Assessment of nerve root function in the upper and lower limbs

ANTHONY P. POHL MD, MB BCh, FRACS, FA(Orth)A

Testing motor and sensory function in the arms and legs requires knowledge of myotomes and dermatomes. Here is a guide to remembering the nerve roots of the upper and lower limbs.

A sound knowledge of nerve root function in the upper and lower limbs is essential for the assessment of many medical and surgical conditions. Spinal injuries, intervertebral disc disease with disc protrusion, poliomyelitis, Guillain–Barré syndrome and spina bifida are but a few examples. In these conditions, the physician has to ascertain that the clinical presentation represents nerve root involvement rather than peripheral nerve involvement and, more importantly, must be able to determine the nerve root level involved. A thorough knowledge of dermatomes and myotomes is mandatory to achieve this. Test your knowledge by completing the pretest box on this page.

This article presents some simple methods that will help you remember the nerve roots of the upper and lower limbs.

Lower limb

The motor system

There are only five facts to remember to determine the nerve roots controlling the muscles in the leg.

The first four facts are:

- in the leg, everything starts at L2
- the muscles that move each joint are innervated by four nerve roots
- as you move down one joint, you move down one nerve root level
- 'front' before 'back' (this will be clarified later).

If everything in the leg starts at L2 and the muscles that move each joint are innervated by four nerve roots then the nerve roots innervating the muscles moving the hip joint will be L2, L3, L4 and L5.

Further, if as you move down one joint you move down one nerve root level then the nerve roots innervating the muscles moving the knee joint will be L3, L4, L5 and S1. Applying the same principles, the nerve roots innervating the muscles moving the ankle joint will be L4, L5, S1 and S2.

What about the terms 'front' and 'back'? I use these terms to avoid confusion with the terms 'flexor' and 'extensor'. For example, moving down the 'front' of the leg, the muscles lying in front of the hip joint will be flexors, those in front of the knee joint will be extensors,

Pretest: nerve roots of the limb myotomes

Do you know the nerve root level of innervation of the muscles listed below?

Upper limb		Lower limb	
Deltoid	———	Iliacus	———
Pectoralis major	———	Psoas	———
Latissimus dorsi	———	Quadriceps femoris	———
Brachialis	———	Semimembranosus	———
Biceps humeri	———	Semitendinosus	———
Triceps	———	Biceps femoris	———
Extensor carpi radialis longus	———	Tibialis anterior	———
Extensor carpi radialis brevis	———	Tibialis posterior	———
Extensor carpi ulnaris	———	Peroneus longus	———
Flexor carpi radialis	———	Peroneus brevis	———
Flexor carpi ulnaris	———	Gastrocnemius	———
Extensor digitorum communis	———	Soleus	———
First dorsal interosseous	———		
Second lumbrical	———		
Adductor pollicis	———		
Abductor pollicis brevis	———		
Opponens digiti minimi brevis	———		

If you are not sure of the nerve roots of all the muscles listed, the points outlined in this article will provide all the answers.

Mr Pohl is Director of Trauma, Department of Orthopaedics and Trauma, Royal Adelaide Hospital, Adelaide, SA.

those in front of the ankle will be dorsiflexors and those in front of the big toe will be extensors. Therefore, for our purposes, the terms 'front' and 'back' are simpler.

The 'front' before 'back' principle is applied as follows. At each joint, merely divide the four nerve roots in two. The first two nerve roots innervate the muscles at the front of the joint, the second two innervate the muscles at the back of the joint. At the hip joint, the four nerve root levels are L2, L3, L4 and L5. Therefore, by dividing them in two, the muscles at the front of the hip joint will be supplied by L2 and L3 and those at the back of the hip will be supplied by L4 and L5. Which muscles lie in front of the hip joint? Answer: the iliopsoas (iliacus and psoas). Which muscles lie behind the hip joint? Answer: the glutei.

Applying the same principles, the nerve roots innervating the muscles moving the knee joint are L3, L4, L5 and S1. The muscles in front of the knee (the quadriceps) will be supplied by L3 and L4, and those at the back (semimembranosus, semitendinosus and biceps femoris) by L5 and S1.

Likewise, the nerve roots innervating the muscles moving the ankle are L4, L5, S1 and S2. The muscles in front of the ankle will be supplied by L4 and L5, and those at the back (the primary plantarflexors – gastrocnemius and soleus) by S1 and S2.

