The Optimal B Value In Diffusion-Weighted Magnetic Resonance Neurography Of The Brachial Plexus

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Citation

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Abstract

Injuries to the brachial plexus typically result from road accidents and occur most commonly in young men involved in motorcycle accidents [1]. Brachial plexus injury is a rare entity, often resulting in lifelong motor and sensory dysfunctions. Moreover, lesions in the brachial plexus may lead to chronic pain [2]. Over the past several years diffusion-weighted imaging (DWI) has been widely applied to a variety of conditions, including infarcts, tumors, and demyelinating disease of the brain. DWI enables noninvasive characterization of biologic tissues based on their water diffusion properties. Diffusion-weighted images are obtained by acquiring T2-weighted images with the addition of a diffusion weighting gradient; the strength of the gradient is indicated as the “b-value”. The sensitivity of diffusion-weighted imaging to water motion can be varied by changing the b value, which is a function of diffusion gradient strength, duration of the gradient, and interval between diffusion gradients. The addition of a diffusion-weighted MR-sequence to a conventional MR imaging protocol leads to a better image interpretation and a better lesion localization [23]. The purpose of this study was to prospectively determine the optimum b factor for depiction of the brachial plexus, providing an improvement of contrast between the elements of the brachial plexus and the surrounding tissues.

INTRODUCTION

Injuries to the brachial plexus typically result from road accidents and occur most commonly in young men involved in motorcycle accidents [1]. Brachial plexus injury is a rare entity, often resulting in lifelong motor and sensory dysfunctions. Moreover, lesions in the brachial plexus may lead to chronic pain [2].

Clinical assessments, electrophysiological examination and diagnostic imaging are used for evaluation of the brachial plexus [3]. Diagnostic imaging consists of standard myelography, computed tomographic (CT) myelography, and magnetic resonance (MR) imaging. According to the scheme of Millesi and Schmidhammer [4], indications for operative treatment can be established.

Diagnostic imaging is important for depicting the type of injury to allow prognosis and treatment planning [5, 6]. Magnetic resonance neurography can show lesions to the peripheral nerve system, including the brachial plexus, and this technique has been used in patients with tumors, trauma, and neuritis [6-16]. The brachial plexus has a complex anatomic structure and it is difficult to define this delicate nervous system within adjacent structures using conventional MR imaging, even if it is uninjured.

Over the past several years diffusion-weighted imaging (DWI) has been widely applied to a variety of conditions, including infarcts, tumors, and demyelinating disease of the brain. DWI enables noninvasive characterization of biologic tissues based on their water diffusion properties. Diffusion-weighted images are obtained by acquiring T2-weighted images with the addition of a diffusion weighting gradient; the strength of the gradient is indicated as the “b-value”. The sensitivity of diffusion-weighted imaging to water motion can be varied by changing the b value, which is a function of diffusion gradient strength, duration of the gradient, and interval between diffusion gradients.

In 2004, Takahara et al. [17] reported a unique concept of whole-body DWI, called “diffusion-weighted whole-body imaging with background body signal suppression” (DWIBS). This technique intentionally uses free breathing scanning, rather than breath-holding or respiratory triggering, to secure relatively long scanning times.

The practicability for use of DWIBS for the detection of thoracic and abdominal lesions has been demonstrated in some reports [18-21].

Postganglionic lesions to the brachial plexus can be classified into lesions in continuity and nerve ruptures. Both may lead to severe loss of nerve tissue, creating a gap that has to be treated using interfascicular nerve grafting techniques [22]. In addition, a detailed anatomic depiction of the postganglionic brachial plexus is important for the localization of brachial plexus tumors and assessment of inflammation. Diffusion-weighted magnetic resonance neurography (DWMRN) provides improved contrast between the postganglionic nerves of the brachial plexus and the surrounding tissues [23]. The images are acquired using a DWIBS whole-body MR technique [17].

The addition of a diffusion-weighted MR-sequence to a conventional MR imaging protocol leads to a better image interpretation and a better lesion localization [23]. The purpose of this study was to prospectively determine the optimum b factor for depiction of the brachial plexus, providing an improvement of contrast between the elements of the brachial plexus and the surrounding tissues.

