• What is the brachial plexus?

The brachial plexus is a network of nerves starting from five nerve roots; C5, C6, C7, C8 and T1, that come out of the spinal cord at the cervical level and end by the formation of the five main nerves that control movement and sensation of the upper limb. It is located near the junction of the neck and shoulder, behind the clavicle. The nerves from the spinal cord join and split in a pattern that forms five sections of the brachial plexus; roots, trunks, divisions, cords and nerves.

Fig(1) The complex anatomy of the plexus

شكل (1) الصفة التشريحيه للضفيرة العضديه
• **What is brachial plexus palsy?**

It is the injury that occurs to the nerves of the brachial plexus that control movement and sensation of the upper limb. When these nerves are damaged, the muscles controlling the shoulder, arm and hand on the same side are weakened. The resulting deficit ranges from partial to full flaccid paralysis. Fortunately, most infants with this condition make complete spontaneous recovery. Some however, are left with varying degrees of arm weakness.

Obstetrical Brachial Plexus Palsy (OBPP) is seen in the newborn. It is a medical term used to describe injuries to the brachial plexus following a birth injury. During difficult labour, delivery of a large baby, in breech delivery and other circumstances, the roots of the plexus may be pulled and injured. This traction injury may result in elongation in the continuity of the nerve, extraforaminal rupture or avulsion from the spinal cord.

![Fig (2): The mechanism of injury during labour](image)

شَکَل (۲) كيفية حدوث الإصابة إثناء الولادة الطبيعية
• **Historical Background**

For centuries, brachial plexus palsy was confused with other congenital disorders, until Smillie, an English pathologist, in 1768, identified its obstetrical origin. In the late 19th century, French neurologist Duchene described the cause of injury as traction on the arm and shoulder during labour and gave it its name of "paralsie obstetrical". Around the same time, German neurologist Wilhelm Erb pin-pointed the lesion at the upper trunk (C5, C6) known as Erb's palsy. A much rarer disorder is Klumpke's palsy involving damage of the lower roots (C8, T1), affecting muscles of the hand. Obstetrical injury to the whole plexus was described later (Seeligmueller, 1877).

Surgery for obstetrical brachial plexus was first described in the early 1900s (Kennedy and Taylor). However, in the first part of this century, surgical treatment was so often unsuccessful, with high rate of associated problems and even death, that it was almost abandoned. The conservative attitude prevailed until the 1970s, when microsurgery and nerve grafting techniques were developed and renewed interest in surgical repair of the plexus.

Since 1970, Narakas from Switzerland and Millesi from Austria revived the surgical repair of the plexus by treating adults, who had traumatic injuries. In 1977, surgeons Gilbert in Paris and Raimondi in Italy established the protocol and treatment that is still currently in use.

Since 2001, a national program for the management of OBPP was initiated in Egypt, with the help of Dr. Gilbert and Dr. Raimondi. The program is supported by La Chaine de L'Ersperie organization during those years, more than two thousand patients with OBPP were seen, with 220 primary procedures and 700 secondary procedures performed for these children. Patients come from every part of Egypt as well as many other Arab countries.
What is the pathogenesis of OBPP?

The brachial plexus is injured by traction on the shoulder during delivery. Infants affected are usually large, so that it is necessary to use force in pulling them from the birth canal.

The severity and extent of the lesion depend on the degree of trauma affecting the nerves. In general, nerve injuries can be classified into three main types:

1. **Neurapraxia**
   (Physiological block of nerve conduction without any anatomical interruption)
   Many infants with birth plexus injury have neurapraxia and recover spontaneously within 4 – 6 weeks.

2. **Axonotemesis**
   (Anatomical interruption of the axons with no or only partial interruption of the connective tissue framework)
   This type of injury requires regrowth of the axon to the target muscle. This regrowth can be inhibited by scar tissue formation. Whether the patient with axonotemesis will require surgical treatment depends on the number of disrupted axons and the extent of scar formation at the site of nerve injury.

