Review

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Review

A Literature Review of Movement Disorder Associated with Medications and Systemic Diseases

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Abstract: Movement disorders can be associated with various drugs and systemic diseases, posing diagnostic challenges for clinicians. This review explores the spectrum of movement disorders associated with pharmacological agents and medical conditions. Drug-induced movement disorders encompass a broad range of conditions resulting from exposure to medications that affect several neurotransmitters. Neuroleptic medications can lead to tardive dyskinesia, characterized by involuntary, repetitive movements. Antipsychotics and antiemetics, including metoclopramide, may induce acute dystonic reactions. Other drugs, such as dopamine receptor-blocking agents, can contribute to drug-induced parkinsonism. Beyond medications, movement disorders can also arise secondary to systemic diseases. Metabolic disorders like Wilson's disease, characterized by copper accumulation, may manifest as chorea or dystonia. Inflammatory conditions such as rheumatoid arthritis and systemic lupus erythematosus can result in secondary movement disorders due to autoimmune-mediated processes affecting the central nervous system. Movement disorders linked to drugs or systemic diseases often necessitate a thorough clinical evaluation, including detailed medication histories and comprehensive systemic assessments. Neuroimaging, laboratory investigations, and, in some cases, cerebrospinal fluid analyses and electrodiagnostic studies help in establishing accurate diagnoses. Management involves addressing the underlying cause, modifying medications, and employing symptomatic treatments.

Keywords: drug-induced; drug-induced parkinsonism; parkinsonism; dystonia; drug-induced side-effects; tardive syndrome; basal ganglia; dyskinesia; secondary; movement disorder

1. Introduction

Movement disorders associated with medications, known as drug-induced movement disorders, are a diverse group of conditions characterized by abnormal involuntary movements or alterations in motor control resulting from the use of certain drugs [1]. These disorders can manifest in various ways, including tremors, dystonia, dyskinesia, and parkinsonism. Several classes of medications are known to be linked to the development of these movement disorders, impacting individuals differently based on factors such as dosage, duration of use, and individual susceptibility [2].

Antipsychotic medications, commonly used to treat psychiatric conditions such as schizophrenia and bipolar disorder, are notable contributors to drug-induced movement disorders. Tardive dyskinesia is a particularly concerning side effect associated with long-term use of certain antipsychotics [3]. This condition is characterized by repetitive and involuntary movements, often involving the face, tongue, and limbs. The risk of tardive dyskinesia increases with prolonged exposure to these medications [4].

Antiemetic medications, such as metoclopramide, are another class linked to drug-induced movement disorders. Metoclopramide, in particular, can lead to tardive dyskinesia, especially in individuals using the medication for an extended period [5]. Parkinsonism-like symptoms, including rigidity and bradykinesia, have been observed in individuals taking these medications. The underlying mechanisms by which these drugs induce movement disorders are complex and may

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involve interactions with several neurotransmitters. Certain mood stabilizers, such as lithium and valproate, may also contribute to drug-induced movement disorders [6]. They have been associated with tremors, ataxia, and other abnormal movements. The prevalence and severity of these side effects vary among individuals, necessitating close monitoring and individualized treatment approaches.

In some cases, drug-induced movement disorders are reversible upon discontinuation of the causative medication, while in other instances, the effects may persist. Management strategies may include adjusting the dosage, switching to alternative medications, or using specific medications to alleviate symptoms.

Movement disorders can be intricately associated with various systemic conditions. Systemic conditions, encompassing a range of medical disorders affecting multiple organs and systems, can give rise to movement abnormalities as secondary manifestations. These disorders may include metabolic conditions, autoimmune diseases, and inflammatory processes, all of which have the potential to impact the central nervous system and its control over motor function.

Metabolic disorders, such as Wilson's disease, offer a compelling example of the intersection between systemic conditions and movement disorders. Wilson's disease, characterized by the accumulation of copper in several systems, can lead to neurological symptoms like chorea or dystonia [7]. The abnormal metabolism associated with this systemic condition directly influences the functioning of the basal ganglia, a key region in the brain involved in motor control.

Autoimmune and inflammatory systemic diseases also contribute significantly to movement disorders. Rheumatoid arthritis and systemic lupus erythematosus, for instance, may have neurological manifestations, leading to conditions like secondary Parkinsonism or other forms of movement abnormalities [8]. In these cases, the immune system's response to systemic inflammation can affect the nervous system, disrupting the finely tuned coordination of movements.

The intricate relationship between movement disorders and systemic conditions underscores the importance of a comprehensive and interdisciplinary approach to diagnosis and management. Neurologists, rheumatologists, and other specialists collaborate to unravel the complexities of these conditions. Understanding the systemic underpinnings of movement disorders not only aids in accurate diagnosis but also guides tailored treatment strategies that address the root causes and optimize overall patient care. The present study aims to describe the different drugs and systemic diseases associated with movement disorders.

2. Medications associated with movement disorders

2.1. Carbamazepine

Carbamazepine is an anticonvulsant and mood-stabilizing medication primarily used to treat epilepsy and bipolar disorder [9]. While carbamazepine is generally well-tolerated, it has been associated with specific side effects, and in rare cases, it may contribute to movement disorders and urinary incontinence [10]. One notable movement disorder linked to carbamazepine use is ataxia. Although ataxia is an uncommon side effect of carbamazepine, individuals taking the medication should be monitored for any signs of motor coordination issues [11]. Moreover, carbamazepine has been reported to cause tremors in some cases. It's important to note that the occurrence of movement disorders with carbamazepine can vary among individuals, and not everyone will experience these side effects. Factors such as dosage, duration of use, and individual susceptibility can influence the likelihood and severity of such adverse reactions [12]. Adjustments to the medication dosage, alternative medications, or additional interventions may be considered based on the individual's situation [13].

2.2. Mirtazapine

Mirtazapine is an antidepressant medication that works by increasing the levels of serotonin and norepinephrine in the brain. It is commonly prescribed to treat major depressive disorder [14]. While mirtazapine is generally well-tolerated, it is not typically associated with causing movement

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disorders. Movement disorders, which involve abnormal or involuntary movements, can be a side effect of some medications, particularly certain antipsychotics or drugs used to treat Parkinson's disease [15]. However, mirtazapine was already associated with restless legs syndrome, tremors, akathisia, periodic limb movement disorder, dystonia, rapid eye movement sleep behavior disorders, dyskinesia, parkinsonism, tic, and other undefined extrapyramidal symptom [16]. While the risk of movement disorders with mirtazapine is low, individual responses to medications can vary [17,18].

