Brachial plexus ultrasound in children with brachial plexus birth injury (BPBI)

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Learning objectives

The purpose of our educational exhibit is to:

1. Show the ultrasound technique for the brachial plexus study in children with BPBI.
2. Describe the most common ultrasound findings which have been found in these patients and their correlation with MR imaging.

Background

Definition:

Brachial plexus birth injury (BPBI) is defined as a flaccid palsy of an upper extremity due to traction and compression forces of the brachial plexus during birth. It results from injury to the cervical roots C5-C8 and thoracic root T1.

Incidence and risk factors:

The incidence of brachial plexus birth palsy is estimated to be between 0.4 and 4 per 1000 live births.

Perinatal risk factors include large for gestational age infants (macrosomia), multiparous pregnancies, previous deliveries resulting in brachial plexus birth palsy, prolonged labor, breech delivery, assisted (vacuum or forceps) and difficult deliveries. Only half of patients have one or more of these risk factors, which highlights the concept that the etiology of BPBI is not yet fully known.

Delivery by cesarean does not exclude the possibility of birth palsy, although the incidence is much lower (0.02%).

Classification of brachial plexus injuries and clinical presentation:

First, the anatomy of the brachial plexus is remembered (fig.1).
The brachial plexus (BP) is a group of nerves that includes anterior divisions of the cervical nerves C5, C6, C7 and C8 and the first thoracic spinal nerve, T1.

The BP is divided into five parts: roots (nerves), trunks, divisions, cords and branches.

Each nerve divides into anterior and posterior nerve fibers. The anterior divisions of spinal nerves C5-T1 pass between the anterior and medial scalene muscles to enter the base of the neck, here, the roots converge, forming three trunks:

- **Superior** (a combination of C5 and C6 roots)
- **Middle** (C7 root)
- **Inferior** (C8 and T1 roots)

The trunks reach the posterior triangle of the neck, and then they divide into two branches, which are known as the anterior and posterior divisions. These divisions are combined together to form three cords in the axilla:

- **Lateral** (the anterior divisions of the superior and middle trunks)
- **Posterior** (the posterior divisions of the superior, middle and inferior trunks)
- **Medial** (the anterior division of the inferior trunk).

The cords give rise to the major branches of the brachial plexus: musculocutaneous, axillary, median, radial and ulnar nerves.
Brachial plexus injuries are classified into three categories (fig. 2): *preganglionic lesions, postganglionic lesions and a combination of the two.*

A preganglionic lesion signifies avulsion of nerve roots from the spinal cord, whereas a postganglionic lesion involves the structure distal to the sensory ganglion. Postganglionic lesions are classified into three types:

- **Neurapraxia:** stretching of the nerve
- **Axonotmesis:** rupture of some axons
- **Neurotmesis:** rupture of the entire nerve

In terms of anatomical location, obstetrical brachial plexus palsies are divided into four categories:
• **Upper**: It involves C5, C6 and sometimes C7 (**Erb's palsy**). It is the most common type of brachial plexus palsies and it results in the characteristic "waiter tip" posture.

• **Intermediate**: It involves C7, and sometimes C8 and T1.

• **Lower**: It involves C8 and T1 (**Klumpke paralysis**). It is very rare and accounts for < 2% of all reported brachial plexus palsies. The main clinical feature is poor hand grasp, whereas more proximal muscles are intact.

• **Total plexus palsy**: It involves C5-C8 and sometimes T1 and is the second most common type of injury. It is the most devastating plexus injury. The infant is left with a clawed hand and a flaccid and insensate arm.

In clinical terms, brachial plexus injuries are divided according to Narakas's classification into four groups:

• **Group I**: C5-C6 involvement (**Erb's Palsy**). This represents 46% of all cases and is associated with the most favorable prognosis. The patient presents paralysis of the shoulder and biceps.

• **Group II**: C5-C7 involvement, it occurs 30% of the time and carries a worse prognosis than C5-C6 injury alone. It causes paralysis of the shoulder, biceps and forearm extensors.

• **Group III**: It denotes total plexopathy with flail extremity and occurs in only 20% of patients.

• **Group IV**: this is the most severe form, characterized by a flail extremity with Horner’s syndrome, which indicates involvement of the sympathetic chain and probable avulsion injury.

The majority (70-95%) of patients make complete spontaneous recovery. It has been reported that up to 92% of patients with BPBI have mild injury and spontaneous recovery within the first 2 months of life.

Both the extent (upper, lower, total) and the severity (avulsion, rupture, stretch) of the injury influence the prognosis. The upper plexus palsies are generally less severe.

Poor prognostic factors include total or lower plexopathy, Horner’s syndrome and increased root avulsions and associated fractures (e.g., ribs, clavicle, and humerus). According to Narakas, recovery in group IV is particularly poor.

Although most cases will resolve spontaneously, the natural history of the remaining cases is influenced by contractures of uninvolved muscle groups and subluxation or dislocation of the shoulder and elbow. Brachial plexus birth injury (BPBI) diagnosis
is based on clinical examination and electrophysiological studies. Imaging studies are complementary.

