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Review Article

The Brief Review of the Epilepsy and ITS Drug Formulations

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ABSTRACT

Epilepsy is one of the most common and disabling neurologic conditions, yet we have an incomplete understanding of the detailed pathophysiology and, thus, treatment rationale for much of epilepsy. Patients with epilepsy suffer from not only seizures but also a decline in quality of life due to psychological issues such as anxiety and depression, as well as social stigma. This article reviews the clinical aspects of epilepsy with the goal of providing introduction to aspects that might be amenable to scientific investigation. Seizures are defined, Types of seizures, diagnostic methods are reviewed, various clinical syndromes are discussed, and aspects of differential diagnosis, treatment, classification, mechanism of drugs, and various formulations of antiepileptic drugs are available in market. All over the study of epilepsy can be reviewed in this article.

INTRODUCTION:

Epilepsy is a chronic neurological disease characterized by recurrent, unprovoked seizures resulting from abnormal, excessive electrical activity in the brain. Epilepsy affecting approximately 50 million people worldwide and is reported as the third most common neurological disease in South Korea, only after stroke and dementia. [1,2] It is estimated that there are more than 10 million persons with epilepsy (PWE) in India. Its prevalence is about 1% in our population.[3] The prevalence is higher in the rural (1.9%) compared to urban population (0.6%)[4,5] In the Bangalore Urban Rural Neuro-epidemiological Survey (BURNS), a prevalence rate of 8.8/1000 population was observed,

with the rate in rural communities (11.9) being twice that of urban areas (5.7).[6]

Patients with epilepsy suffer from not only seizures but also a decline in quality of life due to psychological issues such as anxiety and depression, as well as social stigma.[7] In addition, it has been reported that the suicide rate and the mortality rate due to accidents in patients with epilepsy are more than twice as high as those of the general population, emphasizing the necessity for systematic support for self-management in patients with epilepsy.[8]

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TYPES OF SEIZURE

Divided into **generalized seizures** (originating in and engaging bilaterally distributed networks) and **focal seizures** (originating in one hemisphere).

1. Generalized Onset Seizures

Genetic Considerations

Generalized seizures may have a genetic component, but only a small number of people with generalized seizures have family members with the same condition.

There is a slight increase in risk for generalized seizures in the children or other family members of an affected person with generalized seizures, but the severity of the seizures can vary from person to person. Genetic testing may reveal a cause for generalized seizures.

Sleep deprivation or drinking large amounts of alcohol can increase the excitatory response and increase the risk of generalized-onset seizures, especially in people with a genetic tendency to have them. Generalized seizures engage or affect networks on both sides of the brain simultaneously from the start.

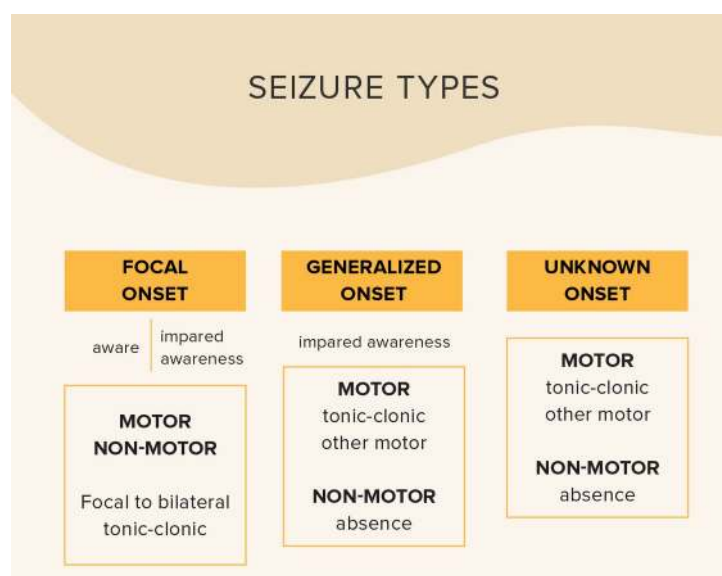


Figure 1: Types of Seizure

2. Absence Seizures (formerly petit mal): Cause a brief loss of awareness lasting a few seconds, often looking like a blank stare or rapid blinking. These are common in children. **Childhood absence epilepsy** shows up as brief staring episodes in children, usually starting between ages four and six. Children usually outgrow these. **Juvenile absence epilepsy** starts slightly later and can persist into adulthood; people with these kinds of seizures may develop tonic-clonic seizures in addition to absence of seizures in adulthood.

