"Toward a Hepatitis-Free World: Reviewing Progress, Gaps, and Emerging Prevention Strategies"

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Abstract

Hepatitis continues to be a significant global public health issue, causing a large number of cases of liver disease and leading to many deaths. It is caused by several viruses, including hepatitis A, B, C, D, and E, and can result in longterm conditions such as chronic liver disease, cirrhosis, and liver cancer. In recent years, progress has been made in various areas such as testing methods, vaccines, antiviral treatments, public health programs, nanotechnology, and artificial intelligence, all of which have helped in preventing, detecting, and managing hepatitis more effectively. This review covers the spread of hepatitis, how it affects the body, the signs and symptoms, ways to diagnose it, methods to prevent it, current treatments, and new developments in its care. Special attention is given to new antiviral drugs, natural remedies, and nanotechnology based solutions, as well as the use of artificial intelligence in diagnosis. The World Health Organization aims to eliminate viral hepatitis by 2030, and this review highlights the importance of combining vaccination, early detection, effective treatment, public education, and technological advancements to achieve this goal. Ongoing research and fair access to healthcare are essential for reducing the worldwide impact of hepatitis.

Keyword : Hepatitis, Viral hepatitis, Hepatitis B, Hepatitis C, Antiviral therapy, Vaccination, Nanotechnology, Artificial intelligence, Liver disease, Hepatitis elimination.

Introduction

Hepatitis refers to the inflammation of the liver, which can occur due to various factors such as viral infections, alcohol use, autoimmune conditions, metabolic issues, or exposure to toxins and drugs. Among these, viral hepatitis is the primary cause of liver disease worldwide. There are five major viruses that specifically affect the liver—HAV, HBV, HCV, HDV, and HEV—each with different ways of spreading, symptoms, and long-term

effects. The World Health Organization reports that hundreds of millions of people are living with chronic hepatitis B and C infections, and viral hepatitis is responsible for over one million deaths each year.

Although effective vaccines are available for hepatitis A and B, and curative treatments exist for hepatitis C, many people who are infected are unaware of their condition and do not receive proper care.

In recent years, there have been significant developments in hepatitis research. Innovations such as advanced diagnostic methods, direct-acting antiviral medications, enhanced vaccination efforts, nanotechnology in drug delivery, and artificial intelligence tools for clinical decisions are reshaping the way hepatitis is managed. This review provides a detailed summary of recent advancements in preventing, diagnosing, treating, and eliminating hepatitis.

Epidemiology

Viral hepatitis affects people in both developed and developing

countries.Hepatitis B virus (HBV) is common in parts of Asia and Africa, while hepatitis C virus (HCV) is a major health issue around the world. Poor sanitation plays a key role in spreading Hepatitis A virus (HAV) and Hepatitis E virus (HEV).Unsafe injections, blood transfusions, and unprotected sexual contact are main causes of HBV and HCV transmission.

