ACTA
ORTHOPAEDICA
et
TRAUMATOLOGICA
TURCICA

Author's translation

Acta Orthop Traumatol Turc 2004;38(3):170-177

Early results of nerve surgery in obstetrical brachial plexus palsy

Doğumsal brakiyal pleksus yaralanmalarında sinir cerrahisinin erken sonuçları

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Amaç: Doğumsal brakiyal pleksus paralizisi nedeniyle sinir cerrahisine başvurulan olgularda uyguladığımız cerrahi teknik ve erken dönem sonuçlar sunuldu.

Çalışma planı: Belirli bir algoritma izlenerek seçilen ve spontan sinir rejenerasyonu ve kas fonksiyonları yeterli görülmeyen doğumsal brakiyal pleksus paralizili 24 bebeğe (12 kız, 12 erkek; ort. yaş 7.9 ay; dağılım 4-14 ay) sinir onarımı uygulandı. Beş olguda sadece nöroliz uygulanırken, yedi olguda spinal aksesuvar sinirden supraskapular sinire ekstrapleksal nörotizasyon, 17 olguda da intrapleksal nörotizasyon yapıldı. Ameliyat edilen olguların 17'sinde (%70) total paralizi (C_5, C_6±C_7 rüptürü ve C_8, T_1 avulsiyonu), dördünde (%17) C_5, C_6 tutulumu, üçünde (%13) C_5, C_6, C_7 tutulumu vardı. Ortalama izlem süresi 15.8 ay (dağılım 8-31 ay) olan hastaların periyodik değerlendirmeleri Hospital for Sick Children (HSC) değerlendirme sistemine göre yapıldı.

Sonuçlar: En az 12 ay izlenen hastalarda ortalama HSC sonuçları omuz abdüksiyonu için 4, dirsek fleksiyonu için 4.5, el bileği ekstansiyonu için 2.3, parmak fleksiyonu için 3.3 bulundu. Nöroma eksizyonu ve sinir grefti uygulanan sinirlerde, sadece nöroliz yapılan sinirlere oranla daha iyi rejenerasyon geliştiği gözlendi. Ameliyat sonrasında hiçbir olguda solunum sorunu, metabolik asidoz veya hipotermi gibi sorunlarla karşılaşılmadı.

Çıkarımlar: Cerrahi müdahale gerektiren, kas aktivitesi yetersiz hastalarda tanının erken dönemde konması ve sinir cerrahisi uygulanması kasların atrofisini önleyerek, daha fonksiyonel bir üst ekstremite kazandırmaktadır.

Anahtar sözcükler: Brakiyal pleksus/yaralanma/cerrahi; elektromiyografi; bebek; sinir rejenerasyonu; sinir transferi; nöroma/cerrahi; paralizi, doğumsal/tanı/cerrahi; fizik muayene; prognoz; hareket açıklığı, artiküler.

Objectives: To present surgical techniques and early postoperative results of patients who underwent nerve surgery for obstetrical brachial plexus palsy.

Methods: Twenty-four infants (12 girls, 12 boys; mean age 7.9 months; range 4 to 14 months) with obstetrical brachial plexus palsy underwent nerve repair following a surgical algorithm that showed inadequate spontaneous nerve regeneration and muscle function. Neurolysis was performed in five cases, intraplexial neurotisation in 17 cases, and extraplexial transfer of the spinal accessory nerve to the suprascapular nerve in seven cases. Seventeen patients (70%) had total palsy (C_5, C_6 and/or C_7 rupture and C_8, T_1 avulsion), four patients (17%) had C_5, C_6 involvement, and three patients (13%) had C_{5-7} involvement. Pre- and postoperative evaluations were made according to the grading system of the Hospital for Sick Children (HSC). The mean follow-up period was 15.8 months (range 8 to 31 months).

