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# Neurolysis of the conducting neuroma-in-continuity in perinatal brachial plexus palsy – evaluation of the results of surgical treatment

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## Abstract

*The aim of the study was to evaluate the surgical treatment results of cases of perinatal brachial plexus palsy with presence of neuroma-in-continuity. Clinical material included 21 children, aged from 3.5 to 36 months, treated surgically between 1996 and 2005. The control examination included 19 children. The shortest postoperative observation period was 4 years. After surgical treatment during clinical evaluation of function dependent on localization of neuroma-in-continuity we observed the following: in upper injury in 1 child good shoulder and elbow function; in upper-middle injuries with neuroma-in-continuity in upper trunk good elbow function in 66.6%, good shoulder function in 83.3% of cases; in upper-middle injuries with neuroma-in-continuity in upper and middle trunk in 1 examined child good function of elbow, shoulder, and wrist; in total injuries with neuroma-in-continuity in upper trunk good elbow function in 75%, and good shoulder function in 50% of cases; in total injuries with neuroma-in-continuity in upper and middle trunk good elbow function in 66.6%, good shoulder function in 33.3%, good wrist function in 66.6% of cases; in total injuries with neuroma-in-continuity in lower trunk grade 2 of motor hand function and return of sensibility to a level of S3+.*

*Conclusions: The choice of microsurgical technique during surgical treatment of perinatal brachial plexus palsies with neuroma-in-continuity should be based on the whole clinical and intraoperative view. The best results after neurolysis should be expected when neuroma-in-continuity is localized in the upper trunk, the injury corresponds to third degree on Sunderland's scale, and during electric stimulation a normal motor response can be obtained.*

***Key words:*** *neuroma-in-continuity, neurolysis, traction, obstetrical brachial plexus injuries.*

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## Introduction

Traction of the neural elements of the brachial plexus as a result of delivery action may cause injury of various degrees of severity [11,19]. Rupture of the endoneurium enables the displacement of the regenerating axons which reach between Schwann cells and fibroblasts instead of the endoneural tubes. The retained continuity of the perineurium resistant to penetration by the regenerating axons limited this process to particular fascicles. Intraoperatively, during the macroscopic evaluation, the presence of a swelling on the nerve is observed (third degree of injury on Sunderland's scale) [22]. Rupture of the perineurium of many fascicles leads to a situation in which regenerating axons relocate to the interfascicular tissue, where they grow and branch in a disorganized way. This process, being limited with retained continuity of the epineurium, occurs with proliferation of fibroblasts and development of a mass exceeding the dimensions of the trunk. Intraoperatively, during the microscopic examination the normal fascicular system is not observed (fourth degree of injury on Sunderland's scale) [22]. The described changes including injuries of third and fourth degree on Sunderland's scale are defined as a neuroma-in-continuity. Most frequently, they are located in ventral branch of the spinal nerves C5, C6 and upper trunk as well as in the ventral branch of the spinal nerve C7 and middle trunk [4,6,10,22]. Exceptionally they affect the lower trunk [3]. The development of neuroma-in-continuity is also possible after neurotmesis (fifth degree of injury on Sunderland's scale), due to a usually observed small gap between neural elements and significant regeneration potential in children [6]. In some particular situations, the development of common neuroma between upper and middle trunks may occur [6,16,22], and even in the lower one [7]. The possibility of conduction through the neuroma-in-continuity will to a great extent depend on whether, due to the traction, an isolated injury of axons and endoneurium has developed (third degree of injury on Sunderland's scale) or discontinuity of the perineurium also took place (fourth degree of injury on Sunderland's scale) [22]. The proportion of injured fascicles in the section of the trunk is also important. The choice of surgical technique in this type of injury raises many controversies. Some authors decided to perform neurolysis or reconstruction based on intraoperative electrodiagnostic studies [13,17,20]. Laurent performed the measurement of the amplitude of functional muscle potentials in relevant muscles with stimulation of the nerve in its proximal and distal area in reference to the neuroma. In case of a drop of amplitude lower than 50% with stimulation in the proximal part, internal neurolysis of the neuroma was performed [13]. Neurolysis of neuromas-in-continuity has also been performed by other authors in cases in which with intraoperative electrical stimulation above the neuroma, a motor response was obtained in relevant muscles [7,14,20]. Adherents of more radical methods of neuroma-in-continuity treatment claim that the optimal solution is resection and reconstruction with grafts [9,18,21]. Attempts to compare the results of treatment with both methods were undertaken by Capek *et al.* [4]. The aim of the study was to evaluate the results of surgical treatment in cases of perinatal brachial plexus palsy with intraoperatively observed presence of neuroma-in-continuity.