2.3. Pregabalin

Pregabalin is an anticonvulsant medication used to treat various conditions, including neuropathic pain, fibromyalgia, and certain types of seizures. While pregabalin is generally well-tolerated, it has been associated with some side effects, although movement disorders are not commonly reported [19]. One potential side effect related to pregabalin is movement is ataxia, a condition characterized by a lack of muscle coordination, leading to unsteady movements and difficulty maintaining balance. Ataxia is an infrequent side effect of pregabalin, and its occurrence tends to be dose-dependent [20]. Individuals taking pregabalin should be monitored for signs of ataxia, mainly if higher doses are prescribed. Tremors, another type of movement disorder involving rhythmic, involuntary shaking of a part of the body, have been reported in rare cases with pregabalin use [21]. Adjustments to the dosage or consideration of alternative medications may be necessary [22]. While movement disorders with pregabalin are not common, individual responses to medications can vary.

2.4. Buspirone

Buspirone is an anxiolytic medication primarily prescribed to treat generalized anxiety disorder [23]. It is not typically associated with causing movement disorders. Movement disorders involve abnormal or involuntary movements and can manifest as tremors, dystonia, or other motor disturbances [24]. Buspirone interacts with serotonin receptors in the brain, specifically targeting serotonin 5-HT1A receptors [25]. It does not have the exact mechanism of action as medications commonly associated with movement disorders, such as antipsychotics. While buspirone is generally well-tolerated, individual responses to medications can vary. Adjustments to the medication regimen or further evaluation may be necessary based on the individual's situation.

2.5. Valproate

Valproate, also known as valproic acid or divalproex sodium, is an anticonvulsant medication used to treat various conditions, including epilepsy, bipolar disorder, and migraine headaches [26]. While valproate is generally effective in managing these conditions, it can be associated with specific side effects, including hematologic side effects and movement disorders [27]. One movement disorder linked to valproate use is tremor. Valproate-induced tremors are generally dose-related, meaning that they may occur more frequently or intensify at higher doses of the medication [28]. In addition to tremors, valproate has been associated with other movement-related side effects, such as ataxia [29]. It's important to note that the occurrence of movement disorders with valproate can vary among individuals. Factors such as the dosage, duration of use, and individual susceptibility can influence the likelihood and severity of these side effects [30]. Depending on the specific situation, the healthcare provider may consider adjusting the medication dosage, exploring alternative treatments, or implementing strategies to manage the movement-related side effects.

2.6. Lamotrigine

Lamotrigine is generally not associated with causing movement disorders. Lamotrigine is an anticonvulsant medication primarily used to treat epilepsy and bipolar disorder [31]. It works by stabilizing electrical activity in the brain. While lamotrigine is generally well-tolerated, it can have side effects, including dizziness, headache, and gastrointestinal issues. Movement disorders,

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however, are not commonly reported as side effects of lamotrigine. Lamotrigine was already reported with tics, dyskinesias, myoclonus, parkinsonism, dystonia, and stuttering [32].

2.7. Amitriptyline

Amitriptyline is a tricyclic antidepressant that is primarily used to treat conditions such as major depressive disorder, neuropathic pain, and certain anxiety disorders [33]. While amitriptyline is generally well-tolerated, it can be associated with various side effects, although movement disorders are not commonly reported. Tricyclic antidepressants, including amitriptyline, primarily affect the levels of neurotransmitters such as serotonin and norepinephrine [34]. While these medications can affect motor function and coordination, they are not typically associated with movement disorders in the same way that some other classes of drugs (dopamine-receptors block). However, individual responses to medications can vary, and in rare cases, some people may experience unusual side effects or adverse reactions. It's important to note that abrupt discontinuation of amitriptyline or any antidepressant should be avoided, as it can lead to withdrawal symptoms [35].

2.8. Lithium

Lithium is a mood-stabilizing medication commonly used to treat bipolar disorder. While lithium is generally effective in managing mood symptoms, it has been associated with specific side effects, and in rare cases, it can be linked to movement disorders [36]. One movement disorder that has been reported in association with lithium use is a tremor. Lithium-induced tremor is typically a fine, rapid tremor that may affect the hands. The tremor is often dose-dependent, meaning it may occur or become more pronounced with higher doses of lithium [37]. The exact mechanism by which lithium induces tremors has yet to be fully understood. It's important to note that not everyone taking lithium will experience tremors, and the occurrence of this side effect can vary among individuals. Factors such as the dosage, duration of use, and individual susceptibility can influence the likelihood and severity of lithium-induced tremors [38]. Regular monitoring of lithium levels in the blood is essential to ensure that the medication remains within the therapeutic range. This helps to optimize its effectiveness while minimizing the risk of side effects, including movement disorders [39].

2.9. Topiramate

Topiramate is an antiepileptic drug that is also used for the prevention of migraine headaches and as an adjunctive treatment for certain psychiatric conditions [40]. While topiramate is generally well-tolerated, it can be associated with side effects, and in some cases, movement disorders may occur. One movement disorder linked to topiramate use is tremors [41]. The tremor can be dose-dependent, meaning it may occur more frequently or intensify with higher doses of topiramate. Factors such as the dosage, duration of use, and individual susceptibility can influence the likelihood and severity of topiramate-induced tremors [42]. Topiramate is also associated with other neurological side effects, including difficulty with concentration and cognitive slowing, which may be relevant to movement coordination [43].

2.10. Phenytoin

Phenytoin is an anticonvulsant medication. While phenytoin is generally effective in managing seizures, it has been associated with specific side effects, including movement disorders and other neuropsychiatric manifestations [44,45]. One movement disorder linked to phenytoin use is called cerebellar ataxia [46]. Phenytoin-induced cerebellar ataxia can result in unsteady gait, difficulty with balance, and coordination problems [47]. Factors such as the dosage, duration of use, and individual susceptibility can influence the likelihood and severity of phenytoin-induced movement disorders [48]. Regular monitoring of phenytoin levels in the blood is essential to ensure that the medication remains within the therapeutic range [49]. This helps to optimize its effectiveness while minimizing the risk of side effects, including movement disorders.

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2.11. Bupropion

Bupropion is an antidepressant medication that is also used for smoking cessation [50]. While bupropion is generally well-tolerated, movement disorders are not commonly associated with its use. Movement disorders such as tremors, dystonia, or parkinsonism are more often linked to other classes of medications, such as antipsychotics or certain medications used to treat neurological disorders [51]. However, individual responses to medications can vary, and rare side effects or idiosyncratic reactions can occur [52]. Bupropion primarily acts on the neurotransmitters norepinephrine and dopamine in the brain [53]. While it impacts the dopaminergic system, it does not typically cause movement disorders like medications affecting dopamine receptors.

2.12. Gabapentin

Gabapentin is an antiseizure medication primarily used to manage seizures and neuropathic pain [54]. While it is generally well-tolerated, movement disorders are not commonly associated with gabapentin use [55]. Movement disorders can encompass a range of conditions, including tremors, dystonia, and ataxia [56]. While some medications may cause movement disorders as side effects, gabapentin is not typically known for inducing these types of issues. However, individual responses to medications can vary, and rare or idiosyncratic reactions may occur. It's also worth noting that gabapentin may cause side effects such as dizziness, drowsiness, or unsteadiness, which can mimic some aspects of movement disorders [57]. Adjustments to the dosage or gradual titration may be considered if these side effects are significant.

