What is the current status of clinical cord imaging?

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Introduction
The spinal cord is an important part of the central nervous system (CNS), and assessment of this structure is essential for the work-up of certain diseases, including multiple sclerosis, spondylosis, and trauma. However, there are a few challenges in imaging the spinal cord, including its small size, motion of the cord caused by cardiac pulsation, cerebrospinal fluid (CSF) flow, and the susceptibility artifacts caused by the surrounding bony structures. In this lecture, I will try to address these issues. As an introduction to this field, I will first cover the basic anatomy of the spinal cord and vertebral body, after which I will explain the current status of routine imaging techniques for daily clinical examinations. In the latter part of this talk, I will touch on some of the modern MRI technology.

Basic anatomy
The cord has three major functions: 1) it serves as a conduit for motor information; 2) it serves as a conduit for sensory information; and 3) it serves as a center for coordinating the reflexes. The sensory information is transmitted to the brain from the peripheral nervous system. The motor impulses arise from the brain and are conducted to the skeletal/cardiac/smooth muscle or the glands via the spinal cord.

When looking at a cross-sectional view of the spinal cord, the peripheral region contains white matter tracts. The central part, shaped like a butterfly, is the gray matter, which contains nerve cell bodies and unmyelinated axons. The central canal is located in the middle of this gray matter, and this is the extension of the CSF space from the ventricles of brain.

The major arterial blood supply to the cord below the cervical region arises from the radicular arteries. These arteries run into the spinal canal alongside the lateral margin of the vertebral bodies and the nerve roots. The largest of the anterior radicular arteries is known as the Adamkiewicz artery (AKA), which usually arises between T8 and L1. Impaired blood flow through the AKA can result in spinal cord infarction and paraplegia.
Routine MRI techniques

The basic imaging planes of the cord/spine are sagittal and axial images. Especially useful is the sagittal view, as it will give you an overview of the structure. These sagittal images allow one to assess the alignment of the vertebral bodies, and this information has substantial impact on clinical decision-making. Transaxial images are obtained using both T1- and T2-weighted sequences. Three-dimensional volume imaging has become a realistic imaging technique of choice with high-field MR scanners.

Visualization of the bones and osteophytes is important in assessing patients with degenerative diseases and trauma. These structures are, however, not truly visible using MRI. This is why plain films and CT scans still have important roles in assessing these patients. On MRI, the bony cortex of the vertebral bodies and the osteophytes are noted as layers of hypointensity. It is also often difficult to separate the bones from the ligaments, since they both contain little or no protons.

Phase-contrast CSF flow studies are often used to assess the pulsating flow within the canal. This is mostly used at the cranio cervical junction in assessing patients with Chiari malformation and stenosis of the foramen magnum in patients with achondroplasia. Heavily T2-weighted images are used to obtain MR cisternography, and these are used to assess the degree and distribution of canal stenosis. Flow-voids within the canal in patients with an arteriovenous fistula are also easily appreciable using this technique.

Modern imaging techniques

Diffusion-tensor imaging (DTI) has now become one of the essential tools in analyzing the CNS. Water diffusion preferentially diffuses in a direction parallel to the axon’s longitudinal axis but is relatively restricted in the perpendicular axis. This phenomenon can be represented mathematically by the so-called diffusion ellipsoid, or tensor. The translation of the longest axis of the tensor (v1) enables tracking of the three-dimensional macroscopic fiber orientation [1]. Such in vivo localization of neuronal fibers was not previously possible. It has been used primarily for brain lesions [2-4], though it has also been used for the spinal cord [5,6].

Q-space imaging

Recent studies have further extended the DTI technique to use much higher b-values (e.g. 10,000 s/mm2)[7-9]. The method is known as q-space imaging or dynamic MR microscopy, and it was originally designed to measure the compartment size of the porous material filled with water [7]. This technique with high b-values enables measurement of the mean displacement (MD) of the most slowly diffusing water molecules. By applying this technique to the CNS, one can now perform ultrastructural
assessment of white matter compartment size. For instance, axonal size as obtained by q-space imaging has been found to be in excellent agreement with that found on histology for swine optic nerves and mouse spinal cord [10,11].
REFERENCES