## Material and methods

Clinical material included 21 children of both genders, treated surgically in the period of 1996-2006 due to perinatal brachial plexus injury, in which, during intraoperative evaluation, the presence of neuroma-in-continuity was observed. The age of the treated children varied from 3.5 to 36 months (the average age was 12.9 months). One child with upper injury (C5-C6), 8 children with upper-middle injury (C5-C7) and 12 children with total injury of the brachial plexus (C5-Th1) were operated on. Clinical type of injury of the brachial plexus, location of neuroma-in-continuity and the type of surgical procedure are presented in Table I. Control examinations and evaluation of the results of treatment were performed in 19 children. The shortest postoperative observation period was 4 years. The following scales of evaluation were used:

1. Gilbert's scale for evaluation of shoulder function [12]:
   - Stage 0 = complete shoulder flail
   - Stage I = abduction or flexion to 45°, no active external rotation
   - Stage II = abduction < 90°, external rotation to neutral
   - Stage III = abduction = 90°, weak external rotation
   - Stage IV = abduction < 120°, incomplete external rotation

Stage V = abduction > 120°, active external rotation

Evaluation: stage V – very good result, stage IV – good result, stage III – average result, stage II – poor result

2. Gilbert's and Raimondi's scale for evaluation of elbow function [12]:
   A. Elbow flexion:
      Nil or some contraction = 0 points
      Incomplete flexion = 2 points
      Complete flexion = 3 points
   B. Elbow extension:
      No extension = 0 points
      Weak extension = 1 point
      Good extension = 2 points
   C. Extension deficit:
      0-30° = 0 points
      30-50° = –1 point
      More than 50° = –2 points

Evaluation: grade I – poor recovery (0-1 points), grade II – average recovery (2-3 points), grade III – good recovery (4-5 points)

3. Al-Qattan's scale for evaluation of forearm rotation moves [1]:
   1 = pronated forearm causing a functional or cosmetic disability
   2 = supinated forearm causing a functional or cosmetic disability
   3 = functional forearm position (mid pronation-supination or slight pronation) with no or minimal active motion
   4 = same as 3 but with good active pronation and supination
   5 = normal power and range of motion

Evaluation: operative correction is necessary in grade 1 and 2

4. Al-Qattan's scale for evaluation of wrist function [1]
   0 = no contraction or flicker of contraction
   1 = active movement with gravity eliminated
   2 = active movement against gravity only
   3 = active movement against resistance with motion reaching ≤ 1/2 normal range
   4 = active movement against resistance with motion reaching > 1/2 normal range
   5 = normal power and range of motion

Evaluation: functional useful is grade 3 and 4 both to flexion and extension function (F/E)

5. Al-Qattan's scale for evaluation of hand motor function [1]:
   0 = useless hand – complete paralysis or slight finger motion of no use, useless thumb
   1 = poor function – only very weak grip possible
   2 = fair function – there is some active flexion and/or extension of the fingers and some thumb mobility but the hand posture is intrinsic minus
   3 = good function – same as 2 but there is no intrinsic minus posture (intrinsic balance)
   4 = excellent function – near normal active finger flexion/extension and thumb mobility, with some active intrinsic function
   5 = normal function

Evaluation functional useful is grade 3 and 4

6. BMRC scale modified by Omer and Dellon for evaluation of hand sensory function [8,15] – only in total palsies.

During evaluation of treatment results, the effect of tenomyoplastic procedure (additionally performed in some cases), indicated in Table II as (T), was also taken into consideration. The following complementary operations were performed: subscapular muscle release in 8 patients (improvement of shoulder function) and transposition of pronator teres muscle in 3 patients (correction of forearm position).