2.13. Fluoroquinolones

Fluoroquinolones are a class of antibiotics commonly used to treat various bacterial infections [58]. While fluoroquinolones are generally well-tolerated, they have been associated with certain side effects, and there have been rare reports of neuromuscular side effects, including movement disorders. One notable neurological side effect linked to fluoroquinolone use is peripheral neuropathy and intracranial hypertension [59]. Peripheral neuropathy involves damage to the peripheral nerves, leading to pain, tingling, numbness, and weakness in the extremities. In severe cases, peripheral neuropathy can affect coordination and lead to gait abnormalities [60]. Movement disorders, such as tremors or muscle spasms, have been reported in some cases, although these occurrences are rare [61]. The exact mechanism by which fluoroquinolones may contribute to movement disorders or neuromuscular symptoms is not fully understood [62]. It's important to note that the occurrence of movement disorders with fluoroquinolones is infrequent, and the overall benefit of these antibiotics in treating bacterial infections usually outweighs the risk of such side effects [63].

2.14. Cinnarizine and Flunarizine

Cinnarizine and flunarizine are piperazine derivatives with antihistaminic properties and calcium channel-blocking activity, sometimes used to treat vestibular disorders and associated symptoms, such as vertigo and dizziness [64]. These medications have calcium channel-blocking properties and are believed to stabilize the inner ear and vestibular system. Abnormal movements secondary to these calcium-channel blockers include extrapyramidal symptoms, which are relatively uncommon with cinnarizine and flunarizine. They have been reported in some cases. Also, some individuals may experience bradykinesia and tremors with cinnarizine and flunarizine therapies [65]. Again, these side effects are considered rare. It's important to note that these movement-related side effects are generally dose-dependent and may occur more frequently at higher doses of these medications [66].

2.15. Cenobamate

Cenobamate is a relatively new antiepileptic medication approved for the treatment of focal-onset seizures in adults [67]. Movement disorders, including tremors or other abnormal movements,

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are potential side effects of certain antiepileptic medications [68]. However, specific information on cenobamate's association with movement disorders may be limited.

2.16. Baclofen

Baclofen is a medication commonly used to treat muscle spasticity and spasms. While it is generally well-tolerated, like any medication, baclofen can have side effects. Baclofen-induced movement disorders are not common, but some individuals may experience adverse effects related to its use [69]. Baclofen can sometimes cause ataxia. While baclofen is intended to reduce muscle spasms, in some cases, it may lead to unintended dyskinetic movements. Baclofen's muscle-relaxing effects can result in weakness, especially when higher doses are used. Excessive muscle weakness may impact voluntary movements. Other common side effects of baclofen include dizziness and drowsiness. These symptoms can indirectly affect movement, coordination, and balance. In rare cases, individuals taking baclofen may experience tremors and catatonic symptoms [70].

2.17. Methylphenidate

Methylphenidate is a central nervous system stimulant commonly used to treat attention deficit hyperactivity disorder [71]. While methylphenidate primarily affects neurotransmitters such as dopamine and norepinephrine to improve attention and focus, it is not typically associated with causing movement disorders. Methylphenidate was rarely associated with dystonia [72].

2.18. Donepezil

Donepezil is a medication commonly prescribed for the treatment of Alzheimer's disease and other forms of dementia [73]. It belongs to a class of drugs known as cholinesterase inhibitors, and its primary function is to increase the levels of acetylcholine, a neurotransmitter involved in memory and cognitive functions. The main focus of donepezil is on cognitive function and memory improvement in individuals with dementia. Movement disorders were uncommonly associated with donepezil. There are reports of myoclonus secondary to donepezil/galantamine. But, there is no report of rivastigmine-induced myoclonus. Also, the most common management approach was discontinuing the acetylcholinesterase inhibitor [74].

2.19. Amantadine

Amantadine is a medication that has multiple uses, including the treatment of Parkinson's disease and certain respiratory viral infections [75]. While amantadine is generally well-tolerated, it can, in some cases, lead to movement disorders, particularly at higher doses or with prolonged use. In some individuals with Parkinson's disease, long-term use of amantadine may lead to the development of dyskinesias. Amantadine can, in rare cases, contribute to ataxia and myoclonus [76]. Amantadine can cause dizziness and lightheadedness, which may affect balance and coordination.

3. Results

3.1. Stroke

The consequences of a stroke can vary, and the public knowledge about stroke is still scarce, even in a population with levels of formal education above the national average [77,78]. The specific movement disorders that may occur after a stroke depend on the location and extent of the brain damage [79]. Frequent abnormal movements following a stroke include hemiparesis/hemiplegia [80]. Stroke often results in weakness or paralysis on one side of the body, known as hemiparesis or hemiplegia [81]. This can significantly impact an individual's ability to control movements on the affected side. Ataxia is a movement disorder characterized by a lack of coordination, affecting balance and fine motor skills. Damage to specific areas of the brain during a stroke can lead to ataxia [82]. Spasticity involves increased muscle tone and stiffness, making movements difficult. Astasia was rarely reported with anterior corpus callosum stroke [83].

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In some cases, stroke survivors may experience tremors, which are involuntary, rhythmic movements [84]. Tremors may affect the hands, arms, or other body parts. Rehabilitation plays a crucial role in addressing movement disorders after a stroke. Physical, occupational, and speech therapy can help individuals regain strength, improve coordination, and learn adaptive strategies for daily activities [85].

3.2. Epilepsy

Epilepsy can sometimes be associated with specific movement disorders or motor abnormalities [86]. Some movement disorders that may be seen in individuals with epilepsy include tics [87]. These can occasionally occur in individuals with epilepsy, especially in certain seizure types or as part of comorbid neurodevelopmental conditions, or even in post-stroke epilepsy [88]. In some cases, epilepsy-related brain abnormalities can lead to dystonic movements [89]. Automatisms are repetitive, purposeless movements or behaviors occurring during certain types of seizures, particularly complex partial seizures [90]. These movements may include lip-smacking, picking at clothing, or fumbling with objects [91,92]. After a seizure, individuals may experience a postictal state characterized by confusion, disorientation, and sometimes abnormal movements [93]. These movements are generally not purposeful and may include flailing or uncoordinated motions [94]. The type of movement disorder observed can also depend on the specific type of epilepsy, the location of the seizure activity in the brain, and individual variations [95]. Management of movement disorders associated with epilepsy often involves treating the underlying seizures with antiepileptic medications.