- Tonic-Clonic Seizures (formerly grand mal):** The most dramatic type, causing muscle stiffness (tonic phase) followed by rhythmic jerking (clonic phase), loss of consciousness, and sometimes a cry, falling, or loss of bladder control. Tonic-clonic seizures can evolve from any of the focal or generalized seizure types. For example, a focal seizure can spread to both sides of the brain and cause

tonic-clonic seizures. A cluster of myoclonic seizures can become continuous and evolve into a tonic-clonic seizure. Generalized onset tonic-clonic seizures can occur alone or as part of another syndrome such as juvenile myoclonic epilepsy (JME) or juvenile absence epilepsy during adulthood.

- Tonic Seizures:** Cause sudden muscle tightening or stiffness without the clonic jerking, often causing the person to fall backward. Some people, usually those with multiple brain injuries and intellectual disability, have tonic seizures consisting of sudden stiffness in the arms and body, which can cause falls and injuries. Many persons with tonic seizures have a syndrome called Lennox Gastaut syndrome. This condition may involve intellectual disability, multiple seizure types including tonic seizures. People with Lennox Gastaut syndrome

can have a distinctive EEG pattern called **slow spike and wave**.

- **Atonic Seizures** (*drop attacks*): Cause a sudden loss of muscle tone and strength, making the person go limp and collapse or drop objects. Persons with diffuse brain disorders also may have atonic seizures, characterized by a sudden loss of body tone that results in collapsing, often with injuries. A sequence of a brief tonic episode followed by an atonic seizure is called a tonic-atonic seizure. Tonic and atonic seizures are often managed with specific medications and sometimes with nerve stimulation and diet therapies.
- **Clonic Seizures**: Feature repeated, rhythmic jerking movements of the muscles, usually affecting the face, neck, and arms.
- **Myoclonic Seizures**: Involve brief, shock-like muscle jerks or twitches in a muscle or group of muscles. Myoclonic seizures consist of sudden body or limb jerks that can involve the arms, head and neck. The spasms occur on both sides of the body in clusters, especially in the morning. When these seizures develop in adolescence along with tonic-clonic seizures, they are part of a syndrome

called **juvenile myoclonic epilepsy**. People can also have myoclonic seizures as part of other epilepsy related-conditions. [9]

3. Focal Onset Seizures

Focal seizures start in one specific area or network on one side of the brain.

- **Focal with Retained Awareness** (*formerly simple partial*): The person remains conscious and alert, though they may experience unusual sensory changes, strange tastes or smells, emotional auras, or isolated muscle twitching.
- **Focal with Impaired Awareness** (*formerly complex partial*): The person has a change or loss of consciousness or awareness, often appearing dazed or confused, and may perform repetitive automatic movements like lip-smacking, hand-rubbing, or wandering.
- **Focal to Bilateral Tonic-Clonic** (*formerly secondary generalized*): The electrical activity starts in one area and then spreads to involve both sides of the brain, turning into a generalized convulsive seizure.

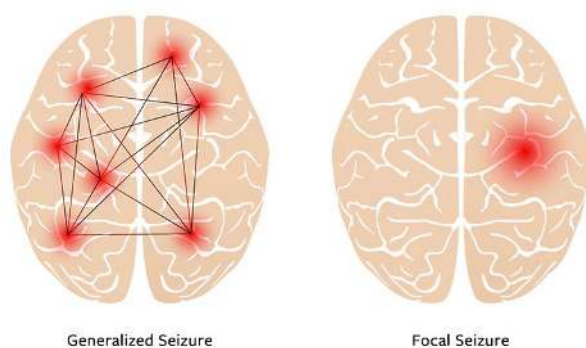


Figure 2: Images of Generalized and Focal Seizure

• 4. Unknown Seizure

When the beginning of a seizure is not known, it's now called an unknown whether focal or generalized seizure. A seizure could also be called an unknown onset if it's not been witnessed or seen by anyone (for example when seizures happen at night or in a person who lives alone). [10,11]

EPILEPSY SYMPTOMS

The main symptom of epilepsy is repeated seizures. Symptoms can look different depending on the type of seizure. But many people have similar symptoms each time they have one.

Common symptoms include:

- Automatic movements, like lip-smacking, chewing or rubbing your hands
- Brief loss of awareness or consciousness
- Confusion or trouble thinking, speaking or understanding others
- Fast heartbeat or rapid breathing
- Staring spells or a blank look
- Stomach discomfort, chills, warmth or goosebumps
- Strong emotions, like fear, anxiety or déjà vu
- Uncontrolled movements, like jerking, twitching or sudden loss of muscle control
- Unusual sensations, like changes in vision, hearing, smell, taste, or feelings of tingling or numbness

ETIOLOGY AND PATHOPHYSIOLOGY

According to the International League Against Epilepsy (ILAE), the etiology of epilepsy is categorized into six main groups: structural, genetic, infectious, metabolic, immune, and unknown.

1) Structural Factors:

Physical damage or abnormal formation in the brain—such as a stroke (the leading cause in adults over 35), traumatic head injury, brain tumors, scarring (like hippocampal sclerosis), or congenital brain malformations—can disrupt nerve cell pathways.

