Treatment of Dementia in Parkinsonian Patients

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Abstract

Among the patients with Parkinson’s disease, 85% show symptoms of a mild cognitive impairment and 40% develop criteria of dementia. Increased levels of glutamate, noradrenaline and serotonin can be found. Diagrams of neural pathways in the extrapyramidal system and hippocampus and temporal cortex are described and compatible treatments for both syndromes are derived. Besides a conventional treatment with the cholinesterase inhibitor, NMDA antagonists, in combination with a decarboxylase inhibitor and selegeline could be administered additionally.

Keywords: Acetylcholine; Dementia; Dopamine; Dopamine agonist; Extrapyramidal system; Glutamate; Hippocampus; l-dopa; Parkinson’s disease; Rivastigmine

Introduction

Parkinson’s disease is a neurodegenerative disease with movement disturbances and mental dysfunction [1]. Among the patients with Parkinson’s disease, 85% show symptoms of a mild cognitive impairment and 40% develop criteria of dementia [2]. A lack of dopamine in the pars compacta of the substantia nigra leads to the Parkinsonian motor-symptoms, while an acetylcholine decline, which begins in the nucleus basalis of Meynert, can be the cause of the dementia symptoms [2]. The alteration in neurotransmitters is associated with a major formation of fibrillary tangles and senile plaques [3]. In Parkinsonian patients showing dementia a neurotransmitter alteration occurs in the hippocampus and temporal cortex. In this syndrome, an acetylcholine and gamma-aminobutyric acid deficiency and a noradrenaline and glutamate surplus can be found in the mentioned brain areas. Diagrams of neural pathways in the extrapyramidal system and hippocampus and temporal cortex are described and compatible treatments for both syndromes are derived from the alterations of classical neurotransmitters [4]. The purpose of this mini-review is to review neurotransmitter alterations acting at specific receptors and the possible neural pathways in the involved brain regions in Parkinson’s disease and dementia. From these findings, it will be concluded which anti-Parkinsonian drugs can be administered in Parkinsonian patients showing symptoms of dementia.

Pathophysiology of Parkinson’s Disease

In Parkinson’s disease, a neurotransmitter imbalance in the extrapyramidal system (EPS) between hypoactivity of D2 dopaminergic and GABAa GABAergic neurons and hyperactivity of M4 muscarinic cholinergic and NMDA glutaminergic neurons occurs. In order to stabilize the neural network described above, l-dopa, dopamine agonists, anticholinergics, which act at the M4 receptor, and NMDA antagonists can be given. In the next chapter, the diagrams of neural pathways in the EPS will be discussed.

Pathophysiology of Parkinson’s Disease Dementia

In patients with Parkinson’s disease who show criteria of dementia, apoptosis occurs as a consequence of the hypo- or hyper-activities of classical neurotransmitters, i.e. dopamine and acetylcholine hypo-activities [4]. In the Landscape study carried out in Denmark, 269 Parkinsonian patients with mild cognitive impairment were included. An anamnestic mild cognitive impairment was more frequent, and altered executive functions were the most detectable symptom. These patients, showing a mild cognitive impairment, have a different risk to develop dementia [5].

Diagrams of Neural Pathways in the Extrapyramidal System

The diagram of neural pathways in the EPS could be the following: dopaminergic neurons in the pars compacta of the substantia nigra and enhance dopamine deficiency. Besides, these neurons inhibit via NMDA receptors GABAaergic neurons in the internal globus pallidus. The latter neurons inhibit glutaminergic neurons in the thalamus, which transmit an activating potential to other glutaminergic neurons in the cortex. The glutaminergic neurons in the cortex transmit a postsynaptic excitatory potential via NMDA receptors to GABAaergic neurons located in the internal globus pallidus, and the latter neurons weakly presynaptically inhibit subthalamic NMDA glutaminergic neurons. The latter neurons strongly inhibit D2 dopaminergic neurons in the substantia nigra and enhance dopamine deficiency. Besides, these neurons inhibit via NMDA receptors GABAaergic neurons in the internal globus pallidus. The latter neurons inhibit glutaminergic neurons in the thalamus, which transmit an activating potential to other glutaminergic neurons in the cortex. The glutaminergic neurons in the cortex transmit a postsynaptic excitatory potential via NMDA receptors to D1 and D2 dopaminergic neurons in the caudate nucleus and to other glutaminergic neurons located in the subthalamic nucleus. In the internal globus pallidus, GABAaergic neurons with a...
weak activity transmit a presynaptic inhibitory potential via GABAA receptors to muscarinic cholinergic and serotonergic neurons in the putamen, which transmit a strong activating potential respectively via M4 and 5-HT2A receptors to glutaminergic neurons. The latter neurons with a high activity presynaptically inhibit dopaminergic neurons in the putamen. The latter neurons receive an activating impulse from nicotinic cholinergic neurons via B2 nACh receptors. Dopaminergic neurons in the putamen transmit a weak postsynaptic excitatory potential via D2 receptors to other dopaminergic neurons in the caudate nucleus.