3. **Neurotemesis**
   (Complete anatomic disruption of both the axon and the surrounding connective tissue; rupture of the nerve.) This is a severe type of nerve injury which occurs at a postganglionic level with no chance for spontaneous recovery. This type of injury usually leads to neuroma formation. A neuroma is a disorganized collection of fibrous tissue and nerve endings, from where a rupture occurs and the nerve attempts to grow and meet the distal end. Early surgical treatment of the plexus is necessary, usually by resection of the neuroma and nerve grafting.

Avulsion is an even more severe type of injury, when the root is avulsed from the spinal cord at the preganglionic level. It is impossible to reattach an avulsed root back to the spinal cord and these roots will not recover at all.

Due to special anatomical features, upper roots (C5, C6) are mostly ruptured and the lower roots (C8, T1) are usually avulsed.
• **Spontaneous Recovery**

The majority of patients with brachial plexus injury recover spontaneously and have little residual weakness. Therefore, surgical intervention is not considered until it is clear that an infant will not recover completely on its own. The reported rates of spontaneous recovery vary widely, ranging from 60% – 90%. Some infants however, fail to regain full strength in the arm and have significant lifelong disabilities. The great majority of infants who will improve spontaneously will do so within a few weeks and by the age of three months, the chance of further improvement is very little.

![Fig(3)Good spontaneous recovery without treatment, child at the age of 8 years with almost normal function](image)

**Fig(3)Good spontaneous recovery without treatment, child at the age of 8 years with almost normal function**

Muscle Strength as an Indicator of Recovery

The speed at which muscle strength is regained helps to determine the extent of the injury. In general, the more rapid the recovery of muscle strength, the less severe the injury. If a complete recovery is to occur, it does so within 2-3 months.

An infant with persistent arm weakness showing little or no improvement probably has severe total brachial plexus palsy, detached nerve root (nerve root avulsion), extensive nerve fiber injury (axonotemesis), or ruptured brachial plexus (neurotmesis) should be suspected. The chance of spontaneous recovery is very small in such cases and thus, surgical intervention should be considered.
• **How common is OBPP?**

This depends on the standard of the obstetrical medical care provided. Incidence is low with improvement in obstetrical care. In countries in which obstetrical care is poor the incidence of OBPP is higher. The incidence ranges globally from 0.2: 4 per 1000 of live births. The incidence in Egypt is not exactly recorded, however, from our preliminary studies it is in the higher side of the range.

• **What are the risk factors?**

Although brachial plexus injuries can occur during any birth, there are particular risk factors. The highest rates of OBPP occur in newborns weighing over 4.5kg (10 lb). Premature and under developed newborns are at a decreased risk for OBPP. Examples of other risk factors for this injury are:-

a) Breech delivery increases the risk of OBPP by 175- fold, often causing bilateral injuries to the lower trunk.

b) Prolonged 2nd stage of labour.

c) Use of forceps or a vacuum device to deliver baby at risk.

d) Injuries occur more frequently in births to mothers who have had several prior births.

e) A mother who had previous brachial plexus – injured infants is at a 14- fold increased risk of having another infant with OBPP.

f) Infants born post-term (>42 wks of pregnancy).

g) Maternal diabetes (especially IDDM type 1).

h) Old maternal age during 1st delivery.

i) Maternal obesity.
What are the types of injury of OBPP?

Brachial plexus injuries are most often classified according to the spinal nerve roots involvement, into three main types:

a) **Upper Brachial Plexus Palsy.**

It is also known as Erb's paralysis. It is an injury to the upper part of the brachial plexus, involving C5, C6 and sometimes C7. There is paralysis of deltoid, supraspinatus, infraspinatus, biceps and brachialis muscles. The arm is adducted and internally rotated. The forearm is pronated and the elbow is extended, while the palm faces backwards (giving the appearance of waiter's tip hand).

Often, these babies have no movement of the arm right after birth but begin to move the fingers and wrist within a few days. The weak shoulder and elbow movement remains a persistent problem, however.

b) **Total Plexus Palsy.**

It involves all of the nerve roots of the plexus. This type of injury is more often associated with avulsion of the nerve roots, which is more difficult to treat. There is complete atonia of the extremity with flail limb. The fingers may rest in a flexed posture. This is the result of tenodesis of the wrist, rather than true power in the long flexors. Horner's syndrome (ptosis, myosis, enophthalmos and anhydrosis) is usually associated with total palsy and indicates involvement of the sympathetic trunk.

