

Normal Myelination

A Practical Pictorial Review

Helen M. Branson, BSc, MBBS, FRACR

KEYWORDS

• Myelin • Myelination • T1 • T2 • MR • Diffusion

KEY POINTS

- MR imaging is the best noninvasive modality to assess myelin maturation in the human brain.
- A combination of conventional T1-weighted and T2-weighted sequences is all that is required for basic assessment of myelination in the central nervous system (CNS).
- It is vital to have an understanding of the normal progression of myelination on MR imaging to enable the diagnosis of childhood diseases including leukodystrophies as well as hypomyelinating disorders, delayed myelination, and acquired demyelinating disease.

INTRODUCTION

Assessment of the progression of myelin and myelination has been revolutionized in the era of MR imaging. Earlier imaging modalities such as ultrasonography and computed tomography have no current role or ability to contribute to the assessment of myelin maturation or abnormalities of myelin. The degree of brain myelination can be used as a marker of maturation.

The authors discuss

1. Myelin function and structure
2. The MR imaging appearance of myelin
3. The normal progression of myelination on conventional MR imaging
4. Terminal zones of myelination

DISCUSSION

Myelin Function and Structure

To discuss normal myelination in the human brain, knowledge of the purpose and function of myelin

and its role in the human nervous system is needed.

Myelin is present in both the CNS and the peripheral nervous system. In the CNS, it is primarily found in white matter (although small amounts are also found in gray matter) and thus is responsible for its color.¹ Myelin acts as an electrical insulator for neurons.¹ Myelin plays a role in increasing the speed of an action potential by 10–100 times that of an unmyelinated axon¹ and also helps in speedy axonal transport.² Edgar and Garbern³ (2004) demonstrated that the absence of a major myelin protein (PLP/DM20) from the oligodendrocyte resulted in major impairments in axonal transport in a mouse model of hereditary spastic paraplegia. It has also been well established that axonal integrity depends on the myelinating cell body for support. Myelin also likely has a role in the regulation of both ion composition and fluid volume around the axon.⁴

Myelination is the formation of a myelin lipid bilayer around an axon.^{4,5} Myelination allows rapid transfer of information needed for cognitive

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Department of Medical Imaging, The Hospital for Sick Children, University of Toronto, 555 University Avenue, Toronto, Ontario, M5G 1X8, Canada

E-mail address: helen.branson@sickkids.ca

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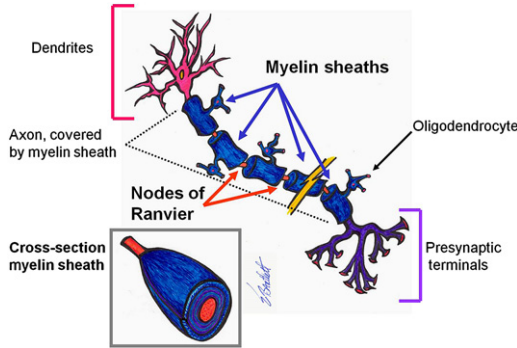


Fig. 1. Schematic of a neuron demonstrating the myelin sheaths wrapped around the axon and the separating nodes of Ranvier. (Courtesy of Dr E. Bartlett, Princess Margaret Cancer Centre, Joint Department of Medical imaging, University of Toronto, Toronto, Canada.)

functioning as well as emotional and behavioral functioning and decision making.⁵ Myelination begins during fetal life^{6,7} and continues after birth. Myelin is a modified extension of an oligodendroglial cell process.^{6,8} An oligodendroglial cell is the key cell in myelination of the CNS and is the predominant type of neuroglia in white matter.⁹ Myelin sheaths are composed of multiple

segments of myelin, which are then wrapped around an axon.^{6,8} This sheath is instrumental in containing an electrical current around an axon and increasing the action potential of an axon because of the nodes of Ranvier, which are sodium channels in between the myelin sheaths that increase the traveling speed of an electric current down an axon (Fig. 1). Thus, myelin is thought to make impulses travel faster by increasing the speed of travel of a current. Myelin is also thought to be symbiotic with the axon.¹⁰ Myelin is metabolically active and involved in the turnover of its own components¹¹ and contains a large number of myelin-intrinsic enzymes.¹² Myelin also has a role in ion transport, which contributes to its own maintenance, and in the buffering of ions around the axon.^{11,12}

A single oligodendrocyte may be responsible for the production and maintenance of up to 40 fibers.⁹ Myelin has a high lipid content, having approximately 70% lipid and 20 to 30% protein.^{8,9,11} The main proteins that play a part in myelin structure are myelin basic protein (30%), proteolipid protein (50%), and cyclic nucleotide phosphodiesterase (4%).¹ Other proteins involved include myelin-associated glycol protein and myelin oligodendrocyte protein. Lipids that contribute to myelin ultrastructure include cholesterol, phospholipids, and glycosphingolipids.^{1,9}

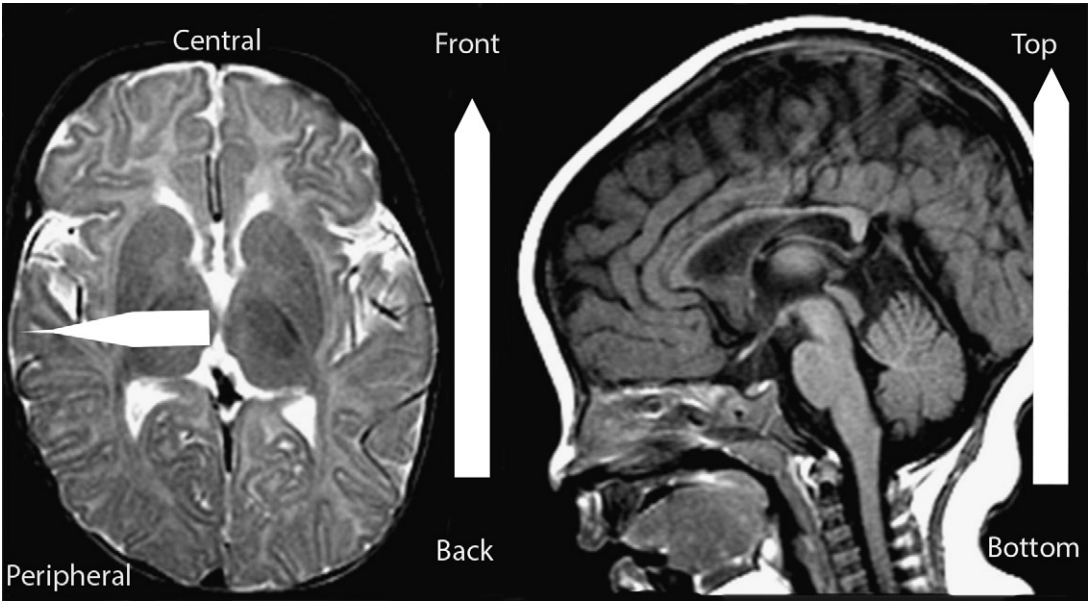


Fig. 2. Myelination progresses in a predictable manner from bottom to top (caudocranial), back to front (posterior to anterior), and central to peripheral (deep to superficial).

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