What about inversion and eversion of the foot? Quite simply, with inversion and eversion everything also begins at L4, but asymmetrically as there are only three nerve roots involved. The invertors are innervated by L4, and the evertors by L5 and S1. Tibialis anterior and posterior are the prime invertors, which are therefore innervated primarily by L4. The tibialis anterior inverts the foot in dorsiflexion while tibialis posterior inverts the foot in plantarflexion. The peronei (peroneus longus and brevis) are the evertors, which are innervated by L5 and S1.

Limb reflexes

Reflex testing may be used to localise a lesion as it provides an assessment of the same nerve roots as motor function. A useful way to recall the nerve root levels involved is to remember that, numerically, they progress sequentially from 1 to 8 as you move up from the ankle jerk (1 and 2), through the knee jerk (3 and 4) to the biceps jerk (5 and 6) and triceps jerk (7 and 8). Only the spinal levels change – that is, sacral for the ankle jerk, lumbar for the knee jerk and cervical for the biceps and triceps jerks (Figures A to D).

When knee or ankle reflexes appear sluggish or are difficult to elicit, Jendrassik's manoeuvre may be useful. Ask the patient to relax his or her legs while pulling on his or her hooked together flexed fingers and clenching the teeth (Figure E). This manoeuvre accentuates the ankle and knee jerks.

Figure A. Ankle jerk, S1 and S2.

Figure B. Knee jerk, L3 and L4.

Figure C. Biceps jerk, C5 and C6.

Figure D. Triceps jerk, C7 and C8.

Figure E. Jendrassik's manoeuvre.

continued

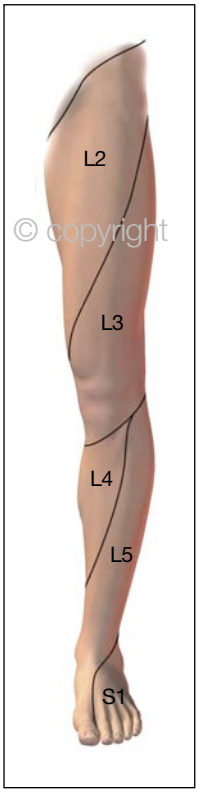

Figure 1 (left). Dermatomal pattern of the front of the lower limb.
Figure 2 (right). Dermatomal pattern of the upper limb (same front and back).

Nerve roots of the lower limb

Motor

- In the leg everything starts at L2
- The muscles that move each joint are innervated by four nerve roots
- As you move down one joint, you move down one nerve root level
- Muscles at the 'front' of the joint before muscles at the 'back'
- Ankle inversion is L4, ankle eversion is L5 and S1

Sensory

Because the leg rotates during embryogenesis, the dermatomes of the front of the leg follow a well defined spiral pattern (remember the emu):

- Medial thigh = L2
- Lateral thigh to knee = L3
- Medial calf = L4
- Lateral calf to big toe = L5
- Lateral foot = S1

The dermatomes of the back of the leg overlap:

- S1, S2 and S3

Therefore, the fifth fact in our list is:

- ankle inversion is L4 and ankle eversion is L5 and S1.

These five facts provide all the information needed for the pretest on myotomes and to determine the motor level of involvement in the lower limb of any nerve root lesion.

Testing motor function

When I test motor function, I test muscle power in the myotomes described above (flexion and extension of the hip, knee and ankle, and inversion and eversion of the foot). I also assess muscle tone and reflexes (see the box on page 57). In the absence of pathology, 'motor power, tone and reflexes were normal' is a good way of expressing normal motor function in the limb.

The sensory system

It is important to remember that the dermatomes of the front of the leg spiral down rather than run straight down. Somehow this is a fact that is frequently forgotten. A useful way to remember this is to think of someone (perhaps your pet aversion in life) looking like an emu with backwards pointing 'knees', bulbous gooseflesh thighs and thin, stalky lower legs. This picture should be so ridiculous that you never forget it. The point of this image is that, embryologically, we start off with our knees pointing backwards early in *utero*. Fortunately, as we develop, our knees rotate around to the front, dragging the dermatomes with them.

Armed with this information, consider the dermatomes in the leg. The skin over the inguinal ligament is supplied by L1 (confirming the fact that everything in the leg then starts at L2). Consequently, the skin on the medial side of the thigh is supplied by L2. The skin on the outer side of the thigh, extending down to and including the knee, is supplied by L3. However, the skin on the outer side of the lower leg is not supplied by L4. This is the reason for remembering the emu.

