Diagnostic Performance of Short MR-Neurography Protocol for Brachial Plexus Injuries

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ABSTRACT

Objective: To study the diagnostic performance of MR neurography (MRN) for brachial plexus injuries and to optimize the protocol using clinical contexts as the reference standard.

Methods: There were 21 patients with brachial plexus injury who were scheduled for conventional myelography. A brachial plexus MRN including T2-weighted image-high resolution (T2WI/HR), mDIXON and diffusion weighted image was performed prior to a conventional myelography on the same day. The results of the conventional myelography and the MR imaging were recorded and compared, with the clinical contexts as the reference standard. The sensitivities, specificities, accuracies, false positive and false negative were calculated and compared.

Results: The accuracy, sensitivity, specificity, false positive and false negative of the conventional myelography were 69.52%, 73.61%, 60.61%, 19.70% and 48.72%, respectively. The diagnostic performance of T2WI/HR were 72.00%, 78.26%, 58.06%, 19.40% and 45.45% for T2WI/HR, respectively which were comparable to those of conventional myelography. The accuracy, sensitivity, specificity, false positive and false negative of the combination of T2WI/HR and mDIXON were 78.00%, 97.10%, 35.48%, 22.99% and 15.38%, respectively which yielded the highest accuracy.

Conclusion: MRN with the combination of T2WI/HR and mDIXON was superior to conventional myelography for the evaluation of brachial plexus injuries due to its shorter processing time, the lack of a need for contrast medium administration, its noninvasive nature, and the provision of information about both preganglionic and postganglionic injuries.

Keywords: MR-neurography; high-resolution MRI; brachial plexus injury; nerve root avulsion (Siriraj Med J 2019; 71: 284-289)

INTRODUCTION

Traumatic brachial plexus injuries in adults mostly occur in young people aged between 20 and 30 years.[1] Preganglionic lesions result from the avulsion, or the tearing off, of the insertion of the nerve root from the spinal cord, while more-distal nerve ruptures within the brachial plexus are defined as postganglionic lesions. The management and prognosis of brachial plexus injuries depend on the degree of damage and the site of the injuries, with a poor prognosis for preganglionic injuries. Many imaging modalities are available to not only differentiate between preganglionic and postganglionic lesions (such as standard myelography, CT myelography, conventional MRI, MR myelography and MR neurography), but also determine the severity of the injuries. Conventional myelography and CT myelography have long been used

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for the assessment of preganglionic root injuries. However, myelography is an invasive procedure, exposes patients to radiation, and carries the risk of adverse reactions to the iodinated contrast medium. Because of its non-invasive nature and ability to evaluate both the proximal and distal parts of the brachial plexus, MR neurography (MRN) has recently been introduced. MRN comprises a set of evolving protocol techniques to evaluate many abnormalities of the brachial plexus.[2] To achieve the objectives of the MRN, good and clear anatomical or structural information on the entire brachial plexus needs multiple planes and pulse sequences. The high-quality of MR imaging, provided by its high resolution, good fat suppression, and 3D imaging (short inversion-recovery sequence or mDIXON), results in excellent images of the peripheral brachial plexus structure. Furthermore, diffusion-weighted neurography can be used to evaluate postganglionic brachial plexus lesions. However, to evaluate preganglionic brachial plexus injuries, a high-resolution heavily T2-weighted pulse sequence offers comparable information to CT myelography.[3]

The purposes of this study were to optimize the protocol of the brachial plexus MRN used by our institute for brachial plexus injuries, and to study the diagnostic performance of the protocol, with clinical contexts used as the reference standard.

MATERIALS AND METHODS

Patient selection

This prospective study was performed between August 2015 and August 2016. It was approved by the ethics committee of the institute before patients were enrolled (Si 427/2015). A total of 21 patients fitted the inclusion criteria, which including age over 18 years, diagnosed with a brachial plexus injury, and scheduled for conventional myelography. Written informed consents were obtained from all patients before enrolment in the MRI study.