3.3. Neurosyphilis

Neurosyphilis is a severe form of syphilis that involves the infection of the central nervous system (brain and spinal cord) by the bacterium Treponema pallidum [96]. While the manifestations of neurosyphilis can be diverse, including cognitive and psychiatric symptoms, it can also lead to movement disorders in some cases [97,98]. Tabes dorsalis is a late-stage manifestation of syphilis that primarily affects the dorsal columns of the spinal cord, leading to sensory ataxia [99]. Sensory ataxia refers to a lack of coordination due to impaired proprioception, the sense of the position and movement of one's own body. The movement abnormalities seen in tabes dorsalis include an unsteady and wide-based gait, difficulty with balance, and problems with fine motor control [100]. These symptoms result from the damage to the sensory nerves in the spinal cord, leading to a disruption in the transmission of signals related to position and movement [101]. Neurosyphilis can also present with other neurological manifestations, including dementia, psychosis, and cranial nerve abnormalities [102]. The specific symptoms can vary widely among individuals. Early detection and prompt treatment are essential to prevent the progression of the disease and the development of severe complications, including movement disorders [103].

3.4. Headaches

Headaches and movement disorders are two distinct neurological conditions, but they can coexist, and in some cases, one may influence the other. Certain movement disorders can be associated with headaches. For example, some individuals with essential tremor or dystonia may experience headaches due to the strain on muscles and the increased effort required for movement [104]. In Parkinson's disease, headaches can be associated with the underlying pathology or may result from tension and muscle stiffness.

Movement disorders that arise from structural or degenerative changes in the brain (such as certain types of parkinsonism) can lead to secondary headaches [105]. These headaches may be due to increased intracranial pressure, inflammation, or other factors related to the underlying neurological condition. Medications used to treat movement disorders may also have headaches as a side effect [106,107].

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Both headaches and movement disorders can have shared underlying causes. For example, certain neurological conditions or vascular issues may contribute to both headaches and movement abnormalities. Stress is a common trigger for both headaches and exacerbation of movement disorders [108]. For instance, individuals with conditions like essential tremor or dystonia may find that stress worsens their symptoms, and headaches can also be triggered or exacerbated by stress. Sometimes, headaches and movement disorders may coexist due to shared risk factors or underlying neurological conditions. For instance, certain genetic factors or vascular issues may contribute to both migraine headaches and certain movement disorders.

3.5. Neurocysticercosis

Neurocysticercosis is a parasitic infection of the central nervous system caused by the larvae of the pork tapeworm, Taenia solium [109]. The infection can lead to various neurological symptoms and complications, including movement disorders. The symptoms of neurocysticercosis are diverse and can include seizures, headaches, cognitive impairments, and movement disorders. Movement disorders associated with neurocysticercosis may include dystonia, tremors, ataxia, and myoclonus [110]. The movement disorders in neurocysticercosis are often a result of the inflammatory response to the presence of cysticerci (larval cysts) in the brain tissue [111]. The location and number of cysticerci in the brain can influence the specific neurological manifestations [112]. The diagnosis of neurocysticercosis typically involves neuroimaging studies to detect the characteristic cystic lesions in the brain. Treatment may include medications to address the infection, manage symptoms, and control inflammation. Antiparasitic medications, such as albendazole or praziquantel, are often used to treat the disease [113]. In some cases, corticosteroids may be prescribed to reduce inflammation. The treatment plan may also include seizure medications and other supportive therapies.

3.6. Guillain-Barré Syndrome

Guillain-Barré Syndrome (GBS) is a rare but serious autoimmune disorder that affects the peripheral nervous system. GBS can lead to a variety of neurological symptoms, including muscle weakness and, in some cases, movement disorders. The hallmark feature of Guillain-Barré Syndrome is the progressive muscle weakness that typically starts in the legs and can ascend to involve other parts of the body [114]. The muscle weakness is usually symmetrical and may be accompanied by sensory disturbances. While GBS primarily affects motor nerves, leading to muscle weakness, movement disorders can also be observed in some cases. Movement disorders associated with GBS may include ataxia, tremors, and myoclonus. It's important to note that movement disorders in GBS are secondary to the primary nerve damage and demyelination rather than being direct manifestations of GBS itself. The severity and specific symptoms can vary widely among individuals with GBS. Treatment for GBS typically involves supportive care, and in severe cases, immunotherapy may be administered to modulate the immune response. Most individuals with GBS experience a gradual recovery, although the timeline and extent of recovery can vary [115].

3.7. Multiple sclerosis

Multiple sclerosis (MS) is a chronic autoimmune disease that affects the central nervous system, including the brain and spinal cord. neuromyelitis optica spectrum disorder and MS are characterized by inflammation and demyelination [116]. The symptoms of MS can vary widely among individuals, and movement disorders are common manifestations of the disease. Movement disorders associated with multiple sclerosis may include spasticity, ataxia, tremors, and dystonia [117]. Also, fatigue-related movements were already described. Fatigue is a common symptom in MS and can exacerbate movement difficulties, leading to increased instability and reduced coordination [118]. The specific movement disorders and their severity can vary among individuals with MS, depending on the location and extent of demyelination and damage to the central nervous system [119].

3.8. Hypoglycemia and Hyperglycemia

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Both hypoglycemia and hyperglycemia can affect the nervous system and, in some cases, lead to movement disorders or related symptoms [120]. Hypoglycemia can lead to various neurological symptoms, including tremors, shakiness, confusion, dizziness, and difficulty concentrating [121]. Severe hypoglycemia may cause more profound effects on the central nervous system, potentially leading to seizures or loss of consciousness. The movement-related symptoms during hypoglycemia are often a result of the brain's response to the inadequate supply of glucose, which is a primary fuel for the brain.

Prolonged periods of uncontrolled hyperglycemia can lead to diabetic neuropathy, affecting the nerves throughout the body. Diabetic neuropathy can cause tingling, numbness, and pain in the extremities. In some cases, it can affect motor nerves, leading to muscle weakness and difficulties with movement coordination. Movement disorders associated with diabetic neuropathy may include gait abnormalities, loss of balance, and reduced fine motor control.

It's important to note that while movement-related symptoms can occur with hypoglycemia or hyperglycemia, they are often just one aspect of the broader neurological effects of these conditions. Prompt management of blood sugar levels is crucial to prevent complications and address symptoms. Individual responses to changes in blood sugar levels can vary, and some people may be more susceptible to neurological symptoms than others. For individuals with diabetes, maintaining tight control over blood sugar levels through medication, diet, and lifestyle adjustments is essential to minimize the risk of complications, including those affecting the nervous system.

3.9. COVID-19

There have been reports of movement disorders associated with COVID-19, the disease caused by the SARS-CoV-2 virus [122]. Some individuals who have contracted COVID-19 have reported experiencing movement disorders, including tremors, myoclonus, and ataxia [123]. COVID-19 has been associated with various neurological manifestations, and evidence suggests that the virus can affect the central nervous system. This can lead to neurological symptoms, including those affecting movement. Some individuals with COVID-19, including those with mild or asymptomatic cases, have reported lingering symptoms even after the acute phase of the illness. This condition is sometimes called "long COVID" or Post-Acute Sequelae of SARS-CoV-2 Infection (PASC) [124]. Movement disorders have been reported as part of the long-term symptoms in some individuals [125]. The exact mechanisms by which COVID-19 may contribute to movement disorders are not fully understood. It is believed that the virus can trigger an inflammatory response that affects the nervous system, leading to various neurological symptoms.