Results: The mean HSC grades of the patients followed at least for 12 months were as follows: shoulder abduction 4, elbow flexion 4.5, wrist extension 2.3, and finger flexion 3.3. Compared to patients who underwent neurolysis alone, improved nerve regeneration was noted in patients who underwent neuroma excision and nerve grafting. No severe complications occurred postoperatively, including respiratory problems, metabolic acidosis, and hypothermia.

Conclusion: Early diagnosis and nerve surgery in patients having insufficient muscle activity and requiring surgical intervention may prevent atrophy of the muscles and provide a more functional upper extremity.

Key words: Brachial plexus/injuries/surgery; electromyography; infant; nerve regeneration; nerve transfer; neuroma/surgery; paralysis, obstetric/diagnosis/surgery; physical examination; prognosis; range of motion, articular.

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Received: 11.12.2003 **Accepted:** 11.05.2004

Poor results after surgery for obstetrical brachial plexus palsy (OBPP) in the beginning of this century caused conservative treatment methods to predominate, and this condition persisted for 50 years. Beginning from 1970's, with the development of microsurgical techniques and routine use of operative microscope, as well as diagnostic supports such as electrophysology, computer tomography, myelography have all enabled surgical treatment to arise as an alternative treatment. In our country, the first nerve surgery for obsterical brachial plexus palsy was performed by Yuceturk (1) in 1993.

Despite improvements in socioeconomical status, the rate of OBPP in the last 20 years has not declined. It is estimated that in our country, the frequency is 1-2 for every 1000 live births (2).

Physicians dealing with obstetrical palsy, for a long time believed that surgical treatment would not be useful. Therefore they advocated conservative treatment and thought in these cases, physical therapy would be successful and adequate.

Our experience in patients with OBPP sequela began with contracture releases, tendon transfers and corrective osteotomies. Later, beginning from 2001 the nerve repair experience and current treatment methods of international centers working on this field were shared with pediatrician, neurologists and rehabilitation specialists. Consequently, controls of these babies at regular intervals beginning from birth with nerve repair in selected cases began.

This study presents early follow up results of patients that have been operated under the influence of multidisciplinary algorithm.

Patients and Methods

Between 2001-2003, of the 92 babies evaluated together with the department of pediatrics, 24 (12 male, 12 female, mean age:7.9 mo, range 4-14 mo) underwent brachial plexus exploration and repair. 23 babies were born with normal spontaneous labor, and one baby with cephalic presentation was delivered with vacuum extraction. Mean birth weight of the babies were 4097 grams (range 2750-4750). The left upper extremity was involved more commonly (54%) than the right (46%).

Seventeen of the 24 cases (70%) had total paralysis (C_5, C_6 and/or C_7 rupture and C_8-T_1 avulsion), four (17%) had C_5, C_6 involvement and three (13%) had C_{5-7} involvement.

During surgery, only neurolysis was performed on five patients, extraplexal neurotization from spinal accessory nerve to suprascapular nerve was made in 7, and intraplexal neurotization was made in 17.

Mean follow up was 15.8 months (range 8-31 months). Periodic follow up was carried out accoding to HSC evaluation.

Preoperative Evaluation and Treatment Algorithm

Although many clinical and laboratory tests are suggested, it is not definite which of them is the best in determining the level and severity of the lesion.

We evaluate our patients in the preoperative period using "Hospital for Sick Children" (HSC) active motion scale performed with pediatric developmental neurologists. Electromoygraphy and magnetic resonance imaging are taken. Motor and sensory activities of all cases are recorded, and videos taken.

The following algorithm is used for the selection of patients who will undergo plexus exploration.

Conventional radiological evaluation, neurologic examination and physical therapy.

Neurologic exam is performed and given a start for physical therapy on the third week.

Table 1. Hospital for Sick Children movement scale

Movement	*Grade*
Gravity Eliminated	
No contraction	0
Contraction (+),no movement	1
Movement< _ ROM	2
Movement >1/2 ROM	3
Full ROM	4
Against Gravity	
Movement < _ ROM	5
Movement >_ ROM	6
Full ROM	7

ROM: Range of Motion

On the twelfth week, if there is neurological examination reveals improvement, physical therapy is continued. If there is no improvement and total plexus injury (hand involvement) is considered, and if the radiologic evaluation and electromyography support the diagnosis, then exploration of the patient is carried out. If there is no improvement in neurological examination and upper trunk lesion is considered, the patient continues follow up with physical therapy.