Structural epilepsies in older children and adults most commonly present with focal seizures and have very similar symptoms from event to event. In some cases, seizures can spread to both sides of the brain, leading to a generalized tonic-clonic seizure.

Persons with structural causes may also have other symptoms that reflect a structural abnormality in one brain area, such as difficulty:

- Using one arm or leg, or one half of the body
- With speech
- With vision on one side

Infants and young children with structural epilepsies may also present with focal seizures or may present with other seizure types such as infantile spasms or

tonic seizures. In such cases, there is often a slowing of development once seizures begin.

In most persons with a structural epilepsy, the brain MRI is abnormal. [12]

2) Genetic Factors:

Specific gene changes or mutations can affect how brain cells communicate. These can be inherited from family members or occur spontaneously as new changes in a child.

Epilepsy is said to have a genetic cause if seizures are the result of a known or presumed underlying genetic change, referred to as a DNA variant. DNA variants impact the structure, function, or amount of a protein coded for by a gene.

If there is a DNA variant in a gene that codes for a protein expressed in the brain, the variant may lead to an increased likelihood of seizures. A DNA variant may be inherited from a parent, leading to genetic epilepsy, and therefore may be present in multiple family members. However, some genetic epilepsies are not inherited. DNA variants that cause epilepsy may occur spontaneously in a child without being present in either parent or other family members. Sometimes, epilepsy may be due in part to genetic factors, but additional environmental factors may play a role as well.

Heredity (genetics or the physical traits we get from our parents) plays an important role in many cases of epilepsy. Advances in science and medicine over the last decade have led to a better understanding of the ways genetic factors contribute to epilepsy. [13]

3) Infectious Diseases:

Brain infections like meningitis, viral encephalitis, HIV, or parasitic infections (such as neurocysticercosis) can scar or inflame brain tissue.

4) Metabolic Conditions:

Rare chemical or electrolyte imbalances in the body can disrupt normal brain function. A metabolic disorder is caused by an underactivity or blockage in enzymes responsible for breaking down the various parts of the food we eat to nourish the body. An issue with one of these enzymes can lead to problems metabolizing or “breaking down” one of the



components in food (proteins, carbohydrates or “sugars,” fats or “lipids” or vitamins) or problems generating energy to sustain the body’s function.

The majority of persons with metabolic epilepsy present with symptoms in infancy or early childhood. Symptoms often include seizures, typically with other symptoms such as:

- Delayed development or loss of skills
- Abnormal movements
- Problems with other body organs such as the liver or kidneys

Types of Metabolic Disorders

- Glut 1 (Glucose Transport) Deficiency Syndrome (SLC2A1)
- Vitamin dependent- Pyridoxine, P5P, Folinic acid
- Creatine transporter
- Mitochondrial
- Storage disorders [14]

5) Immune (Autoimmune) Factors:

An overactive or misdirected immune system can cause inflammation or attack nerve cells in the brain (such as in autoimmune encephalitis).

Autoimmune epilepsy (AE) is caused by a change in the body’s immune function. Seizures are the main features of AE.

Our immune system protects the body from foreign substances or things that could harm the body. Key cells for the immune response include macrophages, lymphocytes (B cells and T cells), and antibodies.

Antibodies are large proteins found in the blood or other body fluids that protect the body. Antibodies that target the brain may be the cause of autoimmune epilepsy. The most common antibodies target specific receptors in the brain, such as N-methyl-d-aspartate receptor (NMDAR), leucine-rich glioma-inactivated protein 1 (LGII), and glutamic acid decarboxylase 65 (GAD65).

If these antibodies are associated with a tumor, they are called paraneoplastic. If an infection of the brain is present, it may be called autoimmune encephalitis. While the paraneoplastic syndromes are usually cancer

related, the autoimmune encephalitis may occur with or without cancer. It is u exactly how often autoimmune epilepsy happens. It is estimated that 1 to 7 out of 20 (5-35%) people with new onset seizures may have an autoimmune cause. These include people with:

- A history of another autoimmune disease (such as rheumatoid arthritis, Graves' disease, Hashimoto's thyroiditis, Crohn's disease, ulcerative colitis, and systemic lupus erythematosus)
- A history of cancer
- A first-degree relative (parent, sibling or child) with an autoimmune disease

A sudden and severe onset of seizures is also a red flag that epilepsy could have an autoimmune cause. Finding an autoimmune cause to seizures is very important and will affect its treatment.

AE often begins with seizures developing over days to weeks. A person may have had an illness with fever too.

- Seizures often happen several times a day right from the beginning.
- Focal seizures are the most common seizure type.
- Seizures that affect one side of the face and arm on the same side of the body (called facial brachial dystonic seizures (FBDS)) strongly suggest autoimmune epilepsy.
- Seizure medicines usually don’t control these seizures well.
- People may also have problems with memory, personality changes, and changes in mood or behavior (e.g., paranoia, depression, or hallucinations).

