La Crosse Encephalitis Virus Infection: Transmission Dynamics, Neurological Outcomes, and Strategies for Prevention and Treatment

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ABSTRACT

La Crosse virus (LACV) is a mosquito-borne orthobunyavirus and a significant cause of pediatric viral encephalitis in North America. First isolated in 1960 from a fatal case of encephalitis in La Crosse, Wisconsin, LACV is maintained in an enzootic cycle between the primary vector, *Aedes triseriatus* (the eastern treehole mosquito), and small mammal amplifier hosts such as chipmunks and squirrels. The virus possesses a tri-segmented, negative-sense single-stranded RNA genome that encodes structural and non-structural proteins, which facilitate viral replication and potent immune evasion. While the majority of human infections are asymptomatic, LACV can cause severe neuroinvasive disease, primarily in children under 16, presenting as meningoencephalitis with symptoms ranging from fever and headache to seizures, coma, and long-term neurological sequelae. Diagnosis relies on serological assays like IgM ELISA and molecular methods such as RT-PCR. No specific antiviral therapy exists, making management supportive and prevention critical. Preventive strategies focus on public education, personal protection against mosquito bites, and environmental management to reduce mosquito breeding sites. This review provides a detailed examination of LACV's history, virology, replication cycle, pathogenesis, clinical presentation, diagnostic methodologies, and the overarching public health strategies required for its containment. The continued emergence and seasonal recurrence of LACV underscore the necessity for sustained surveillance, vector control, and research into novel therapeutics and vaccines.

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La Crosse Virus, Orthobunyavirus, Pediatric Encephalitis, Arbovirus, *Aedes triseriatus*, Neuroinvasive Disease, Zoonosis, Viral Pathogenesis, Public Health..

INTRODUCTION

La Crosse virus (LACV) is a significant human pathogen that belongs to the Bunyaviridae family, which comprises a group of viruses characterized by their segmented, single-stranded RNA genomes. LACV is primarily transmitted through the bite of infected mosquitoes, particularly the Aedes triseriatus, and is a leading cause of pediatric encephalitis in the United States. La Crosse virus (LAC) is an arthropod-borne virus (arbovirus) in the family Bunyaviridae, the largest family of arboviruses with over 300 members (Grace et al, 2021).

The La Crosse virus was isolated from the 4-year-old girl by Dr. Robert E. Shope and his colleagues, specifically Thomas P. Thompson, and G. R. Deibel's team at the Yale University School of Medicine, however, the actual isolation was done by Thomas P. Thompson (Elizabeth et.al, 2022).

La Crosse virus is a significant public health concern, particularly in the Midwestern and Southeastern United States. Understanding the transmission. La Crosse virus (LACV) is a virus that causes encephalitis and other illnesses in humans through the bite of an infected mosquito. It's the most common cause of pediatric neuroinvasive arboviral disease in the United States (Corey et.al, 2023).

La Crosse virus infection can cause a range of symptoms, from mild to severe. Mild cases may present with fever, headache, and fatigue, while more severe cases can progress to encephalitis, which is characterized by inflammation of the brain. Severe cases of La Crosse encephalitis can lead to seizures, coma, and even death. The disease is most severe in children under the age of 16 (Reem et.al, 2024).

The virus is typically diagnosed through laboratory tests, including serological tests, viral isolation, and molecular tests such as PCR. Treatment for La Crosse encephalitis is primarily supportive, involving hospitalization, fluids, and management of seizures and increased intracranial pressure. Antiviral medications such as ribavirin may also be used in some cases.The virus is typically transmitted during the summer months when the mosquito population is at its peak (Quellete, 2024).

La Crosse virus, a zoonotic virus, is maintained in the environment through a cycle involving mosquitoes and small mammals, such as chipmunks and squirrels.The virus has a wide geographic range, with cases reported in the Midwestern and Southeastern United States. However, it is most commonly found in the Ohio and Mississippi river valley (CDC, 2024).

La Crosse virus is a significant public health concern, particularly in areas where the virus is endemic. Efforts to control the spread of the virus focus on reducing mosquito populations and preventing mosquito bites (Trout et.al, 2022).

HISTORY/ORIGIN OF LACV (LA CROSSE VIRUS)

La Crosse virus (LACV) was first isolated in 1960 from a 4-year-old girl in La Crosse, Wisconsin, who died from encephalitis. The virus was identified by Dr. Robert E. Shope and his colleagues, specifically Thomas.P. Thompson and G.R Deibel at the Yale University School of Medicine. In the late 1950s and early 1960s, a series of mysterious encephalitis cases occurred in the Midwestern United States, particularly in Wisconsin, Minnesota, and Illinois. The cases were characterized by severe neurological symptoms, including seizures, coma, and paralysis (Byrrd et.al, 2023).