## Results

The results of surgical treatment are presented in Table II. Analysing the function depending on the localization of neuroma-in-continuity, the following results were obtained. In upper injury, in 1 child good shoulder and elbow function. In the group of upper-middle injuries with neuroma-in-continuity in the upper trunk (6 children), good elbow function was achieved in 4 (66.6%), and good function of the shoulder in 5 treated children (83.3%). However, in 3 of them an additional tenomyoplastic operation was performed (improvement from stage III to IV). In upper-middle injuries with neuroma-in-continuity in the upper and middle trunk (2 children) in 1 examined child good functions of the elbow, shoulder (with improvement after tenomyoplasty from stage III to IV) and wrist were obtained. In total injuries with neuroma-in-continuity localized in the upper trunk (5 children), good function of the elbow was observed in 3 of 4 examined children (75%), and good shoulder

**Table I.** Location of injuries with presence of neuroma-in-continuity

| Case *n* | Clinical type of injury | Location of neuroma-in-continuity | Type of surgical procedure |
|---|---|---|---|
| 1. | upper | upper trunk | external neurolysis |
| 2. | upper-middle | upper trunk | external neurolysis |
| 3. | upper-middle | upper trunk | external neurolysis |
| 4. | upper-middle | upper trunk | external neurolysis |
| 5. | upper-middle | upper trunk | external neurolysis |
| 6. | upper-middle | upper trunk | external neurolysis |
| 7. | upper-middle | upper trunk | external and internal neurolysis |
| 8. | upper-middle | upper and middle trunk | external neurolysis |
| 9. | upper-middle | upper and middle trunk | external neurolysis |
| 10. | total | upper trunk | external neurolysis |
| 11. | total | upper trunk | external neurolysis |
| 12. | total | upper trunk | external neurolysis |
| 13. | total | upper trunk | external neurolysis |
| 14. | total | upper trunk | external neurolysis of upper and lower trunk + extra anatomical direct reconstruction of spinal nerve C7 with cervical plexus |
| 15. | total | upper and middle trunk | external neurolysis |
| 16. | total | upper and middle trunk | external neurolysis |
| 17. | total | upper and middle trunk | external and internal neurolysis |
| 18. | total | middle trunk | external neurolysis |
| 19. | total | spinal nerve C7 roots avulsion | external neurolysis |
| 20. | total | lower trunk | external neurolysis |
| 21. | total | lower trunk | external neurolysis of middle and lower trunk + reconstruction of upper trunk with grafts (2 × 3 cm) |

function in 2 of 4 of those examined (50%), including 1 child with improvement after tenomyoplastic operation (from stage III to IV). In total injuries with neuroma-in-continuity in the upper and middle trunk (3 children), good function of the elbow was observed in 2 children (66.6%), good function of the shoulder in 1 child (33.3%) with improvement after tenomyoplastic operation (from stage III to IV), and good function of the wrist in 2 children (66.6%). In total injuries with neuroma-in-continuity localized in the middle trunk, in 1 child average function of the shoulder was observed as well as lack of useful function of the elbow and wrist. In case of spinal nerve C7 roots avulsion, good function of the elbow was observed and poor function of the shoulder and wrist. In total injuries with neuroma-in-continuity in the lower trunk, grade 2 of motor hand function and return of sensibility to level S3+ was observed.

## Discussion

The proper management in cases with presence of neuroma-in-continuity is still not a completely solved