MATERIAL AND METHODS

PATIENTS

The local ethics committee granted ethical approval for the study, and informed consent was obtained from all subjects. Eleven healthy volunteers included four men and one seven woman (age range, 32–87 years; mean age ± standard deviation (SD), 59.2±15.7 years) underwent diffusion-weighted magnetic resonance imaging sequences of the brachial plexus in addition to the normal magnetic resonance routine imaging.

MR IMAGING METHODS

All MR examinations were performed with a 1.5 T whole-body system (Philips Medical System, Best, The Netherlands) with 30 mT/m maximum gradient capability. A standard receive-only 15 channel head and neck coil was used for diffusion-weighted MR-imaging. The imaging sequences used for examinations were as follows: Short TI inversion recovery (STIR) echo-planar imaging was performed in the axial plane (repetition time ms/echo time ms/inversion time ms, TR/TE/TI= 7559/10/170; field of view (FOV) =210x214x107 mm; matrix 232x168; 30 slices with 3-mm slice thickness and without gaps).

Diffusion-weighted images were obtained using a DWIBS sequence [17]. DWIBS was performed in the transversal orientation, using the following parameters: TR/TE/TI= 2387/76/180 ms; FOV=200x370 mm; voxel size of 2.5×2.5×3 mm^3; matrix 80x146; 30 slices with 3-mm slice thickness and without gaps. Diffusion- weighted MR images were acquired with b values of 500, 1000, and 1500 s/mm^2.

DATA PROCESSING

Quantitative and visual assessment of the brachial plexus using DWIBS was performed by two experienced radiologist in consensus. The resulting diffusion-weighted images were evaluated with focus on the signal intensity of a nerve of the brachial plexus. A visible nerve was defined as a band-like structure with its origin lateral to the spinal cord or connected to a visible ganglion and coursing from the superomedial aspect to the inferolateral aspect.

For three-dimensional display of the diffusion-weighted data from the DWIBS, maximum intensity projection (MIP) was employed, followed by gray-scale inversion.

On visual inspection, the signal intensity of the peripheral nerve was arbitrarily given one of three grades: markedly hyperintense, moderately hyperintense, slightly hyperintense to the surrounding tissue. In addition, the depictions of the ganglia of selected nerves were evaluated.

For quantitative evaluation the signal intensity was measured in manually defined circular regions of interest (ROI), which were confined within the peripheral nerve, adjacent lymph nodes, and surroundings, using a DICOM image viewer provided by the vendor of the MR system (Philips Medical Systems, Best, The Netherlands).

For higher statistical reliability, three ROIs were defined at three different positions within each structure by two experienced radiologist in consensus.

The signal intensity ratio of the peripheral nerve to the normal surrounding tissue and the ratio of the lymph node to the normal surrounding tissue were evaluated in each patient. This method of measurement was described by Kim JY et al [24] for the discrimination of brain abscesses and necrotic or cystic brain tumors.

STATISTICAL ANALYSIS

Data were analyzed using statistical software (GraphPad Inc, San Diego, CA).

The results for the signal intensity ratio values of the peripheral nerve to the normal surrounding tissue and lymph

node to surrounding tissue were compared using a Tukey´s Multiple Comparison Test. Comparisons of signal intensity ratio values of peripheral nerve to the lymph node were performed using the paired t test.

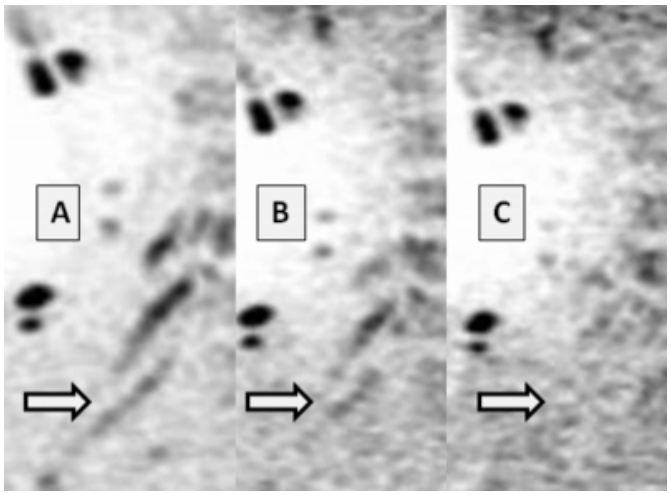
Probability values of less than 0.05 were considered significant.