Studies suggest that immunotherapy may be very effective in AE. Immunotherapy is a way of treating the inflammation in the brain. The treatment is typically steroids (such as methylprednisolone or prednisone) given by mouth or into the blood stream (intravenous, IV). Immunoglobulin (IVIg) may also be given into the bloodstream.

How well this works depends on the type of antibody the person has:



Generally, those with cancer-related autoimmune epilepsy may not do as well as people with antibodies that target the surface of brain cells (e.g., NMDA receptor antibody or LGI-1 antibody encephalitis).

In paraneoplastic AE, treating the underlying tumor is also critical where feasible. Starting immunotherapy early in non-paraneoplastic AE is important to quickly

stop seizures and prevent injury to brain cells. [15.16.17,18]

6) Unknown Causes:

In roughly 50% of cases, no clear structural, genetic, or environmental reason can be identified despite thorough testing.

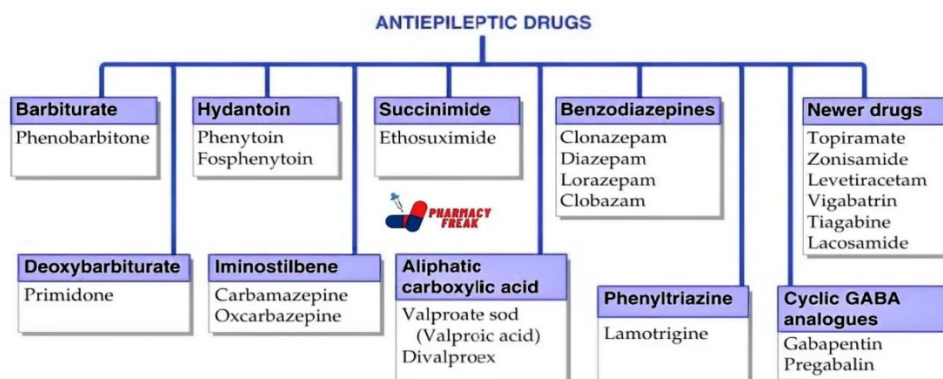


Figure 3: Classification of Antiepileptic Drug

CLASSIFICATION OF ANTIEPILEPTIC DRUG

A. Sodium Channel Blockers (Voltage-Gated Sodium Channel Inhibitors)

These drugs work by inhibiting voltage-gated sodium channels in neurons, reducing the excitability of these cells. By limiting the influx of sodium ions, these medications help stabilize neuronal membranes, making it less likely for seizures to occur. Common sodium channel blockers include:

- Phenytoin: Effective for partial and tonic-clonic seizures.
- Carbamazepine: Used for various seizure types, including partial, generalized tonic-clonic, and trigeminal neuralgia.
- Lamotrigine: Prescribed for generalized and focal-onset seizures.

B) Calcium Channel Blockers (Voltage-Gated Calcium Channel Inhibitors)

Calcium channel blockers, primarily used to treat conditions like hypertension and angina, can also have antiepileptic properties. These drugs reduce calcium influx into neurons, which can help control seizure activity. An example of such a drug is Ethosuximide, used for absence seizures.

C) GABA Enhancers (Gamma-Aminobutyric Acid Enhancers)

Gamma-aminobutyric acid (GABA) is an inhibitory neurotransmitter that helps regulate neuronal excitability. Drugs in this class enhance GABA's inhibitory effects, reducing the likelihood of seizures. Some common GABA enhancers include:

- Benzodiazepines: Medications like Diazepam (Valium) and Clonazepam (Klonopin) are used for acute seizure control.
- Barbiturates: Though less commonly prescribed today due to their sedative effects, drugs like Phenobarbital can still be used for certain seizure types.

D) Glutamate Inhibitors

Glutamate is an excitatory neurotransmitter, and excessive glutamate signaling can trigger seizures. AEDs in this class work by inhibiting glutamate receptors, reducing excitatory transmission. Topiramate is an example of a glutamate inhibitor used to treat various seizure types.

E) GABA Analogs

These drugs mimic the effects of GABA, the brain's natural inhibitory neurotransmitter. By binding to

GABA receptors, they enhance inhibitory signaling, helping to prevent seizures. Gabapentin and Pregabalin are common GABA analogs used in epilepsy management.

F) Carbonic Anhydrase Inhibitors

Carbonic anhydrase inhibitors like Zonisamide are used to control seizures. They work by reducing neuronal excitability and enhancing inhibitory neurotransmission.

G) Potassium Channel Modulators

AEDs in this class, like Ezogabine, modulate potassium channels, stabilizing neuronal membranes and reducing the likelihood of seizures.