**Table II.** Results of surgical treatment in injuries with presence of neuroma-in-continuity

| Case | Evaluated function | | | | |
|---|---|---|---|---|---|
| *n* | Hand | Wrist F/E | Forearm | Elbow | Shoulder |
| 1. | 5 | 5/5 | 3 | 5 | IV |
| 2. | 5 | 5/4 | 3 | 4 | IV |
| 3. | 5 | 5/3 | 3 | 5 | IV |
| 4. | 3 | 5/1 | 1 | 3 | III |
| 5. | 5 | 5/4 | 4 | 5 | III#/IV(T)## |
| 6. | 4 | 5/1 | 3(T) | 3 | III#/IV(T)## |
| 7. | 5 | 5/4 | 4(T) | 4 | III#/IV(T)## |
| 8. | n/a | n/a | n/a | n/a | n/a |
| 9. | 5 | 5/4 | 4 | 5 | III#/IV(T)## |
| 10. | n/a | n/a | n/a | n/a | n/a |
| 11. | 3-S4* | 4/1 | 2 | 4 | IV |
| 12. | 2-S2* | 3/3 | 3 | 2 | II |
| 13. | 4-S4* | 0/0 | 3(T) | 4 | III |
| 14. | 2-S3+**/S2*** | 1/1 | 2 | 4 | III#/IV(T)## |
| 15. | 3-S4* | 4/1 | 1 | 5 | II#/III(T)## |
| 16. | 1-S3+**/S0*** | 3/3 | 3 | 5 | III#/IV(T)## |
| 17. | 4-S4* | 4/3 | 3 | 2 | I |
| 18. | 3-S4* | 4/1 | 1 | 0 | III |
| 19. | 3-S3+* | 3/1 | 3 | 5 | II |
| 20. | 2-S3+* | 3/4 | 3 | 5 | III#/IV(T)## |
| 21. | 2-S3+* | 3/3 | 3 | 4 | IV |

** – level of sensibility in all examined areas*
*** – level of sensibility in thumb and index finger*
**** – level of sensibility in fifth finger*
*# – shoulder function before tenomyoplasty*
*## – shoulder function after tenomyoplasty*

problem [2]. Extremely interesting is the analysis conducted by Belzeberg *et al.*, who presented, in order to perform the evaluation, the case of a 5-month-old child with neuroma-in-continuity in the area of the upper trunk and only partial return of function of the deltoid, supraspinatus and infraspinatus muscles as well as the biceps brachii muscle. Out of 49 specialists participating in evaluation of the case, 14 (29%) were for continuity of conservative treatment, and 35 (71%) for surgical treatment. Among the latter, 17 declared performing the reconstruction with the use of grafts, 4 partial resection of neuroma-in-continuity, and 14 neurolysis of neuroma-in-continuity [2]. Gilbert indicates the necessity of resection of each neuroma-in-continuity during the operation performed in the 3rd month of life. The justification of that approach should be lack of worsening of motor function of the limb, which is observed after surgery conducted at a later date [9]. The resection of neuroma-in-continuity is also suggested by Chen *et al.* [5]. Capek *et al.* compared the

results of treatment after applying two surgical techniques (resection + grafts or neurolysis). The average age of children in the groups was 9.0 ± 2.3 and 9.6 ± 2.0 months. In the group in which the reconstruction was performed, deterioration of upper limp function was observed, during the first 6 weeks after the operation. After 6 months the functional condition reached the preoperative level, and after 12 months clinical improvement regarding the initial condition was obtained. During the period of 12 months observation the grade of improvement of upper limb function in both groups did not differ significantly [4]. A slightly earlier analysis conducted by Clarke *et al.* showed the efficiency of neurolysis as a surgical method in treatment of neuroma-in-continuity localized in the upper part of the brachial plexus. Useful abduction in the shoulder, according to the AMS scale, was obtained in 78%, and useful elbow flexion was observed in 89% of patients operated on. In total injuries the results were significantly worse. Useful abduction was obtained in 14%, and useful elbow flexion in 43% of cases. However, it should be emphasized that the term "total injury" in Clarke's material did not mean a clinical view but the presence of extensive neuroma including the entire brachial plexus, and including cases of avulsion injuries [7]. Xu *et al.* while comparing the results of treatment after neurolysis (9 patients) and reconstruction (6 patients) implied higher efficiency of the second method. Attention should be drawn to the fact that only in 1 of 6 cases did they perform resection of the neuroma. In the other 5 cases, the neuroma-in-continuity remained untouched, and an additional connection between the accessory nerve and suprascapular nerve as well as between the phrenic nerve and anterior part of the upper trunk was performed. All neuromas-in-continuity according to those authors referred to the fourth degree of injury on Sunderland's scale [22]. Extensive neuromas-in-continuity that developed as the result of rupture of the upper or middle trunk (fifth degree of injury on Sunderland's scale) were often observed in Chuang's material [6]. In own material the neuromas-in-continuity were localized mainly in the upper part of the brachial plexus (12 cases) (Fig. 1). In 5 children partial rupture of the upper trunk was accompanied with neuroma-in-continuity of the middle trunk. In each of these cases the development of common extensive neuroma was not observed. Rarely neuroma-in-continuity was localized in the lower trunk (2 children) and in an isolated way in the middle trunk (1 child). Moreover, in 1 child avulsion of roots of spinal nerve C7 and its significant accretion to the upper trunk was observed (Fig. 2). Observed neuromas-in-continuity (excluding avulsion of C7) referred to third degree of injury on Sunderland's scale, and during their stimulation a motor response in muscles was achieved, with the exception of two neuromas-in-continuity localized in the lower trunk. According to the evaluation of the authors, the choice of proper surgical technique in elaborated cases should be based on analysis of numerous factors. They include macroscopic evaluation of the neuroma-in-continuity, location and size of the neuroma-in-continuity, microscopic evaluation of fascicular structure, response to electric stimulation, the period of undertaking the surgical treatment, preoperative clinical presentation and upper limb function before the operation. It allows one to distinguish degrees of the neural tissue injury. Third degree injuries are prognostically better than injuries of fourth degree, in which