The prognosis for spontaneous recovery is nil and in time the infant will develop atrophy of the hand.

c) **Lower Brachial Plexus Palsy.**

It is an isolated injury involving the lower roots of the plexus. Lower plexus injury is extremely rare. Typically the lower brachial plexus is involved as part of more extensive injury, such as total palsy. Affected children have normal use of the shoulder and elbow but weakness or paralysis in the hand and fingers.
Bilateral Plexus Palsy

The brachial plexus can be injured on both sides of the body, although such cases are rare. Bilateral injuries can be mistaken for other problems such as spinal cord injury.

![Image of bilateral total Plexus Palsy](image)

**Fig (4) Bilateral total Plexus Palsy**

#### When is medical advice sought?

Although OBPP mostly heals spontaneously and rapidly, with mild or no residual functional deficit, the infant may begin physical therapy within the first two weeks of age and should be evaluated by a specialist by six weeks of age. Daily physical therapy aids in maintaining a range of motion of the shoulder, elbow, wrist and hand, to prevent joint stiffness or contractures. By the age of 3 months, if no improvement has occurred, with total flaccid paralysis of part or all of the upper limb, surgical intervention becomes essential. This is because the younger the age of surgical correction the better is the opportunity for regeneration of the nerves and restoration of responsiveness of the muscles to nervous stimulation, before atrophy occurs.
What you have to do when you are confronted with a case of OBPP?

Immediately after birth

- Examine the baby and have an idea about the type, level and extent of the lesion. Diagnosis is usually straightforward and no special investigations are needed.
- Assure the family. There is a very high chance for spontaneous recovery (75%).
- Start immediately with gentle range of motion exercises.
- Refer the baby to physiotherapy. The child should have passive and active mobilization of all joints of the limb. It is important to teach the family how to do the exercises by themselves.

At one month

- The baby should be seen at this age by a brachial plexus specialist.
- Continue physiotherapy.
- No need for splinting.

At three months

Decision is very critical

- If muscle power is recovering progressively, continue conservative management.
- If there is absence of recovery of biceps muscle or complete hand paralysis, refer the baby for primary surgical repair (see algorithm).
- At this stage specific investigation might be requested to determine the extent and nature of the lesion and whether the injured roots are ruptured or avulsed.
  - EMG
  - CT myelogram
  - Fluoroscopy
- Continue physiotherapy guided by surgeon’s recommendations.

Every three months

- After primary surgery the child is seen by the surgeon to follow recovery and check for development of complications.
- Continue physiotherapy.
After two years

The upper roots have completed their recovery. This is the best time for secondary surgery if indicated, to improve function. Continue physiotherapy modification according to surgical procedure.

After 4 years

- The whole plexus is almost completed recovery after primary surgery
- The child is reevaluated for the possibility of tendon transfer in the hand or bone surgery (osteotomies, joint release)
- Active physiotherapy is slowly replaced by daily physical activities and swimming.
- Physiotherapy follow up is very important and should continue throughout the child’s life.

![Flowchart diagram]

1-2m Check for biceps 3 months

- Wrist extensors

3m some biceps no biceps hand recovery no hand recovery

- (Horner)

- no operation operation no biceps operation
What are the signs and symptoms of OBPP?

Clinical Presentation

The signs of OBPP vary greatly, depending on the extent and severity of damage. They are usually identified at birth or shortly later. The most obvious feature of the disorder is lack of mobility in the arm.

Typically, signs that may be recognized early in life include the following:

Signs of upper palsy include:

- a) Limited abduction and external rotation of the shoulder joint.
- b) No elbow flexion.
- c) Limited supination of forearm.
- d) Normal hand movement.

Fig (5) infants with upper (Erb's) palsy.