3.10. Copper

Copper is an essential trace element that plays a crucial role in various physiological processes in the human body. However, abnormal copper metabolism can be associated with certain movement disorders [126]. Wilson's disease is a rare genetic disorder characterized by impaired copper metabolism, leading to the accumulation of copper in various organs, especially the liver and brain. Excess copper can cause damage to the central nervous system, resulting in neurological symptoms and movement disorders [127]. Frequent movement disorders associated with Wilson's disease include dysarthria, dystonia, and tremors. The neurological symptoms of Wilson's disease can be diverse, and movement disorders may manifest differently in each individual. If left untreated, Wilson's disease can lead to severe complications affecting the liver and brain. Excessive copper intake, whether through diet or other sources, can lead to copper toxicity. While this is rare, symptoms of acute copper toxicity can include gastrointestinal issues and neurological symptoms. Long-term exposure to high levels of copper may lead to chronic neurological symptoms. It's important to note that a well-balanced diet usually provides enough copper without causing toxicity. Wilson's disease is a genetic condition, and its association with movement disorders is primarily related to the genetic mutation affecting copper metabolism.

3.11. Hashimoto's Thyroiditis

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Hashimoto's thyroiditis, an autoimmune condition affecting the thyroid gland, primarily impacts thyroid function [128]. However, in some cases, individuals with Hashimoto's thyroiditis may experience neurological symptoms and movement disorders have been reported as rare manifestations. Some individuals with Hashimoto's thyroiditis may develop cerebellar ataxia, resulting in unsteady gait, tremors, and difficulties with fine motor skills. Hashimoto's encephalopathy is a rare and potentially severe complication of Hashimoto's thyroiditis. It involves inflammation of the brain and can present with various neurological symptoms, including catatonia, confusion, seizures, and movement abnormalities [129].

In some cases of Hashimoto's encephalopathy, myoclonus may be observed as a neurological symptom [130]. It's important to note that neurological symptoms associated with Hashimoto's thyroiditis are uncommon, and the majority of individuals with Hashimoto's thyroiditis do not experience movement disorders. The exact mechanisms linking Hashimoto's thyroiditis to neurological symptoms are not fully understood. Treatment often involves addressing the underlying thyroid dysfunction with thyroid hormone replacement therapy. In cases of Hashimoto's encephalopathy or significant neurological involvement, corticosteroids or other immunosuppressive therapies may be considered.

3.12. Pregnancy

Pregnancy can have various effects on movement and neurological function [131]. Several factors may influence the presence or progression of movement disorders during pregnancy. In general, Parkinson's disease tends to improve during pregnancy. This improvement is related to hormonal changes, particularly the increase in estrogen levels. However, symptoms may fluctuate, and adjustments to medication may be necessary under the guidance of a healthcare provider. Essential tremor is a common movement disorder characterized by rhythmic shaking, typically of the hands. Pregnancy can lead to changes in the severity of tremors [132]. Some women may experience improved essential tremor symptoms during pregnancy, while others may see no change or a worsening. Restless leg symptoms may fluctuate during pregnancy, with some women experiencing relief and others deteriorating symptoms [133]. Iron deficiency, which can contribute to restless leg symptoms, is common during pregnancy. Pregnancy can influence dystonia symptoms, and individual responses vary. Medication adjustments may be necessary, and careful management is required.

3.13. Cough

A persistent or severe cough can sometimes be associated with movement disorders, particularly if the cough is causing repetitive or stereotypical movements. Here are a few scenarios where cough and movement disorders may be connected [134]. Individuals with certain movement disorders, such as Tourette syndrome or other tic disorders, may exhibit tics or stereotypical movements. Coughing could be incorporated into these movement patterns, especially if it becomes a repetitive or involuntary behavior. In some cases, coughing may be associated with functional movements. A severe or chronic cough can lead to secondary movements [135]. For example, individuals may develop specific postures or movements in response to the effort of coughing [136]. Certain medications, including those used to manage cough or respiratory conditions, can have movement-related side effects. Movement disorders such as tremors or dyskinesias may occur as a side effect of medication. Neurological conditions affecting the motor system can sometimes involve abnormal movements. While a direct link between cough and movement disorders is uncommon, underlying neurological conditions may contribute to both symptoms.

3.14. Mucormycosis

Mucormycosis, also known as black fungus, is a severe and rare fungal infection caused by a group of molds called mucormycetes [137]. It most commonly affects immunocompromised individuals, such as those with diabetes, cancer, or immunocompromising conditions. Mucormycosis

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typically presents as a severe and invasive infection affecting various organ systems, including the respiratory and central nervous systems [138]. While mucormycosis primarily manifests as a fungal infection, it is not directly associated with movement disorders. The symptoms of mucormycosis are more related to the site of infection [139].

3.15. Toxoplasmosis

Toxoplasmosis is a parasitic infection caused by the protozoan parasite Toxoplasma gondii [140]. While toxoplasmosis primarily affects the central nervous system, it is not commonly associated with movement disorders. The symptoms of toxoplasmosis are diverse and depend on the severity of the infection, the immune status of the individual, and the organs involved [141]. While motor coordination issues may be observed in toxoplasmosis, it is not characterized as a primary movement disorder [142]. Movement disorders, such as tremors, dystonia, or chorea, are not typical features of toxoplasmosis. The severity of toxoplasmosis and the associated neurological symptoms can vary widely [143]. The infection may be asymptomatic or cause only mild flu-like symptoms in individuals with intact immune systems. However, in immunocompromised individuals, such as those with HIV/AIDS or undergoing immunosuppressive therapy, toxoplasmosis can lead to severe complications.

3.16. Spinal cord

Spinal cord lesions can significantly impact motor function and may lead to various movement disorders, depending on the location and extent of the damage. The spinal cord plays a crucial role in transmitting signals between the brain and the rest of the body, and any disruption in this communication pathway can result in motor abnormalities. Spinal cord lesions can lead to spasticity, increased muscle tone, and stiffness. This can result in muscle spasms, difficulty moving, and exaggerated reflexes. Spasticity often affects the lower limbs but can also involve other muscle groups. Individuals with paraplegia or quadriplegia may experience difficulty controlling and coordinating movements below the level of the lesion. Lesions affecting the dorsal columns of the spinal cord can lead to ataxia, resulting in unsteady gait, clumsiness, and difficulties with fine motor tasks. Spinal cord lesions may cause hyperreflexia, leading to rapid and forceful muscle contractions, impacting coordinated movements. Lesions affecting proprioception can lead to difficulty coordinating movements due to a lack of awareness of limb position. Spinal cord lesions may sometimes contribute to dystonia, resulting in abnormal postures or twisting movements [144].