Thomas.P. Thompson isolated a virus from the brain tissue of the 4-year-old girl who died from encephalitis in La Crosse, Wisconsin. The virus was initially thought to be a new strain of the California encephalitis virus, but further studies revealed that it was a distinct virus. The virus was named La Crosse virus (LACV) after the city of La Crosse, Wisconsin, where it was first isolated.

Since its discovery, LACV has been responsible for numerous outbreaks of encephalitis in the Midwestern and Southeastern United States. According to the Centers for Disease Control and Prevention (CDC), LACV is responsible for approximately 80-100 reported cases of encephalitis annually in the United States (Harding et.al, 2018). The origin of LACV is not fully understood, but it is believed to have evolved from a virus that infects small mammals, such as chipmunks and squirrels. The virus is thought to have been transmitted to humans through the bite of infected mosquitoes.

Phylogenetic studies have revealed that LACV has undergone significant genetic changes over the years, resulting in distinct strains of the virus. The virus continues to evolve, and ongoing research is focused on understanding its genetic diversity and transmission dynamics(Iqbal et.al,2023).
The discovery of La Crosse virus in 1960 marked a significant milestone in the field of virology. The isolation of the virus from a 4-year-old girl in La Crosse, Wisconsin, by Dr. Robert E. Shope and his colleagues, paved the way for further research into the virus's transmission dynamics, clinical manifestations, and prevention strategies.

Since its discovery, La Crosse virus has been recognized as a leading cause of pediatric encephalitis in the United States, with numerous outbreaks reported across the Midwestern and Southeastern regions.

The history of La Crosse virus serves as a testament to the importance of ongoing research and surveillance in understanding and controlling emerging infectious diseases. As our knowledge of the virus continues to evolve, it is essential that we remain vigilant in our efforts to prevent and treat La Crosse virus infections, ultimately reducing the burden of this disease on public health (Matthews et.al, 2022).

GENOME NATURE OF LACV (LA CROSSE VIRUS)

La crosse virus is a member of the bunyavirdae family, which comprises a group of viruses characterized by their segmented, negative-sense, single-stranded RNA. They consist of three single stranded RNA segments, designed as large(L), medium (M) and small(S). These segments are encapsulated within a lipid envelope (Rondeau et.al, 2024).

STRUCTURAL PROTEINS AND THEIR FUNCTIONS

There are three structural proteins in La Crosse virus; namely,

1. Glycoprotein G1 (G1)
G1 is a transmembrane glycoprotein that plays a crucial role in viral attachment, entry, and replication. It is embedded in the viral envelope and is responsible for:
- Binding to host cell receptors: G1 interacts with specific receptors on the surface of host cells, facilitating viral attachment and entry.
- Mediating viral entry: G1 works in conjunction with G2 to facilitate viral entry into host cells.
- Regulating viral replication: G1 may also play a role in regulating viral replication, although the exact mechanisms are not fully understood (Pekosz et.al, 2015)

2. Glycoprotein G2 (G2)
G2 is another transmembrane glycoprotein that works in conjunction with G1 to facilitate viral attachment, entry, and replication. G2 is also embedded in the viral envelope and is responsible for:
- Mediating viral entry: G2 works with G1 to facilitate viral entry into host cells.
- Regulating viral replication: G2 may also play a role in regulating viral replication, although the exact mechanisms are not fully understood (Agnihothram S. 2017)

3. Nucleocapsid Protein (N)
The N protein is a structural protein that encapsidates the viral genome, forming the nucleocapsid. The N protein is responsible for:
- Encapsidating the viral genome: N protein binds to the viral RNA, forming a nucleocapsid that protects the genome.
- Interacting with the viral RdRp: N protein interacts with the viral RdRp, facilitating the transcription and replication of the viral genome (Shokeen et.al, 2025).

Accessory Proteins and their Functions

La Crosse virus has two accessory proteins; namely
1. Non-Structural Protein (NSs)
Function: NSs is a non-structural protein that plays a role in regulating viral replication and transcription. It has been shown to:

- Inhibit the host cell's interferon response, allowing the virus to evade the host's immune system
- Regulate the expression of viral genes.
- Interact with other viral proteins to facilitate viral replication (Wang et.al, 2025)

2. Non-Structural Protein (NSm)
Function: NSm is another non-structural protein that plays a role in regulating viral replication and transcription. It has been shown to:

- Interact with the viral glycoproteins (G1 and G2) to facilitate viral entry and replication.
- Regulate the expression of viral genes.
- Play a role in the formation of viral replication complexes (Ren et.al, 2021).

