Imaging of the spinal cord injury: techniques for diagnosis, follow up and research

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Abstract

The consolidation of new treatment strategies for acute spinal trauma and rehabilitation demands precise and specific approach to the pathophysiology and anatomy of the neural axis and vertebral contents. Neuroimaging modalities have been used to evaluate spinal cord injury (SCI) in clinical practice and the recent advances in imaging techniques allowed to assess details of the tissue microstructure improving the insights about prognosis, interventional targets and neuroplasticity.

Structural magnetic resonance imaging (MRI) is the modality of choice to evaluate the spinal cord and soft tissue, being capable to identify and quantify hemorrhage, edema and the extension, degree or type of spinal cord injury both in acute and chronicle phases. Computed tomography (CT) should be used to assess bony anatomy and vertebral stability. MRI- diffusion weighted (DWI) and diffusion tensor imaging (DTI) may be useful to characterize the cord microstructure and in quantifying the extent of axonal loss and demyelination and possibly to identify signs of neural tracts regeneration and response to neural plasticity.

The following article provides a review of the most important imaging techniques used in the assessment of SCI and proposes a brief discuss about their application in research and rehabilitation strategies.

Keywords: *Spinal cord injury, neuroimaging, magnetic resonance imaging, computed tomography, diffusion tensor imaging.*

Introduction

The spinal cord establishes the communication between periphery and central nervous systems controlling the inflow of sensory information and transmitting and coordinating the neural stimulus to the muscles [1]. Traumatic injuries to the spinal column can damage the neural tissue and disrupt these neural pathways. The biomechanics of the trauma, the characteristics and degree of injury can determine the patient's clinical outcome and prognosis [2].

Medical imaging these days have developed to an advanced level providing detailed information about critical structures in neural axis. Each imaging modality targets different structures within spinal cord and spinal canal. Computed tomography (CT) and magnetic resonance imaging (MRI) are the most important tools used in diagnosis and classification of the structural damages and are critical to guide the treatment both in acute and chronicle phases [3]. Advanced MRI techniques based on diffusion tensors (DT) and magnetization transfer (MT) seems to provide sensitive and specific markers of white matter pathology [4].

The aim of this article is to review the main neuroimaging modalities in the assessment of SCI and to discuss some applications in the research, rehabilitation and clinical strategies.

Computed Tomography

Although conventional plain film radiographs still being a fast and non-expensive tool to evaluate the alignment of the vertebral column, there is a concern that a percentage of craniocervical and dorsal lesions can be underdiagnosed because of inadequate technique. The traditional CT scans used to have time consuming protocols and limited resolution, so they were always used as a complementary modality to plain radiographs. Multislice CT (MSCT) is faster and offers higher imaging definition and it has been widely used to evaluate acute spinal trauma. Most of the spinal trauma healthcare institutions nowadays recommend mandatory MSCT of the cervical spine for conscious patients following high-energy blunt trauma, for patients older than 60 years old following head trauma or for unconscious politrauma patients. The thoracic and lumbar spine should be explored depending on the suspected symptoms or mechanisms of trauma [5].

CT enables accurate assessment of bone structure, vertebral and facet joint alignment and integrity, being useful to define the cervical canal and to make the distinction between stable and instable fractures (Figure 1). MSCT has proven to detect 97-100% of fractures [5].

Figure 1. CT in acute spinal trauma. Odontoid fracture (left) in a 68y male patient after fall. This patient had previous spinal surgery.
The image in the right shows an L1 compress fracture in an 80y old female subject after fall. The diagnosis of an acute lesion was made because of the absence of sclerosis in the fracture edges and the points of cortical disruption.

Magnetic resonance imaging

CT is important to detect skeletal abnormality but it is not accurate to detect ligamentous and soft tissue injury. MRI is the modality of choice for evaluation of the spinal cord and its surrounding elements, such as arachnoid and epidural spaces and ligaments [3]. The variable ways to manipulate the magnetic field and gradients offers to MRI a wide range of imaging contrast making it possible to detect intra and extra-axial hemorrhage, edema, cord compression, laceration or transection (Figure 2) with satisfactory histological correlation.

