Assessment of the Brachial Plexus  EMG Course – CNSF Halifax 2018

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What do these notes add?

If you attended our presentation and have a copy of the power-point presentation, then these notes may not add very much! We have provided them because they will explain some of the points we make in more detail (so if you think you missed something you can refer to them). The notes also explain some things that will not be covered in the presentation (such as the needle exam of the rhomboids and serratus anterior muscles). We have not re-produced the figures here; please refer to the power-point.

I. Objectives

1. Understand the limitations of routine nerve conduction studies (NCS) in brachial plexus assessment.

2. Be aware of less-commonly used NCS that can aid in brachial plexus assessment.

3. Have an approach to needle EMG examination for suspected disorders of the plexus.

II. Purpose

The presentation (and these notes) are intended for a general audience with some knowledge of EMG and brachial plexus anatomy. This is not intended to be a review of the differential diagnosis of conditions affecting the brachial plexus. Hopefully it will allow you to become more familiar (and more comfortable) with assessment of the brachial plexus by EMG (including ordering, performing and interpreting the testing). The presentation will not cover all aspects of electrophysiological testing of the brachial plexus, but instead will emphasize a few tests in detail with the hope that this will give you something practical you can take away and use.

III. Introduction

Many experienced electromyographers are not entirely comfortable with assessment of the brachial plexus simply because brachial plexus problems are not commonly seen in the EMG laboratory.

In Wilbourn’s study of the utility of different sensory nerve conduction studies in assessment of the brachial plexus (1) he reviewed 417 cases of brachial plexopathy seen over a period of 11 years at the Cleveland Clinic, which equates to approximately 3 cases per month. More
recently, Lindstrom and Ashworth reviewed all cases seen in their EMG laboratory over a one-year period and reported 59 cases of brachial and lumbosacral plexus injury (2). If there were equal numbers of brachial and lumbosacral plexus cases, then this too equates to about three cases per month.

So, if tertiary care EMG labs are only seeing 3 cases of brachial plexopathy per month it is difficult for an individual electromyographer to become experienced and comfortable with brachial plexus assessment.

The anatomy of the brachial plexus should not be difficult because it is well known. Although anatomy references will describe 5 parts to the plexus (roots, trunks, divisions, cords, and nerves) it is often useful to consider the roots and nerves separately because the pathology of nerve and root lesions differs from that of the main plexus trunks, divisions and cords.

As part of the history it is very important to consider the potential mechanism of injury and decide if injury to the plexus is plausible. For example, if the patient fell to the ground, asking what the position of their arm was and what the velocity of the fall was can suggest whether a stretch injury to the plexus is likely or not.

On examination it is important to look for muscle atrophy in the arm and muscles of the shoulder girdle, and to test the power of the muscles of the shoulder girdle. It is important to become comfortable with examination of the infraspinatus, teres major, rhomboids, latissimus dorsi, and serratus anterior muscles.

If you suspect a brachial plexus injury you should always ask which element(s) of the plexus may be involved. What does the mechanism of injury suggest? What does the pattern of muscle weakness suggest? It is often useful to sketch the main elements of the plexus:

![Diagram of the brachial plexus]

If necessary, refer to a reference to add in individual nerves arising from the plexus. Use your diagram to decide what to request when ordering the EMG, what elements of the plexus to test with the EMG, or to judge whether appropriate testing was done.

IV. Case

An 18 year-old man is referred for lack of improvement in right arm weakness 3 months after an MVA. On examination there is wasting of the right deltoid, infraspinatous, supraspinatous, and biceps muscles. Right shoulder abduction and elbow flexion are
essentially impossible. Right shoulder external rotation is very limited. Other movements are relatively normal. The right biceps and brachioradialis reflexes are absent. There is reduced sensation over the lateral arm and forearm.

Imagine you have this case in front of you. You think there could be a brachial plexus injury due to the mechanism of injury and the pattern of muscle weakness. Routine median and ulnar nerve conduction studies are normal. What do you do next?

V. **Nerve Conduction Studies**

* * * * *Routine median and ulnar nerve conduction studies test a very limited portion of the brachial plexus.*

Median motor, ulnar motor, and ulnar sensory studies (recording digit 5) all test axons passing through C8-T1 roots, the lower trunk, and the medial cord. The median sensory study (recording digit 2) tests the C7>C6 roots, middle trunk, and lateral cord.