H) Miscellaneous AEDs

Some antiepileptic drugs do not fit neatly into the above categories. For instance:

- Valproate: It has multiple mechanisms of action and is used for various seizure types.
- Levetiracetam: Its precise mechanism is not fully understood but involves modulating neurotransmitter release. [19,20]

MECHANISM

Involves an imbalance between neuronal excitation (such as glutamate receptor overstimulation) and inhibition (such as GABA dysfunction).

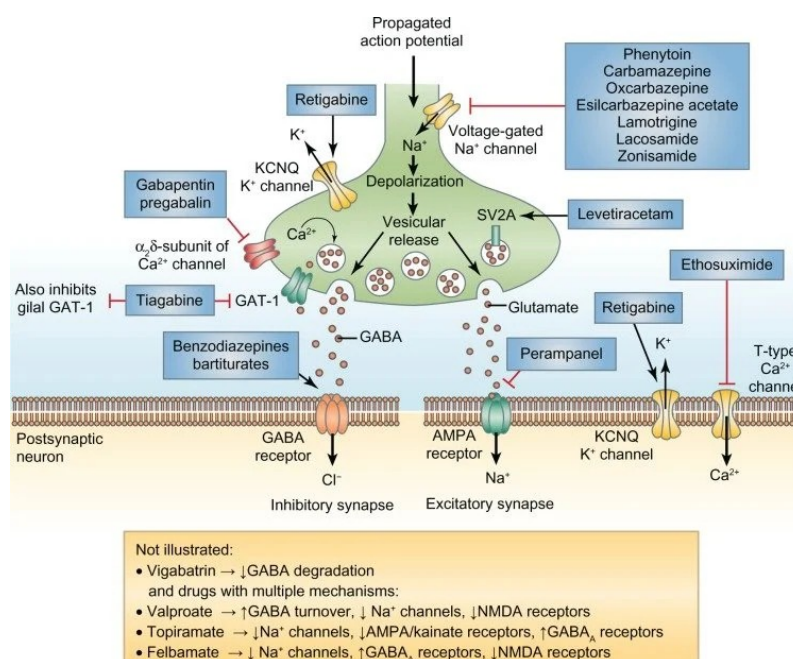


Figure 4: Mechanism of Antiepileptic Drugs

Established antiepileptic drugs (AEDs) decrease membrane excitability by interacting with neurotransmitter receptors or ion channels. AEDs developed before 1980 appear to act on sodium channels, gamma-aminobutyric acid type A (GABA_A) receptors, or calcium channels. Benzodiazepines and barbiturates enhance GABA_A receptor-mediated inhibition. Phenytoin (PHT), carbamazepine (CBZ), and possibly valproate (VPA) decreases high-frequency repetitive firing of action potentials by enhancing sodium-channel inactivation. Ethosuximide (ESM) and VPA reduce a low threshold (T-type) calcium-channel current. The

mechanisms of action of the new AEDs are not fully established. Gabapentin (GBP) binds to a high-affinity site on neuronal membranes in a restricted regional distribution of the central nervous system. This binding site may be related to a possible active transport process of GBP into neurons; however, this has not been proven, and the mechanism of action of GBP remains uncertain. Lamotrigine (LTG) decreases sustained high-frequency repetitive firing of voltage-dependent sodium action potentials that may result in a preferential decreased release of presynaptic glutamate. The mechanism of action of oxcarbazepine (OCBZ) is

not known; however, its similarity in structure and clinical efficacy to CBZ suggests that its mechanism of action may involve inhibition of sustained high-frequency repetitive firing of voltage-dependent sodium action potentials. Vigabatrin (VGB) irreversibly inhibits GABA transaminase, the enzyme that degrades GABA, thereby producing greater available pools of presynaptic GABA for release in central synapses. Increased activity of GABA at postsynaptic receptors may underline the clinical efficacy of VGB. [21]

DIAGNOSIS AND MANAGEMENT

For diagnosis epilepsy, reviews symptoms and medical history. They have several tests to diagnose epilepsy and to detect the cause of seizures. They may include:

- **A neurological exam.** This exam tests patient behavior, movements, mental function and other areas. The exam helps diagnose epilepsy, including the type of epilepsy.
- **Blood tests.** A blood sample can detect signs of infections, genetic conditions or other conditions that may be linked with seizures.
- **Genetic testing.** In some people with epilepsy, genetic testing may give more information about the condition and how to treat it. Genetic testing is most often performed in children but also may be helpful in some adults with epilepsy.

They have brain-imaging tests and scans that detect brain changes.

- A) **Electroencephalogram (EEG).** This is the most common test used to diagnose epilepsy. In this test, small metal discs called electrodes are attached to scalp with an adhesive or cap. The electrodes record the electrical activity of brain.