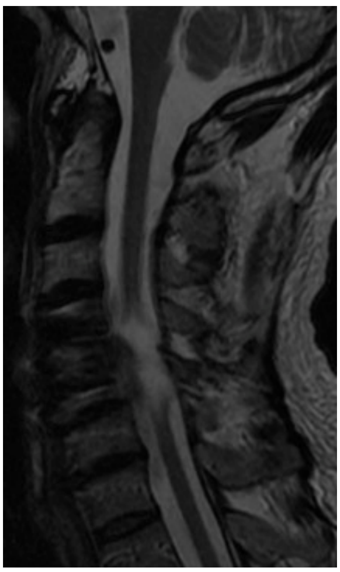

Figure 2. Sagital T2 MRI in a 43y old male tetraplegic patient 5 years after cervical C4 spinal trauma showing complete transection of the spinal cord.

The information provided by the MRI is useful to diagnosis and to the clinical approach and also it is important to determine the severity of the lesion and to predict the prognosis and clinical outcome after SCI [2]. Studies have showed that the extent of edema and hemorrage in the acute phase significantly correlated to the neurological recovery after injury. The patients with more substantial cord swelling and hemorrhage tended to present more severe disability.
Moreover, the MRI is also important to the patient's follow up being important to detect and characterize residual damage and delayed complications. It is know the high frequency of arachnoidits and myelomalacia after SCI. This fibrotic and damaged tissue, associated to oscillations in cerebral spinal fluid, can cavitate and evolve to siringomyelia, a critical condition that can lead to overall neurological disability and compromise the patient's rehabilitation.

Diffusion tensor imaging

Diffusion imaging is based in the random motion of water in isotropic condition. The neural tissue has a complex organization in white matter tracts and pathways creating an anisotropic site (Figure 3). Novel MR techniques are capable to detect the water motion within the white matter (WM) tracts and access the microstructure features of the spinal cord. It is possible to model this diffusion profile using diffusion tensor imaging (DTI) (Figure 4) and obtain both structural information about the orientation and integrity of the WM tracts and derive metrics of fractional anisotropy (FA) and mean diffusivity (MD) that correlates to the complexity and density of the tissue. It is also possible to extract vectorial information, which offers two other indices: axial and radial diffusivities, good predictors of axonal loss and demyelination, respectively [4].

Figure 3. Apparent diffusion coefficient (ADC) map of an axial spinal cord section. The darker spots represents areas of more restricted diffusion, corresponding to more compact WM tracts.

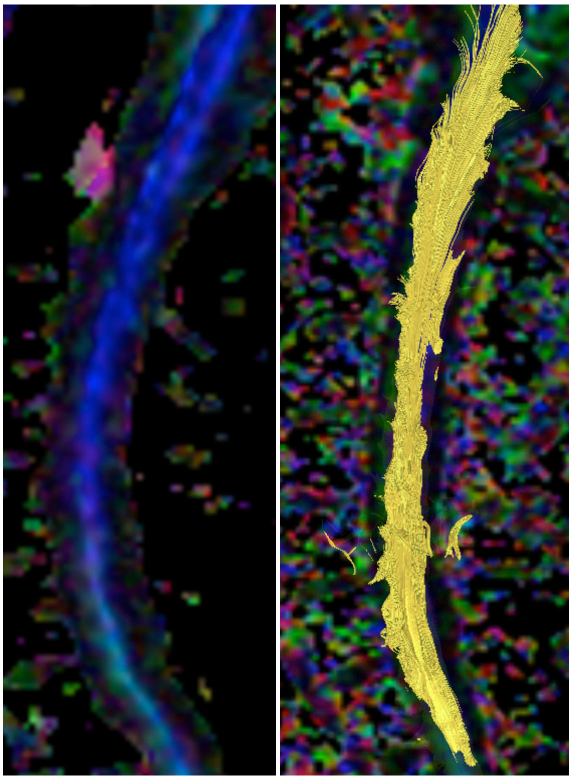

Figure 4. Fractional anisotropy colour map (right) and tractrography reconstruction of the cervical spinal cord.

Discussion

The extension and severity of the spinal trauma injury depends of several factors secondary not only to the features of the acute lesion but to the treatment strategies and the degree of secondary lesions, demyelination and Wallerian degeneration [9].

After SCI injury, the establishment of fast and efficient treatment strategy will depend of specific and detailed anatomic and pathological information that can be precisely provided by CT and MRI.

Even in the more severe injuries, some pathways may be preserved and contribute to functional recovery, what can be achieved by regeneration, remyelination or by neural plasticity, sprouting undamaged pathways. The advent of new rehabilitation and treatment strategies demands more precise and advanced techniques to approach the pathophysiology and anatomy of the spinal cord, offering more accurate and non-invasive support to research and clinical follow up.

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