Imagine a picture of a leg, seen from the front, with five vertical 'panels' of innervation (L2 to S1) marked out as shown in Figure 1. The inguinal ligament runs obliquely from the anterior superior iliac spine to the pubic tubercle. The L2 dermatome lies below that, spiralling round from the lateral side to the medial side. The L3 dermatome lies below that, spiralling round from the lateral thigh down to and including the knee. Because of this spiralling pattern, the L4 dermatome then lies on the medial side of the leg, not the lateral side. The L5 dermatome lies on the lateral side of the leg, rotating around medially, down to and including the big toe. The area of skin left on the lateral side of the foot is supplied by S1.

Testing sensory function

In my screening examination of the well defined dermatomes of the front of the leg I test light touch only, using my finger to touch the skin. I test the most central portion of the dermatome, furthest away

from junctional areas of innervation. If there is any abnormality, or if a more detailed examination is required, I test light touch with cotton wool, pin-prick, temperature (conveniently, a tuning fork is usually cold), vibration and joint position sense.

The sensory supply to the back of the leg is through the sacral segments S1 to S3, but variation in the dermatomal pattern of distribution does not allow accurate localisation of a lesion. Therefore, in a screening examination I do not test sensation on the back of the calf or thigh; I do, however, always test perianal sensation, which is supplied by S4. The dictum 'If you don't put your finger in, you put your foot in' applies equally to neurological assessment as it does to surgical assessment. A digital assessment of anal tone and perianal sensation is the only way to adequately test motor and sensory function of the lower sacral segments.

Nerve roots of the upper limb

Motor

Remember the upper limb 'dance'

- The muscles that move the shoulder joint are innervated by four nerve roots asymmetrically – i.e. abduction = C5, adduction = C6, C7, C8
- The muscles that move the elbow are innervated by the same four nerve roots symmetrically – i.e. flexion = C5 and C6, extension = C7 and C8
- Thereafter, as you move down one joint you move down one nerve root level, but each joint is innervated by only two nerve roots – i.e. wrist flexors and extensors = C6 and C7, metacarpophalangeal joint flexors and extensors = C7 and C8
- In the hand, all small muscles are innervated by T1

Sensory

Remember the nerve arising from the cervical vertebra with the longest spinous process – C7 – innervates the longest finger:

- Lateral upper arm = C5
- Lateral forearm, lateral hand, thumb and index finger = C6
- Middle finger = C7
- Medial forearm, medial hand, ring finger and little finger = C8
- Medial upper arm = T1

Upper limb

The motor system

The pattern of innervation of the nerves controlling the muscles of the arm is not as simple as in the leg, but the following principles apply:

- the muscles that move the shoulder joint are innervated by four nerve roots (C5, C6, C7 and C8) asymmetrically – that is, the muscles controlling abduction are innervated by C5 and the muscles controlling adduction are innervated by C6, C7 and C8
- the muscles that move the elbow joint are innervated by the same four nerve roots but symmetrically – that is, flexion is controlled by C5 and C6 and extension is controlled by C7 and C8
- thereafter, as you move down one joint you move down one nerve root level, but each joint is innervated by only two nerve roots – that is, at the wrist, both the flexors and extensors are innervated by C6 and C7; at the metacarpophalangeal joints, both the flexors and extensors are innervated by C7 and C8
- in the hand, all small muscles are innervated by T1.

It will be useful now to stand up and move your arm through the sequence of movements outlined in the four points above. To an outsider this may look like a dance, but it will help to firmly entrench the myotomes in your mind. When you examine a patient in an emergency situation, this knowledge has to be immediately available to you – preferably in your mind, not in your briefcase.

The sensory system

To remember the dermatomes of the arm, imagine an arm in the anatomical position (palm forward). A useful association to remember is that the nerve arising from the cervical vertebra with the longest spinous process ('vertebra prominens') – C7 – innervates the longest finger. Imagine a line down the centre of the arm splitting at the hand to encompass the long (middle) finger and crossed at the elbow, as shown in Figure 2. The areas thus formed are innervated as follows:

- the lateral upper arm by C5
- the lateral forearm, lateral hand, thumb and index finger by C6
- the middle finger by C7
- the medial forearm, medial hand, ring finger and little finger by C8
- the medial upper arm by T1.

Summary

The principles described in this article for remembering the nerve roots of the lower and upper limbs are summarised in the boxes on page 58 and this page. MT

DECLARATION OF INTEREST: None.