



Indications of Plexus Reconstruction in Obstetrical Paralysis

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Introduction

Since 40 years there have been a lot of controversies on the indications for repair of the Brachial Plexus. These controversies come from differences in expected recovery in the different clinical situations. It shows how critical is the quality of the clinical evaluation prior to the decision.

Evaluation of the Paralysis

This evaluation is mostly clinical. Let's first eliminate the idea that an association of EMG, MRI, Echography, could give a precise definition of the clinical situation of a child.

However these studies may be useful in some situations and we will see that they can be used with success.

- History of the pregnancy and child may be very useful -
- The birth weight is usually superior to the average, sometimes over 4.2 or 4.3 kg. It is necessary to determine if the mother is diabetic and the birth weight of the previous children. A very low birth weight is possible and usually corresponds to a breech delivery. As published previously, a breech delivery will often result in a severe avulsion injury and may provoke a bilateral lesion^{1,2}. In front of a breech delivery and an upper roots lesion, there will be a high risk of avulsion of the upper roots.
- Initial examination (0-2 months) will give precious informations-
- is the hand involved ?
- did it recover very quickly ?
- is it still paralysed ?
- is there a Claude Bernard-Horner Syndrome ?

The extent of the paralysis can be determined after a few weeks but, except for patients with a complete paralysis and a Horner Syndrome, the prognosis cannot be determined at that time. At that time, there is no need for Electrical studies or MRI. Gentle rehabilitation is prescribed. At 3 months is the crucial examination.

Why 3 months? Because we (and other authors) have shown that a reasonable prognosis can be done at that age³. When spontaneous evolution of a series of children has been followed and evaluated, we have been able to show that there was a correspondence between the age of recovery of key muscles and the final result. Of the different muscles followed only the biceps has been kept as representatively easy to evaluate, and statistically correct. In those patients who had recovered at 3 years, only those whose biceps had recovered before 3 months had an excellent result. Those started the biceps recovery after 3 months had sometimes good but incomplete results (Stages II, III Mallet). A very important point is that the examination the biceps must be done in abduction, with 2 fingers holding the muscle, in order to feel any contraction. Even a slight contraction is positive. The greatest error would be to consider elbow flexion instead of biceps contraction.

There are still surgeons describing this technique and speaking of elbow flexion, forgetting that this flexion can be given by the brachioradialis. One should be very strict on this examination (Fig 1).

Other movements are also examined but in small babies it is difficult to separate muscles from functions; abduction, external rotation, elbow extension are noted.

The hand must be very precisely studied. An absence of fingers flexion immediately draws attention on a severe injury. The difficulties come with examination of fingers and wrist extension.

In upper root (C5, C6) lesions, fingers extension is usually present. It is common to say that absence of wrist extension is often or a marker of C7 lesion. I have found it often uncorrelated. Wrist extension comes from several roots. In C7 transfer there is (usually) no

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wrist extension paralysis. Determination of wrist extension is however a very important marker for the surgical decision. After this examination, it is usually possible to make a prognosis and take a decision. This situation must be discussed with the family and some tests may be useful.



Fig. 1 Examination for biceps

EMG

Rarely useful for diagnosis except in avulsion injury where the “electric desert” may lead to the diagnosis of avulsion. It will be useful later, to see signs of recovery before clinical recovery and to determine, in late cases if the muscles are still alive or if there are no hope of reinnervation.

MRI or CT myelogram

In the past, I have used routinely CT myelograms but the results have shown a high number of false positives. MRI has improved the situation despite the need of a general anesthesia. Recently I had 2 unexpected failures after grafting of apparently good roots. A

secondary MRI, in these cases showed that these roots were avulsed in situ and that the decision was a mistake. In view of these cases I feel that wherever possible, an MRI can be of use, in order to avoid wrong decisions on the quality of a root.

Fluoroscopy of the Diaphragm

It is necessary as it may show a paralysis on the operated side or on the contralateral side. It can become an important medico-legal piece. Most of the time there will be spontaneous recovery after a few months but it is important to determine if it happened before or during the operation.