The simple bottom line is that large sections of the plexus are not tested and proximal nerves arising off the plexus are not tested. Thus, it is often useful to test additional, less-commonly studies nerves. Two examples are the median and lateral antebrachial cutaneous (MAC and LAC) nerves.

The LAC is the distal continuation of the musculocutaneous nerve, while the MAC is a branch off the medial cord, arising just before the ulnar nerve.

The MAC and LAC are useful for three reasons in a case of suspected brachial plexus injury:

1. The MAC and LAC study plexus elements that are not tested by routine median and ulnar sensory NCS.

   For example, when compared to the routine median sensory digit 2 NCS, the LAC nerve is more likely to contain C6 axons and pass through the upper trunk (1).

2. Testing the MAC and LAC can avoid confounding from common compressive neuropathies.

   For example, the MAC nerve conduction study tests similar pathways to the routine D5 ulnar sNCS, but it is not prone to compression like the ulnar nerve (at the elbow or wrist).

3. Showing involvement of sensory axons suggests that the lesion is distal to the dorsal root ganglion (and distal to the nerve roots).

   In root lesions the distal axon (of the pseudo-unipolar sensory neuron) remains connected to the sensory neuronal cell body in the dorsal root ganglion and sensory nerve conduction studies will be normal. If sensory NCS are abnormal (and not due to confounding by a coincident compressive neuropathy) then the lesion must be distal to
the roots. The MAC and LAC are not commonly injured distally (by compression or other lesions) so if they are abnormal it strongly suggests plexus involvement.

VI. **Medial and Lateral Antebrachial Cutaneous NCS Technique**

The best position for performing these sNCS is with the patient supine and the shoulder slightly abducted.

For the LAC, measure from the stimulation site just lateral to the biceps tendon at the elbow in a straight line towards the radial artery/styloid, and mark at 12cm (G1) and 15cm (G2) for placement of the recording electrodes.

For the MAC, mark the stimulation site by measuring 4-5 cm proximally up the arm from a point just medial to the biceps tendon at the elbow (so towards the biceps muscle, staying medial to the brachial artery). Then measure from just medial to the biceps tendon at the elbow in a straight line towards the ulnar styloid process, marking first at 7-8cm (G1) and then 3cm more distally (G2) for placement of the recording electrodes.

Below are some suggestions that may help to troubleshoot certain technical problems:

<table>
<thead>
<tr>
<th>ISSUE</th>
<th>LIKELIEST SOLUTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lateral Antebrachial Cutaneous Nerve</td>
<td></td>
</tr>
<tr>
<td>No response</td>
<td>Stimulate directly over biceps tendon</td>
</tr>
<tr>
<td>Large motor artifact</td>
<td>Stimulus intensity too high, try reducing intensity/reduce pulse width to 0.05ms</td>
</tr>
<tr>
<td>Unexpected low amplitude</td>
<td>Make minor G1/G2 adjustments laterally</td>
</tr>
<tr>
<td>Medial Antebrachial Cutaneous Nerve</td>
<td></td>
</tr>
<tr>
<td>No recordable response</td>
<td>Stimulation site – feel for brachial artery at the height of your measurement and stimulate just medial to the pulse.</td>
</tr>
<tr>
<td>Unexpected low amplitude</td>
<td>Make minor G1/G2 placement adjustments (laterally)</td>
</tr>
<tr>
<td>Large stimulus artifact/motor artifact</td>
<td>Decrease stimulus intensity, use a very light touch with stimulator</td>
</tr>
</tbody>
</table>

VII. **Needle EMG Examination**

The needle EMG exam has two purposes in brachial plexopathy:

1. Localize pathology to one element of the plexus.

   To do this we take the same approach as we would for localizing a radiculopathy. It is important to first ask what muscles seem to be involved (and what do they have in common). Then, you can plan your testing by asking what other muscles can help you with localization. This is where it can be very useful to sketch out the brachial plexus,
mark off what parts seem to be involved, and then decide which muscles you can study to further narrow down the localization.

2. Test proximal muscles to confirm involvement of nerves arising proximally from the plexus and which cannot be tested with NCS.