Imaging techniques, in the diagnosis, are used to exclude *causes of pseudoparalysis* such as epiphyseal separation of the humeral head (fig.3.A and B), fracture of clavicle (fig.3.C) or humerus (fig. 3. D) and to *assess associated lesions* such as diaphragmatic paralysis (fig.4). In this context, techniques of choice are the ultrasound and radiography, specially the first one.

**Fig. 3**: Causes of pseudoparalysis. Ultrasound is the technique of choice. A) Epiphysiolysis: Moderate epiphyseal separation of the humeral head. B) Normal location of the humeral epiphysis (red arrow) to compare. C) Fracture of the middle third of the right clavicle with separation and angulation of fragments (white arrows). There is haematoma (red arrow) in both fragments. D) Fracture of the humeral diaphysis (red arrow)

*References:* - Malaga/ES
**Fig. 4:** Associated lesions. Ultrasound is the technique of choice too. Evaluation of diaphragmatic movement with M mode US. A) Sagital US image of the left hemidiaphragm and M mode tracing show normal diaphragmatic movement. During inspiration, the diaphragm moves toward the transducer; during expiration, it moves away from the transducer. B) Sagital US image of the right hemidiaphragm and M mode tracing demonstrate there is not movement during inspiration nor expiration, a finding indicative of diaphragmatic paralysis.

**References:** - Malaga/ES

At follow-up of these patients, when there is no spontaneous recovery or severe injuries are suspected such as root avulsion or Horner’s syndrome..., resonance is the technique of choice because it allows us a more accurate determination of the extent, location and severity of brachial plexus injury.

In infants and children, conventional MR besides MR myelography is the technique of choice for the study of the brachial plexus. It allows to assess the spinal canal and brachial plexus postganglionic.

Imaging studies play an essential role in differentiating preganglionic injuries from postganglionic lesions, a differentiation that is crucial for determining the prognosis and management of BPBI. The management of BPI depends on the degree of damage, the site of injury, the type of involved roots, the time interval between the injury and the surgical procedure and the patient's age. The degree of damage and the site of injury are the most important factors.

Treatment of brachial plexus injury is either conservative or surgical.

Preganglionic injuries are not considered amenable to repair; consequently, the functions of some denervated muscles are restored with nerve transfers. In nerve transfer, donor
nerves are attached to the ruptured distal stumps, sacrificing the original function of the nerve for more beneficial results in the upper limb.

Postganglionic lesions with disruption of the nerve fiber (neurotmesis) are repaired with nerve grafting, that is, excision of the damaged segment and nerve autograft between two nerve ends. In postganglionic lesions with intact fascicles (axonotmesis and neurapraxia) spontaneous recovery is usually expected with conservative management.

Fig. 5: Shows a summary of therapeutic management of brachial plexus injury.

References: - Malaga/ES

Images for this section:
**Fig. 1:** Brachial plexus diagram

**Fig. 2:** Brachial plexus injuries
Fig. 3: Causes of pseudoparalysis. Ultrasound is the technique of choice. A) Epiphysiolysis: Moderate epiphyseal separation of the humeral head. B) Normal location of the humeral epiphysis (red arrow) to compare. C) Fracture of the middle third of the right clavicle with separation and angulation of fragments (white arrows). There is haematoma (red arrow) in both fragments. D) Fracture of the humeral diaphysis (red arrow).

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Fig. 5: Shows a summary of therapeutic management of brachial plexus injury.
Findings and procedure details

To perform a brachial plexus ultrasound, patient is placed in supine position with the neck turned to the contralateral side (fig. 6). Sometimes, the use of a pillow under neck can be useful for the exploration. High-frequency linear transducers (7-15 MHz) are used. No sedation is required.

First, the paravertebral area (fig.6. A) in transverse and longitudinal views is evaluated. After, the probe is move down for the neck to evaluate the interscalenic triangle (fig.6. B) in transverse and longitudinal views too.

Fig. 6: Shows how to do a brachial plexus ultrasound. High-frequency linear transducers (7-15 MHz) are used.

References: - Malaga/ES

As you can see here below (fig 7 y 8), the normal ultrasound anatomy of the paravertebral area and interscalene triangle is expounded, as well as its correlation with an anatomical diagram for a better understanding.
Fig. 7: Paravertebral area: normal ultrasound anatomy. Spinal nerves appear as hypoechoic structures with elongated morphology without flow at color Doppler study. A and C) Longitudinal and transverse scans respectively of the paravertebral area. B and D) Its correlation respectively with Sobotta's diagram.

References: - Malaga/ES

The interscalene triangle is bounded by the anterior and medial scalene muscles and first rib. This contains the spinal nerves and trunks of the brachial plexus.
BETWEEN MEDIAL AND ANTERIOR SCALENE MUSCLES
Spinal nerves and trunks of the brachial plexus

**Fig. 8:** Interscalene triangle: normal ultrasound anatomy. Spinal nerves and trunks of the brachial plexus appear as hypoechoic round structures between medial and anterior scalene muscles. A and b), Sobotta’s diagrams, show interscalene triangle. B image is the same than A image but 90° rotated in the opposite direction of clockwise. C) Transverse scan ultrasound of this.