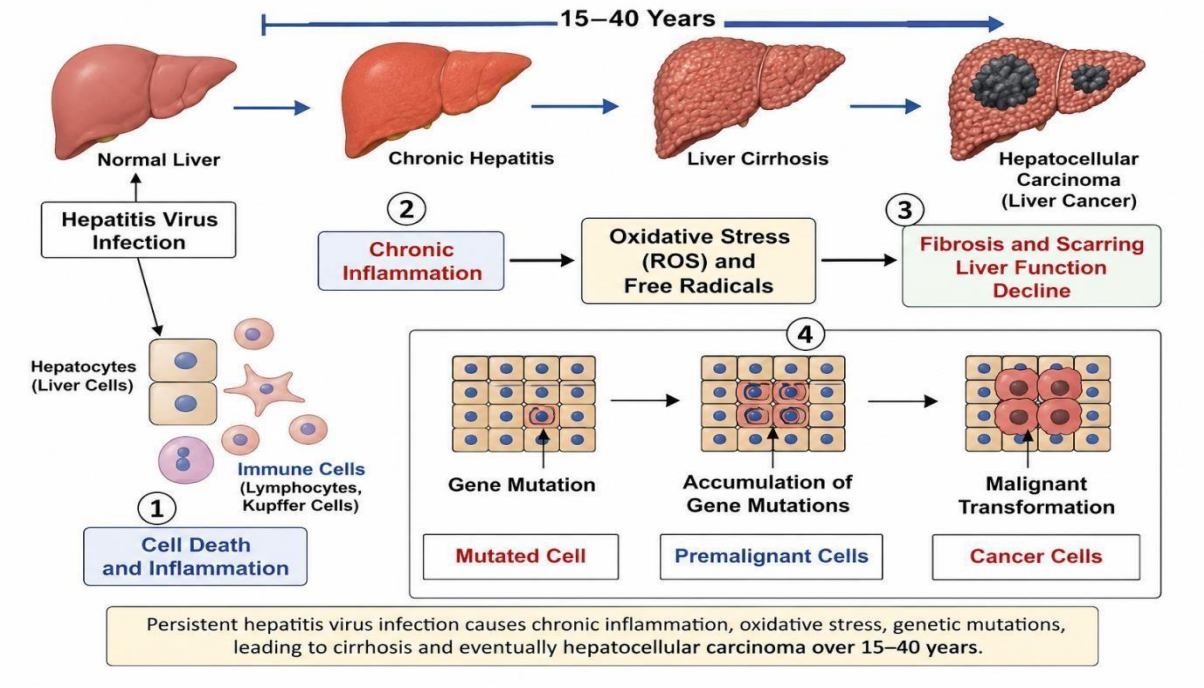


Figure 1

Global Epidemiology

Viral hepatitis continues to be one of the leading causes of liver-related health problems and deaths globally.

According to the World Health Organization, viral hepatitis causes about 1.3 million deaths each year, making it one of the top infectious causes of death. Most of these deaths are due to chronic infections with HBV and HCV, which can lead to serious complications like liver cirrhosis and hepatocellular carcinoma.

Around 254 million people have chronic hepatitis B infection, and approximately 50 million are living with chronic hepatitis C.

Hepatitis A and Hepatitis E mainly cause short-term liver inflammation and are closely linked to poor sanitation, unsafe drinking water, and contaminated food.

The greatest burden of viral hepatitis is found in low- and middle-income countries, especially in sub-Saharan Africa, South-East Asia, and the Western Pacific Region.

In these areas, low vaccination rates, limited access to healthcare, delayed diagnosis, and lack of proper treatment greatly increase the spread of the disease.

Even though there have been major advances in vaccination and antiviral treatments, millions of people who are infected remain undiagnosed.

WHO data shows that only a small number of people with chronic HBV and HCV know they are infected, which remains a big challenge for efforts to eliminate the disease.

Table 1: Types of Viral Hepatitis

Type	Main Transmission	Major Risk Factors
HAV	Faecal oral route	Contaminated food, contaminated water, poor sanitation
HBV	Blood, sexual, perinatal	Blood transfusion, sexual transmission, childbirth, needle sharing
HCV	Blood exposure	Blood exposure, injectable drug use, unsafe medical procedures
HDV	Requires HBV infection	Chronic HBV infection, blood exposure
HEV	Faecal–oral route	Unsafe drinking water, poor hygiene contaminated food.

Epidemiology of Different Hepatitis Viruses

Hepatitis A (HAV)

HAV infection is found around the world, but it is more common in countries where there is not enough sanitation.

It is usually spread through food and water that is not clean.In areas where the infection is common, children often get infected, and this usually gives them immunity that lasts for life.

Hepatitis B (HBV)

HBV continues to be a big problem for global health.

It spreads through infected blood, sexual contact, shared needles, and from a mother to her baby during childbirth. Having a long-term HBV infection greatly raises the chances of getting liver cirrhosis and hepatocellular carcinoma.

Hepatitis C (HCV)

HCV is mainly passed on through contact with blood that has the virus.

The use of direct-acting antiviral (DAA) treatments has greatly increased the number of people who are cured. However, many people who have HCV do not know they are infected.

Hepatitis D (HDV)

HDV can only occur in people who already have HBV.

When HDV occurs at the same time as HBV (coinfection) or later

(superinfection), it speeds up liver damage and increases the risk of cirrhosis.

Hepatitis E (HEV)

HEV outbreaks often happen in places with poor sanitation and contaminated drinking water.

Pregnant women are especially at risk, and they have a higher chance of dying from the infection.

Major Risk Factors

- Being exposed to blood that is infected
- Receiving unsafe blood transfusions
- Using contaminated syringes or needles more than once

- Using drugs injected into the body
- Having unprotected sexual activity
- Passing the infection from a mother to her child
- Poor sanitation and water that is not clean
- Eating contaminated food
- Not being vaccinated against hepatitis
- Healthcare workers who are exposed to blood on the job
- Getting tattoos or piercings with unclean tools
- Undergoing haemodialysis
- Having an organ transplant
- Being in a weakened immune system
- Having many sexual partners
- Traveling to areas where hepatitis is common

**Fig 1.2**

High-Risk Populations

- Healthcare workers

- People who use intravenous drugs
- Patients who get frequent blood transfusions
- Patients on haemodialysis
- People living with HIV
- New-born babies whose mothers have HBV
- People with many sexual partners
- People in prison
- People who move from countries where hepatitis is common
- People living in areas without good sanitation

Public Health Importance

Understanding how hepatitis spreads and knowing who is at risk is key for stopping the disease.

Vaccination for all, screening blood for infection, using safe needles, raising awareness in the public, improving sanitation, and finding infections early are the main ways to control and stop hepatitis.

Clinical Manifestations

The symptoms of viral hepatitis depend on which virus is causing it, the person's immune system, their age, and whether the infection is short-term or long-term.