Surgical Technique

It is not our aim to describe all the techniques used for repairing the obstetrical plexus. We will concentrate only on the specific aspects of our choices for repair.

Anesthesia

Anesthesia is a crucial part of the technique as it will allow a bloodless field, good response to stimulation (no neuromuscular blocking agent during exploration), and a soft wake-up, avoiding dangerous movements. A safe and sophisticated environment, as well as an experienced pediatric anesthesiologist is necessary to avoid hyperthermia and post-operative apnea. A too early operation (less than 60 weeks of corrected age) increases the risk of complications.

Exposure

The only specific aspect of exposure for Plexus exploration is the use of clavicle osteotomy in complete lesions and in most cases of C8, T1 lesions⁴. Since 40 years, I have used clavicular osteotomy. Two periosteal flaps are designed on the clavicle. The superficial with a lateral base, the deep with a medial base. The periosteum is elevated with a spatula and the bone is cut obliquely, using an electric saw. In cases where I could not use electrical saw, I have used bone cutters with a risk of secondary pseudoarthrosis. A hole is drilled in each extremity of the bone with a 1.0 K wire. The two parts of the clavicle are held with a self-retaining retractor, giving a large access to the plexus, (Fig 2). After repair, a 2.0 polyglactin suture is passed into the holes and osteosynthesis is achieved with a suture. The 2 periosteal flaps are closed (Fig 3).

Repair

Direct repair is rarely possible but in C7 or C8 avulsions, it is sometimes possible to do a direct repair with the upper roots. When the ganglion is avulsed with the root, it is possible, instead of shortening the root by resection the ganglion, to use only the motor root, separate it from the ganglion and suture it directly to one of the upper roots (Fig 4).

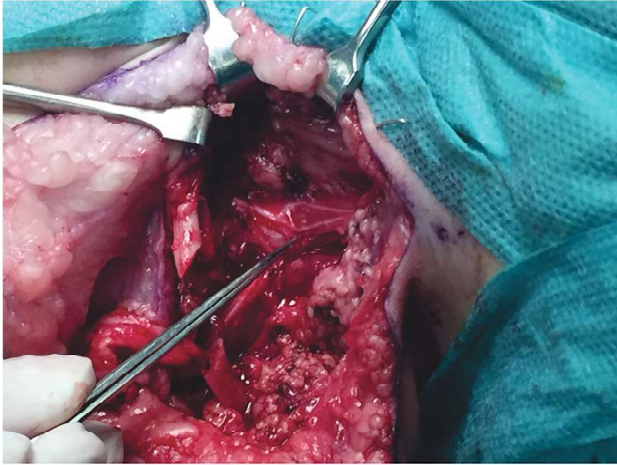


Fig 2. The clavicle is opened showing a wide access. In this case a duplicated phrenic nerve



Fig. 3 The clavicle is sutured .