During the follow up period between 3-6 months, in patients with upper trunk lesion, if the biceps development is greater than 5 (HSC evaluation), the physical therapy continues, if less than 5, exploration is carried out.

Persistance of denervation potentials in electromyography, pseudomeningocele suggests (figure 1); trophic changes in the hand, Horner's sign (figure 2) and phreinc nerve paralysis are criteria for exploration.

Surgical Technique

The patient is placed in supine position. The head is turned to the noninvolved side. The chest is elevated with a roll pillow placed vertically between the two scapulae, and the neck is hyperextended. The neck, all of the involved upper extrmity, and both lower extremities are prepared. Long acting muscle relaxants should be not be used to avoid prevention of nerve stimulation during the operation.

An incision is made posterior to and parallel to the upper border of the clavicle. If this incision is not enough, it can be extended through the deltopectoral groove to expose the lesion completely. The omohyoid muscle, transverse cervical vessels, and the phreinc nerve are structures that can be helpful during exploration. The phrenic nerve takes origin from C_{3-5} roots, is located on the anterior scalene muscle. When this nerve is followed proximally, first C_5 and then C_6 is reached. Often we see a neuroma formation in the upper truncus formed by C_5 and C_6 roots. Occasionally, C_7 or its distal continuation,the middle trunk, joins this neuroma. If the patient has a total paralysis, C_8 and T1 roots should be exposed as well. At this point of the dissection, care should be taken not to injure the parietal pleura. The dissection continues until macroscopically normal structures are reached proximally and distally. To observe the muscle response related to each nerve that has been explored, an electric stimulation of 0.5, 1 and 2 mA electrical stimulation is applied and muscle contraction is observed.

The final diagnosis concerning which nerve is injured at which level is established by physical examination, electromyography, radiological examinations, and findings of the intraooperative nerve stimulation. Among these, the most important one in determining the reconstructive strategy are data of preoperative physical examination and clinical observation.(3)

Although the lower roots are avulsed from the spinal cord, injury of the upper roots generally occur after they leave the neural foramen. Horner's sign

Figure 1. In magnetic resonance imaging, there is a pseudomeningocele that suggests root avulsion, which forms an opaque image.

Figure 2. Horner's sign characterized by enopthalmos, myosis, ptosis indicate a root pathology and usually an avulsion

and hand involvement indicate a C_8-T_1 avulsion, despite the normal appearance of the roots and the lower trunk. Neuroma formation or ruptures are very rare in lower roots. On the other side, insufficiency of shoulder and elbow functions or co-contractions are often associated with "neuroma in continuity".The neuroma or the injured nerve segments are excised until a normal fascicular structure is seen. Following neuroma resection, the proximal stumps are evaluated and decision is made whether they are appropriate for distal targets. The observation of ganglion cells in histopathologic examinations made with frozen section, indicate a root avulsion, i.e. that this root is not in continuity with the first motor neuron. Therefore, this cannot be used as a donor root for neurotization. In these histologic sections, healthy axons are sought for nerve coaptation outside the zone of injury.

Neurolysis, neuroma excision and subsequent nerve grafting are techniques used for nerve repair.

In nerve grafting, if both sural nerves are not adequate, the superficial radial and supraclavicular sensory nerves of the involved upper extremity can also be used. To avoid traction trauma during graft harvest, longitudinal incisions between the lateral malleolus and poplitea are made.

In our cases, we use fibrin glue, which is known as a biological tissue adhesive and topical hemostatic agent. Fibrin glue is produced by the combination of fibrinogen and factor XIII with trombin and calcium. It has been shown that fibrin glue does not show a barrier effect in the coaptation lines and prevents the growth of regenerating axon buds (4,5). After the distance betweeen the motor sources and targets are carefully measured, the graft materials are attached to each other to ease application (figure 3a). Later, the grafts are attached to the roots and every graft is sutured with a single microsuture, increasing the reliability and durability of the coaptation (figure 3b).

