Neuromelanin-Sensitive MRI
Basics, Technique, and Clinical Applications

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Abstract
The basics and the technique of magnetic resonance imaging (MRI) for visualizing the neuromelanin present in dopaminergic and noradrenergic nuclei in the substantia nigra pars compacta (SNc) and locus caeruleus (LC) are introduced. Neuromelanin, a black pigment produced during catecholamine synthesis, has paramagnetic T1-shortening effects. Conventional MRI techniques fail to depict the contrast generated by neuromelanin, but neuromelanin-sensitive T1-weighted fast spin echo technique at 3 T allows the direct visualization of the SNc and LC as hyperintense areas. In Parkinson’s disease, neuromelanin-related signals from the SNc and LC are diminished, suggesting neuronal degeneration in both the nuclei. In depression and schizophrenia, signals from the LC are reduced while those from the SNc are augmented, suggesting monoamine and dopamine hypotheses, respectively. Neuromelanin-sensitive MRI is a promising technique to elucidate the pathologic or functional changes in the catecholamine neurons of the brain stem that occur in degenerative and psychiatric diseases.

Key Words: Neuromelanin · Magnetic resonance imaging · Substantia nigra · Locus caeruleus

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Neuromelaninsensitive MRT. Grundlagen, Technik und klinische Einsatzmöglichkeiten

Zusammenfassung

Schlüsselwörter: Neuromelanin · Kernspintomographie · Substantia nigra · Locus caeruleus

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Introduction
It is widely known that some catecholamine neurons in the human brain stem, such as those of the substantia nigra pars compacta (SNc) and locus caeruleus (LC), contain a black pigment called neuromelanin [1]. These neuromelanin-containing nuclei can be easily identified as black areas in gross specimens. However, these nuclei have remained invisible on magnetic resonance imaging (MRI), and the neuromelanin-generated contrast has hardly been studied. Recently, we proposed a new MRI technique that can depict the neuromelanin-related contrast generated by these nuclei and demonstrate pathologic changes occurring in some degenerative and psychiatric diseases [2–5]. In this review, we introduce the basics, the imaging technique, and clinical applications of neuromelanin-sensitive MRI.

What Is Neuromelanin?
Neuromelanin is a dark polymer pigment measuring 0.5–2.5 µm that exists within certain catecholamine neurons of the human brain, such as the dopaminergic neurons of the SNc and the noradrenergic neurons of the LC [6]. Neuromelanin is structurally similar but not identical to peripheral melains (i.e., eumelanin and pheomelanin): it is a polymer of eumelanin, pheomelanin, and cysteinyl-dopa with lipid/protein components [6, 7]. It is considered to form as a by-product of the catecholamine metabolism cascade by enzymatic and/or oxidative polymerization. Its formation is proportional to the activities of catecholamine synthesis (Figure 1) [6, 7].

Neuromelanin plays protective roles against the accumulation of toxic catecholamine derivatives and

Figure 1. Suggested pathways for the synthesis of neuromelanin.