RESULTS

On visual assessment, the peripheral nerve was markedly hyperintense in all volunteers (100%) on diffusion-weighted images compared with surrounding tissue, using a b factor of 500 s/mm² and in only one (8%) at a b value of 1000 s/mm². No patient (0%) was markedly hyperintense with a b value of 1500 s/mm², whereas 10 (91%) patients were moderately hyperintense with a b value of 1000 s/mm² DWI. No patient (0%) was moderately hyperintense with a b value of 1500 s/mm² (Fig 1).

Figure 1

Fig 1.

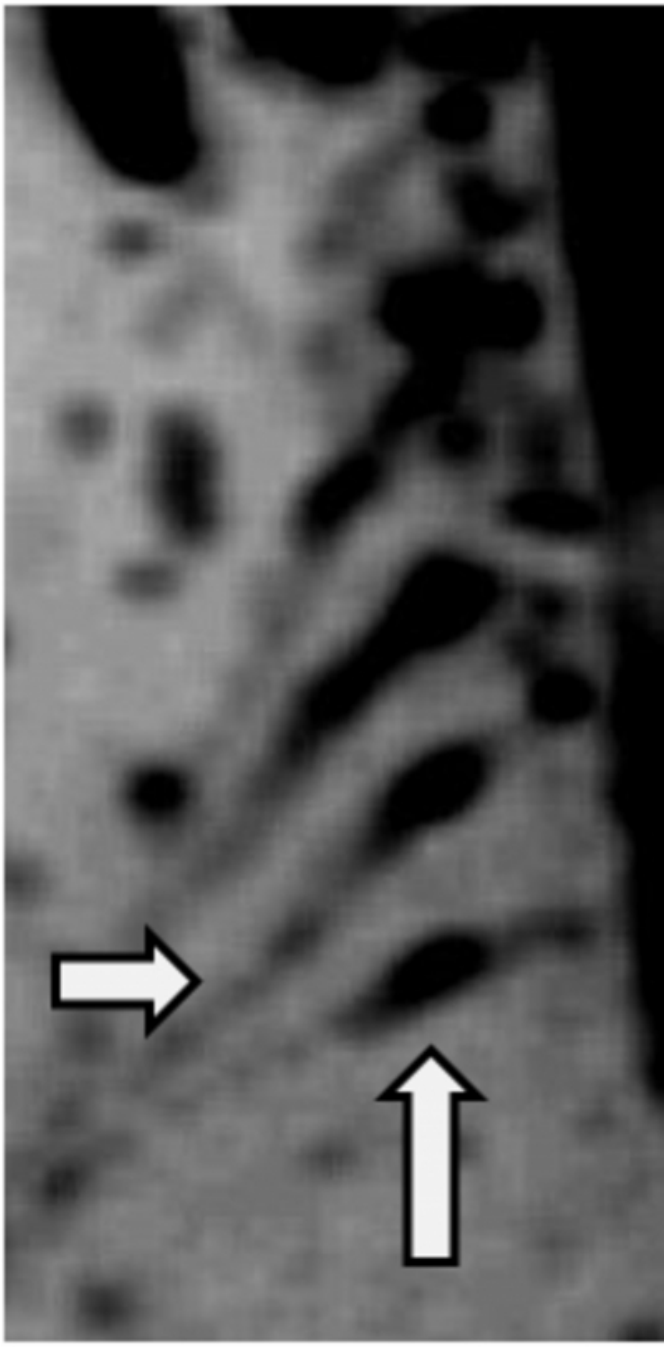


Nerves of the brachial plexus are depicted using a b value of (A) 500 s/mm^2, (B) 1000 s/mm^2, and (C) 1500 s/mm^2.

The DWMRN images clearly showed the ganglia and the postganglionic portion of the brachial plexus in all patients (100%) with a b value of 500 s/mm² (Fig 2).

Figure 2

Fig. 2 DWMRN image of the brachial plexus obtained with a b value of 500 s/mm (short arrow). Ganglia on the right side of the body can be seen (long arrow).