Diagram of Neural Pathways in the Temporal Cortex and Hippocampus in Parkinson's Disease Dementia

Diagrams of neural pathways could be the following: in the nucleus basalis of Meynert, muscarinic cholinergic neurons, which present a progradient lack of acetylcholine, send an activating projection via M1 receptor to other muscarinic cholinergic neurons located in the hippocampus (Figure 2). These neurons send a weak activating potential via M1 receptors to GABAergic neurons, which weakly affect noradrenergic neurons through a presynaptic inhibitory influence via GABAA receptors. The noradrenergic neurons with a high activity at the beginning of the disease, which decreases constantly [6], transmit a strong postsynaptic excitatory impulse via alpha 1 receptor to glutaminergic neurons, which strongly presynaptically inhibit muscarinic cholinergic neurons via NMDA receptors. In the hippocampus, an antagonistic interaction occurs also between muscarinic cholinergic and serotonergic neurons [3]. Muscarinic cholinergic neurons send a weak activating potential via M1 receptor to GABAergic neurons which weakly affect serotonergic neurons through a presynaptic inhibitory influence via GABAA receptors. These neurons, the activity of which also decreases, send an activating potential via 5-HT1A receptors to glutaminergic neurons, which strongly presynaptically inhibit muscarinic cholinergic neurons via NMDA receptors [7]. In the temporal cortex, muscarinic cholinergic neurons with a decreasing activity send a weak post-synaptic excitatory potential, via alpha 1 receptors to glutaminergic neurons which affect muscarinic cholinergic neurons in the hippocampus through a strong presynaptic inhibitory influence.

Treatment of Parkinson's Disease Dementia

For the treatment of Parkinson's disease dementia the following drugs can be administered:

- L-dopa in combination with a decarboxylase inhibitor, because increased dopamine levels exert an anti-apoptotic effect.
- Dopamine agonists, for example rotigotine, applicable as a therapeutic plaster.
- Selegeline, a monoamine oxidase inhibitor.
- NMDA antagonists, which regulate dopamine levels in the extrapyramidal system and acetylcholine levels in the temporal cortex [8].

Figure 1: Physiological neuronal pathways, classical neurotransmitters and neuropeptides involved in the extrapyramidal system with neurotransmitter and neuropeptide alterations in Parkinson's disease. 5-HT: serotonin; ACh: acetylcholine; DA: dopamine; Dyn: dynorphin; GABA: gamma-aminobutyric acid; Glu: glutamate; SP: substance P. The following subreceptors are indicated: B2nACh: B2nACh receptor; a subtype of the nicotinic cholinergic receptor; GABAA: GABAA receptor, a subtype of the GABA receptor; 5-HT2A: 5-HT2A receptor, a subtype of the serotoninergic receptor; D1: D1 receptor, a subtype of the dopaminergic receptor; D2: D2 receptor, a subtype of the dopaminergic receptor; kappa: kappa receptor; a subtype of the opioid receptor; M4: M4 receptor; a subtype of the muscarinic cholinergic receptor; NK1: NK1 receptor; a subtype of the substance P receptor; NMDA: NMDA (N-methyl-D-aspartate) receptor, a subtype of the ionotropic glutaminergic receptor. A plus mark indicates a postsynaptic excitatory potential; a minus mark indicates a presynaptic inhibitory potential. ↑: increase; ↓: decrease. The receptors of the neurotransmitters with a high activity are in bold type, the receptors of the neurotransmitters with a decreased activity are printed normally.
Figure 2: Physiological neuronal pathways, classical neurotransmitters and neuropeptides in cortical and limbic brain regions and neurotransmitter alterations in Parkinson's disease dementia. 5-HT: serotonin; Ach: acetylcholine; GABA: gamma-aminobutyric acid; Glu: glutamate; NA: noradrenaline. The following subreceptors are indicated: 5-HT1A: 5-HT1A receptor, a subtype of the serotonergic receptor; alpha 1: alpha1 receptor, a subtype of the noradrenergic receptor; GABAA: GABAA receptor, a subtype of the GABAergic receptor; M1: M1 receptor, a subtype of the muscarinic cholinergic receptor; NMDA: NMDA (N-methyl-D-aspartate) receptor, a subtype of the ionotropic glutaminergic receptor. A plus mark indicates a postsynaptic excitatory potential; a minus mark indicates a presynaptic inhibitory potential. ↑: increase; ↓: decrease. The receptors of the neurotransmitters with a high activity are in bold type, the receptors of the neurotransmitters with a decreased activity are printed normally.

Aim of an appropriate treatment of Parkinson’s disease dementia is to find a treatment, which improves motor symptoms and cognitive deficits at the same time. It is important to maintain an anti-Parkinsonian pharmacotherapy, for example to combine rotigotine, a dopamine agonist with rivastigmine, a cholinesterase inhibitor. Both drugs can be applied as therapeutic plasters.

Conclusion
Among the patients with Parkinson’s disease, 85% show symptoms of a mild cognitive impairment and 40% develop criteria of dementia. In the concerned brain areas, acetylcholine and dopamine deficiencies are anti-apoptotic. In the hippocampus, acetylcholine and GABA deficiencies and a surplus of glutamate, noradrenaline and serotonin occur. In order to deduce compatible treatments for both syndromes, diagrams of neural pathways are pointed in the involved brain areas. In addition, the cholinesterase inhibitor rivastigmine, NMDA antagonists, l-dopa in combination with a decarboxylase inhibitor and selegeline could be administered. In the treatment of Parkinsonian patients who show symptoms of dementia, it is important to continue the anti-Parkinsonian pharmacotherapy and to improve cognitive deficits. It can be recommended to combine rotigotine, a dopamine agonist with rivastigmine, a cholinesterase inhibitor. Both drugs are applicable as therapeutic plasters. Further research should be undertaken in order to improve the therapeutic and maybe prophylactic pharmacotherapy of this form of dementia.

References

Cholinesterase inhibitors, i.e. rivastigmine, which do not activate cholinergic neurotransmission in the extrapyramidal system [4].

Anticholinergics have no therapeutic effect, because they enhance cognitive deficits [1].