The injury involves the upper roots (C5, C6 ± C7)

Notice that:

- Shoulder is adducted and internally rotated.
- Elbow is extended, so that the arm is in the typical (waiter's tip hand) position.
- The infant cannot elevate the shoulder or do external rotation, cannot flex the elbow or turn the arm outwards.
- Hand is normal
**Signs of total plexus palsy include:-**

a) Total paralysis of the entire upper limb.
b) Horner's syndrome occurs in one third of total palsy cases.

![Infants with total palsy](image)

**Fig (6) infants with total palsy,**
The injury involves the whole plexus (C5, C6, C7, C8 and T1)

شکل (6 ) إصابة بشلل كامل بالضفيرة العضدية , غالبا ما يصاحبها متلازمة هورنر

Notice that:

- The shoulder, elbow, hand and fingers have no movement.
- There is associated Horner's syndrome affecting the eye of the same side.

**Other Associated Symptoms**

- **Phrenic Nerve Injury**
  
  The phrenic nerve controls the diaphragm. A paralysed diaphragm causes breathing difficulties, asymmetric chest movements during respiration and frequent lung infections. Chest X – ray shows marked displacement of the diaphragm away from the normal level and bowels are seen in the chest cavity. Paralysis of the diaphragm can resolve spontaneously but requires particular attention because it may be fatal. Sometimes surgical repair is mandatory.

- **Associated Fractures or Dislocations.**
  
  Fractures of the clavicle are relatively common. Other bones as humerus or scapula can occasionally be fractured too. Plain X – ray can confirm the diagnosis.
  
  Shoulder dislocation can occur anytime, even after birth, due to lack of muscular protection of the joint.
How is OBPP diagnosed and evaluated?

Usually, the clinical picture is very clear and diagnostic. However, there are some investigations that are useful for evaluation in selected cases.

a) **X-ray** can diagnose fractures of the clavicle, ribs, humerus, as well as dislocation of the elbow and shoulder joints. In addition, an X-ray is also important to check for diaphragm paralysis, due to phrenic nerve injury.

b) **Nerve conduction velocity (NCV)** and **electromyogram (EMG)** to measure the muscle response to nerve impulses. Both are important to diagnose OBPP in selected cases, but are not used as a routine.

c) **Magnetic resonance imaging (MRI)**. It obtains images of nerves as they exit the spinal cord and travel into the plexus, as well as to identify any significant injury to the nerve roots.

d) **CT Myelography** can determine the presence of a pseudomeningeoecele that indicates avulsed roots from the spinal cord, so it is important to diagnose the type of root injury.

Fig (7) **CT Myelography showing pseudomeningeoecele**

شكل (٧) صور الرسم الطبقي مبينة مزعج جذور الأعصاب من الحبل الشوكي
• Is it possible to prevent OBPP?

The primary prevention for OBPP is to provide standard obstetrical care and avoid a potentially difficult delivery by choosing cesarian section. Some physicians suggest that women whose previous children had shoulder dystocia should be offered an elective cesarian section delivery. However, cesarians deliveries also have risks associated with them, as large-scale studies have shown that 1% of OBPP occur during cesarian delivery. The use of an epidural anaesthesia during labour may contribute to the risk of OBPP, since the anaesthesia decreases the mother's ability to push during labour and may force the physician to use forceps to deliver the baby.
How is OBPP treated?

Treatment Goals

The main goals of treatment are to improve muscle strength and sensation and to alleviate muscle and joint contractures in the upper limb. Specific goals are to;

1. Increase shoulder abduction to more than 90 degrees.
2. Increase flexion and extension against resistance in elbow, wrist and fingers.
3. Improve sensation in the arm and hand
4. Prevent deformities in the arm and hand.
5. Correct rotation of the arm.

There are two main types of treatment.

• Surgical treatment
• Physiotherapy

1. Surgical treatment

There are two types of surgeries that can be done. "The primary" surgery involves exploration of the plexus and nerve repair. This type of surgery is done early in life. There are also many types of "secondary" procedures that might be necessary at a later age.

Early recognition of OBPP with referral to an appropriate treatment center provides the best chance for a full recovery.

For primary surgical intervention to be effective, it has to be performed when the baby is three months of age or shortly after, since the time factor is very important.