**Fig. 1.** Intraoperative view: neuroma-in-continuity in upper trunk of brachial plexus.

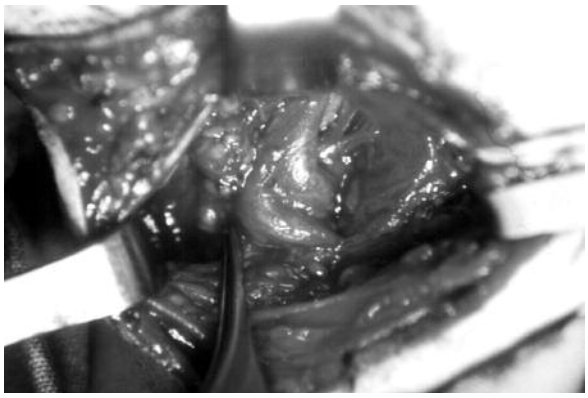

**Fig. 2.** Intraoperative view: status after spinal nerve C7 roots avulsion and accretion to upper trunk.

the capacity of conduction due to the fascicular structure lesion is incomparably worse. Development of neuroma-in-continuity including more than one trunk requires injury of the epineurium, i.e. total rupture of continuity of neural elements. Chaotic reinnervation in the upper and middle trunk joined with each other may lead to innervation of antagonistic muscles from one of the sources, e.g. the biceps brachii muscle and triceps brachii muscle [6]. Also the age of the child at the operation time has an influence on the decision. The delay in arrival at the specialist centre caused that in some children, improvement of upper limb function progressive with time, but not satisfactory for efficient use, was observed. Resection of neuroma in these cases may cause deterioration of function, which always receives a negative reaction from the child's parents. Obtained results of surgical treatment of neuroma-in-continuity after neurolysis in our own material do not disqualify this surgical method (Table II). They are similar to the results obtained by Clarke *et al.* after performing neurolysis of neuroma-in-continuity localized in the area of the upper and middle trunk. The much worse results obtained by this author in the group of total injuries resulted from the character of those injuries presented earlier [7]. In total injuries in our own material, the neuromas-in-continuity were mainly localized in the upper and middle trunk and in these two groups the best results were obtained (Table II). However, a poor result was observed in two cases of injuries of the middle trunk as well as in two cases of neuromas localized in the lower trunk.

## Conclusions

The choice of microsurgical technique during surgical treatment of perinatal brachial plexus palsies with neuroma-in-continuity should be based on the whole clinical and intraoperative view. The best results after neurolysis should be expected when the developed neuroma-in-continuity is localized in the upper trunk, the injury corresponds to third degree on Sunderland's scale, and during electric stimulation a normal motor response can be obtained.

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