CLASSIFICATION OF LACV (LA CROSSE VIRUS)

1. Order - Bunyavirales (Kuhn et.al, 2024)
2. Family - Peribunyaviridae (formerly Bunyaviridae) (Jneidi et.al, 2024)

3. Subfamily - Peribunyavirinae (Hudghes et.al, 2017)
4. Genus - Orthobunyavirus (Feracci et.al, 2024)
5. Species - La Crosse orthobunyavirus (Bergevin et.al, 2024)
6. Vernacular name - La Crosse virus (LACV) (Faw et.al, 2023)

Based on Particulate Nature

1. Type – Virion
2. Morphology - Spherical
3. Size - Approximately 80-120 nanometers (nm) in diameter
4. Enveloped - La Crosse virus is an enveloped virus, meaning it has a lipid envelope surrounding its protein capsid.
5. Capsid – Icosahedral
6. Nucleocapsid - Helical

Based on Genome (Arragain *et al*., 2022)

1. Genome type - Sngle-stranded RNA (ssRNA)
2. Genome polarity - Negative-sense
3. Genome segmentation - Segmented (three segments: Large, Medium, and Small)
4. Genome size - Approximately 12 kilobases (kb)
5. Genome organization - The three segments are:

- Large (L) segment: encodes the viral RNA-dependent RNA polymerase (RdRp)
- Medium (M) segment: encodes the viral glycoproteins (G1 and G2)
- Small (S) segment: encodes the viral nucleocapsid protein (N) and non-structural protein (NSs)

Based on Route of Infection (Bewick *et al.*, 2016)

1. Route of infection - Bite of an infected mosquito
2. Vector - Primary vector is the eastern treehole mosquito (Aedes triseriatus)
3. Transmission route - Arthropod-borne (vector-borne)

Properties of LACV (La Crosse Virus)

Biological Properties (Harding *et al*., 2019)

1. Host: Infects animals and humans
2. Cells: Infects brain and nerve cells
3. Reproduction: Makes copies of itself inside host cells
4. Transmission: Spread by mosquito bites
5. Disease: Causes fever, headache, and brain inflammation

Physical Properties

1. Size: Very small (80-120 nanometers)
2. Shape: Round
3. Outer layer: Has a fatty envelope
4. Density: Lighter than water
5. Stability: Sensitive to heat and pH changes

Chemical Properties

1. Proteins: Makes up the virus's structure
2. Lipids: Helps form the virus's outer layer
3. Carbohydrates: Attached to proteins, helps with function
4. RNA: Genetic material of the virus
5. pH level: Affects how the virus behaves
6. Disulfide bonds: Helps hold proteins together
7. Glycosylation: Adds carbohydrates to proteins, affects function

Structure of the virus

LACV is a spherical virus with a diameter of approximately 80-120 nanometers (nm). It has a lipid envelope with glycoprotein spikes protruding from the surface (Fig. 1).

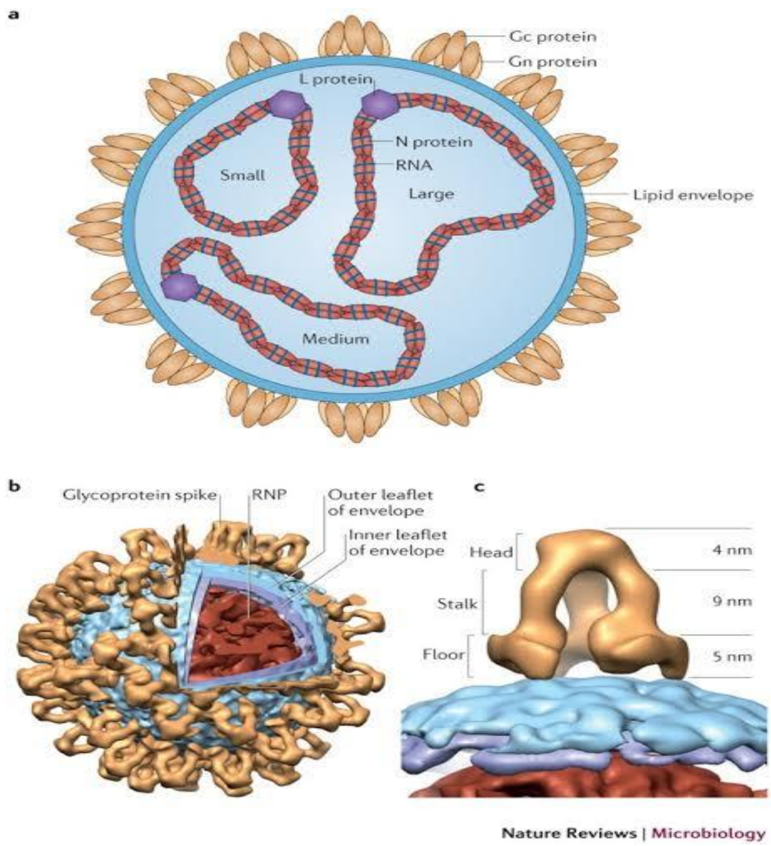

Figure 1: The orthobunayvirus particle
Source: Elliott (2014)

MODE OF TRANSMISSION

La Crosse virus is primarily transmitted through Mosquito bites. The virus is spread by the bite of an infected mosquito, typically Aedes triseriatus (Reese *et al*., 2016).