If it is delayed, the outcome will be much less favorable. Primary surgery gives the baby the best chance for full recovery. If however, the baby missed this chance and is seen later when he is above the age of two years it will be too late for primary surgery as the motor and sensory receptors are atrophic and cannot be properly reinervated.
# What are the types of surgery? Primary & Secondary

## Primary surgery
*(Exploration & plexurepair)*
- Early at age of 3 months or shortly after
- As the child grows up the quality of recovery will be less.
- Indicated if no biceps function or no hand movement at the age of three months
- It give the baby the best chance for full recovery
- Post operative physiotherapy and follow up are essential
- Child might need secondary surgery after two years to improve function

## Secondary surgery
*(Direct surgery on muscles, tendons and bones)*
- After the age of 2 years
- When spontaneous recovery is not adequate or following primary plexus exploration with residual functional deficit.
- Many procedures are available for each joint
- Post operative physiotherapy and follow up are essential
A - Primary surgery

Indications for primary surgical repair

1. Absence of recovery of the biceps muscle at the age of 3 months in upper palsy.
2. No hand recovery at 3 months even with biceps recovery, in total palsy. Horner's syndrome is a sign of severity in those cases and indicates surgery.

Plexus exploration and repair

Primary surgery is a full microsurgical procedure performed early in life at the age of three months or shortly after. The injured part of the plexus is fully explored under magnification to assess the extent and nature of the injury.

Primary surgical repair will almost always include these three basic operative procedures:
1. Neurolysis (removal of scar tissue surrounding the injured nerves)
2. Resection of severely injured parts of the plexus.
3. Reconstruction of the plexus with nerve grafts.

The steps for exploring brachial plexus palsy include;

1) Preparation of the baby.

The procedure is done under general anesthesia. The baby lies on his back with the face turned to the opposite side of the lesion. The neck is extended and the head supported. The neck, shoulder, the whole affected upper limb and the two lower limbs are prepared to obtain sural nerve grafts. The operative region is infused with a solution of diluted epinephrine (1/200000) as a vasoconstrictive material. No patient in our series has ever needed blood transfusion.

2) The incision.

For upper palsy (C5, 6 and 7 lesions) a supraclavicular incision is made. The classic incision has a vertical limb on the posterior edge of the sternomastoid muscle and a horizontal limb along the upper border of the clavicle. For total palsy the incision is supra and infraclavicular and the previous incision is extended along the delto-pectoral groove. In total palsy, osteotomy of the clavicle is mandatory and gives a better and less risky access to the lower roots.
3) **Plexus exposure**

The cutaneous triangular flap is lifted upwards with the underlying platysma muscle and the supraclavicular fat pad is mobilized laterally. The transverse cervical vessels cross the plexus in the posterior triangle and must be ligated. The supraclavicular nerves and superficial cervical vessels are also divided. The inferior belly of the omohyoid muscle is divided, followed by opening the deep fascia covering the scalenus anterior. The phrenic nerve is then identified and protected as it crosses the scalenus anterior obliquely from lateral to medial and confirmed with a nerve stimulator. Tracing the phrenic nerve superiorly will lead to the C5 spinal nerve as it exits the neural foramen. The C6 through T1 spinal nerves are identified as indicated deep to the scalenus anterior muscle:

![Fig (8) Exploration of the plexus.](image)

Typical finding of a neuroma involving the ruptured C5, C6 and C7

The spinal nerves normally emerge into the posterior triangle of the neck between the anterior and middle scalene muscles, and the fibrotic scar usually involves those muscles. Nerve stimulation is extremely important during plexus exposure. In any event, no muscle contraction during electrical stimulation to a given nerve root is a strong indication for nerve grafting procedure. By the end of exposure, the exact level, type and extent of the lesion should be determined for planning the method of reconstruction.
Fig (9) Exploration of the plexus showed avulsion of the lower roots C8, T1 from the spinal cord. A very severe type of injury

4) Plexus Reconstruction

Once the anatomic elements of the injured plexus have been identified proximally and distally, the surgeon must decide a plan for neural reconstruction based on the operative findings and pre-operative assessment. The most common intraoperative finding after surgical exposure of the plexus is a neuroma-in-continuity and the question of possible neurolysis versus resection of the neuroma and nerve grafting arises. Intraoperative stimulation can be useful as a guide for deciding between the two options. Neurolysis has been performed extensively, for many years with bad outcome. Now, most centers have abandoned neurolysis as an independent procedure. So, the finding of a neuroma is almost an indication for neuroma excision and nerve grafting.

