurgines procedūras skubiai rekonstruojant traumos pažeistą peties rezgınį ir vėliau.

Tyrimo medžiaga ir metodai. Vienas paskui kitą atvykę 14 ligonių, patyrusių peties rezgino traumą, ištirti ir operuoti Kauno universiteto klinikų Plastinės ir rekonstrukcinės chirurgijos bei nudeginių skyrė. 43 proc. jų kreipėsi dėl chirurginės pagalbos 12 mėnesių laikotarpio po pažeidimu, t. y. ankstvyriosios stadijos metu. 57 proc. ligonių atvyko 1–15 metų po traumas, t. y. vėlyvosios stadijos metu. Ligoniams atliktos 23 operacijos (neurolizė, nervų perkėlimas, sąsugyslių perkėlimas, artrodėzė). Kontroliniais tyrimais šių ligonių atlikti praejus vidutiniškai 12,5 mėn. (savyra nuo 4 iki 19) po operacijos. Popieracinei motorinėi rankos funkcija vertinta remiantis Mallet ir British Medical Research Council Muscle Grading (M₀-M₅) klasiifikacijos sistemomis. Rankos funkcija vertinta teigiamai, jei raumens jėga padidėjo ne mažiau kaip 1–2 laipsniais (M₀→M₁ ar M₂→M₃), o aktyviių jėgų amplitudė, priklausomai nuo pažeidimo lygio, padidėjo ne mažiau kaip 5–10 laipsnių.


Ivados. Neurolizė ar nervų perkėlimas, esant ankstyvajai peties rezgino pažeidimo stadijai, ir sąsugyslių perkėlimas, esant vėlyvajai peties rezgino pažeidimo stadijai, gali žymiai pagerinti rankos motorinę funkciją. Todėl tikimės, kad issamesnė informacija apie peties rezgino rekonstrukciją neonatologams, neuropatologams, traumatologams ir kineziterapeutams būtų tikslinga, kad tokią ligonii būtų operuojami laiku, t. y. esant ankstyvaijai peties rezgino pažeidimo stadijai, o po operacijos jiems būtų skirtas tinkamas gydymas.
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