MR imaging

All patients underwent an MRI just prior to conventional myelography. All MRI examinations were performed on a 3.0-T MR unit (Ingenia, Philips Medical Systems, Best, the Netherlands), with a 16-element, head and neck matrix coil. We designed three pulse sequences of MRN brachial plexus protocol for the setting of brachial plexus injury and covering C4-T1 levels. The 3 MR pulse sequences acquired were axial T2-weighted image-high resolution (repetition time = 3000; echo time = 140; matrix, 180 x 178; field of view, 180 mm x 180 mm; turbo spin echo factor, 38; Sense factor, 1.7; slice thickness, 2.0 mm, no gap; number of signal average, 2); coronal T2-weighted image-mDIXON (repetition time = 2721; echo time = 90; matrix, 444 x 217; field of view, 400 mm x 252 mm; Sense factor, 2; slice thickness, 2.0 mm, gap, 0.2 mm; number of signal average, 2); and axial diffusion weighted image (repetition time = 9000; inversion time = 250; echo time = 67; matrix, 112 x 112; field of view, 300 mm x 300 mm; Sense factor, 2.5; slice thickness, 3.0 mm, no gap; number of signal average, 6; b factor = 0 and 800 s/mm^2; directions of gradient sampling, 16). The scan time took 13 minutes for T2-weighted image-high resolution, 5 minutes for mDIXON and 8 minutes for diffusion weighted image; the total scan time was therefore 26 minutes.

Conventional myelography

All patients underwent conventional myelography. Under a sterile technique, the subarachnoid space at the L3-L4 intervertebral level was punctured by a spinal needle. Then, 10 ml of water-soluble, non-ionic contrast medium (iopamiro) was injected via the spinal needle. The cervical myelography was performed with fluoroscopic guidance for the AP, lateral and both oblique views. After that, patients had to rest with their head elevated to observe for any immediate complications. It took about 90-120 minutes to perform the conventional myelography.

The results of the conventional myelography and MR imaging were recorded as a normal or abnormal nerve from C5-T1 levels, bilaterally. With the conventional myelography, abnormal nerve roots were defined as the loss of normal configuration (i.e. blunting) of nerve roots and/or demonstrable pseudomeningocele (Fig 1). As for the MR imaging, abnormal nerves were defined as the loss of normal nerve alignments, distributions and/or architectures in either the preganglionic or postganglionic portions (Fig 1, Fig 2, Fig 3). The preganglionic nerve root was interpreted from T2-weighted image-high resolution, and the postganglionic nerve root was observed by using T2-weighted image-mDIXON and diffusion weighted image. The abnormality of the nerve roots was interpreted and compared with the normal contralateral side in both the conventional myelography and MR imaging.

Two neuroradiologists separately reviewed the MRN study and the conventional myelography, and they were blind to the clinical data. Disagreements between the readers were resolved by consensus.

Statistical analysis

The results of conventional myelography and each sequence of MR imaging were correlated, with the clinical contexts being used as the gold standard. The accuracies,

