Chapter 6
Microglia and Neuroinflammation

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ABSTRACT

Microglia, specialized immune cells within the central nervous system (CNS), are central to maintaining CNS health and protecting against damage and infections. However, their improper activation can contribute to the development and progression of various neurological diseases, including Alzheimer's, Parkinson's, multiple sclerosis, autism, and traumatic brain injury. Neuroinflammation, a complex process involving microglia and other glial cells, is considered a key factor in the pathogenesis of many neurological disorders. To comprehensively address this, this chapter introduces microglia's essential role in CNS homeostasis and sets the stage for understanding the concept of neuroinflammation, range of neurological and psychiatric disorders, cutting-edge imaging and genetic tools, the potential therapeutic strategies for modulating microglial function and targeting neuroinflammation.

1. INTRODUCTION

Microglia, often referred to as the resident macrophages of the CNS, serve as the first line of defense against damage and infection. Their multifaceted role encompasses not only surveillance and immune response but also the preservation of homeostasis within the intricate neural circuits. However, the pendulum of microglial function swings delicately, and dysregulation in their activation can tip the balance, contributing to the pathogenesis of various neurological diseases.

DOI: 10.4018/978-1-6684-9675-6.ch006

Neuroinflammation—a dynamic process involving the activation of glial cells, prominently microglia, and recognized as a significant player in the genesis of numerous neurological disorders. The relationship of microglial activation and neuroinflammation is of utmost importance in understanding the pathology of many diseases like Alzheimer's disease to Parkinson's disease, multiple sclerosis, and depression.

Advancements in technology have bestowed upon researchers a powerful arsenal of tools for studying microglial function in vivo. The latest imaging and genetic techniques afford us a glimpse into the dynamic world of microglia, shedding light on their interactions with other cell types within the CNS. By understanding the intricacies of microglial function and neuroinflammation, we may uncover new avenues for therapeutic intervention.

This introductory chapter sets the stage for a comprehensive exploration of the symbiotic relationship between microglia and neuroinflammation—a relationship that, when harmonious, preserves neurological health, but when disrupted, can contribute to the intricate tapestry of neurological diseases.

2. INTRODUCTION TO MICROGLIA AND NEUROINFLAMMATION

2.1. Microglia

The central nervous system's (CNS) resident immune cells, or microglia, are crucial for preserving brain homeostasis and controlling immunological responses in the brain. Here, we go into some basic facts concerning microglia, such as their anatomy, origin, and purposes (Nayak et al., 2014).

Myeloid progenitor cells, which start off in the yolk sac during embryonic development, give rise to microglia cells. Early in embryogenesis, these progenitor cells go to the CNS where they give birth to progenitors of the microglia. After then, the precursors settle into the brain tissue and develop into adult microglia (Yin et al., 2017). A microglia's structure in the CNS is depicted in Figure 1.

Microglia have a characteristic shape with a tiny cell body and many, ramified processes that are both extremely active and numerous. Microglia has a highly branching phenotype while at rest, which aids in their ability to keep an eye on their environment. Continuously scanning the brain microenvironment for indications of damage, infection, or aberrant cellular activity, the processes are active (Morris et al., 2013).

The functions of microglia is summarized in Figure 2 and described briefly below.

As immunological sentinels, microglia keeps an eye out for any changes in the CNS. They are naturally able to identify and react to a variety of signals, including aberrant protein aggregates, damage-associated molecular patterns, and pathogen-associated molecular patterns (PAMPs). When microglia receives these signals, immunological responses are triggered by pattern recognition receptors (PRRs) produced on their surface, such as toll-like receptors (TLRs) (Kigerl et al., 2014).

Highly phagocytic microglia effectively engulfs and removes infections, dead cells, and other detritus from the brain. They are essential for preserving tissue integrity and eliminating noxious materials to stop tissue damage.

By generating and releasing several immune mediators, including cytokines, chemokines, and growth factors, microglia control immunological responses in the CNS. The balance of these chemicals, which can have both pro- and anti-inflammatory actions, is essential for preserving brain homeostasis (Guo et al., 2022).