“Nerves arising proximally from the plexus” refers to nerves other than the 5 main terminal branches of the plexus (median, ulnar, radial, musculocutaneous, and axillary nerves). There are some conditions involving the brachial plexus in which the pathology can be very focal. The best example is idiopathic brachial neuritis, which can sometimes involve only one or two proximal branches of the plexus.

A third use of the needle exam is to assess prognosis. For example, it may be possible to detect some intact motor units in a muscle that the patient appears to be completely unable to activate clinically. This is important because it implies that there is a good chance for clinical improvement (either via regeneration of damaged axons or collateral sprouting from intact axons). In the case of traumatic brachial plexus injury, one would usually not consider surgical treatment if some intact axons are present (and vice versa).

VIII. Examples of Specific Muscles

1. Infraspinatous

The infraspinatous muscle is located inferior to the spine of the scapula. It is innervated by the suprascapular nerve that arises proximally, either from or just before the upper trunk. It is a useful muscle to study because if it is involved it shows that the lesion affects the upper proximal part of the plexus. It is also useful because it tests a specific nerve, the suprascapular nerve.

To study this muscle, position the patient lying on their contralateral side, facing away from you, with their upper arm resting on their side, and their elbow flexed. Palpate the spine of the scapula and insert the needle inferior to the mid-point of the spine, perpendicular to the skin. Advance the needle until you feel it touching the scapula and then withdraw slightly. This is necessary because the infraspinatous muscle is usually at least partially covered by the trapezius and posterior deltoid muscles. Fortunately, this area is relatively less sensitive so advancing the needle to touch the scapula is not extremely painful for the patient. You can easily confirm correct needle placement by asking the patient to activate the muscle. To do so they lift their hand while keeping the elbow flexed and held against their side (thus externally rotating their shoulder).

2. Paraspinal Muscles

In theory testing paraspinal muscles is very useful. Paraspinal muscles are innervated by the dorsal ramus of spinal nerves, while it is the ventral rami that contribute to the brachial plexus. Therefore, if you detect fibrillation potentials in the paraspinal muscles the lesion must also be involving the roots. Unfortunately, there are a number of potential
difficulties with testing paraspinal muscles. The patient is often unable to relax and so the presence of multiple motor units can obscure fibrillations. It can be difficult to be certain what level you are testing, and it is often necessary to test multiple levels. Most importantly, paraspinal muscles often receive earlier reinnervation by collateral sprouting and so by the time you are testing the patient fibrillation potentials are no longer present.

The bottom line is that showing paraspinal muscle involvement is very helpful, but the apparent absence of involvement is not (3).

3. Rhomboids

The rhomboid muscles are located at the medial border of the scapula. It is innervated by the dorsal scapular nerve that arises proximally to the upper trunk. It is a useful muscle to study because if it is involved it shows that the lesion is proximal to the upper trunk. It also tests a specific nerve, the dorsal scapular nerve.

To study this muscle, position the patient in a similar manner as you would for testing the infraspinatous. They should be lying on their contralateral side, facing away from you, with their hand on their hip. The muscle is activated by having the patient push their elbow backwards towards you and it can usually be easily palpated, so needle insertion is not difficult. This position is often more comfortable than the other described position, in which the patient has their arm behind their back with their palm facing you.

4. Serratus Anterior

The serratus anterior covers/coats the posterior ribs underneath the scapula. It acts to stabilize the scapula with shoulder abduction. It is innervated by the long thoracic nerve that arises even more proximally, before the upper trunk. Like the rhomboids it is a useful muscle to study because if it is involved it shows that the lesion is proximal to the upper trunk. It is also useful because it tests a specific nerve, the long thoracic nerve, which can be commonly (and disproportionately) involved in certain pathologies like acute brachial neuritis.

There are two techniques described. In the first, the patient is positioned in a similar manner to the infraspinatous and the needle is inserted just below the inferior tip of the scapula. The muscle is deep and it is often necessary to have the patient activate the muscle (by extending their arm forwards in front of them) in order to confirm placement.

For the second technique, the patient can be positioned in the same manner or can be supine. The needle is inserted in the mid-axillary line above the sixth rib. Once again, activation of the muscle can confirm correct needle placement.