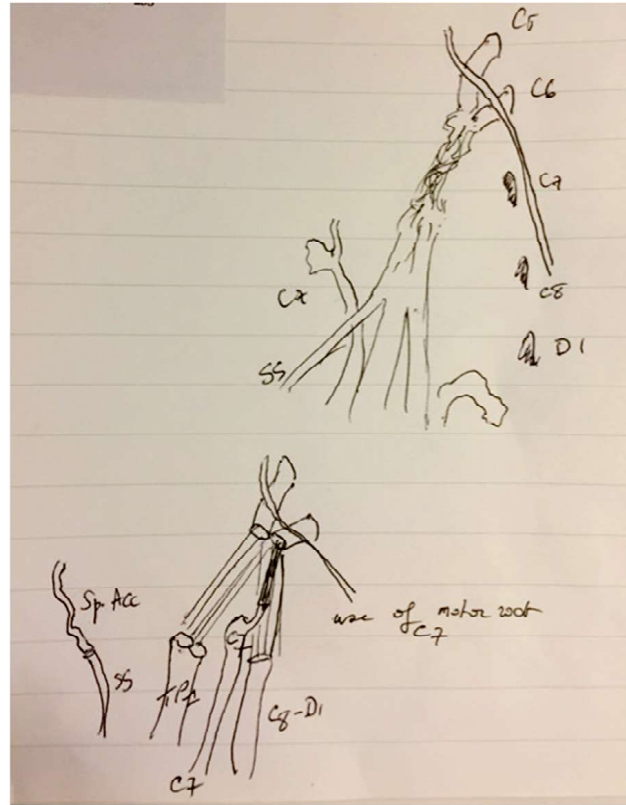


Fig. 4 In a severe case of multiple avulsions , the motor root of C7 is directly grafted from C6

Grafts

Most of the times, grafting is necessary. I always harvest the sural nerves by longitudinal incisions. Short incisions, like in the adult, should be avoided as the nerve is very weak and traction can provoke rupture. The sural nerve has a Y shape and must be dissected with care⁵. It usually measures 12-14 cm in a 3 months baby. The nerve is cut in cables for the necessary length and the cables are glued on the table. It is then brought to the operating field, inserted and glued again (Fig 5).

Allografts

Another problem is the use of allografts. Widely used in the US and many countries, several thousands have been implanted in peripheral nerves, often with good results. There was no convincing experience with brachial plexus (Fig 6). In the past 2 years, 40 OBP cases have been repaired using exclusively allografts and we are following them. The follow-up is still too short but, as the end result cannot be assessed yet, it is possible to say that the allograft allow regeneration, even in longer grafts (7 cm). Some of the best results up till now have been the use with contralateral C7 transfer (Fig 7).

I am still waiting for the results before we continue and use it routinely. There are advantages, an unlimited access and no scars in the leg. But there is still a doubt on their capacity to completely replace autografts.



Fig. 5 The grafts are prepared on the table .

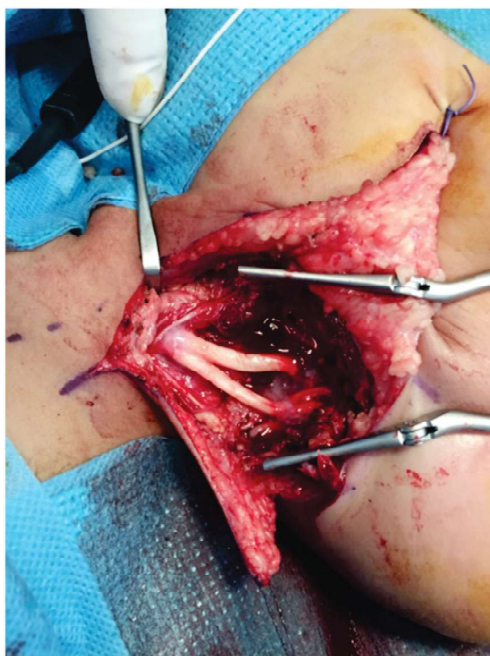


Fig. 6 Use of Allografts

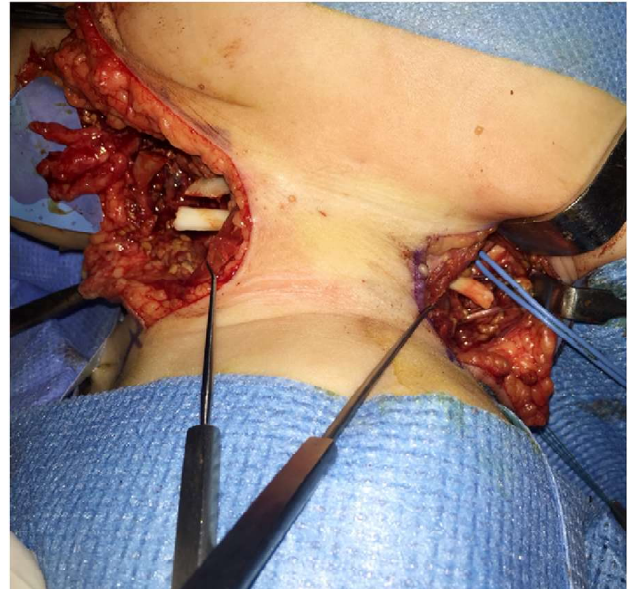


Fig. 7 In case of CLC7 transfer in babies , a graft or allograft is always necessary

Nerve Transfers

There are multiple nerve transfers described since almost a century. The most common are, *Spinal Accessory nerve to Suprascapular nerve* transfer-

It is an excellent transfer as the sizes are equivalent, end to end suture is possible without tension and the defect is very limited.