3.17. Alzheimer's Disease

Alzheimer's disease is a progressive neurodegenerative disorder primarily characterized by cognitive decline, memory loss, and changes in behavior [145]. While Alzheimer's disease mostly affects cognition, it can also have secondary effects on motor function and coordination [146]. However, Alzheimer's disease is not classified as a primary movement disorder. As Alzheimer's disease progresses, individuals may experience changes in their gait. They may shuffle, take smaller steps, or exhibit difficulties with balance. Alzheimer's disease can impact the brain regions responsible for motor coordination, impairing routine activities requiring precise movements. Some individuals with Alzheimer's disease may exhibit restlessness, pacing, or repetitive movements, which can be related to agitation or anxiety [147]. In advanced stages, individuals with Alzheimer's disease may develop specific involuntary movements, such as tremors or myoclonus.

3.18. Adrenoleukodystrophy

Adrenoleukodystrophy (ALD) is a rare genetic disorder that primarily affects the nervous system and the adrenal glands. It is characterized by the accumulation of very long-chain fatty acids in various tissues, leading to brain, spinal cord, and adrenal gland damage [148]. ALD is an X-linked genetic disorder whose severity and manifestations can vary widely. In some cases of adrenoleukodystrophy, movement disorders may be observed as part of the neurological symptoms.

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Spasticity is a common feature in the neurological presentation of ALD. Ataxia can occur in individuals with ALD. Dystonia may be observed in some individuals with ALD [149]. Myoclonus can be a component of the movement disorders seen in ALD. The movement disorders in ALD are often secondary to the damage and degeneration of the white matter in the brain, particularly in the areas responsible for motor control. The severity and specific movement-related symptoms can vary depending on the subtype of ALD and the extent of neurological involvement. ALD can present in different forms, including childhood cerebral ALD, adrenomyeloneuropathy (AMN), and Addison-only presentation. Childhood cerebral ALD is the most severe form and is associated with rapid neurological deterioration, while AMN typically has a later onset and a more gradual progression [150].

3.19. Sjögren's syndrome

Sjögren's syndrome is an autoimmune disorder that primarily affects the exocrine glands, leading to symptoms such as dry eyes and mouth [151]. While Sjögren's syndrome primarily targets the glands, it is essential to note that it is a systemic autoimmune condition that can affect various organs and tissues in the body [152]. In some cases, individuals with Sjögren's syndrome may experience neurological manifestations, including movement disorders. However, movement disorders are not considered primary features of Sjögren's syndrome, and their occurrence is relatively uncommon. Sjögren's syndrome can cause inflammation of the peripheral nerves, leading to symptoms such as numbness, tingling, and weakness in the extremities. Central nervous system (CNS) involvement in Sjögren's syndrome can lead to various neurological symptoms, including cognitive impairment, difficulty concentrating, and, in rare cases, movement disorders. Myelitis may occur in some individuals with Sjögren's syndrome, potentially leading to motor and sensory disturbances. Cerebellar ataxia, characterized by coordination and balance problems, may occur due to CNS involvement in Sjögren's syndrome. While these neurological manifestations are possible, it's important to emphasize that movement disorders related explicitly to Sjögren's syndrome are relatively rare. When movement disorders are present, they are usually part of a broader spectrum of neurological symptoms.

3.20. Fahr's disease

Fahr's disease, also known as Fahr's syndrome or bilateral striatopallidodentate calcinosis, is a rare neurological disorder characterized by abnormal calcium deposits in some regions of the brain, particularly the basal ganglia [153]. The basal ganglia are involved in motor control, and calcifications in this region can lead to movement disorders. Symptoms resembling Parkinson's disease may occur, including tremors, bradykinesia (slowness of movement), rigidity, and postural instability [154]. Involuntary muscle contractions can lead to abnormal postures or repetitive movements. Chorea involves sudden, involuntary, jerky movements that may affect various body parts. Difficulties with coordination and balance may result from the involvement of the basal ganglia. Abnormal, involuntary movements may be present, including chorea-like or dystonia-like movements. The movement disorders in Fahr's disease result from the calcifications disrupting the normal functioning of the basal ganglia, which play a crucial role in motor control and coordination [155]. In addition to movement disorders, Fahr's disease can manifest with other neurological and psychiatric symptoms, including cognitive impairment, mood disorders, and personality changes [156]. The age of onset and progression of symptoms can vary widely among individuals.

3.21. Posterior reversible encephalopathy syndrome

Posterior reversible encephalopathy syndrome (PRES) is a neurological disorder characterized by a variety of symptoms, including headaches, seizures, altered mental status, and visual disturbances [157]. PRES is often associated with reversible brain vasogenic edema (fluid accumulation), particularly in the posterior regions of the brain [158]. While PRES primarily affects the central nervous system, movement disorders are not considered typical features of this syndrome.

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While movement disorders are not typically observed in PRES, it's essential to recognize that the syndrome can have a wide range of neurological symptoms, and the specific manifestations can vary among individuals [159]. The primary focus in managing PRES is identifying and addressing the underlying cause or triggers and providing supportive care to manage symptoms [158].

3.22. Giant cell arteritis

Giant cell arteritis (GCA), also known as temporal arteritis, is a type of vasculitis that primarily affects medium and large vessels, particularly the temporal arteries [160]. It can cause inflammation, which can cause headaches, jaw pain, and visual disturbances. GCA is more commonly associated with vascular and systemic symptoms than movement disorders. However, movement disorders can indirectly affect motor function due to complications or symptoms related to GCA [161].

3.23. Dengue virus infection

Dengue fever is a viral illness transmitted by mosquitoes, primarily the Aedes aegypti mosquito. While dengue fever is mainly known for causing flu-like symptoms such as high fever, severe headache, joint and muscle pain, and rash, it is not typically associated with causing movement disorders. The neurological complications of dengue fever are generally rare but can include a condition known as dengue encephalitis or dengue-associated neurologic manifestations [162]. These neurological manifestations are diverse and may include symptoms such as encephalopathy, seizures, cranial nerve involvement, myelitis, and Guillain-Barré Syndrome [163,164]. It's important to note that most dengue fever cases are mild and do not involve severe neurological complications [165]. Severe manifestations are more commonly associated with dengue hemorrhagic fever and dengue shock syndrome, which are characterized by vascular leakage and can be life-threatening [166].

3.24. Limb-Shaking and Transient Ischemic Attack

Limb-shaking is sometimes used to describe limb-shaking episodes that occur in transient ischemic attacks [167]. These episodes can manifest as rhythmic movements, often affecting one side of the body. Limb-shaking TIA could be defined as involuntary, rhythmic, brief (<5 min), recurrent, jerky movement usually precipitated by activities that may reduce cerebral blood flow. The "shaking" phenomenon was primarily described as a manifestation of symptomatic complete internal carotid artery obstruction [168].