REPLICATION OF LACV (LA CROSSE VIRUS)

Attachment

The replication cycle of La Crosse virus begins with **attachment**, where the viral glycoprotein G1 on the surface of the virus recognizes and binds to specific receptors on the host cell membrane. This receptor–ligand interaction determines the host range and tissue tropism of the virus, initiating the infection process (Khan *et al*., 2023; Iheukwumere *et al*., 2025a).

Penetration

After attachment, La Crosse virus gains entry into the host cell through **receptor-mediated endocytosis**. During this process, the host cell membrane engulfs the virus, enclosing it within a vesicle known as an endosome. This mechanism allows the virus to cross the plasma membrane barrier and enter the cytoplasm (Jason, 2015; Iheukwumere *et al*., 2025b).

Targeting Site of Replication

Once inside the cell, the virus must reach its **site of replication**, which is the **cytoplasm**. Like other negative-sense RNA viruses, La Crosse virus replicates primarily in the cytoplasm of neurons and other susceptible cells, where the cellular machinery required for viral genome replication and protein synthesis is located (Rampersad *et al*., 2018; Iheukwumere *et al*., 2025c).

Uncoating

Following endocytosis, **uncoating** occurs. This is the step where the viral envelope fuses with the endosomal membrane, releasing the viral ribonucleoprotein complexes (vRNPs) into the cytoplasm. The uncoating process frees the viral RNA genome from its protective protein coat so it becomes accessible for transcription (Yamauchi *et al*., 2016; Iheukwumere *et al*., 2025d).

Early Transcription

In the **early transcription** stage, the viral RNA-dependent RNA polymerase (RdRp) transcribes the negative-sense RNA genome segments into positive-sense messenger RNAs (mRNAs). These early transcripts primarily encode non-structural proteins that regulate replication and modulate host responses (Arragain *et al*., 2022; Iheukwumere *et al*., 2025e).

Early Translation

The newly synthesized viral mRNAs undergo **early translation** using host ribosomes. This leads to the production of non-structural viral proteins, which are essential for establishing a suitable environment for viral genome replication, shutting down host defenses, and assembling replication complexes (Choi, 2017; Iheukwumere *et al*., 2025f).

Genome Replication

Once sufficient non-structural proteins are produced, the virus proceeds to **genome replication**. Here, the viral polymerase synthesizes complementary positive-sense RNA strands that serve as templates for generating additional copies of the negative-sense genomic RNA segments, thereby amplifying the viral genome pool (Borucki *et al*., 2020).

Late Transcription

During **late transcription**, the viral polymerase shifts towards producing high levels of mRNAs encoding structural proteins, which will form the physical components of the virion. This stage marks the transition from genome amplification to virion production (Edward, 2023).

Late Translation

The structural protein mRNAs are then translated during the **late translation** phase. This leads to the synthesis of viral structural proteins such as the nucleocapsid (N) protein and envelope glycoproteins (G1 and G2), which are necessary for virion assembly (Gale *et al*., 2015).

Maturation (Assembly)

In the **maturation or assembly** phase, the newly synthesized viral genomes are packaged into nucleocapsids, which then bud into the Golgi apparatus where they acquire their envelope containing the viral glycoproteins. This intracellular assembly ensures the proper formation of infectious virions (Veesler *et al*., 2018).

Release

Finally, mature La Crosse virions are transported to the cell surface and **released** through exocytosis or budding. This process allows newly formed infectious particles to exit the host cell and spread to adjacent cells, continuing the cycle of infection (Rheinemann *et al*., 2021; Iheukwumere *et al*., 2025g).

PATHOGENESIS OF LACV (LA CROSSE VIRUS)

1. Entry of the virus into the host

La Crosse Virus passes the plasma membrane through endocytosis (i.e the host cell engulfs the virus, forming a vesicle) (Burrell et.al, 2017; Iheukwumere *et al*., 2024a)

2. Contact with susceptible cells

During pathogenesis, La Crosse virus contacts susceptible cells through:

- Mosquito saliva: Infected mosquito saliva containing the virus is injected into the host's skin during a bite.
- Langerhans cells: Virus-infected mosquito saliva encounters Langerhans cells, a type of dendritic cell, in the skin.
- Dendritic cell migration: Infected Langerhans cells migrate to lymphoid organs, where they encounter and infect other immune cells.
- Viral dissemination: The virus is disseminated through the bloodstream and lymphatic system, allowing it to reach and infect susceptible cells in various tissues (Iheukwumere *et al*., 2024b).
-Neuroinvasion: The virus invades the central nervous system (CNS) by crossing the blood-brain barrier or through retrograde transport via neurons (Basu et.al,2023).

3. Replication within the cell: The viral genome is replicated using the host cell's machinery, producing new viral RNA (Xizhen et.al, 2022; Iheukwumere *et al*., 2024c).

