Brachial Plexus Injury: Diagnosis of Nerve Root Avulsion Using Multislice CT Myelography

Ahmed Fathy Abdel Ghany¹, Noha Mohamed Osman Rabie¹, Ayman Abdel Raoof El-Shazly²
Departments of Radiodiagnosis¹, Neurosurgery², Ain Shams University; Egypt

ABSTRACT

**Background:** Recent advances in neurosurgical treatment of traumatic and birth-related brachial plexus injuries require differentiation of pre-ganglionic nerve rootlet avulsion from postganglionic lesions. **Objective:** The purpose of this study was to evaluate the efficacy of thin-section multislice CT myelography for revealing cervicothoracic nerve rootlet avulsion in patients with brachial plexus injuries before surgery. **Methods:** CT myelography for 11 patients suffering from brachial plexus injury manifestations was performed by intrathecal injection of the lumbar subarachnoid space by water soluble contrast medium followed by multi-slice axial CT scans then coronal, sagittal and oblique coronal reconstructions were created. The results of CT myelography were evaluated and classified with presence of pseudo-meningocele, intradural ventral or dorsal nerve rootlets injuries. Its diagnostic accuracy was correlated with surgical and clinical correlation in 20 cervical roots in these 11 patients suffering from brachial plexus injury in which avulsion root injury was suspected. **Results:** Coronal and oblique coronal views were superior to axial views in visualization of the nerve roots and orientation of its exact level. Sensitivity and specificity of CT myelography for diagnosis of intradural ventral or dorsal nerve root injury with or without pseudo-meningocele in pre-ganglionic avulsion were 95% and 95% respectively. **Conclusion:** The information provided by CT myelography enable to assess the roots of the brachial plexus and added valuable data for helping to decide whether to proceed with exploration, nerve repair, and primary reconstruction or not. [Egypt J Neurol Psychiat Neurosurg. 2011; 48(1): 63-69]

Key Words: CT myelography, brachial plexus injury, nerve root avulsion.

INTRODUCTION

Brachial plexus injury is caused by severe traction force exerted on the upper limb, resulting in complete or partial motor paralysis. An upper brachial plexus lesion involves spinal nerves C5 and C6 that leads to paralysis of the shoulder muscles and biceps. When the damage extends to spinal nerve C7, some of the wrist muscles are also impaired. A lower brachial plexus lesion involves spinal nerves C8 and T1, it involves paralysis of the forearm flexor and the intrinsic muscles of the hand¹. Injuries to the stellate ganglion or cervical sympathetic trunk cause Horner's syndrome. The most common cause of BPI is traffic accidents, especially motor cycle accidents, with most of the victims being young males. The other common cause of BPI is birth palsy. The majority of obstetric BPI involves the upper brachial plexus and is referred to as Erb's or Duchenne's palsy. Lower type obstetric BPI (Klumpke's palsy) is rare. Other traumatic causes include accidents at work, sports injuries, incised wounds, gunshot wounds, carrying heavy objects, and patient mal-positioning during surgery². Tumors, Irradiation, and congenital abnormalities such as cervical ribs can be non-traumatic causes of brachial plexopathy. BPI is classified into three categories: pre-ganglionic lesions, post-ganglionic lesions, and a combination of the two. A pre-ganglionic lesion signifies avulsion of nerve roots, whereas a post-ganglionic lesion involves the nerve structure distal to the sensory ganglion. Postganglionic lesions are further classified into nerve ruptures and lesions in continuity (Figure 1)³. 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, sex, and occupation. The degree of damage and the site of injury are the most important factors³. Treatment of BPI is either conservative or surgical. Representative surgical procedures include neurolysis, nerve grafting, nerve transfer, and other reconstructive procedures involving the transplantation of various structures.

Pre-ganglionic injuries are not considered amenable to repair; consequently, the functions of some denervated muscles can be 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 limb⁴. It is generally agreed that the top priority of nerve repair is restoration of biceps muscle function and the second goal is reanimation of shoulder...
function. Intercostal nerves are commonly used as the donor nerves transferred to the musculocutaneous nerve to regain elbow flexion. Functional recovery of the shoulder is largely achieved with spinal accessory nerve–suprascapular nerve transfer. Reconstructive surgery is indicated for infants with severe obstetric BPI, but management details are controversial even among professional peripheral nerve surgeons.

Postganglionic lesions with disruption of the nerve fiber are repaired with nerve grafting that is, excision of the damaged segment and nerve autograft between two nerve ends. In cases in which (a) postganglionic lesions in continuity are non degenerative or (b) fascicles are intact, spontaneous recovery is usually expected with conservative management. Lesions in continuity of degenerative type with damaged fascicles are treated with nerve grafting. Some surgeons doubt the benefit of neurolysis, although this technique has been reported to be effective.