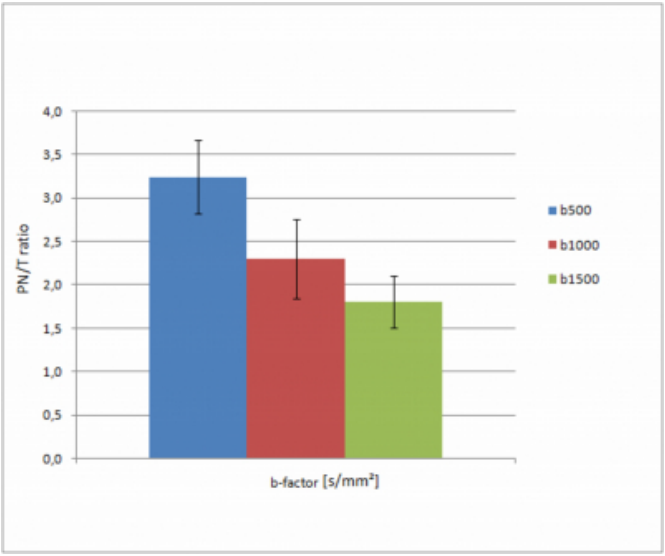
Ten ganglia (91%) of the selected nerves were seen at a b factor of 1000 s/mm².

Only four (36%) ganglia were seen for b values of 1500 s/mm².

On quantitative assessment, the signal intensity ratio of the peripheral nerve to the surrounding tissue (PN/T ratio) ranged from 2.6 to 3.7 using a b factor of 500 s/mm² (Fig 3).

Figure 3

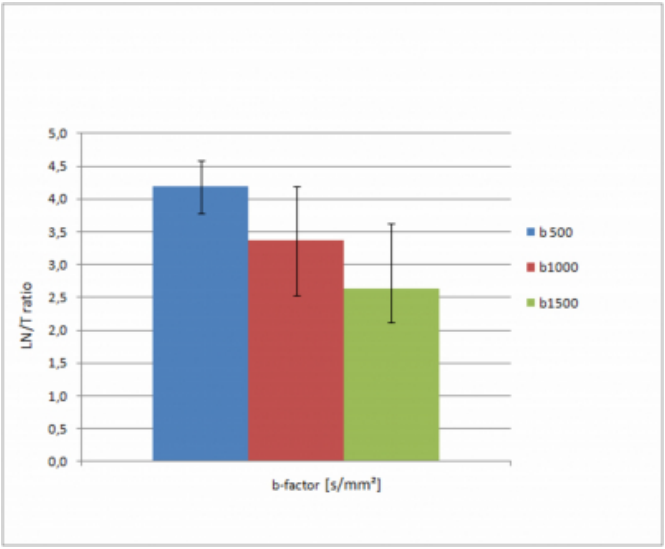
Fig. 3 The diagram demonstrates the mean signal intensity ratio of the peripheral nerve to the normal surrounding tissue.



In contrast, those of the lymph node to the normal surrounding tissue (LN/T ratio) ranged from 3.3 to 4.7 (Fig 4).

Figure 4

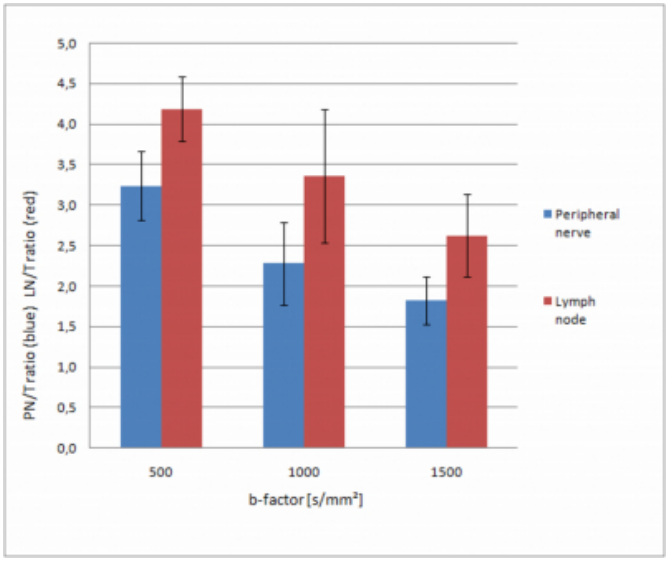
Fig. 4 The diagram demonstrates the mean signal intensity ratio of the lymph node to the normal surrounding tissue.



