Neuroimmune alterations of ENS functioning

L Bueno

Introduction

Only recently has it been considered that numerous interactions between the enteric nervous system and local immunocytes are responsible for adaptive functional changes, including motility and secretion (fig 1). Several neuropeptides such as tachykinins, vasoactive intestinal peptide, somatostatin, and opioids are involved in both intrinsic and extrinsic innervation but can also affect immune reactions directly. They exert a dual role in the regulation of local and peripheral motor and secretory reflexes and affect the release of cytokines and proinflammatory mediators. On the other hand, proinflammatory mediators such as eicosanoids and cytokines may activate intrinsic neurones directly or stimulate extrinsic neurones indirectly, releasing neuropeptides which act on intrinsic neurones, smooth muscle cells, or enterocytes. These acute immediate neuroimmune reactions are often followed by long term changes in the number of receptors at the presynaptic or postsynaptic level as well as phenotypic changes of the effector cells, as evidenced for smooth muscle cells and enteric neurones which can synthetise cytokines.

Major gut targets in inflammation

There are at least three major target cells affected by the presence of inflammatory mediators: smooth muscle cells, glial cells, and neurones. Both intrinsic enteric neurones and terminals of extrinsic afferent and efferent nerves are affected (fig 2). Indeed, phenotypic changes in smooth muscle cells under the influence of proinflammatory mediators consist mainly of expression and release of cytokines.1 Up and downregulation of a number of receptors for neuromediators3 and neuropeptides4 have also been demonstrated. Indeed, the number of alpha and beta adrenoceptors is inversely altered in the acute phase of inflammation in the guinea pig ileum. Mast cells, leukotrienes, and prostaglandins are involved in this up and downregulation of receptors, and changes in the physical properties of smooth muscle have also been demonstrated both in vitro and in vivo.

Inflammation induces neuronal phenotypic changes and affects the release of mediators in the gut intrinsic nervous system (fig 3). The myenteric plexus may secrete cytokines such as interleukin (IL) 1 and tumour necrosis factor α (TNF-α)4, but also interferon γ and transforming growth factor β, although the physiological role of such secretions remains unknown. The presence of cytokines in the proximity of the myenteric plexus during inflammation may affect the release of classical neurotransmitters and the number of receptors for them and for neuropeptides, as well as altering electrophysiological properties. For example, it has been shown that IL-1β, through release of leukaemia inhibitory factor, de-

Abbreviations used in this paper: ACh, acetylcholine; IL, interleukin; TNF-α, tumour necrosis factor α; NAd, noradrenaline; 5-HT, 5-hydroxytryptamine.

Figure 1 Interaction between the central nervous system and the immune system. VIP, vasoactive intestinal peptide; SP, substance P; SOM, somatostatin; G, ganglion; GALT, gut associated lymphoid tissue; MLN, mesenteric lymph node. (From Ottaway.)

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creases the release of acetylcholine (ACh)\textsuperscript{7} and increases the activity or expression of inducible nitric acid synthase.\textsuperscript{8} TNF-\textgreek{a} may also selectively affect noradrenergic function by reducing the release of noradrenaline (NAd)\textsuperscript{9} from myenteric plexus, while IL-6 may decrease or increase this NAd release, depending of its concentration.\textsuperscript{10} Release of other mediators may also be influenced by inflammatory mediators as altered responsiveness to histamine and 5-hydroxytryptamine (5-HT), as well as to carbachol, was observed in inflamed guinea pig ileal strips.\textsuperscript{11} Electrophysiological measurements have recently permitted the characterisation of changes in resting potential or in spontaneous firing, as well as in the duration and amplitude of fast excitatory postsynaptic potentials in the guinea pig jejunal myenteric plexus during \textit{T spiralis} infection.\textsuperscript{12} From a functional point of view, the time course of inflammation development in trinitrobenzene sulphonic acid induced colitis in rats is associated with typical alterations in electrical spike activity, corresponding to a progressive increase in the duration of electrical spike bursts. These alterations are transiently suppressed by systemic administration of IL-1 receptor antagonist, suggesting that the activity of myenteric neurones controlling colonic motility during inflammation are permanently modulated by cytokines.\textsuperscript{13} In addition, some neuroimmune connections may ini-

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure2}
\caption{Influence of inflammatory mediators on extrinsic afferent and efferent nerves. LT, leukotriene; PGs, prostaglandins; NGF, nerve growth factor; CGRP, calcitonin gene related peptide; 5-HT, 5-hydroxytryptamine; diHETE, dihydroxyeicosatetraenoic acid.}
\end{figure}

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure3}
\caption{Inflammation induced phenotypic changes and mediator release in the gut intrinsic nervous system. IL\textsubscript{1-\greek{i}}, interleukin; TNF-\textgreek{a}, tumour necrosis factor \textgreek{a}; TGF-\textgreek{\beta}, transforming growth factor \textgreek{\beta}; LIF, leukaemia inhibitory factor; ACh, acetylcholine; iNOS, inducible nitric acid synthase; NAd, noradrenaline.}
\end{figure}
Table 1  Pathological motility disorders and the enteric nervous system

<table>
<thead>
<tr>
<th>Type</th>
<th>Inflammatory mediators</th>
<th>Cytokines</th>
<th>Neurotransmitters</th>
<th>Neuropeptides</th>
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<tbody>
<tr>
<td>Inflammation (acute)</td>
<td>LTB4</td>
<td>IL-1</td>
<td>5-HT (5-HT&lt;sub&gt;1&lt;/sub&gt;,5-HT&lt;sub&gt;2&lt;/sub&gt;)</td>
<td>BK (B&lt;sub&gt;2&lt;/sub&gt;)</td>
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<td></td>
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<td>IL-1</td>
<td>5-HT (5-HT&lt;sub&gt;1&lt;/sub&gt;)</td>
<td>SP (NK&lt;sub&gt;1&lt;/sub&gt;)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Histamine (H1)</td>
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<td>SP (NK&lt;sub&gt;1&lt;/sub&gt;)</td>
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<tr>
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<td>NKA (NK&lt;sub&gt;2&lt;/sub&gt;)</td>
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<tr>
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</tr>
<tr>
<td></td>
<td></td>
<td>NO</td>
<td>SP (NK&lt;sub&gt;1&lt;/sub&gt;)</td>
<td>meizotheline</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NO</td>
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<tr>
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<td>IL-1</td>
<td>5-HT (5-HT&lt;sub&gt;3&lt;/sub&gt;)</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>NO</td>
<td>Crf</td>
<td></td>
</tr>
</tbody>
</table>

LTB<sub>4</sub>, leukotriene B<sub>4</sub>; IL, interleukin; PGE<sub>2</sub>, prostaglandin E<sub>2</sub>; PAF, platelet activating factor; TNF-α, tumour necrosis factor α; 5-HT, 5-hydroxytryptamine; NO, nitric oxide; NAd, noradrenaline; BK, bradykinin; ACh, acetylcholine; SP, substance P; NK, neurokinin; CRF, corticotrophin releasing factor.

Roles of enteric neural mechanisms

Inflammation and gut motility.

Inflammation (acute) involves the release of inflammatory mediators such as histamine and serotonin, which can activate local sensory neurons and promote intestinal motility.

**Role of ENS in altered gut secretory and motor patterns**

There is increasing evidence that substances such as histamine and serotonin are involved in local activation of intrinsic neurons in the gut. These substances can also be released in response to various stimuli, such as food ingestion or infection. The enteric nervous system (ENS) plays a crucial role in regulating gut motility and secretory functions. Inflammation, parasitism, and septic shock can all alter the gut motility patterns.

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