In epilepsy, it's common to have changes in the pattern of brain waves. These changes occur even not having a seizure. It's monitor patent on video during an EEG to detect and record any seizures. This may be done while they awake or asleep. Recording the seizures may help determine what kind of seizures you're having or rule out other conditions.

The test may be done in a healthcare professional's office or the hospital. Or you may have an ambulatory

EEG. The EEG records seizure activity over the course of a few days at home.

You may get instructions to do something that can cause seizures, such as getting little sleep prior to the test.

- **High-density EEG.** In a variation of an EEG test, you may have a high-density EEG. For this test, electrodes are placed closer together compared with a conventional EEG. High-density EEG may help more precisely determine which areas of your brain are affected by seizures.
- **Computerized tomography (CT) scan.** A CT scan uses X-rays to obtain cross-sectional images of your brain. CT scans can detect tumors, bleeding or cysts in the brain that might be causing epilepsy.
- **Magnetic resonance imaging (MRI).** An MRI uses powerful magnets and radio waves to create a detailed view of the brain. Like a CT scan, an MRI looks at the structure of the brain to detect what may be causing seizures. But an MRI provides a more detailed look at the brain than does a CT scan.
- **Functional MRI (fMRI).** A functional MRI measures the changes in blood flow that occur when specific parts of the brain are working. This test may be used before surgery to find the exact locations of critical functions, such as speech and movement. This allows surgeons to avoid those areas while operating.
- **Positron emission tomography (PET).** PET scans use a small amount of low-dose radioactive material. The material is injected into a vein to help visualize metabolic activity of the brain and detect changes. Areas of the brain with low metabolism may indicate places where seizures occur.
- **Single-photon emission computerized tomography (SPECT).** This type of test is used if MRI and EEG didn't pinpoint the location in the brain where the seizures start.

A SPECT test uses a small amount of low-dose radioactive material. The material is injected into a vein to create a detailed, 3D map of blood flow during



seizures. Areas of higher than typical blood flow may indicate areas where seizures occur.

Another type of SPECT test called subtraction ictal SPECT coregistered to MRI (SISCOM) may provide even more-detailed results. The test overlaps the SPECT results with brain MRI results.

B) Neuropsychological tests. These tests assess thinking, memory and speech skills. The test results help determine which areas of the brain are affected by seizures. Along with your test results, a combination of other techniques may be used to help pinpoint where in the brain seizures start:

- **Statistical parametric mapping (SPM).** SPM looks at the areas of the brain with more blood flow during seizures. It's compared to the same areas of the brains of people who don't have seizures. This provides information about where seizures begin.
- **Electrical source imaging (ESI).** ESI is a technique that takes EEG data and projects it onto an MRI of the brain. This is done to show areas where seizures are occurring. This technique provides more-precise detail than does EEG alone.
- **Magnetoencephalography (MEG).** MEG measures the magnetic fields produced by brain activity. This helps find the potential areas where seizures start. MEG can be more accurate than EEG because the skull and tissue surrounding the brain interfere less with magnetic fields. MEG and MRI together provide images that show areas of the brain both affected by seizures and not affected by seizures.

Diagnosis of your seizure type and where seizures begin gives you the best chance for finding an effective treatment.

TREATMENT

Treatment can help people diagnosed with epilepsy have fewer seizures or even completely stop having seizures. Possible treatments include:

- Medicines.
- Surgery.
- Therapies that stimulate the brain using a device.
- A ketogenic diet.

A) Medicines

Most people with epilepsy can become seizure-free by taking one anti-seizure medicine, also called an anti-seizure medicine. Others may be able to decrease the number and intensity of their seizures by taking more than one medicine.

Many children with epilepsy who aren't having epilepsy symptoms can eventually stop taking medicines and live a seizure-free life. Many adults can stop taking medicines after two or more years without seizures. Your healthcare team can advise you about the appropriate time to stop taking medicines.

Finding the right medicine and dosage can be complex. Your healthcare professional may consider your age, condition, how often you have seizures and other factors when choosing a medicine. Your healthcare professional also may review other medicines you're taking to ensure the anti-seizure medicines won't interact with them.

You may first take a single medicine at a low dose. Then your healthcare professional may raise the dosage gradually until your seizures are well managed.

There are more than 30 different types of anti-seizure medicines available. The medicines that you take depend on the type of seizures you have, your age and other health conditions.

Anti-seizure medicines may have some side effects. Mild side effects include:

- Fatigue.
- Dizziness.
- Weight gain.
- Loss of bone density.
- Skin rashes.
- Loss of coordination.
- Speech problems.
- Memory and thinking problems.

More-serious but rare side effects include:

- Depression.
- Suicidal thoughts and behaviors.
- Severe rash.



- Inflammation of certain organs, such as the liver.