Neurotization or nerve transfer are preferred if there is no suitable proximal stump. Spinal accessory nerve is an effective donor with less morbidity. Intercostal nerves, phrenic nerve and contralateral C7 should be kept in mind as alternative nerve donors. The spinal accessory nerve is frequently used to neurotize the supraclavicular nerve. The most proximal branches of this nerve to the trapezius are saved and and the nerve is transferred to the suprascapular nerve, directly or with a graft.

Reconstructive Strategy

C_5, C_6 and/or C_7 injury : If there is a single root that can be used, this is transferred to the upper and middle trunks. Since this innervates many important targets, more grafts are applied to the the upper trunk. On the other hand, the middle trunk, which has a crucial role in wrist extension, and which is mandatory for a functional hand, should not be discarded. In these cases, the spinal accessory nerve can be transferred to the suprascapular nerve. If

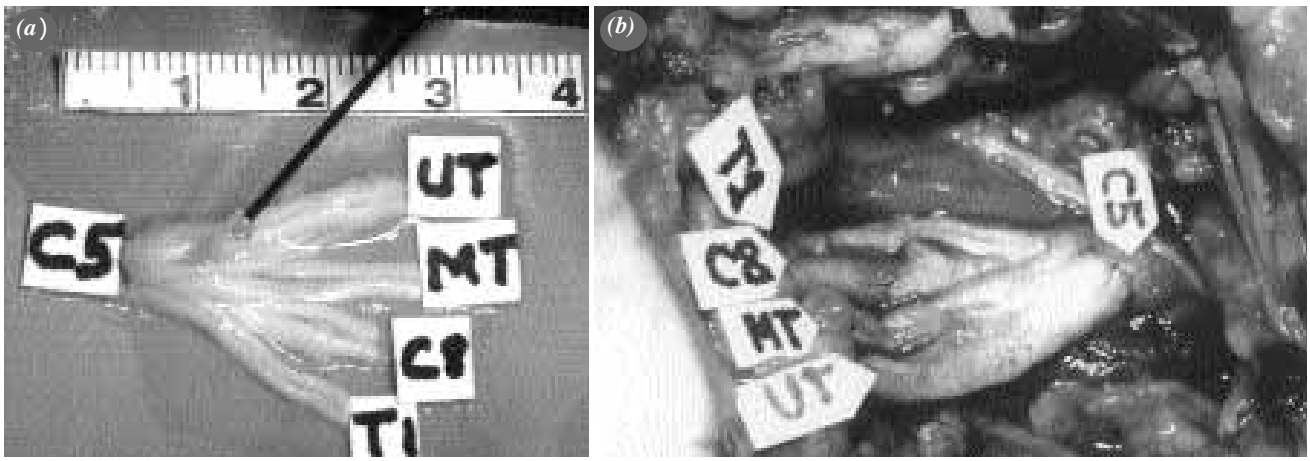


Figure 3. (a) after the distance betwen the motor sources and targets are carefully measured, the nerve graft is transected according to these defects and attached to each other with fibrin glue.**(b)** The grafts are attached to the roots and the targets with fibrin glue and each graft is sutured with a microsuture, to improve the security and endurance.

there are two or three roots that can beused, suprascapular nerve is innervated from C_5 using a graft. Additionally, as the C_5 is directed to the posterior part of the upper trunk, C_6 root giving most fibers of the biceps, is given to the anterior part of the upper trunk to have elbow flexion. If there is any root that can be used, this root is used for middle trunk.