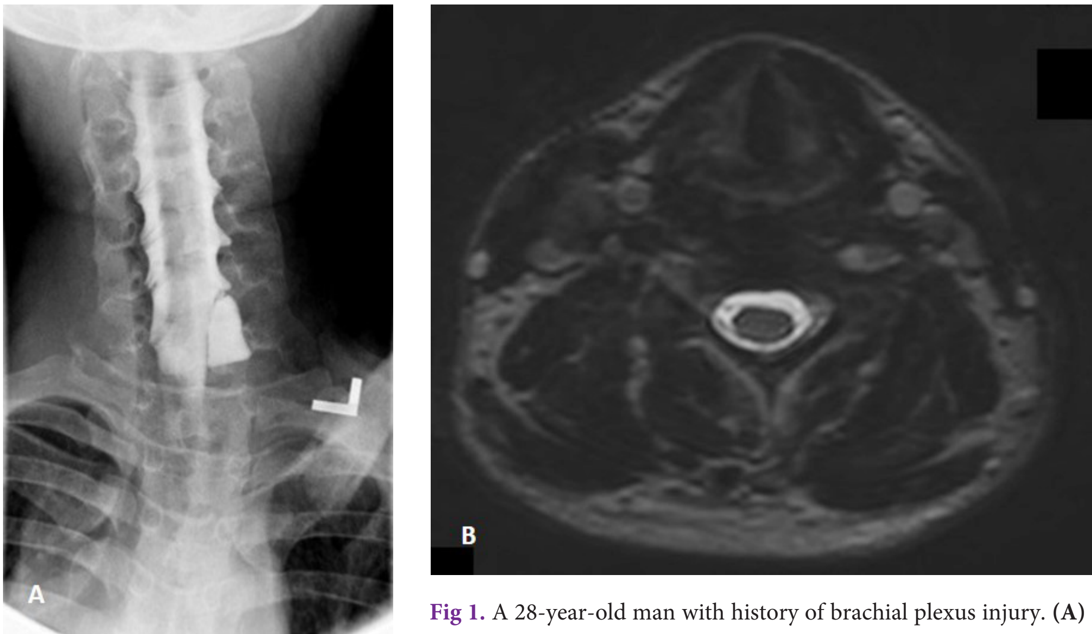

Fig 1. A 28-year-old man with history of brachial plexus injury. **(A)** Conventional myelography reveals no demonstration of normal left C5-T1 preganglionic nerve roots with pseudomeningocele at left C8 nerve root. **(B)** T2-weighted image-high resolution, no detectable normal ventral and dorsal left C5 nerve roots, representing nerve root avulsion.

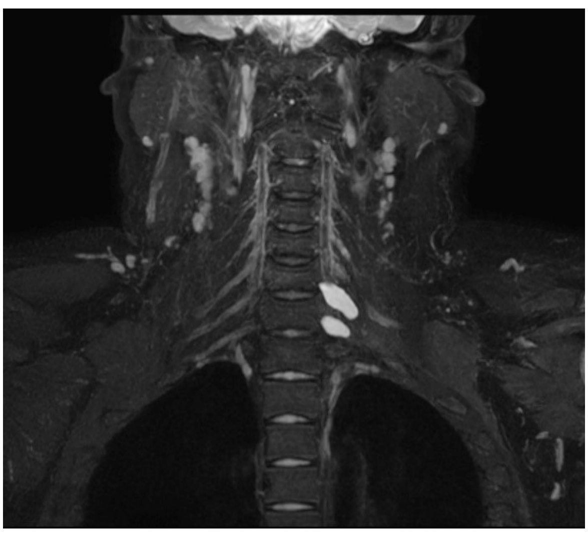

Fig 2. Coronal MIP image of mDIXON of a 20-year-old man reveals abnormal contour with irregularity of left C5 and C6 roots and total avulsion of left C7 and C8 roots with associated pseudomeningoceles at left C7 and C8 roots.

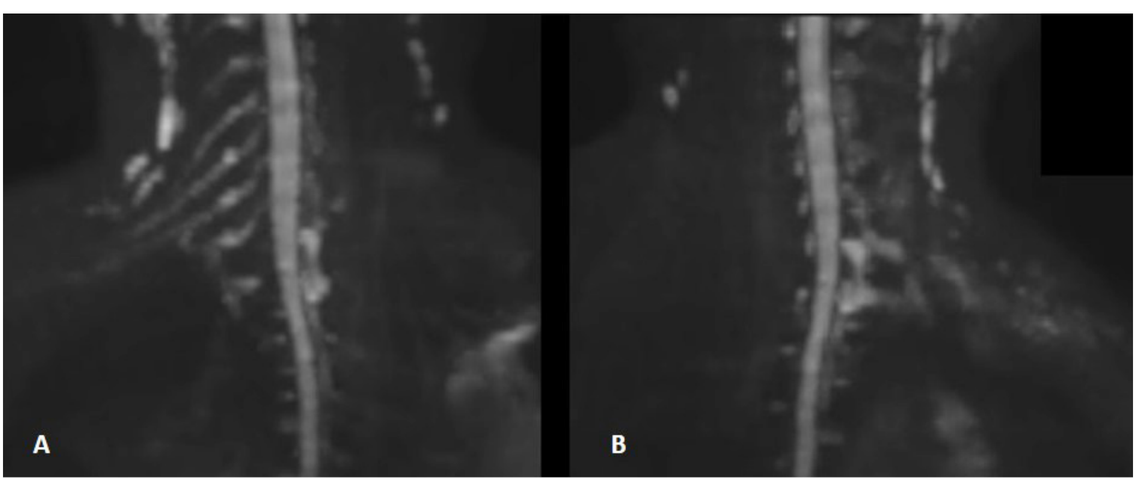

Fig 3. Coronal MIP image of diffusion weighted image of a 28-year-old man reveals abnormal contour with total irregularity of left C5-T1 nerves (B) as compared with the contralateral normal appearance (A)

sensitivities, specificities, and the false positive and false negative values were calculated. All data analyses were performed using SPSS software version 18.0 (SPSS Inc., USA).