4. Release from the host cell: During pathogenesis, La Crosse virus is released from host cells through:

-Budding: New virus particles bud out from the host cell membrane.
-Lysis: The host cell bursts, releasing new virus particles.

5.Viral spread and cell tropism : Viral spread refers to the movement of a virus throughout the body, infecting more cells while Cell tropism refers to the preference of a virus to infect specific cells or tissues in the body (Ashfaq *et al*, 2024; Iheukwumere *et al*., 2024d).

6. Cell injury and clinical illnesses: Cell injury refers to the harm or damage caused to cells, particularly brain cells and immune cells, due to La Crosse virus infection. This injury can lead to cell death, disrupted cell function, and inflammation (Iheukwumere *et al*., 2024e).
Clinical illnesses associated with La Crosse virus infection involve inflammation of the brain, membranes surrounding the brain and spinal cord, and sudden onset of brain dysfunction, which can result in severe symptoms such as seizures and coma. Examples of clinical illnesses caused by La Crosse virus include encephalitis, meningitis, and acute encephalopathy (Christopher, 2024).

7. Recovery from infection: Recovery from La Crosse virus infection occurs when the immune system successfully fights off the virus, and the damaged cells begin to heal. As the body clears the virus, symptoms improve, and the individual returns to normal health, no longer being contagious (Iheukwumere *et al*., 2024f).

8. Viral shedding: Viral shedding refers to the release of a virus from an infected host, making it available to infect other individuals (Baron et al., 2016).

Diseases associated with LACV (La Crosse Virus)
La Crosse virus is primarily associated with encephalitis, a serious and potentially life-threatening inflammation of the brain (Gudlavalleti et.al, 2025).

CLINICAL MANFESTATION OF THE DISEASE (ENCEPHALITIS)

SIGNS (Said et.al, 2023)
- Stiff neck
- Seizures
- Fever
- Vomiting
- Disorientation

SYMPTOMS (Ali et.al, 2023)
- Confusion
- Fatigue
- Headache
- Altered mental status

SYNDROMES (briceno et.al, 2024)
-Acute encephalitic syndrome
- Meningoencephalitic syndrome
- Post-encephalitic syndrome.

DISTRIBUTION OF LA CROSSE VIRUS

The distribution of La Crosse encephalitis, caused by the La Crosse virus (LACV), can be described in terms of its occurrence among people, across places, and over specific periods. Understanding this distribution is critical for public health surveillance, risk assessment, and the implementation of effective preventive strategies.

People
La Crosse encephalitis primarily affects children and adolescents, particularly those under the age of 16, who are more susceptible to developing severe neurological symptoms upon infection. Epidemiological data indicate that the disease is reported slightly more often in males than in females, although both sexes are vulnerable (Hamid et al., 2017). The infection can occur in children of diverse ethnic backgrounds, and while ethnicity does not appear to be a major risk factor, differences in case reporting may reflect varying environmental exposures and healthcare access. Marital status is not relevant in the distribution of this disease because it largely affects children and teenagers, most of whom are unmarried. This demographic pattern underscores the importance of targeting educational and preventive measures toward younger populations, especially those who engage in outdoor activities that increase their exposure to mosquito vectors.

Place
Geographically, La Crosse encephalitis is predominantly found in North America, with the majority of reported cases occurring in the United States, particularly in the Appalachian and Midwestern regions (Messacar et al., 2018). Within these areas, forested environments provide ideal breeding habitats for the primary mosquito vector, *Aedes triseriatus* (the eastern treehole mosquito). These regions often contain hardwood forests with abundant tree holes and artificial containers that collect water, creating suitable larval habitats. The disease is rarely reported from tropical regions or West African countries, as the ecological conditions there do not support the survival and reproduction of the specific mosquito vector involved. Within the United States, the virus is primarily concentrated in eastern and midwestern states, illustrating a strong geographical association with the vector's distribution and habitat preferences.

Period
The temporal distribution of La Crosse encephalitis is closely linked to climatic and seasonal patterns that influence mosquito activity. Cases are most common during wet periods, when rainfall creates numerous standing water sources that support mosquito breeding. The peak incidence occurs in the warmer months, particularly during the summer and early fall (July to October), which aligns with the active breeding season of *Aedes triseriatus* (Ramesh *et al*., 2015). Humid conditions and abundant vegetation during this time enhance the survival of both mosquitoes and their larvae. Although the virus does not show a marked diurnal pattern of transmission, human exposure often increases during daytime outdoor activities typical of the summer months. This seasonal trend highlights the need for heightened vector control efforts and public health awareness during the peak transmission period.

DIAGNOSIS OF ENCEPHALITIS

The diagnostic process involves clinical evaluation, sample collection, laboratory testing, and molecular techniques, while treatment strategies are largely based on the use of antiviral medications.