The PN/T ratio was significantly higher for a b value of 500 s/mm² in comparison to a b value of 1000s/mm² (P<0.001) or 1500s/mm² (P<0.001). The mean signal intensity ratio of PN to normal surrounding tissue was significantly lower than the lymph node to normal surrounding tissue (LN/T) at a b factor of 500 s/mm² (P<0.0001) or at 1500 s/mm² (P<0.001) (Fig 5).

Figure 5

Fig. 5 The mean signal intensity ratio of peripheral nerve to normal surrounding tissue was significantly lower than lymph node to normal tissue at a b factor of 500 s/mm² and 1500 s/mm².



The LN/T ratio also demonstrated a significant difference for a b value of 500 s/mm² in comparison to a b factor of 1000s/mm² (P<0.01) or 1500s/mm² (P<0.001). The signal intensity ratio values of the peripheral nerve to the normal surrounding tissue and the ratio of the lymph node to the normal surrounding are summarized in Table 1.

DISCUSSION

Although DWIBS is primarily used for cancer screening, this technique can also be used to depict the nerves of the brachial plexus. MR neurography using DWIBS is a novel approach for visualizing abnormalities of peripheral nerves, including the brachial plexus. In this study, a b value range of 500 s/mm^2, 1000 s/mm^2 and 1500s/mm^2 was investigated. We did not use a b value lower of 500 s/mm^2 in order to diminish the influence from T2 Signal intensity. To our knowledge, until now, there have been no studies to determine the ideal b factor for the visualization of the brachial plexus. We found that DWMRN using a b value of 500 s/mm² results in improved overview images of the uninjured brachial plexus, leading to an improvement in contrast between the elements of the brachial plexus and the surrounding tissues. The contrast between nervous tissue and the surrounding tissue and lymph nodes decreased significantly when the b value was set above 500 s/mm². The results of our quantitative measurements were also in agreement with qualitative assessments of the peripheral nerve of the brachial plexus. Qualitative ranking of the

brachial plexus showed the best image quality at a b value of 500 s/mm². Our data demonstrate that the discrimination between the nerve and the lymph node is best given by a b factor of 500 s/mm². Therefore, our opinion is that DWMRN images obtained with a b factor of 500 are most suitable for the soap-bubble MIP postprocessing procedure, as reported by Takahra (14). A limitation of DWMRN was the lack of depiction of the preganglionic part of the brachial plexus, because of cerebrospinal fluid flow fluctuations and the small diameter of this part of the brachial plexus. An additional potential limitation of our investigation was the use of only a 1.5-T MRI system for image acquisition. Imaging at a higher field strength (3T) would have afforded the opportunity for increased SNR relative to 1.5-T imaging.

We obtained a significant increase in the nerve signal using a b value of 500 s/mm². Similar to other tortuous, narrow, long structures, such as coronary arteries, conventional slab MIP images do not result in optimal depiction of the brachial plexus, because the cuboid shaped MIP section results in superimposition of the nerves and surrounding bone structures and lymph nodes.

Another difficulty was the use of a lower matrix value to decrease the overall acquisition time. However, in general, a higher matrix value should be used to get a better signal to noise ratio. Major advantages of DWMRN over conventional MR imaging are the high conspicuity between the nerve roots of the brachial plexus and the surrounding structures and the ability of DWMRN to depict a long trajectory of the brachial plexus on coronal reformatted MIP images. This technique may improve evaluation of the normal and affected brachial plexus and the proximal peripheral nerves. DWMRN could be an effective method to depict nerves and to recognize the anatomic relationship between lesions and nerves.

The results of this study provide information about the optimal b value for 1.5T DWMRN and illustrate the feasibility of DWMRN of the brachial plexus at 1.5T.

Optimal qualitative and quantitative indexes for DWMRN of the brachial plexus were found with data acquisitions at a b value of 500 s/mm² on a 1.5T MRI system.

Future research should be performed to evaluate the diagnostic improvement of brachial plexus pathology using a b value of 500.

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