**References:** - Malaga/ES

The ultrasounds of 24 patients with BPBI, which were performed in our department from January 2010 to November 2014, were analyzed retrospectively.

The age of our patients was between one day and nine months old.

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<tr>
<td>19 cases</td>
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**Table 1:** Shows the number of patients who had normal and pathological ultrasound study

**References:** - Malaga/ES
Table 2: Shows the imaging findings found in the cases with pathological ultrasound study

References: - Malaga/ES

Periscalene soft tissue (PST) is the most common ultrasound finding in our series of subjects with BPBI. This one indicates a postganglionic lesion of the brachial plexus.

PST may correspond to neuromas or fibrosis. Specific characteristics have not been found to distinguish between one and another, therefore the definitive diagnosis is the histological study.

PST may have several distinct patterns, possibly reflecting different histologic compositions.

The figures 9 and 10 show different patterns of PST found among our cases.
Fig. 9: Periscalenene soft tissue (PST): several patterns. A) Normal anatomy of brachial plexus B) PST appears as two round hypoechoic mass. The result was a neuroma in the histologic study. C) Small well defined mass between anterior and medial scalene muscles.

References: - Malaga/ES
Fig. 10: Periscalene soft tissue (PST): other patterns. A) PST appears as "T" morphology mass. It was a neuroma in the histologic study. B) Wrong defined mass. C) Fusiform morphology soft tissue. The result was fibrosis in the histologic study.

References: - Malaga/ES

Our cases and their correlation with resonance:

| 19 cases pathological ultrasound study → Resonance has been done for 13 cases |
| Correlation in all cases between ultrasound and MR to determine that there was periscalene soft tissue |
| 3 of these patients had pseudomeningoceles in resonance which were not seen in ultrasound due to the fact that they had not extraforaminal extension |
| 2 cases with extraforaminal pseudomeningoceles which were seen in ultrasound were confirmed in resonance |

Table 3: Cases and their correlation with resonance
Next, some cases are exhibited (figures 11, 12 and 13)

**Fig. 11:** Case 1: A 5 month old patient with left BPBI. A) Normal right braquial plexus. B) Transverse scan ultrasound of the interscalene triangle shows increased interscalene space. C) A transverse scan more below than B image demostrates wrong defined PST (red arrow) with poorly defined scalene muscles. D) A longitudinal scan of the paravertebral area shows three thickened and slightly hyperechoic roots (yellow arrows). E) STIR coronal image demostrates a hyperintense, irregularity and thickened root (yellow arrow), which is matched one of the described roots in the D image. F) FSE T2 axial image shows hyperintense and increased PST coursing through a fat plane between left scalene muscles (yellow arrow). Right normal interscalene space (green arrow) to compare. These imaging findings indicate a postganglionar lesion of the left brachial plexus.

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Fig. 12: Case 2: A 2 month old patient with right BPBI. A) Normal left braquial plexus. B and C) Transverse scan ultrasound of the interscalene triangle shows heterogeneous echogenicity mass and with fusiform morphology in the interscalene space (red arrow). D) FATSAT T1 axial with intravenous contrast demonstrates thickened and enhancement of roots between scalene muscles. E) FSE T2 axial image shows hyperintense and increased PST coursing through a fat plane between left scalene muscles (orange arrows). Left normal interscalene space to compare. These imaging findings indicate a postganglionic lesion (neuroma or fibrosis) of the right brachial plexus.

References: - Malaga/ES
Fig. 13: Case 3: A 3 month old patient with right BPBI. A) Normal anatomy of the paravertebral area (transverse scan). B) Transverse scan shows a hypo-anechoic collection in relation with pseudomeningocele in proximity to intervertebral foramina (red arrow). C) FSE T2 axial image demonstrates a right pseudomeningocele as a cerebrospinal fluid (CSF) intensity focus extending into the neural foramen (red arrow), similar imaging findings to B image. These findings mean a preganglionic injury (root avulsion).

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Ultrasound detects postganglionic brachial plexus injuries (outside the neural foramina), but has low sensitivity for pseudomeningoceles. Ultrasound is promising for demonstrating lesions outside the spinal canal and for establishing the site and level of nerve involvement.

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<td><strong>17 cases</strong></td>
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<td>Periscalene soft tissue + pseudomeningocele</td>
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Conclusion

Ultrasound can identify and locate properly the brachial plexus postganglionic lesions without sedation or contrast administration, due the fact that, it could replace to MR in the study of extraforaminal component plexus. It has a low sensitivity to detect pseudomeningoceles so it can not replace the resonance in the evaluation of the spinal canal.

The most common ultrasound finding is the periscalene soft tissue, which indicates a postganglionic injury and may correspond to neuromas or fibrosis.

Personal information

References