Physical Examination
The clinical evaluation of a suspected case of La Crosse encephalitis begins with a thorough physical examination.

Common clinical manifestations include fever, altered mental status such as confusion and disorientation, seizures, stiff neck suggestive of meningismus, and severe headache. In some cases, patients may also present with dermatological findings such as skin lesions or rashes (Bohmwald et al., 2021). These symptoms are vital indicators that guide further laboratory testing.

Sample Collection

For laboratory confirmation, various biological specimens are collected. Cerebrospinal fluid (CSF) is usually obtained through lumbar puncture, while blood serum is collected via venipuncture. In rare and severe cases, tissue samples may also be collected for histopathological and molecular investigations (Ambrose et al., 2015; Iheukwumere *et al*., 2025h).

Transportation of Samples

Proper handling and transportation of collected specimens are crucial for ensuring diagnostic accuracy. CSF and serum samples must be transported on ice packs at approximately 4°C or kept refrigerated, reaching the diagnostic laboratory within 24–48 hours (CDC, 2020). Tissue samples, however, require stricter storage conditions; they should be frozen at -70°C or transported on dry ice with secure packaging and appropriate labeling to prevent leakage and contamination (Armstrong et al., 2016).

Serological Tests

Serological assays are a cornerstone in the laboratory diagnosis of La Crosse encephalitis. The most widely used test is the immunoglobulin M (IgM) antibody capture enzyme-linked immunosorbent assay (MAC-ELISA), which detects recent infections. Additional methods include IgG antibody ELISA, plaque reduction neutralization test (PRNT), and hemagglutination inhibition (HI) tests (Lambert et al., 2015; Iheukwumere *et al*., 2025i). These tests help differentiate La Crosse virus from other arboviruses with similar clinical presentations.

Culturing of Samples

Virus isolation through culturing is another diagnostic approach, though less commonly used due to its technical demands. Samples such as CSF, serum, or tissue are inoculated into cell lines, including Vero or mosquito cells, to recover the virus. In some specialized laboratories, mosquito inoculation techniques are used to confirm viral presence (Gerhardt et al., 2018; Iheukwumere *et al*., 2025j).

Molecular Analysis

Molecular techniques provide highly sensitive and specific diagnostic tools. Reverse Transcription Polymerase Chain Reaction (RT-PCR) and real-time RT-PCR (rRT-PCR) are used to detect and quantify viral RNA in CSF, serum, or tissue samples. Nucleic acid sequencing further identifies the viral genome, while nested PCR enhances detection sensitivity (Patel et al., 2019). These molecular methods are indispensable in confirming diagnosis and characterizing viral strains.

Other Diagnostic Tests

Beyond serology and molecular diagnostics, other laboratory techniques are available. Immunofluorescence assay (IFA) and immunohistochemistry (IHC) detect viral antigens in tissues, while electron microscopy (EM) provides visualization of viral particles. Advanced technologies such as next-generation sequencing (NGS) enable comprehensive genome identification and the detection of genetic variations, thereby contributing to viral surveillance and epidemiological studies.

TREATMENT OF LA CROSSE ENCEPHALITIS

Currently, there are no universally approved antiviral drugs specifically targeting La Crosse encephalitis. However, certain antiviral agents have been explored for their therapeutic potential.

Ribavirin

Ribavirin has been identified as the primary antiviral drug investigated for treating La Crosse encephalitis. It can be administered either intravenously (IV) or orally, depending on disease severity. The IV dosage typically ranges from 1–2 grams per day for a period of 7–10 days, while the oral dosage is usually 400–800 mg every 8 hours over the same treatment duration (Kumar et al., 2020).

Interferon-Alpha

In addition to ribavirin, interferon-alpha has shown potential as a supportive therapeutic option. When administered subcutaneously or intramuscularly, it helps modulate the immune response against viral replication. Recommended dosages are between 3–5 million IU per day, administered over 7–10 days. Studies suggest that interferon-alpha may have greater efficacy when used in combination with ribavirin (Kumar et al., 2019).

TREATMENT USING MEDICINAL PLANTS

In addition to conventional antiviral drugs, medicinal plants have been explored for their therapeutic potential against viral infections, including arboviral diseases such as La Crosse encephalitis. Phytochemicals derived from traditional medicinal plants possess antiviral, anti-inflammatory, and immunomodulatory properties that can support clinical management (Kim et al., 2020). One of the most promising plants in this regard is *Andrographis paniculata*, widely known as the "King of Bitters.
"

Andrographis paniculata (King of Bitters)

Andrographis paniculata (Fig. 2) is a medicinal herb traditionally used in Ayurveda, Traditional Chinese Medicine (TCM), and other ethnomedical practices. It is primarily recognized for its anti-inflammatory, antipyretic, and immune-boosting effects, which make it a suitable adjunct therapy in managing viral encephalitis symptoms such as fever and inflammation. The herb can be consumed as tea or administered in capsule form. The recommended dosage typically ranges from 400–800 mg per day, depending on the severity of the condition and patient tolerance (Kim et al., 2020).