Spinal Accessory to Musculo-cutaneous nerve-

In complete avulsions a good solution to recover elbow flexion. It needs a graft (8 to 10 cm) but nevertheless gives good results.

Phrenic nerve transfer-

Popular for traumatic repairs. Dangerous in small babies; a post-op phrenic paralysis may become a problem and need a placcation of the diaphragm. Better avoid if it possible.

Intercostal nerve transfers-

I am personally very reluctant to use the intercostals in a small baby. There is a double risk - diminished pulmonary capacity, even if some authors think it will recover progressively, and long term anomalies in the development of the ribs and lungs. Some authors have shown severe hypoplasia of the thoracic cavity after extensive removal of rib periosteum.

Biceps Reconstruction with Nerve Transfers-

Since Oberlin, the biceps reconstruction by nerve transfer is very commonly used. The discussion is

whether the results are consistent. They are difficult to assess.

In obstetrical palsy, spontaneous recovery of the elbow flexion is not rare. Repairing either biceps or brachialis alone, if the neuroma at the neck is not excised, does not show a proper result of the nerve transfer. Only double nerve transfers to biceps and brachialis muscles can be assessed properly and can be compared to grafts of the upper roots.

The extent of the plexus lesion is very important to assess as the nerves used for the transfer (median and ulnar) can be severely impaired by the roots lesions. The difficulty is also to determine if a recovering ulnar nerve can be used before its complete recovery.

Deltoid Reconstruction-

The use of triceps branches has been growing in the past years, either through a posterior approach (which will need a change of positioning) or an axillary approach (compatible with nerve transfers to the biceps). I prefer the second approach as it is simple and not time consuming⁶.

The choice of the branch is important. The anterior approach allows selective stimulation and extensive dissection of the triceps branches. The best branch seems to be the most proximal branch to the lateral head.

Distal transfers

Several distal transfers have been described for reconstruction of the forearm and hand. I have been using a number of times the brachialis nerve transfer⁷ essentially to the flexors, but also to the extensors.

It is sometimes possible to dissect the AIN (Anterior Interosseous Nerve) inside the median nerve, up to the lower arm, allowing a direct suture with the brachialis nerve. The results have been sometimes interesting, restoring fingers flexion in paralysed hands but many times disappointing resulting only in very weak movements, inefficient if there is no wrist and fingers extension.

Other distal transfers have been developed by Bertelli⁸ and Mackinnon⁹. They can give good results but they oblige to make the choice to sacrifice a useful muscle, in order to obtain a movement. Only large members with results will show if the risk is not an excess to the benefits. I see very few indications of these distal transfers for the moment.

Controlateral C7 transfer

Described by Gu (1989) the use of an healthy contralateral C7 root has been widely used for adult brachial plexus reconstruction. However the results have not (at least in the western world) been very convincing¹⁰. Two problems remained; the use of an hemi-C7 which did not have enough strength to give good reinnervation, and the obligation to use an intermediate graft. Wang¹¹ published recently a series using the whole C7 and a direct suture, using a retropharyngeal approach and sometimes a shortening of the humerus. His results rose to an acceptable level.

In babies, the problem is different. As in our experience, it has never been possible, even with a retropharyngeal approach to do a direct end to end suture. Graft has always been necessary, this limiting the indications as we will see.

Conduits

The only experience we have with artificial conduits has been removing them. In these few cases, the results of using them has been totally negative.