Surgical nerve repair can provide a functional, useful limb in most patients with BPI. Nagano et al. reported that elbow flexion was restored in 82% of patients who were under 40 years of age and underwent intercostal nerve transfer within 6 months of injury. A recent report demonstrated good or excellent results in 75% of suprascapular nerve reconstructions, 40% of deltoid reconstructions, and 48% of biceps reconstructions. Some physicians still believe that there is rarely a need for surgery. However, patients with severe BPI should undergo an appropriate reconstructive procedure before denervated muscles become irreversibly atrophic and they are no longer good candidates for primary nerve repair.

The purpose of this study was to evaluate the efficacy of thin-section multislice CT myelography for revealing cervicothoracic nerve rootlet avulsion in patients with brachial plexus injuries before surgery.

**Figure 1.** Drawings showing the different possibilities of root avulsion (ventral or dorsal) after traction injury of the brachial plexus. **Upper left:** single ventral rootlet avulsion. **Upper right:** single avulsion of dorsal rootlet. **Lower left:** complete root avulsion. **Lower right:** complete root avulsion at the level of the inter-vertebral foramen (Quoted from Carvalho et al., 1997).

**Patients and Methods**

Between January 2009 and March 2010, 11 patients with brachial plexus injury were examined at MRC CT unit. The group comprised 5 males and 6 females, ranging in age from 3 months to 50 years (mean, 29 years). Three patients had a complete brachial plexus palsy, three had lower brachial plexus palsy, and five patients had upper brachial plexus palsy. Intrathecal contrast administration was performed by lumbar puncture employing watersoluble contrast medium using a concentration of 240 mg/ml Iotrolan (Isovist (R), Osaka, Japan), the dose was 10 ml in adults and 2-3 mm in infants. Contrast administration was successful in all patients. CT myelography was performed within 10 minutes afterwards. It was performed at a 16-slice helical CT scanner (Bright Speed 16, General Electric Medical Systems Co., Ltd., Milwaukee, USA) with the following scanning protocol: Scanning parameters consisted of 16 slices with 1mm x-ray beam collimation, 0.75 sec of rotation time, and a reconstruction interval of 0.5 mm. The patient was positioned supine with some flexion of the cervical spine. This position aligns lordotic curvature of the
cervical spine in a straight line, which is very important to gain the good quality CT myelography in coronal view. Helical images were transferred from the scanner to a workstation, (Advantage Window 4.0; GE Medical Systems, USA). The transverse (axial) sequence was acquired to determine the status of the ventral and dorsal roots. Coronal and sagittal views were then reconstructed based on transverse slice. Oblique coronal views were achieved by reconstructions parallel to the neural foramen. The best views for evaluating the dorsal root sleeves and nerve roots were the 20° to 30° anterior oblique projection. Reconstructions were successfully generated for all the patients. In good quality CT myelogram on axial view, the ventral root and the dorsal root were clearly demonstrated in a single image (Figure 4d). The presence of the roots was aided by comparison with the contralateral intact root. We followed the diagnostic criteria of Yamazaki et al, who classified CT myelographic diagnosis of root avulsion based as follows: A(+); ventral root can be recognized, A(-); ventral root cannot be recognized, P(+); dorsal can be recognized, P(-); dorsal root cannot be recognized, M(+); meningocele can be recognized, M(-); meningocele cannot be recognized. A nerve root was considered avulsed from the spinal cord when either ventral or dorsal roots were unrecognizable on axial view, while on coronal and oblique coronal views, nerve roots were considered avulsed when the number or size of rootlets was decreased or the roots were absent.

**Data analysis**

We compared the sensitivity, specificity, and diagnostic accuracy between the axial CT images and the coronal and oblique coronal CT images.

**RESULTS**

A hundred and ten nerve roots were examined (10 in each patient), 20 roots proved to be avulsed by surgical exploration and clinical tests, 16 (80%) out of the 20 roots were identified on axial views. On coronal and oblique coronal views, 19 (95%) roots were diagnosed, some motion artifacts degraded image quality in the remaining root, while 14 meningoceles were equally seen in the axial as well as the coronal views (Figure 2).

Nerve root avulsion was positive in 16 roots and negative in 4 roots as identified at axial CT images. Statistical analysis showed 80 % sensitivity, 80 % specificity, and 80 % diagnostic accuracy, with 16 true-positive findings, no true-negative findings, no false-positive findings, and four false-negative findings for diagnosing root avulsion.

Nerve root avulsion was positive in coronal and oblique coronal views in 19 roots and negative in 1. Statistical analysis showed 95 % sensitivity, 95 % specificity, and 95 % diagnostic accuracy, with 19 true-positive findings, no true-negative findings, no false-positive findings, and one false-negative findings for diagnosing root avulsion.

![Figure 2. Avulsed nerve roots and meningeoceles identified in CT myelography.](image-url)
Figure 3. A one year old patient with right sided Klumpke's palsy, axial (a), coronal (b) and (c) CT myelogram showed avulsed right C7 and C8 identified in sequential coronal scans as well as a small right C8 meningocele, the diagnosis was confirmed intra-operatively.