For the best seizure management possible with medicine, follow these steps:

- Take medicines exactly as prescribed.
- Always call your healthcare professional before switching to a generic version of your medicine or taking other medicines. This includes medicines you get with or without a prescription and herbal remedies.
- Never stop taking your medicine without talking to your healthcare professional.
- Tell your healthcare professional immediately if you notice new feelings of depression or suicidal thoughts. Also contact your healthcare professional right away if you have changes in your mood or behaviors.
- Tell your healthcare professional if you have migraines. You may need an anti-seizure medicine that can prevent your migraines and treat epilepsy.

At least half the people newly diagnosed with epilepsy become seizure-free with their first medicine. If anti-seizure medicines don't provide good results, you may be able to have surgery or other therapies. You'll likely have regular follow-up appointments with your healthcare professional to check on your condition and medicines.

B) Epilepsy surgery

When medicines do not provide enough management of seizures, epilepsy surgery may be an option. With epilepsy surgery, a surgeon removes the area of your brain that's causing seizures.

Surgery usually is done when tests show that:

- Your seizures start in a small, well-defined area of your brain.
- The surgery wouldn't affect vital functions such as speech, language, movement, vision or hearing.

For some types of epilepsy, minimally invasive approaches such as MRI-guided stereotactic laser ablation may help symptoms. These treatments may be used when open surgery is too risky. This procedure involves using a thermal laser probe directed at the area in the brain causing seizures. It destroys tissue to better manage seizures.

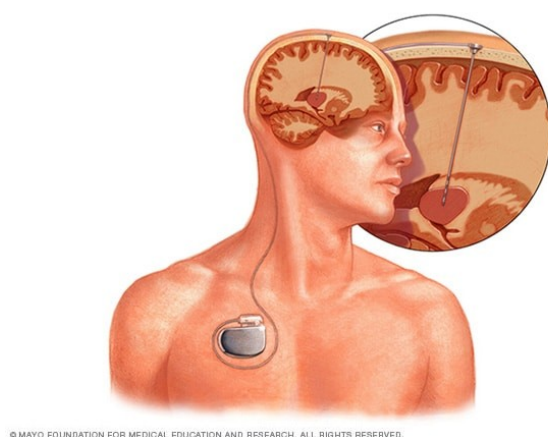
You may continue to take medicine to help prevent seizures after successful surgery. However, you may be able to take fewer medicines and reduce your doses.

In a small number of people, surgery for epilepsy can cause complications. Complications may include a permanent change in thinking abilities. Talk to your surgical team members about their experience, success rates and complication rates with the procedure you're considering.

C) Therapies

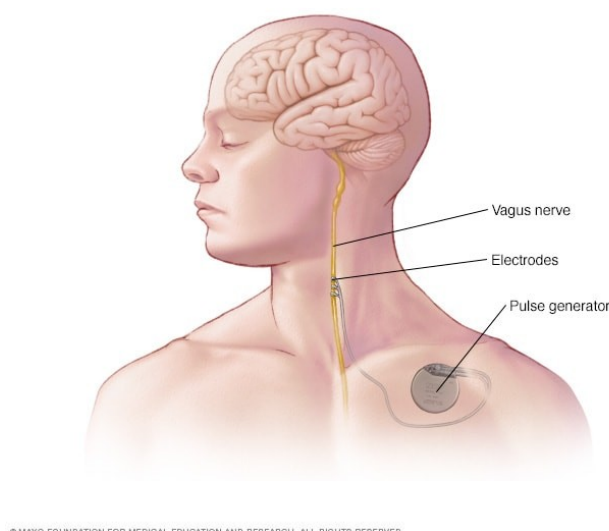
Apart from medicines and surgery, these potential therapies offer an alternative for treating epilepsy:





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Figure 5: Implanted Vagus Nerve Stimulation



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Fig 6: Deep Brain Stimulation

- **Vagus nerve stimulation.** Vagus nerve stimulation may be an option when medicines haven't worked well enough to manage seizures, and surgery isn't possible. A device called a vagus nerve stimulator is implanted underneath the skin of the chest, similar to a heart pacemaker. Wires from the stimulator are connected to the vagus nerve in the neck.

The battery-powered device sends bursts of electrical energy through the vagus nerve and to the brain. It's not clear how this inhibits seizures, but the device can usually reduce seizures by 20% to 40%.

Most people still need to take anti-seizure medicine. But some people may be able to lower their medicine dose. Vagus nerve stimulation side effects may include

throat pain, hoarse voice, shortness of breath or coughing.

- **Deep brain stimulation.** In deep brain stimulation, surgeons implant electrodes into a specific part of the brain, typically the thalamus. The electrodes are connected to a generator implanted in the chest. The generator regularly sends electrical pulses to the brain at timed intervals and may reduce seizures. Deep brain stimulation is often used for people whose seizures don't get better with medicine.
- **Responsive neurostimulation.** These implantable, pacemaker-like devices can help reduce how often seizures occur. The devices analyze brain activity patterns to detect seizures as they start. They deliver electrical stimulation to stop the

seizure. Research shows that this therapy has few side effects and can provide long-term seizure relief.