Total Plexus Injury : The worst clinical picture that we observe is in cases which has avulsion of four roots and rupture of one root. In this situation, it is almost mandatory to use the spinal accessory nerve for suprascapular nerve. The single ruptured root is used to innervate all the remaining distal targets. Since the lower trunk or C8 and T1 are responsible for hand functions, their repair must have priority. Although the supraclavicular sensory nerves are readily located on the sternocleidomastoid musle, their length is not musc and can be used only when short grafts are required. If there are two or more roots which can be used, the reconstructive strategy is followed as described for upper root paralysis.

After the operation, a thermoplastic splint that was prepared preoperatively, and which keeps the arm in adduction and elbow in 90 degrees flexion. A cervical collar is used to prevent tension and rupture in the coaptation lines, resulting from uncontrolled head movements. This splint is used for three weeks, taken off only during dressing changes. Immediately after that, rehabilitation and electrical stimulation are started.

Results

Electrophysiologic reinnervation potentials and muscle activities were observed first in the shoulder, followed by elbow and finally hand muscles. With a minimum follow up period of 12 months, the patients were evaluated by HSC muscle avoding scale. Mean scores were for shoulder abduction, 4.5 for elbow flexion, 2.3 for elow extension, 3.3 for finger flexion. Developments in each of these movements are displayed in figure 4a-d. Since we began the first operations in 2001, we were not able to see the improvements in hand muscles in all cases, however the evaluations for shoulder abduction and elbow flexion revealed that on the 4-5. postoperative month, preoperative muscle activity values were catched through nerve regeneration reaching into the muscle. Postoperative results for one of the cases are shown in Figure 5a,b.

Nerves that were treated with neuroma excision and nerve grafting had better regeneration compared to only neurolysis.

Botulinum toxin at 25 U was applied to four cases which had co-contraction that developed between biceps and triceps and limited elbow flexion. One case underwent latissimus dorsi and teres major tendon transfer for more effective shoulder abduction and external rotation, 24 months after nerve surgery.

Immediately for the surgery, none of the patients developed problems that would require intensive care, such as respiratory problems, metabolic acidosis, and hypothermia. Three cases had infection of the incision which regressed with antibiotics. Four cases had hair loss in the occupital region due to the pressure of the thermoplastic splint.

Discussion

There is no single consensus on the indications and timing for the surgical treatment of brachial plexus palsy. Most authors in this field agree that a child with hand involvement and Horner's sign should be operated on the third month. Some authors can operate earlier if the conditions of the baby permit general anesthesia (6-8). Most discussions are about upper trunk palsy (Erb palsy). The frequent pathologic lesion is a neuroma that involves C5,C6 or C5,C6,C7 roots. The problem is whether enough fibers from the neuroma will reach the related muscles. Some authors suggest surgery in patients with upper trunk lesion if there is still not adequate motor activity in the "biceps" muscle by the third month (7,8). Marcus and Clarke (9), stated that surgery can be postponed until the ninth month in a patient with biceps function that is less than half of the range of motion against gravity.

In our clinic, neurologic consultations in the first three months are made and conventional radiograms are obtained to rule out lesions such as clavicle or humerus fractures. On the third month, magnetic resonance imaging and electromyogrpahic examinations are made.