Figure 4. 40 years patient with traumatic left sided brachial plexus injury, coronal (a), sagittal (b) and oblique (c) CT myelogram showed avulsed left C5, C6 and C7 roots with left C5 and C7 meningoceles, diagnosis was confirmed by surgery and managed by nerve transfer.
Figure 5. 40 years patient with traumatic right sided brachial plexus injury, coronal (a and b), sagittal (c) and axial (d and e) CT myelogram showed avulsed right C6 and C7 roots with two small intra spinal meningoceles (note absence of the nerve rootlets in the meningocele and their presence in the normal contra-lateral side), it was inoperable, diagnosis was confirmed after conservative follow up.

DISCUSSION

Diagnostic imaging of brachial plexus injuries is important to locate the level of the injury, as prognosis and treatment planning depend on differentiating nerve root avulsion from lesions distal to the sensory ganglion. Preoperative imaging has previously been performed using conventional myelography, computerized tomography (CT) myelography, and magnetic resonance imaging (MRI). Doi et al reported that overlapping coronal-oblique slices MRI technique, which provide clear image of the rootlets and ganglia had the same accuracy as that of CT myelography. MRI has recently been shown to be as sensitive as CT myelography, MRI has many advantages without considerable exposure to radiation, a possible adverse reaction to contrast material, and the risk of lumbar puncture. The most common findings with nerve root avulsion are traumatic meningoceles. MRI is superior to conventional myelography and CT myelography in visualizing small meningoceles, which do not fill with contrast medium in a presence of a dural scar. This MRI technique, however, require special skill to obtain good-quality images and evaluate the images. Despite the advent of MRI, which has replaced other imaging techniques for evaluation of almost all disease of the spine, conventional myelography and CT myelography are still considered the first-choice examinations in the evaluation of brachial plexus injury.
In the 20 cases of nerve root avulsion seen in our study, six (30%) had no associated deformity of the subarachnoid space or pseudomeningocele. Other studies have reported nerve root avulsion without pseudomeningocele in 20% and only minimal deformity of the subarachnoid space in 44% of cases.13 The length of time required for pseudomeningocele development is unknown and no patient in our study was examined at two different times to determine whether delayed pseudomeningocele formation occurs.

CT myelography was able to show ventral and dorsal roots exiting or entering the spinal cord at 95% of the levels evaluated. In any evaluation of brachial plexus injuries, all contributing cervicothoracic nerve roots originating from C5 to T1 must be included. Incomplete evaluation of all contributing levels limits presurgical planning and may necessitate a more extensive surgical exploration. We have found high-resolution CT myelography with thin contiguous axial sections to be highly useful for evaluating nerve roots avulsions in brachial plexus birth palsies and post-traumatic brachial plexus injuries. We found a 95% sensitivity and 95% specificity for complete nerve rootlet avulsion with diagnostic accuracy of 95%.

Preoperative CT myelography allows more complete injury evaluation for accurate prognosis and surgical planning. In summary, we found high-resolution CT myelography helpful when evaluating brachial plexus injuries. We recommend the use of 1 mm contiguous axial images in infants and a 1.5 mm slice thickness in adults with a 1 mm overlapping interval followed by coronal, oblique and sagittal reconstructed images. Imaging from the C3 vertebral body to the superior aspect of T2 is required to include all nerve roots contributions to the brachial plexus.

CT myelography is superior to conventional myelography in visualizing the nerve roots. It is, however, sometimes difficult to determine the exact level of the root with axial imaging, because the roots run obliquely. It is difficult to detect the entire extent of root injuries with single axial slice of the images.

CT myelography with axial view allowed demonstration of the roots and also differentiation between the ventral and dorsal roots (Figure 5). As the spinal nerve roots run in oblique direction, the continuity of some nerve roots from the cord to the exit foramen can not be identified in axial views. Coronal and oblique coronal views were superior to conventional axial views in visualization of the number and size of roots and their connection to the cord, and in orientation of the exact level of the root (Figures 3 and 4). Coronal views visualized the whole image of the ventral roots, and oblique coronal views visualized the dorsal roots.

We believe that CT myelography is useful for determining the status of the nerve roots and detecting nerve root avulsion, although diagnostic utility was not significantly different. In this study, we reviewed twenty roots from C5 root down to D1 root. Exploration of the all the roots was not routinely performed, since the nerve graft is not effective in the lower roots. Brachial plexus exploration cannot reveal intraforaminal rootlet lesions unless laminectomy is performed. Intraoperative nerve action potentials obtained at the proximal cervical root attempt to evaluate the intraspinal status of the roots extraspinally.

Conclusion

CT myelography, in spite of its invasiveness, is still indispensable for preoperative evaluation of cervical nerve root avulsion of brachial plexus injury because of its precise delineation of the nerve roots integrity.

[Disclosure: Authors report no conflicts of interest]

REFERENCES