Nomenclature of *Andrographis paniculata*

To understand its widespread use, it is important to consider the different names by which this plant is known across cultures:

- **Botanical Name**: *Andrographis paniculata* (Burm.f.) Nees
- **English Names**: King of Bitters, Indian Echinacea, Kalmegh

- **Local/Regional Names**:
    - Hindi: Kalmegh, Mahatika
    - Sanskrit: Mahatika
    - Tamil: Nilavembu
    - Telugu: Nelavemara
    - Malayalam: Kiriyattu
    - Bengali: Kalmegh

The diverse nomenclature reflects its extensive use in traditional medicine across Asia. Its bioactive compounds, particularly andrographolide, are reported to have antiviral properties, making it a candidate for integrative approaches to viral encephalitis treatment.

Figure 2: *Andrographis paniculata*

Bacopa monnieri (Brahmi)

Bacopa monnieri (L.) Wettst (Fig. 3), commonly known as Brahmi, is another medicinal plant with significant neuroprotective and cognitive-enhancing effects. It is traditionally used in Ayurveda to improve memory, reduce anxiety, and protect brain function. In the context of viral encephalitis, *Bacopa monnieri* is valued for its ability to support neuronal recovery and reduce oxidative stress in the brain. The herb is usually prepared as tea or in capsule form, with a recommended dosage of 300–400 mg per day (Kim et al., 2020).

Nomenclature of _Bacopa monnieri_

- **Botanical Name**: *Bacopa monnieri* (L.) Wettst.
- **English Names**: Brahmi, Water Hyssop, Indian Pennywort
- **Local/Regional Names**:
    - Hindi: Brahmi
    - Sanskrit: Brahmi
    - Tamil: Neerbrahm
    - Malayalam: Neerbrahmi

Its neuroprotective properties make *Bacopa monnieri* especially beneficial in treating viral encephalitis cases where cognitive and neurological impairments occur.

Figure 3: *Bacopa monnieri*

Cannabis sativa (Marijuana)

Cannabis sativa L. (Fig. 4), commonly known as marijuana or hemp, has gained increasing attention in recent years for its therapeutic properties. It contains cannabinoids such as tetrahydrocannabinol (THC) and cannabidiol (CBD), which have demonstrated anti-inflammatory, anticonvulsant, and neuroprotective effects. In the context of viral encephalitis, *Cannabis sativa* may help reduce seizures, alleviate inflammation, and protect neuronal integrity. The plant is typically consumed in the form of oils or edibles. Since dosage varies depending on formulation and patient condition, it is recommended that administration be guided by a healthcare professional (Kim et al., 2020).

Nomenclature of _Cannabis sativa_

- **Botanical Name**: *Cannabis sativa* L.
- **English Names**: Hemp, Marijuana, Ganja
- **Local/Regional Names**:
    - Hindi: Bhang, Charas, Ganja
    - Sanskrit: Vijaya
    - Telugu: Ganja
    - Malayalam: Cannabise

Figure 4: *Cannabis sativa*

Ginkgo biloba (Maidenhair Tree)

Ginkgo biloba L. (Fig. 5), also called the "Maidenhair Tree," is renowned for its ability to improve cerebral blood circulation. By enhancing blood flow to the brain, it supports neuronal activity and may aid in preventing cognitive decline during viral encephalitis. It is commonly prepared as tea or in capsule form, with an effective dosage ranging between 120–240 mg per day.

Nomenclature of _Ginkgo biloba_

- **Botanical Name**: *Ginkgo biloba* L.
- **English Names**: Maidenhair Tree, Ginkgo, Living Fossil
- **Local/Regional Names**:
    - Hindi: Ginkgo
    - Sanskrit: Arkaghatta
    - Telugu: Ginkgo
    - Malayalam: Ginkgo
    - Chinese: Yin Xing (Silver Apricot)
    -

Figure 5: *Ginkgo biloba*

***Hypericum perforatum* (St. John's Wort)**

Hypericum perforatum L. (Fig. 6), commonly known as St. John's Wort, possesses antiviral and antidepressant properties. In encephalitis management, it is particularly valued for its ability to inhibit viral replication and support mood stabilization in patients experiencing neurological stress. Typically, it is consumed as tea or capsules, with a dosage of 300–500 mg per day.