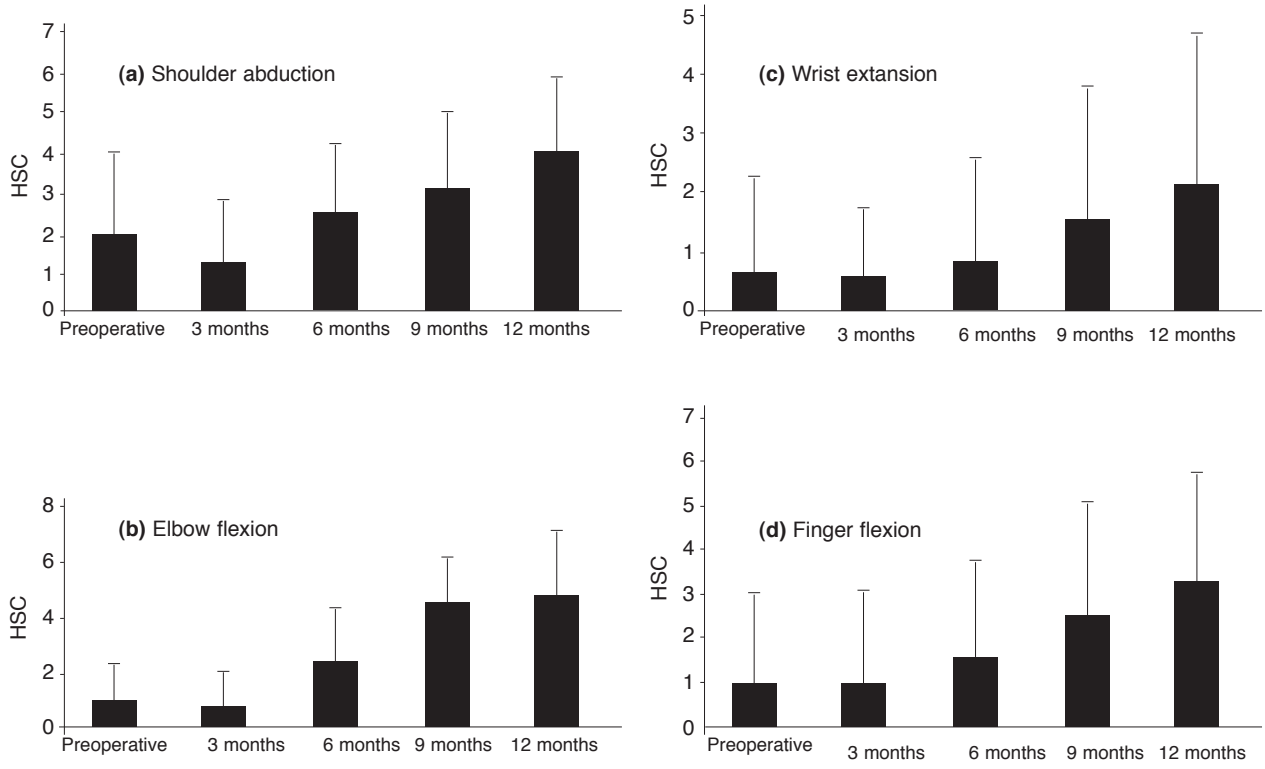
Children with total paralysis, who had hand involvement and Horner's finding that indicates lower trunk lesion are explored on the third month. Those with upper trunk involvement are operated between 3. – 6. months if they have an activity less than grade 5 according to HSC in the biceps and deltoid muscles.

In some cases, it was observed that motion in the biceps and deltoid muscles that can never reach adequate levels (<grade 5) can be as late as 5-6.months. This can lead to optimistic expectation in the parents, and when combined with fatalism of the Mediterranean and Middle East populations can lead to total refusal of surgical treatment. Parents believe that minimal improvement in their child can be totally lost with surgery.(10).

One of the biggest discussions in obstetrical brachial plexus palsy is the choice of treatment in cases of neuroma in continuity. Clarke et al (11) stated that in cases with Erb's palsy with neuroma in continuity, neurolysis positively affects muscle power and functional capacity, but does not work in cases with total paralysis. In a further study, same authors evaluated 26 patients who were repaired with neuroma excision and nerve grafting and 17 patients who had only neurolysis. They found that the results were better in patients who had resection and nerve grafting.(12)

In our clinic, neurolysis is preferred in nerves which have a near normal macroscopic appearance and near normal function, and that have a tendency to bulge after the surrounding scar tissue, epineurium and perineurium are removed.

Another problem that we face is the choice of treatment in patients who have missed the ideal time of operation. Although the upper limit for the benefit of surgery is not known, in our clinic this limit is accepted as 1.5 years. Undoubtedly, the earlier the patient is operated, the earlier the regeneration and the less is the atrophy of motor end plate. The most important question of the families is "with this operation will my child lose what he already has? " rather than "what will my child gain from this operation?".