Because of the nature of traction injuries, direct suture for repair is generally impossible and gaps after neuroma resection have to be bridged by means of cable nerve grafts. Although, there is a long list for donor nerve grafts, the most commonly used nerve is the sural nerve in the leg. Usually bilateral grafts of the whole nerve are needed for plexus reconstruction. They are taken by longitudinal or lazy S incisions along the whole length of the baby legs. Grafts are prepared on the table to match the exact length of the nerve defects in the plexus. The cables are glued together, and then transferred to bridge the plexus defects under the microscope using tissue glue or 10/0 fine sutures to achieve proper coaptation between the grafts and native elements of the plexus.
Fig (10A) Harvesting of sural nerve graft along
The whole leg, usually bilateral

Fig(9B) Different designs of cable grafts, prepared according to the extent of plexus injury and plan of repair. They are glued together with fibrin glue, ready for transfer

Fig (11) The grafts are put in place and glued together to replace the injured nerves after exposure and excision of neuroma

With root avulsion, the proximal portion of the nerve is not available for repair or grafting and neurotization is then necessary. The donor nerves may be from other parts of the plexus or extraplexual. Several donor areas have been used as spinal accessory nerve, intercostals nerves, cervical plexus, and contralateral C7

5) Wound closure
The supraclavicular fat pad is reapproximated for good soft tissue coverage of the repaired plexus. If the clavicle was osteotomised, ends are coapted with 3/0 vicryl, the skin is then closed in 2 layers with fine absorbable sutures. The baby
is put in a plaster cast (head and thorax) with the face turned towards the site of surgery to promote immobilization of the repaired site for 3 weeks. Donor sites for nerve grafts are also closed and dressed well using crep bandages. After 3 weeks the splint is removed and physiotherapy is resumed.

Fig (12) Postoperative, the cervical scar is usually invisible

6) Postoperative care and follow up.

The parents have to be taught how to remove the cast, to do bathing of the baby and dressing of the neck wound and then how to put it back during this period. Clinical signs of reenervation of the biceps and deltoid muscles cannot be expected before 6 months and may not appear before 9 months. Muscle strength will increase gradually over the next 18 months. Improvement of the hand and forearm muscles' function is detectable around 8 months and continues for 3-4 years.
**Potential Complications**

During brachial plexus repair, there is a minimal but documented possibility for the occurrence of certain complications, which commonly include:

a) Phrenic nerve injury, which is adjacent to the upper trunk of the brachial plexus. This injury will result in paralysis of the diaphragm. Repairing the nerve allows the paralysis to eventually resolve.

b) Injury to the pleura will cause pneumothorax.

c) Injury to the subclavian artery is possible.

d) Additional injury to the brachial plexus is possible, but can be easily avoided. It should be noted however, that a decrease in muscle strength can follow reconstruction of the brachial plexus with nerve grafts. This occurs because a functioning nerve root is sometimes cut and connected to the other part of the brachial plexus using nerve grafts. The muscle strength will most likely return by time, and the risk of such complications is very little.

e) Wound infection can occur around the incisions in the neck or the lower limbs.
B - Secondary surgery

Older children who continue to have major movement problems that limit the use of the affected upper limb require procedures which are applied directly to muscles, tendons and bones. Such surgeries include:

- Muscle release and transfer
- Tendon transfer
- Rotational osteotomies for bone alignment

**Indications for secondary surgery**

1) Neglected OBPP which has not been repaired primarily at the proper age
2) Cases which have been repaired at optimum age but recovered poorly.
3) Cases left for spontaneous recovery with only partial improvement achieved.

It is of great importance to apply a strict follow up program for all cases with plexus lesions whether surgically repaired or when spontaneous recovery is expected to evaluate the correct development of recovery and to decide the need for any secondary surgical procedure in the proper time.