3.25. Cerebral venous sinus thrombosis

Cerebral venous sinus thrombosis (CVST) is a relatively rare but severe condition characterized by the formation of blood clots in the dural venous sinuses of the brain [169]. These sinuses are responsible for draining blood from the brain. Thrombosis can lead to increased pressure inside the skull, potentially resulting in various neurological symptoms [170]. While CVST primarily manifests with symptoms related to increased intracranial pressure, such as headaches, visual disturbances, and seizures, movement disorders are not considered a primary feature of this condition [171]. However, depending on the location and extent of the thrombosis, individuals with CVST may experience a wide range of neurological manifestations, some of which could indirectly impact motor function [172]. While CVST may not directly cause movement disorders, the associated neurological symptoms can lead to motor abnormalities. Additionally, if CVST causes damage to specific brain regions involved in motor control, it may result in movement-related issues.

3.26. End-Stage Renal Disease

There are several ways in which movement disorders can be associated with end-stage renal disease (ESRD) [173]. Individuals with ESRD, including those undergoing hemodialysis, may be more prone to developing restless leg syndrome. Uremic encephalopathy can lead to cognitive impairment, confusion, and, in severe cases, movement disorders. Myoclonus may occur as a

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neurological manifestation. Some individuals with ESRD may develop parkinsonian features, such as bradykinesia (slowness of movement), tremors, and postural instability [174]. Peripheral neuropathy is a common complication in individuals with ESRD. This can lead to motor symptoms, including muscle weakness and impaired coordination. While less common, individuals with ESRD may develop dystonia. It's important to note that movement disorders in the context of ESRD and hemodialysis are often multifactorial, involving a combination of uremic toxins, metabolic imbalances, and other complications associated with kidney failure.

3.27. Tolosa-Hunt syndrome

Tolosa-Hunt syndrome (THS) is a rare neurological disorder characterized by severe unilateral headaches and ophthalmoplegia [175]. THS is considered a painful ophthalmoplegia syndrome. While the primary features of THS involve headaches and eye-related symptoms, movement disorders are not typically recognized as part of the syndrome [176]. The exact cause of Tolosa-Hunt syndrome is not well understood, but it is thought to involve inflammation of the cavernous sinus or adjacent structures [177]. Magnetic resonance imaging is often used to visualize the affected area and rule out other potential causes. While movement disorders are not recognized as primary components of THS, severe headaches, and associated eye symptoms can indirectly influence motor function and coordination. The focus of treatment for THS typically involves using corticosteroids to reduce inflammation and alleviate symptoms [178].

3.28. Subacute sclerosing panencephalitis

Subacute sclerosing panencephalitis (SSPE) is a rare, progressive, and usually fatal neurological disorder caused by persistent infection with the measles virus. SSPE primarily affects the central nervous system, leading to inflammation, demyelination, and subsequent neurological decline [179]. While movement disorders are not the primary feature of SSPE, they can develop as the disease progresses. The typical clinical course of SSPE includes stages of cognitive decline, behavioral changes, and motor dysfunction. Movement-related symptoms may emerge in later stages of the disease and can consist of myoclonus, dystonia, ataxia, spasticity, and choreoathetosis [180]. In SSPE, myoclonic jerks are a characteristic feature and often become more pronounced over time. SSPE typically affects children and adolescents who had measles infection earlier in life. The disease can have a variable onset, with symptoms appearing several years after the initial measles infection. The course of SSPE is progressive, and there is currently no cure.

3.29. Glutaric aciduria type 1

Glutaric aciduria type 1 (GA-1) is a rare inherited metabolic disorder affecting the metabolism of some amino acids, particularly lysine, hydroxylysine, and tryptophan. It is caused by a deficiency of the enzyme glutaryl-CoA dehydrogenase, leading to the accumulation of glutaric acid and its derivatives in the body [181]. GA-1 can have significant neurological implications, and movement disorders are among the neurological symptoms associated with this disorder. The accumulation of glutaric acid and its metabolites can damage the basal ganglia, a brain region involved in motor control. The basal ganglia play a crucial role in regulating voluntary movements, and its dysfunction can lead to various movement disorders. The movement disorders associated with GA-1 are dystonia, athetosis, chorea, hypotonia, and ataxia [182]. The severity and specific movement-related symptoms can vary among individuals with GA-1, and they may manifest during infancy or early childhood. Symptoms may sometimes be triggered by metabolic stressors such as infections or fasting. Early diagnosis and intervention are crucial in managing GA-1. Treatment involves dietary management to restrict the intake of specific amino acids, particularly lysine and tryptophan. Close monitoring and ongoing medical management are necessary to prevent metabolic decompensation and to address the neurological symptoms [183].

3.30. Varicella-zoster virus

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Varicella-zoster virus (VZV), which causes chickenpox during the primary infection, can later lead to a condition known as herpes zoster, or shingles, upon reactivation [184]. While movement disorders are not typically considered direct consequences of herpes zoster, there are neurological complications that can affect movement and coordination, especially when the virus involves specific areas of the nervous system. In some cases, herpes zoster can lead to more severe neurological complications, such as encephalitis or myelitis [185]. Encephalitis is inflammation of the brain, and myelitis is inflammation of the spinal cord. Both conditions can result in a wide range of neurological symptoms, including movement disorders. Individuals affected may experience muscle weakness, coordination difficulties, and, in severe cases, paralysis. It's important to note that the occurrence of movement disorders due to herpes zoster is relatively rare, and most people with shingles do not develop such complications [186]. The risk of neurological complications tends to be higher in individuals with weakened immune systems or other underlying health conditions.

3.31. Creutzfeldt-Jakob disease

Creutzfeldt-Jakob disease (CJD) is a rare, rapidly progressive, and fatal neurodegenerative disorder belonging to a group of conditions known as transmissible spongiform encephalopathies [187]. Some variants of CJD can have abnormalities in neuroimaging showing a cruciform-shaped of the pons [188]. Movement disorders are a prominent feature of CJD, contributing to the characteristic clinical presentation. CJD is caused by the accumulation of abnormal prion proteins in the brain, leading to neuronal damage and the formation of microscopic holes, giving the affected brain tissue a spongy appearance [189]. The disease progresses rapidly, and the symptoms encompass various neurological abnormalities, including movement disorders. The movement disorders observed in CJD can manifest in different forms, such as myoclonus, ataxia, dystonia, chorea, and parkinsonism. The specific manifestation and severity of movement disorders in CJD can vary among individuals and may be influenced by the particular subtype of CJD.