There is often a concern about the risk of pneumothorax when testing this muscle. However, the muscle lies superficially to the ribs, so as long as the needle is not inserted deep to the ribs there should be minimal risk. Inserting the needle slowly and activating the muscle can be helpful.
IX. Back to the Case

“An 18 year-old man is referred for lack of improvement in right arm weakness 3 months after an MVA. On examination there is wasting of the right deltoid, infraspinatus, supraspinatous, and biceps muscles. Right shoulder abduction and elbow flexion are essentially impossible. Right shoulder external rotation is very limited. Other movements are relatively normal. The right biceps and brachioradialis reflexes are absent. There is reduced sensation over the lateral arm and forearm.”

Median and ulnar NCS were normal.

Testing of the lateral antebrachial cutaneous nerve was done. A normal result was easily obtained on the left but no response was obtained on the right.

How does this help?

Involvement of a sensory nerve on NCS means pathology must be distal to the nerve roots. In the case of an absent LAC response, it means there is a lesion somewhere between the upper trunk of the brachial plexus and the LAC. It is unusual to have a lesion in the arm or forearm directly affecting the musculocutaneous nerve or the LAC, it’s terminal branch the LAC. A lesion involving either of these nerves would not explain all of the clinical findings. Therefore, the absent LAC nerve study localizes the pathology to the upper brachial plexus.

What can the needle EMG exam do to help?

A standard root screen would confirm the involvement of the deltoid, localizing the problem further to the upper trunk or it’s division contributing to the posterior cord:

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Fibrillations</th>
<th>Motor units</th>
<th>Recruitment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deltoid</td>
<td>2+</td>
<td>Prolonged, poly</td>
<td>↓↓</td>
</tr>
<tr>
<td>Pronator teres</td>
<td>1+</td>
<td>Prolonged, poly</td>
<td>↓</td>
</tr>
<tr>
<td>Triceps</td>
<td>0</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>First dorsal interosseus</td>
<td>0</td>
<td>N</td>
<td>N</td>
</tr>
</tbody>
</table>
Adding the biceps would not help localize the problem further, but demonstrating involvement of the infraspinatous means the problem must be at or proximal to the origin of the suprascapular nerve (from the most proximal part of the upper trunk). Showing that the rhomboids are spared would localize the lesion even more precisely, after the origin of the dorsal scapular nerve but before the origin of the suprascapular nerve:

<table>
<thead>
<tr>
<th></th>
<th>Biceps</th>
<th>Infraspinatous</th>
<th>Rhomboids</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2+</td>
<td>2+</td>
<td>0</td>
</tr>
<tr>
<td>Prolonged, poly</td>
<td></td>
<td>Prolonged, poly</td>
<td>N</td>
</tr>
<tr>
<td>↓↓</td>
<td></td>
<td></td>
<td>N</td>
</tr>
</tbody>
</table>

**X. Conclusions**

1. **Consider the mechanism of injury, look for atrophy, test the muscles of the shoulder girdle.**

   If you go back over the case presented here, you will see there were many clinical clues to the presence of a brachial plexus injury, likely involving the upper plexus, even before performing the EMG. Although the EMG is certainly helpful it is important not to forget your history and physical examination, and you should remember that you do not need to rely on EMG alone to localize a lesion.

2. **Sketch the brachial plexus and look it up if needed (brachial plexus anatomy is known!)**

   Don’t be intimidated by the anatomy. Take things step-by-step, mark off on your diagram what may or may not be involved, and plan further testing.

3. **Perform medial and lateral antebrachial cutaneous nerve conduction studies.**

   Once again, go back over the case here. Simply by showing involvement of LAC we were able to localize the problem to the upper trunk of the plexus or it’s division to the posterior cord. The needle exam “fine-tuned” this localization.

   If you are ordering an EMG in a case in which you suspect involvement of the brachial plexus, it can be very useful to both ask a specific question (“is there involvement of the upper trunk”) AND ask for specific testing to be done (ask for LAC and MAC nerves to be tested).

4. **Know how to needle proximal muscles of the shoulder girdle.**

   These muscles are not “more difficult” to test, so try them!
5. **Ask what else can be tested.**

There are other tests you can use to help in the diagnose of brachial plexopathies; radial sensory and motor NCS, median sNCS recording different digits (see reference 1), needle exam of other muscles, etc…. Simply put, we didn’t show you everything! What we have tried to do is show a general approach to a suspected brachial plexus lesion, as well as providing you with some practical details about a few specific tests.

Think about what you could test to help your localization, and don’t be afraid to try things.

**References**