RESULTS

The 21 patients with brachial plexus injury in this study were investigated 2 to 13 months after injury (mean: 5.1 months). The mean age of the patients was 27.1 years, with an age range of 16 to 39 years; 19 were male, and 2 were female. A total of 210 nerves of the brachial plexus (bilateral C5-T1) were interpreted for their individual modalities/MR sequences. In the case of T2-weighted image-high resolution, one patient was excluded due to motion artifact during imaging, leaving 200 nerve roots. The number of nerve abnormalities evaluated for each nerve level and for the different modalities are at Table 1.

Table 2 summarizes the diagnostic performance (specifically, the accuracy, sensitivity, specificity, false positive and false negative values) of each diagnostic tool (conventional myelography, T2-weighted image-high resolution, mDIXON, diffusion weighted image, and the combination of T2-weighted image-high resolution and mDIXON and T2-weighted image-high resolution and diffusion weighted image). The diagnostic performances of conventional myelography and T2-weighted image-high resolution were similar. The combination of T2-weighted image-high resolution and mDIXON had the highest accuracy for the diagnosis of brachial plexus injury.

A comparison of the critical performance factors of the conventional myelography and the MRI study is at Table 3. The benefits of the MRI study over the conventional myelography were its shorter processing time, lack of radiation exposure, lack of the need for contrast medium administration, and the ability to evaluate both pre- and postganglionic lesions. However, the cost of using an MRI study was much higher than that for conventional myelography.

TABLE 1. Number of nerve abnormalities, by nerve level, for different modalities.

Diagnostic tool (total patients)	Number of nerve abnormalities				
	C5	C6	C7	C8	T1
Clinical (21)	17	19	15	11	10
Myelography (21)	5	17	18	16	10
T2WI/HR (20)	9	15	17	16	10
mDIXON (21)	17	21	20	18	9
DWI (21)	14	19	21	20	10

Abbreviations: T2WI/HR = T2-weighted image-high resolution, DWI = diffusion weighted image

TABLE 2. Diagnostic performance of imaging modalities in brachial plexus injury compared with clinical contexts.

Diagnostic tool	Accuracy	Sensitivity	Specificity	False positive	False negative
MYELOGRAHY	69.52%	73.61%	60.61%	19.70%	48.72%
T2WI/HR	72.00%	78.26%	58.06%	19.40%	45.45%
mDIXON	76.19%	91.67%	42.42%	22.35%	30.00%
DWI	67.62%	84.72%	30.30%	27.38%	52.38%
T2WI/HR + mDIXON	78.00%	97.10%	35.48%	22.99%	15.38%
T2WI/HR + DWI	71.00%	91.30%	25.81%	26.74%	42.86%

Abbreviations: T2WI/HR = T2-weighted image-high resolution, DWI = diffusion weighted image

TABLE 3. Comparison of the critical performance factors of conventional myelography and MRI study.

Factor	Conventional myelography	MRN study
Time [Minutes]	90-120	26
Cost [Baht]	3300	17 600
Contrast medium	Yes	No
Radiation exposure	Yes	No
Evaluation	Preganglionic injury	Both pre- and postganglionic injury

DISCUSSION

Most Thai patients with brachial plexus injuries are male and of a younger age because the injuries commonly occur in motor vehicle accidents, as has been reported in multiple studies.[4-6] Brachial plexus injuries are classified into three categories: preganglionic lesions, postganglionic lesions, and a combination of both.[7] Multiple root injuries are also seen in most patients. Adequate surgical technique requires the differentiation of preganglionic lesions from postganglionic lesions. This is because the surgical procedure for preganglionic lesions consists of neurotization (nerve transfer), whereas postganglionic lesions may be treated by neurolysis or repair with nerve grafting.[8,9] The accurate diagnosis of brachial plexus injuries before surgery remains challenging. Many methods are used to evaluate the injury pattern, including physical examination, a nerve conduction study, electromyography, conventional myelography, CT myelography, and MRI. However, none of those methods is considered the reference standard.[10] Some studies have used the results of operative findings or have combined them with intraoperative electrodiagnostic studies to establish a reference standard.[4,8,11] Some studies have also used CT myelography as the gold standard for the imaging of nerve root avulsion.[7,9] However, in experienced surgeons at our institute use physical examination to diagnose brachial plexus injuries in combined modality with a nerve conduction study or an electromyogram test in some cases. Sometimes, surgeons cannot identify the entire course of the nerves, probably due to fibrosis, so making a definite diagnosis by using operative findings is not possible. Therefore, we used the clinical contexts as the reference standard in our study.