3.32. Sarcoidosis

Sarcoidosis is a multisystem inflammatory disease characterized by the formation of granulomas [190]. Neurological involvement in sarcoidosis, known as neurosarcoidosis, occurs in approximately 5-15% of cases [191]. Movement disorders are among the diverse neurological manifestations that can arise due to sarcoidosis affecting the central nervous system. Some potential abnormal movements associated with neurosarcoidosis are tremor, dystonia, ataxia, myoclonus, and parkinsonism. The exact mechanisms through which sarcoidosis induces movement disorders are not fully understood [192]. Granulomatous inflammation in the central nervous system, particularly in the basal ganglia or other regions involved in motor control, may contribute to these manifestations.

4. Predictors of drug-induced parkinsonism

Drug-induced parkinsonism (DIP) is a condition characterized by parkinsonian symptoms caused by the use of certain medications. While the symptoms mimic those of Parkinson's disease, DIP is usually reversible upon discontinuation of the causative drug. Some common predictors and factors associated with drug-induced parkinsonism include medication class, individual susceptibility, duration and dosage of medication, comorbidities, age, and gender [193]. Certain antipsychotic drugs, particularly the older ones known as typical antipsychotics, have a higher risk of causing parkinsonism. Haloperidol is a well-known example. Some medications used to treat nausea and vomiting, such as metoclopramide and prochlorperazine, have been associated with DIP [194].

Some individuals may have a genetic predisposition that makes them more susceptible to developing Parkinsonian symptoms in response to certain medications. Older adults may be more prone to DIP due to age-related changes in the central nervous system [195]. The risk of DIP may increase with higher doses of the offending medication. Long-term use of drugs associated with DIP may elevate the risk. Individuals with pre-existing neurological conditions may be more vulnerable

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to developing DIP. Certain medical conditions may increase susceptibility, although the relationship is complex. Concurrent use of multiple medications, especially those with potential interactions, may increase the risk of DIP. Elderly individuals, particularly females, may have a higher risk of developing drug-induced parkinsonism. In some cases, DIP may develop shortly after initiating treatment with the causative drug [196].

5. Neuroimaging in drug-induced parkinsonism

Neuroimaging can play a valuable role in the assessment of drug-induced parkinsonism (DIP), helping clinicians differentiate it from other forms of parkinsonism and identify potential underlying causes [197]. Drug-induced parkinsonism is characterized by parkinsonian symptoms caused by certain medications, and it is generally reversible upon discontinuation of the causative drug. Structural MRI of the brain can help rule out other structural causes of parkinsonism, such as tumors or vascular lesions. It is also valuable for assessing the integrity of brain structures, including the basal ganglia and substantia nigra. Functional imaging techniques can evaluate cerebral blood flow, glucose metabolism, and neurotransmitter function [198]. In the context of drug-induced parkinsonism, imaging the dopamine system is particularly relevant. Imaging agents like DaTSCAN (SPECT) or fluorodopa (PET) can provide information about presynaptic dopamine function and help differentiate drug-induced parkinsonism from other forms of parkinsonism, such as Parkinson's disease. DAT-SPECT technique explicitly targets the dopamine transporter, which is affected in parkinsonian disorders. In drug-induced parkinsonism, a reduction in dopamine transporter binding may be observed, and this reduction is reversible upon discontinuation of the offending medication. Neuroimaging findings should be interpreted in conjunction with the clinical presentation and history of medication use [199]. A clear temporal relationship between the initiation of a specific drug and the onset of parkinsonian symptoms can strengthen the suspicion of drug-induced parkinsonism. Repeat imaging after discontinuation of the causative drug can be valuable in assessing any changes in neuroimaging findings. If parkinsonism is indeed drug-induced, improvements in imaging findings may be observed over time.

6. Deep brain stimulation on drug-induced movement disorders

Deep brain stimulation (DBS) is a surgical procedure involving the implantation of a device that delivers electrical stimulation to specific brain areas. While DBS is more commonly used to treat movement disorders such as Parkinson's disease, essential tremor, and dystonia, its role in addressing drug-induced movement disorders is less established [200]. DBS is typically considered for individuals with movement disorders that are not adequately controlled by medications or when medication side effects become problematic. However, the decision to use DBS for drug-induced movement disorders is complex and depends on several factors. DBS is generally more established and studied for primary movement disorders like Parkinson's disease or essential tremor [201]. Its role in treating drug-induced movement disorders may vary based on the specific underlying condition. Before considering a surgical intervention like DBS, healthcare providers will assess whether the drug-induced movement disorder is reversible. If discontinuing or changing medications can alleviate symptoms, DBS may not be immediately pursued. DBS involves a surgical procedure with potential risks, and its benefits need to be carefully weighed against these risks. The decision is made based on the individual's overall health, the severity of symptoms, and the potential for improvement with DBS. A comprehensive evaluation by a movement disorder specialist or neurologist is crucial to determine the most appropriate treatment approach. This may include medication adjustments, rehabilitation, or, in some cases, DBS. The evidence supporting the use of DBS for drug-induced movement disorders is limited compared to its well-established role in primary movement disorders [202]. Research in this area is ongoing, and decisions are often made on a case-by-case basis.

7. Future perspectives

Future perspectives on movement disorders associated with medications and systemic diseases hold promising avenues for advancements in diagnosis, treatment, and overall patient care. As technology evolves, novel diagnostic tools and imaging techniques may enhance our ability to identify subtle movement abnormalities earlier in the disease course. Advanced neuroimaging modalities, coupled with biomarker research, provide valuable insights into the underlying mechanisms of drug-induced movement disorders and those associated with systemic conditions. In therapeutics, emerging pharmacological interventions and targeted treatments are being explored. Research efforts are focused on developing medications with fewer side effects while maintaining efficacy in managing movement disorders. Additionally, personalized medicine approaches based on genetic and molecular profiling may offer more precise and tailored treatments, minimizing adverse reactions and optimizing outcomes for individuals with these conditions.

8. Conclusions

Movement disorders associated with medications and systemic diseases represent a multifaceted and challenging field of neurology, necessitating a comprehensive understanding of the intricate connections between pharmacological agents, different systems, and the central nervous system. One of the central themes emerging from exploring these movement disorders is their complexity and manifestations. Medications designed to alleviate various health conditions can paradoxically give rise to abnormal movements, affecting the quality of life for individuals undergoing treatment. Simultaneously, systemic diseases, ranging from metabolic disorders to autoimmune conditions, underscore the interplay between the body's overall health and neurological function. Recognizing these intricate relationships is essential for accurate diagnosis, as movement abnormalities may serve as crucial indicators of an underlying systemic issue or a side effect of prescribed medications. Therefore, movement disorders associated with drugs and systemic diseases demand a nuanced and evolving approach in research and clinical practice. Ongoing research endeavors and advancements in diagnostic tools, therapeutic strategies, and healthcare technologies are poised to redefine the landscape of managing these disorders. Ultimately, the goal remains to improve the quality of life for individuals affected by these disorders, acknowledging their uniqueness and tailoring interventions to address the multifaceted aspects of their health.

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