Nomenclature of *Hypericum perforatum*

- **Botanical Name**: *Hypericum perforatum* L.
- **English Names**: St. John's Wort, Common St. John's Wort, Klamath Weed
- **Local/Regional Names**:
    - Hindi: Chaulmoogra, Ban Triloki
    - Tamil: Sengazhuneer
    - Telugu: Chaulmoogra
    - Malayalam: Sengazhuneer
    - German: Johanniskraut

Figure 6: *Hypericum perforatum*

***Melissa officinalis* (Lemon Balm)**

Melissa officinalis L. (Fig. 7), also known as Lemon Balm, is traditionally used to reduce stress, anxiety, and insomnia. In La Crosse encephalitis, where neurological symptoms are prominent, its calming effects help alleviate stress-related complications. It is generally consumed as tea (1–2 cups daily) or used in oil form (1–2 drops daily).

Nomenclature of *Melissa officinalis*

- **Botanical Name**: *Melissa officinalis* L.
- **English Names**: Lemon Balm, Balm, Common Balm
- **Local/Regional Names**:
    - Hindi: Billi Lemon
    - Sanskrit: Bhringaraja
    - Telugu: Elumichai
    - Malayalam: Elumichai
    - French: Mélisse officinale
    - German: Zitronenmelisse

Figure 7: *Melissa officinalis* L

***Silybum marianum* (Milk Thistle)**

Silybum marianum (L.) Gaertn. (Fig. 8), widely known as Milk Thistle, is renowned for its hepatoprotective properties. Since antiviral drugs and encephalitic infections can affect liver function, Milk Thistle helps preserve liver health. It is administered as tea or capsules, with a dosage of 200–400 mg per day.

Nomenclature of *Silybum marianum*

- **Botanical Name**: *Silybum marianum* (L.) Gaertn.
- **English Names**: Milk Thistle, St. Mary's Thistle, Holy Thistle
- **Local/Regional Names**:
    - Hindi: Katuki
    - Sanskrit: Kshirkakoli
    - Tamil: Kattukkay
    - Telugu: Adadoddu
    - Marathi: Kandagokharu
    - French: Chardon-Marie
    - German: Mariendistel

Figure 8: *Silybum marianum*

***Tinospora cordifolia* (Guduchi)**

Tinospora cordifolia (Thunb.) Miers (Fig. 9), known as Guduchi or Amrita, is a widely recognized immune booster in Ayurvedic medicine. In viral encephalitis, it supports the immune system's ability to combat viral infections and promotes faster recovery. It is usually consumed as tea or in capsule form, with a recommended dosage of 300–400 mg per day.

Nomenclature of *Tinospora cordifolia*

- **Botanical Name**: *Tinospora cordifolia* (Thunb.) Miers
- **English Names**: Heart-Leaved Moonseed, Guduchi, Amrita
- **Local/Regional Names**:

- Hindi: Giloy, Guduchi
- Sanskrit: Amrita, Guduchi
- Tamil: Silambragudi
- Telugu: Tippatiga
- Marathi: Gulvel
- Gujarati: Galo
- Kannada: Amruta Balli

Figure 9: ***Tinospora cordifolia***

***Withania somnifera* (Ashwagandha)**

Withania somnifera (L.) Dunal (Fig. 10), popularly called Ashwagandha, is a rejuvenating herb known for reducing stress, anxiety, and fatigue. Its adaptogenic properties make it beneficial in managing neurological symptoms of encephalitis. It is prepared as tea or in capsule form, with a dosage ranging from 300–500 mg per day.

Nomenclature of *Withania somnifera*

- **Botanical Name**: *Withania somnifera* (L.) Dunal
- **English Names**: Ashwagandha, Winter Cherry, Indian Ginseng
- **Local/Regional Names**:
  - Hindi: Ashwagandha
  - Telugu: Ashwagandha
  - Malayalam: Amukkara

Figure 10: *Withania somnifera*

PREVENTION

Below are some preventive measures against La Crosse Encephalitis:(Matthewset.al, 2022)

1. Wear protective clothing: Wear long-sleeved shirts, long pants, and socks when outdoors, especially during peak mosquito hours.
2. Use insect repellents: Apply insect repellents containing DEET, picaridin, or oil of lemon eucalyptus to exposed skin and clothing.
3. Avoid peak mosquito hours: Mosquitoes that transmit La Crosse virus are most active during dawn and dusk.
4. Eliminate standing water: Remove standing water around homes, such as pet water dishes, flowerpots, and clogged drains, to prevent mosquito breeding.
5. Use mosquito nets: Install mosquito nets around outdoor areas, such as patios and decks.
6. Use mosquito traps: Use mosquito traps, such as CO2 traps or UV light traps, to capture and kill mosquitoes.
7. Public education: Educate the public about the risks of La Crosse encephalitis and the importance of preventive measures.
8. Mosquito surveillance: Conduct regular mosquito surveillance to monitor for the presence of La Crosse virus.
9. Mosquito control programs: Implement mosquito control programs, such as larval control and adult mosquito control, to reduce mosquito populations.
10. Screening of blood donations: Screen blood donations for La Crosse virus to prevent transmission through blood transfusion.
11. Monitoring of animals: Monitor animals, such as mosquitoes and ticks, for the presence of La Crosse virus.

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