Indications of plexus reconstruction

The indications depend on many factors - age, evolution, parent expectations, social context. We will try to define them according to situations-

- **At 3 months, recovery of some abduction, essentially with pectoralis major.** The biceps can be felt using very precise examination. There is usually some elbow flexion (but not necessarily) or resistance to elbow release. The wrist and fingers usually show some extension, even weak. In that situation waiting is the reasonable decision. Improvement should show very soon.
- **At 3 months, some abduction but no biceps contraction.** There may be sometimes some elbow flexion due to brachioradialis muscle which has no significance. In that case, waiting another month will show more evidently the difference. It is crucial to understand that elbow flexion has no significance in this evaluation, contrary to what has been popularized by some authors. Only the biceps recovery is important.

If in this case there is no wrist extension, we feel that the distal nerve transfers are not, for the moment, a reasonable alternative and the indication is surgical exploration with grafts of the upper roots.

- **At 3 months the clinical aspect is the same but with wrist extension.** The situation will not be the same as we will not need to reconstruct wrist extension. Nerve transfers for the upper roots are a valuable choice as they will give a similar result without needing grafts (scars). In these cases, we favor a double nerve transfers, spinal accessory to suprascapular and Isolated biceps reconstruction. If we leave the neuroma, we must take in account the possible partial spontaneous recovery of deltoid and brachialis, very common in those cases. The existence of wrist extension is crucial, as it allows to wait one or 2 months if necessary and reassure the parents about grafting.
- **At 3 months, there is no abduction, no elbow flexion, sometimes no wrist extension the shoulder is totally flail.** EMG will show no signs of recovery in the upper part of the plexus. If done, MRI may show meningoceles, signing root avulsions. The history, often finds a breech presentation or a very hectic birth. These signs will lead to surgery with nerve transfers. When there are signs of complete upper root avulsions, the nerve transfers used will be-
 - Spinal Accessory to suprascapular
 - Double nerve transfer to biceps and brachialis, using the best available nerve (with stimulation of branch)
 - Anterior Deltoid reinnervation using a branch to the Triceps, if available-

In that case, future deltoid recovery is not expected and it is better to try to reinnervate it.
- **At 3 months, complete palsy, no or very weak hand movements, some or no recovery of upper roots.** Usually associated with Horner's syndrome but as it is a good indication, it is not pathognomonic and there are patients with a Horner syndrome and an excellent hand. This complete paralysis is an absolute indication for nerve repair. MRI may sometimes be useful but exploration and stimulation will give a precise state of the lesions. The extent of spontaneous recovery of the upper roots may give an indication of the number of usable roots for repair. Of course the strategy for repair is difficult one in this case and experience is paramount.

Cutting the clavicle is necessary if one want to explore completely the plexus and the repair will be function of the number of donor roots left, the quality of the roots, the size of the defect and the corresponding number of grafts.

One of the great difficulties is the result of stimulation of the lower roots. More than 30 years ago, I thought that with a positive stimulation of C8 T1, even very weak, there was a good chance of spontaneous recovery. I was wrong. Almost all of these cases did not recover proper hand movements and their final result was a catastrophe. Once at 3 or 4 months, or later, the clinical picture is that of a severe lesion of C8 T1, the roots should be grafted and one should not rely on "positive stimulation".

The only situation where we could still contemplate leaving a poor but stimulating lower root is when there is an association with upper avulsions and only C5 is left (often bad looking) and without good donors, the slightest chance of spontaneous recovery should be preserved. In these case the options are scarce. C7 transfer is rarely contemplated in primary repair. In a case where clinically there seem to be no signs of upper recovery or where an MRI show extensive avulsion, the parents should be aware of the possibility of deciding for a contralateral C7 transfer at the time of the operation (Fig 8).

