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ORIGINAL ARTICLE

Usefulness of conventional magnetic resonance imaging, diffusion tensor imaging and neurite orientation dispersion and density imaging in evaluating postoperative function in patients with cervical spondylotic myelopathy

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KEYWORDS
Anteroposterior diameter;
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Abstract *Objective:* The objective of this study was to evaluate the usefulness of T2 high signal intensity (T2-HSI) and decreased anteroposterior diameter (APD), diffusion tensor imaging (DTI) and neurite orientation dispersion and density imaging (NODDI) in evaluating postoperative cervical cord function.
Methods: The study included 57 postoperative cervical spondylotic myelopathy patients. Clinical evaluation and functional recovery assessments were performed using the modified

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Diffusion tensor imaging;
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T2 high signal intensity

Japanese Orthopaedic Association (mJOA) score and recovery rate. The presence of T2-HSI and decreased APD was recorded for exploring the relevance. Spearman correlation was applied to investigate the relationships between DTI and NODDI metrics and mJOA score. Multiple comparisons of T2 signal intensity, APD and diffusion metrics were evaluated by using multiple linear regression.

Results: Only the recovery rate was significantly different between T2-HSI and non-T2-HSI (nT2-HSI) patients ($\chi^2 = 4.466$, $p = 0.045$). Significant differences were not observed between cervical cords with and without decreased APD. Diffusion metrics, including fractional anisotropy ($p = 0.0005$), mean diffusivity ($p = 0.0008$), radial diffusivity ($p = 0.0003$) and intracellular volume fraction ($p = 0.001$), were significantly correlated with mJOA score. The ability of T2 signal intensity ($p = 0.421$) and APD ($p = 0.420$) to evaluate the postoperative function was inferior to that of fractional anisotropy ($p = 0.002$), mean diffusivity ($p = 0.001$), radial diffusivity ($p = 0.001$) and intracellular volume fraction ($p = 0.004$).

Conclusion: Conventional magnetic resonance imaging signs could be considered as a reference to make an approximate assessment, whereas DTI and NODDI could be better quantitative tools for evaluating the postoperative function and may help in interpreting residual symptoms.

The translational potential of this article: DTI and NODDI could provide reliable postoperative evaluation and analysis for cervical spondylotic myelopathy patients.

Introduction

Cervical spondylotic myelopathy (CSM) is currently a common disease that causes serious nervous lesions. Its low-risk and optimal therapeutic method is posterior cervical laminoplasty that enlarges the spinal canal [1,2]. In clinical practice, some patients show symptoms even after surgery, and their clinical symptoms are inconsistent with conventional magnetic resonance imaging (MRI) signs, including high signal intensity in T2-weighted image or decreased anteroposterior diameter (APD) of the cervical cord, which are often considered to indicate severe myelopathic lesions. However, not all postoperative patients with poor outcomes have such signs. Furthermore, these signs could appear in well-recovered patients. It is troublesome for physicians to convey the interpretations to their patients. Therefore, the usefulness of conventional MRI signs in such circumstances should be evaluated.

The principle of diffusion tensor imaging (DTI) is the measurement of the dispersive anisotropy of water molecules in intravital tissues [3,4]. It can reveal the pathological microstructure of the spinal cord indirectly through a diffusive change in water molecules [5]. Several previous studies have confirmed that DTI is more sensitive than conventional MRI and is capable of identifying lesions of the cervical cord in preoperative CSM patients and thus has diagnostic significance [6—10]. To our knowledge, DTI is rarely used in postoperative studies of CSM patients. However, we believe that DTI is a potential technique to evaluate the postoperative function of the cervical cord.

Neurite orientation dispersion and density imaging (NODDI) was developed from diffusion-weighted MRI. According to the three-compartment model, including intracellular, extracellular and cerebrospinal fluid (CSF) compartments, NODDI can reveal specific morphological features of neurites, which could account for changes in diffusive anisotropy [11], including neurite orientation distribution [orientation dispersion index (ODI)], neurite density [intracellular volume fraction (Vic)] and fraction of free water [isotropic volume fraction (Viso)]. Although NODDI was originally developed for brain-related applications [12,13], it is considered as a valuable imaging technique for spinal cord diseases [14], for example, multiple sclerosis in the cervical cord [15]. Therefore, this technique may be helpful for providing specific information to patients with poor postoperative outcomes.

The purpose of this study was to verify the efficacy of postoperative signs on conventional MRI and to provide evidence for DTI being a potential evaluation technique for the postoperative function of the cervical cord and NODDI being a potential technique for providing reasoning for residual myelopathic symptoms.

Materials and methods

Patients

The institutional review board of research ethics approved all study procedures. This study enrolled 59 CSM patients with multiple-level cervical stenosis. All patients preoperatively underwent conventional MRI to exclude other spinal diseases (trauma, tumour, infection, cervical spondylotic radiculopathy and so on) and posterior cervical laminoplasty for treatment. The material used to close the enlarged spinal canal or disconnected vertebral plate was biosynthetic bone extracted from coral, which helps avoid the metal susceptibility artifact [16]. All patients provided informed consent. The follow-up MR scan, including conventional MRI, DTI and NODDI, was performed between 12