Şekil 4. Evaluation of obstetrical plasy patients postoperatively according to Hospital for Sick Children (HSC) active motion scale, a)shoulder abduction b)elbow flexion c) wrist extension d)finger flexion

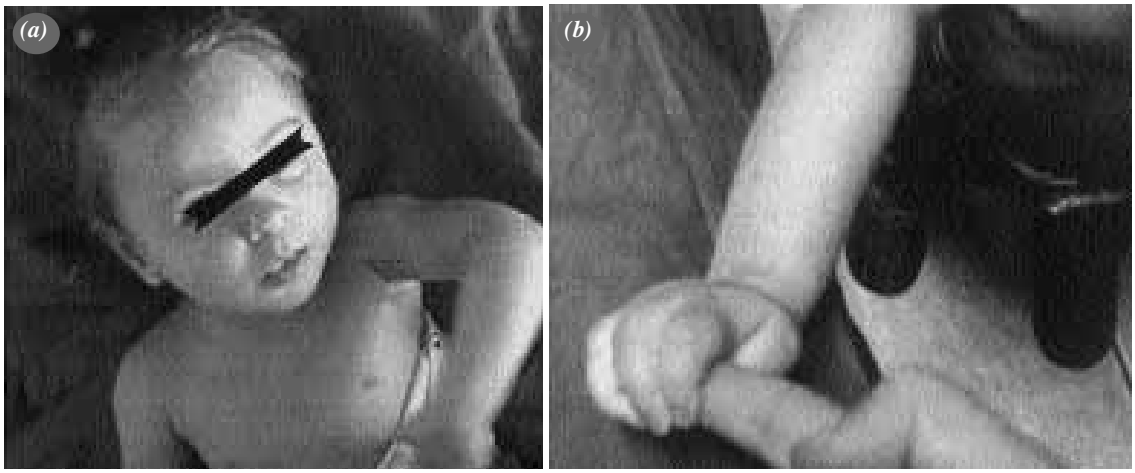


Figure 5. a) View of a patient who had C_5,C_6,C_7 rupture and C_8,T_1 avulsion in exploration. Neurotization with nerve grafts were applied to the upper and lower trunks, from C_5-C_7 roots. View of the patient on the 18th postoperative month. The evaluation of this case for shoulder abduction and elbow flexion is at level 6 according to Hospital for Sick Children (HSC) scale. **b)** Finger flexion in the postoperative 24th month is at level 6.

Even in patients with total paralysis, there may be a small amont of anterior flexion of the shoulder, which can direct the families into unrealistic expectations. One of the greatest difficulty that we face in the preoperative period is the need to transfer this root, which only can serve a useless movement, to nerves that control more basic functions of the upper extremity. As a result of this, the child loses temporarily the already present motion. In the case that we operated, we saw that on the fifth postoperative month shoulder abduction and elbow flexion reached and even exceeded preoperative values (Figure 4a,b).

The earlier diagnosis by physicians working on obstetrical palsy in patients without adequate regeneration and application of nerve surgery will enable a timely muscle function and a functional upper extremity.

Since most patients have an upper trunk involvement (C_5, C_6 and / or C_7) who recovered spontaneously or with physical therapy support, has led to the misbelief of a " very high success rate " in ones who favor conservative treatment. In the liteature, Gilbert (10) in his study of 241 cases, reported that C_5,C_6 involvement was 39%, C_{5-7} involvement was 33% and C_5-T_1 involvement was 73%. By Baylor Clinic, these rates were reported to be 73% for C_5,C_6 and/or C_7 involvement, and 20% for C_5-T_1 involvement. In our study, the severe total paralysis cases with hand involvement constituted 70%, and the less severe C_5,C_6, and/or C_7 involvement formed 30% of the patients.

Early postoperative follow up of patientsshowed that the results were satisfactory for shoulder abduction and elbow flexion and promising for hand functions. We believe that as the number of cases increase, our results will be as successful as other international plexus centers working on obstetrical palsy.

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