*The secondary surgeries* include many procedures for each joint. The child might need more than one procedure.

1. **Shoulder**

   Normally the internal rotators and adductors are not affected by the paralysis and the child is able to internally rotate and adduct the arm but not the contrary.

   In most cases there is limited abduction, which does not reach the right angle (90 degrees) with a partial or total lack of external rotation of the arm. The hand can reach the mouth and frequently to do this movement, the child elevates the shoulder, which is called the "trumpet sign". The child's hand can hardly reach his ear and head and very seldom he can reach the nape of the neck.
At the age of two years the recovery of the shoulder functions, either spontaneously or after primary surgery, is considered completed. At that age, if a deficit of abduction or external rotation does still exist, an indication for secondary surgery has the aim to improve function by means of transferring active muscles by changing their original bone insertion and turning them towards the paralyzed or poorly functioning muscles.

There are many secondary surgical procedures that can be done to improve shoulder function, which include:

a) **Subscapularis muscle release**
   The muscle is completely detached from the scapula to improve the passive external rotation, strengthen the weak external rotator muscles and avoid long lasting joint deformities.

b) **Latissmus dorsi muscle transfer**
   The aim of the operation is to change the insertion of the muscle from the anterior aspect of the humerus to the rotator cuff posteriorly, transforming the action of the muscle from an internal to external rotation of the joint.

Fig(13A)Latissmus Dorsi Transfer
Drawing the incision, release of the tendon, dissection of the upper part of the muscle and keeping the blood and nerve supply intact
Fig (13 B) Latissmus Dorsi Transfer Tendon is released And transferred to rotator cuff (in the back of the humerus) this improves shoulder abduction and external rotation and allows the hand to reach the head

شکل (۱۳) خطوات نقل العضلة الظهرية العريضة

Fig (14) A four years old child with Upper OBPP left for spontaneous recovery with only 90° of shoulder abduction with no external rotation
Notice: Trumpet's sign

شکل (۱۴) إعاقة مفصل الكتف في طفلة عمرها ۴ سنوات تعاني من شلل علوي بالضفيرة العضدية
Fig (15) The result one year after surgery
(subscapular release and latissmus dorsi transfer)
With good recovery of active external rotation and shoulder abduction

(5) ) النتيجة بعد عام لإطلاق عضلة تحت لوح الكتف ونقل العضلة الظهرية العريضة

c) Teres major muscle transfer
With the same principles

d) Levator scapulae and trapezius muscle transfer
In severe deficit of shoulder with a complete abduction and external rotation, this procedure can restore even though partially, a useful function.

2. Elbow

It is not common to experience a deficit in active movement of the elbow joint but if this occurs, it is possible to replace the action of the biceps muscle by transferring a well-functioning muscle from its origin.
The rationale of these operations is to utilize good functioning muscles, changing their original bony insertion and to direct them to substitute the biceps muscle.

The following procedures are commonly used to improve elbow function:

a) Pectoralis major transfer
The pectoralis major is dissected and reinserted to the scapula and the biceps flexor
b) **Latissimus dorsi transfer**
Latissimus doris muscle is isolated and the upper part is reinserted to the coracoid bone while the distal part is inserted to the biceps tendon on the elbow.

c) **The Steindler operation**
The procedure consist of detaching the epitrochlear muscles, which are wrist flexors with a fragment of bone and transforming them into elbow flexors by reinserting them more proximally on the anterior surface of the humerus

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3. **Forearm**
In upper OBPP the forearm is pronated and supination is usually not possible. This is corrected by transferring the biceps tendon from its insertion into the ulna, allowing supination of the forearm or later by rotational osteotomy.

Another example of muscular imbalance that needs surgical correction is the supinated forearm that may be seen in severe total palsy. This useless and unaesthetic position of the hand can be solved by means of a surgical procedure through rerouting of the biceps tendon to transform it into a pronator of the forearm, therefore allowing the hand to turn the palm downward.