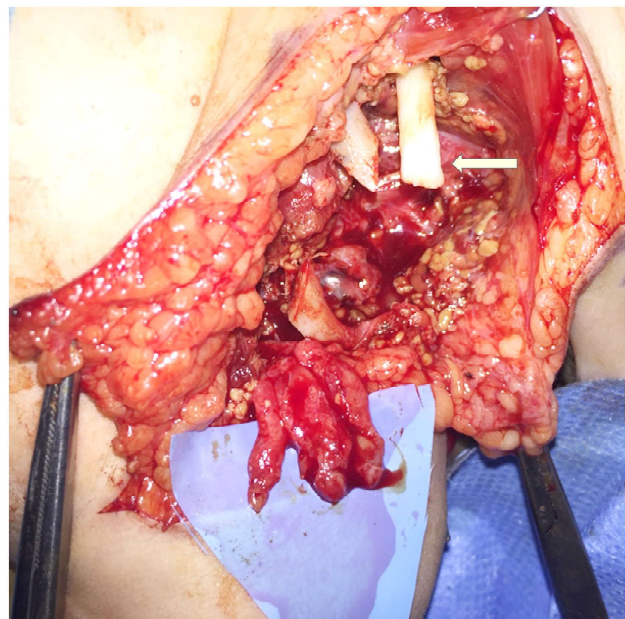


Fig. 8 In case of 5 roots avulsion a Contralateral C7 transfer may be used . The arrow shows the allograft

• Late presentation

If the patient is seen at 6-9 months, we call it a late presentation, although for some surgeons this is the normal age for decision.

Then, the psychological response of the family is important. If a baby has recovered a good elevation of the shoulder and even good elbow flexion, it is very difficult for the family to accept to lose everything after an operation, in order to, may be, recover the hand. We can be sure of the loss but never promise the recovery. It takes very clever families to understand and accept the risks. A large number refuse the procedure and prefer to wait for an unexpected recovery. Delayed surgery can give probably as good results as early surgery but we do not know the influence of this timing on future shortening of the upper extremity. Even more difficult is the presentation after 12-18 months. Usually the proximal recovery is quite good and there is no way that after such a long time waiting for recovery, the family will accept a complete reshuffle of the plexus without being sure of a better result. The only possibilities for improvement will be nerve transfers. If the upper roots have not recovered well, a Spinal Accessory transfer or an Oberlin transfer are still possible. There is no specific limit and our experience with late nerve transfers show excellent results, even after 2 years. The condition is to have fibrillation in the muscles. If the flexors are alive (fibrillations +) and there is a good musculo-cutaneous nerve recovery, the brachialis transfer can be used. If there is a doubt on the biceps and brachialis, this is the indication for a contralateral C7 transfers. Our best results have been with allografts. If there are no more fibrillations, a free vascularized muscle transfer is indicated.

Reoperations of the Plexus

The failed repair is difficult to treat because of heavy scar and lack of grafts. I have reoperated more than 60 obstetrical plexuses previously repaired. Improvement can come from nerve transfers, avoiding the scar. Even the suprascapular nerve can be repaired posteriorly.

In severe complete cases this is not sufficient and redo procedures may be necessary. In these cases only an allograft can palliate the lack of autografts. My results have been partial and limited after reoperation for a previously operated plexus.

Discussion

The indications for surgical repair in obstetrical palsy are complex due to the multiple factors-

- the evaluation is not always easy,
- the grading systems are sometimes complex and based on continuously repeated mistakes (elbow flexion instead of biceps contraction)

The social environment is very important; follow-up, physiotherapy, EMG of good quality are necessary for these very sophisticated repairs. Most important is the family. There should be respective trust between the surgeon and the family. Often the family sees the medical profession as responsible for the problem, especially when there has been initial lies and bad information. The diagnosis of the surgeon has to fight in the mind of the parents against all the incompetent diagnosis and prognoses saying that the paralysis will resolve by itself. Again, delaying the decision to 6-9 months may be possible in highly educated families but usually, the partial recovery that will occur will be interpreted as a favorable sign and a secondary procedure suppressing some of this recovery carries a high risk of destroying the trust of the family towards the surgeon even if there is a good chance of secondary recovery.

The diagnosis must be accurate. The diagnosis must be as early as possible. The decision must be taken rapidly.

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