For the evaluation of preganglionic root injuries, conventional myelography is the diagnostic tool currently used by our institute. However, it is an invasive procedure, and it takes considerably longer to perform than an MRI study. D. Somashekar et al. found that a high-resolution MRI had a similar sensitivity to CT myelography when evaluating neonatal brachial plexus palsy.[3] According to our results, T2-weighted image-high resolution was also comparable to conventional myelography in terms of its accuracy, sensitivity, specificity, and false positive and false negative values. In addition, T2-weighted image-high resolution is noninvasive and needs a noticeably shorter performance time (approximately 13 minutes) than conventional myelography (approximately 90-120 minutes). Furthermore, the patients are not exposed to the contrast medium, have no risk of iodine contrast allergy, and do not suffer from any side effects or radiation exposure. Therefore, we suggest that T2-weighted image-high resolution replace conventional myelography for the diagnosis of brachial plexus injuries. However, in our study, both conventional myelography and T2-weighted image-high resolution had a diagnostic accuracy of preganglionic nerve root injury of only 69.52% and 72.00%, respectively. The inaccurate interpretations are probably due to partial nerve root avulsions, intradural fibroses, scars, or postganglionic lesions.

Conventional myelography and T2-weighted image-high resolution demonstrate preganglionic injuries, whereas mDIXON and diffusion weighted image detect postganglionic injuries. In our study, mDIXON had a slightly higher diagnostic yield than diffusion weighted image in the diagnosis of postganglionic brachial plexus injuries. In addition, mDIXON can provide accurate, indirect signs of root avulsion injuries, namely, the regional denervation of muscle changes which are seen as muscle atrophy, or a high T2 signal change, consistent with the article by A. Chhabra et al.[12] Therefore, mDIXON may have more benefits than diffusion weighted image in the detection of postganglionic lesions. However, it is also feasible to apply diffusion tensor imaging by improving the spatial resolution in order to obtain better information on nerve abnormalities than diffusion weighted image, including microstructural changes and fiber tractography. By contrast, mDIXON only provides information on the structural changes of nerves. The combination of T2-weighted image-high resolution with mDIXON or diffusion weighted image provided better results for the detection of brachial plexus injuries than mDIXON or diffusion weighted image alone because a combination can detect lesions in both pre- and postganglionic injuries. Given that the combination of T2-weighted image-high resolution and mDIXON had the highest diagnostic yield, we recommend it be used as the diagnostic tool for brachial plexus injuries in preference to conventional myelography.

The present study used the clinical contexts as the reference standard. The low specificities and high false-positive values in the results were probably due to the following:

1. At our institute, expert hand orthopedists use the clinical contexts as the gold standard, and only total avulsion tears are considered as abnormal findings. In other words, partial tears are excluded. However, there is a view that the clinical contexts might be inaccurate. Some believe that surgery might be more accurate, but in practice, orthopedists cannot explore the brachial plexus for each root level in all patients. This is because some patients need no surgery, and if surgery is performed, the brachial plexus still cannot be well identified, not only due to the anatomical defect but also fibrosis. Thus, there is still doubt as to what should be used for the definition of the gold standard.

2. There might be overinterpretation by the radiologists as the study defined abnormal findings in the myelography and MRI as a loss of normal nerve root alignment, distribution and/or architecture relative to the normal contralateral side, which may have included a partial tear at the site of the nerve injuries.

LIMITATIONS

The reference standard in our study only used a physical examination, which might be an inaccurate reference. Using a combination of physical examination, surgical findings, and electromyogram as the reference standard might improve the diagnostic yield.

In addition, the reference standard used in our study could not differentiate preganglionic from postganglionic lesions.

CONCLUSION

We recommend that the combination of T2-weighted image-high resolution and mDIXON be adopted as the diagnostic tool for the diagnosis of brachial plexus injuries in preference to conventional myelography. This is because of its faster processing time, the lack of the need for contrast medium administration, and its usefulness in evaluating both preganglionic and postganglionic injuries.

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