4. **Hand and wrist joint.**
The most common problem is inability to extend the wrist and phalangeal joints and this produces a severe handicap. This usually occurs in total plexus palsies in which the roots are avulsed from the spinal cord. To restore extension, a tendon transfer procedure is needed. The tendon of flexor carpi ulnaris is usually transferred from its insertion to the extensor surface of the wrist, to allow its extension. Other types of transfer are usually possible.

The hand is placed in a splint for 4:5 weeks post-operative. The optimum age for this procedure is 4 years because muscles of the hand and wrist take the longer time to recover.
5. Free muscles transfer
In selected cases in which no function at all is recovered especially for elbow flexion, there is still the possibility to transfer with microsurgical techniques a muscle from other parts of the body (usually the thigh)
2. Physiotherapy

From the first day of life, the child should have active and passive mobilization of the arm. Physiotherapy will not allow the nerves to heal any faster, but it can help prevent problems such as joint stiffness and muscle contractures (shortening).

The passive mobilization of the joints must be carried out not only by the hand therapist, but several times a day by the parents (home exercise program). These maneuvers that provoke a gentle stretching of the muscles and the joint structures avoid the development of capsular contracture and the excessive contraction of the functioning muscles not contrasted by the paralyzed muscles. It is of paramount importance to prevent all types of joint stiffness in order to induce as much as possible, the normal growth of the bones by maintaining correct relationships between their articular surfaces. Therapists provide parents with ideas for what positions will be beneficial for the child during play and sleep.

Direct muscular electrical stimulation is still a controversial issue and there is still no general consensus on this treatment and there is no scientific proof of the real trophic action on the muscle fibers.

Therapists have a more comprehensive role in the management of those cases than ever thought before. The following are the most important:

- Initially evaluate the child's arm strength, range of motion, active movement and motor development, sensation and functional use.
- Monitor splinting and positioning needs.
- Track progress and improvement.
- Educate parents on precautions, home exercise programs and positioning.
- Provide post-surgical therapy.

Rehabilitation program will, of course, change as the child grows. The first program embarked on will be performed in the hope of a possible spontaneous recovery or as a preparation for primary repair of brachial plexus. After primary surgery, the rehabilitation program will continue during the time necessary for the nerve recovery. Afterwards, when the surgeon will identify a possible deficit which could be treated in a second time by palliative surgery, the therapist will increase the exercises targeted to improve the function of muscle transfers. After the secondary surgery, again the therapist will aid the patient to cortically integrate the new movements.

All this longstanding, rehabilitative program will continue until the complete development of the arm.
**What is the prognosis after treatment?**

About 85% of infants with OBPP make a complete neurological recovery within 3:6 years. However, the prognosis for an individual OBPP depends on the location, severity and extent of damage and may be difficult to predict. In general, damage to the nerve sheath alone has a good prognosis. Praxis-type injuries, in which the nerve is damaged but not torn, usually improve within 3 months and eventually heal completely. Stretch injuries heal on their own, with 90:100 % of function returning within 1:2 years. Nerve roots avulsed from the spinal cord have poorer prognosis. In severe cases there may be permanent partial or total loss of nerve function and weakness or paralysis of the upper limb may be permanent.

Erb's palsy has the best prognosis because the hand and fingers are spared. However, infants with Erb's palsy that involves C7 have a poorer prognosis. It is possible to anticipate improvement in the function of the biceps 6 months after surgery and progressive recovery over the following 18 months. Muscles of the hand and forearm begin to recover within 8 months and continue to recover over a period of 3:4 years.

![Child with Upper OBPP, Operated upon at the age of 4 months](image)

**Fig (16A) Child with Upper OBPP, Operated upon at the age of 4 months**

![Post operative result after 3 years](image)

**Fig (16B) Post operative result after 3 years**
Fig (17A) Child with Total OBPP with Horner's syndrome, operated upon at the age of 5 months

شكل (١٧٢) طفلة مصابة بشلل كلي بالسفيرة العضدية مع متلازمة هورنر، تم التدخل الجراحي عند عمر ٥ شهور

Fig(17B) Post operative result after 4 years

شكل (١٧٣) التحسن الوظيفي بعد ٤ سنوات من إجراء الجراحة الأولية للطفلة مبكراً
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