D) Ketogenic diet

Some children and adults with epilepsy reduce their seizures by following a diet high in fats and low in carbohydrates. This may be an option when medicines aren't helping to manage epilepsy.

In this diet, called a ketogenic diet, the body breaks down fats instead of carbohydrates for energy. After a few years, some children may be able to stop the ketogenic diet and remain seizure-free. It's important for this to be done under close supervision of healthcare professionals.

Experts don't fully know how a ketogenic diet works to reduce seizures. But researchers think that the diet creates chemical changes that suppress seizures. The diet also alters the actions of brain cells to reduce seizures.

Get medical advice if you or your child is considering a ketogenic diet. It's important to make sure that your child gets enough nutrients when following the diet.

Side effects of a ketogenic diet may include dehydration, constipation and slowed growth from not getting enough nutrition. Side effects also may include a buildup of uric acid in the blood, which can cause kidney stones. These side effects are not common if the diet is properly and medically supervised.

Following a ketogenic diet can be hard. Low-glycemic index and modified Atkins diets offer less restrictive alternatives that may still provide some improvement for seizures.

Potential future treatments

Researchers are studying many potential new treatments for epilepsy, including:

- **Continuous stimulation of the seizure onset zone, known as subthreshold stimulation.** Subthreshold stimulation is continuous stimulation to an area of the brain below a level that's physically noticeable. This type of therapy appears to improve seizure outcomes and quality of life for some

people with seizures. Subthreshold stimulation helps stop a seizure before it happens.

This treatment may work in people who have seizures that start in an area of the brain called the eloquent area. This area can't be removed because it would affect speech and movements. Or it might help people with seizure types that may not improve with responsive neurostimulation.

- **Minimally invasive surgery.** New minimally invasive surgical techniques, such as MRI-guided focused ultrasound, show promise for treating seizures. These surgeries have fewer risks than traditional open-brain surgery for epilepsy.
- **Transcranial magnetic stimulation (TMS).** TMS applies focused magnetic fields on areas of the brain where seizures occur to treat seizures without the need for surgery. It may be used for patients whose seizures occur close to the surface of the brain and can't be treated with surgery.
- **Transcranial direct current stimulation (tDCS).** This technique provides electrical stimulation through the scalp to the brain to reduce seizures over time. This treatment may be provided at home. []

FORMULATIONS:

Antiepileptic drugs (AEDs)—also known as anti-seizure drugs (ASDs)—are manufactured and delivered in various formulations to match chronic management, pediatric needs, and acute emergency care. [22]

Oral Formulations (Chronic Treatment)

- **Immediate-Release (IR) Tablets and Capsules:** Standard solid oral forms that dissolve and absorb quickly, typically requiring twice-daily or three-times-daily dosing. [23]
- **Extended-Release (ER/XR) / Modified-Release Formulations:** Formulations like lamotrigine XR, levetiracetam XR, topiramate XR, or carbamazepine ER prolong drug absorption, lower peak-to-trough serum fluctuations, and allow once-daily or twice-daily dosing to improve adherence.



Note: Modified-release tablets generally must be swallowed whole and cannot be crushed. [24]

- **Liquids, Syrups, and Crushable Tablets:** Formulations such as liquid concentrations (e.g., 40 mg/ml) or crushable tablets are used for pediatric patients, elderly patients, or administration via enteral feeding tubes. [25]
- **Dispersible and Chewable Tablets:** Lamotrigine chewable/dispersible tablets and topiramate sprinkle capsules make administration easier for children or people with swallowing difficulties. [26]

Parenteral Formulations (Acute Seizures and Status Epilepticus)

- **Intravenous (IV) Injections:** Used for acute seizure emergencies or when oral administration is impossible (e.g., intravenous valproate, levetiracetam, lacosamide, or fosphenytoin as a safer alternative to IV phenytoin). [27]
- **Intramuscular (IM) Injections:** Provides rapid bioavailability when IV access is not immediately available, with intramuscular midazolam frequently preferred in pre-hospital settings. [28]

Non-Invasive Rescue Formulations (Out-of-Hospital & Acute Care)

- **Rectal Gels:** Rectal diazepam gel (Diastat) is used for acute breakthrough seizures outside the hospital. [29]
- **Buccal, Sublingual, and Intranasal Sprays/Solutions:** Formulations such as buccal or intranasal midazolam allow rapid absorption across mucous membranes for early status epilepticus. [30]
- **Refractory Epilepsy:** Drug-resistant epilepsy occurs when two appropriate ASMs fail; alternatives include resective surgery, neurostimulation (like vagus nerve stimulation), and dietary therapies like the ketogenic diet.

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