Many people do not have symptoms in the early stages, but others may have mild to severe inflammation of the liver. Chronic infections from HBV and
HCV can be quiet for a long time before leading to cirrhosis or hepatocellular carcinoma (HCC).

The disease usually goes through four stages:

1.Incubation period

2.Prodromal (Pre-icteric) phase

3.Icteric phase

4.Recovery or Chronic phase

Common Signs and Symptoms

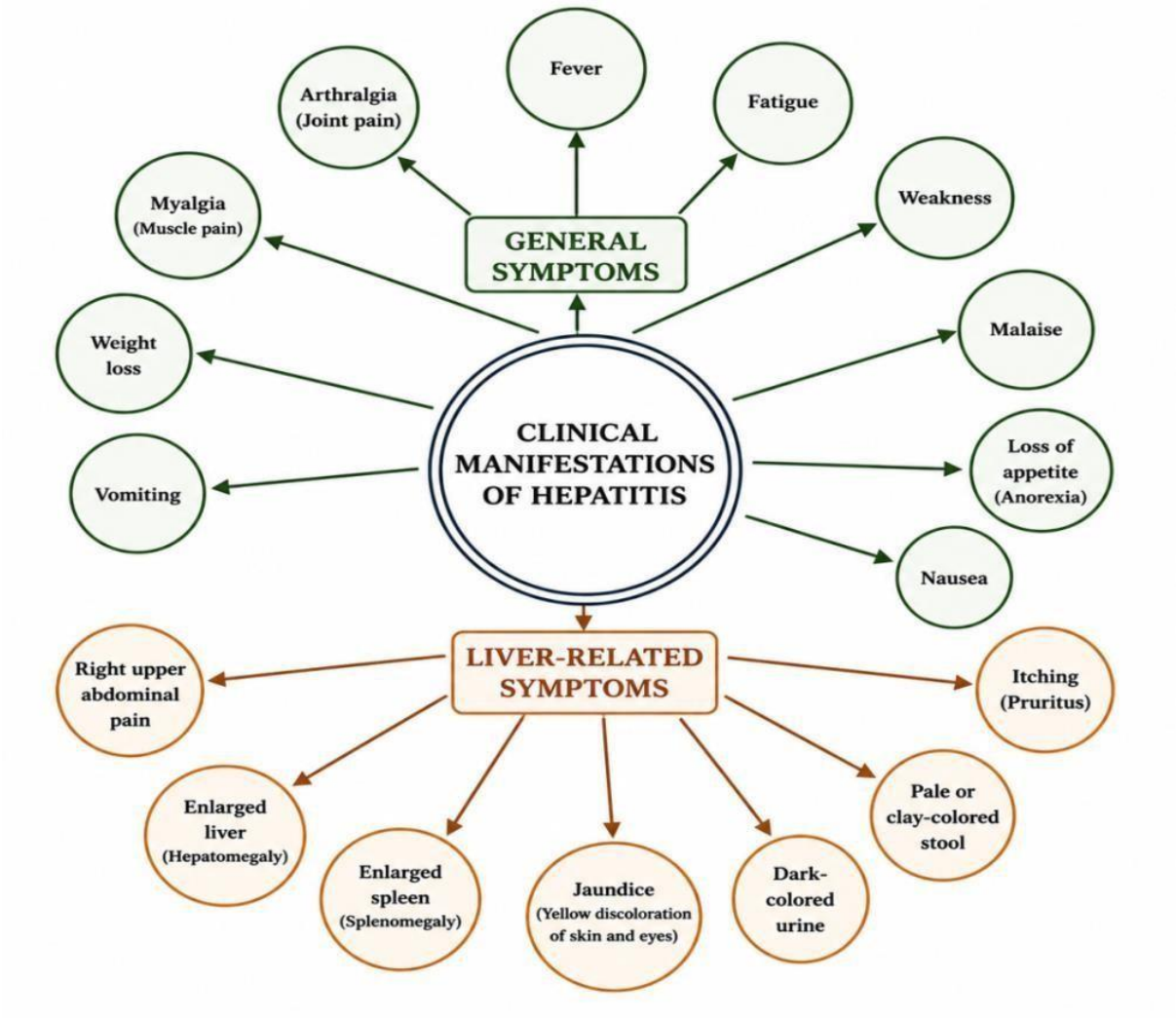


Figure 3

Table: 2 Clinical Manifestations According to Hepatitis Type

Hepatitis A (HAV)	**Hepatitis B (HBV)**	**Hepatitis C (HCV)**	**Hepatitis D (HDV)**	**Hepatitis E (HEV)**
1.Sudden onset	Acute HBV:		1.Severe hepatitis	1.Acute hepatitis

	1.Fever	1.Usually asymptomatic initially		
2.Fever	2. Malaise	2.Mild fatigue	2.Rapid liver damage	2.Fever
3.Fatigue	3. Joint pain	3. High risk of liver failure	3. High risk of liver failure	3.Vomiting
4.Loss of appetite	4.Jaundice	2.Cirrhosis after several years		
5.Nausea	5.Elevated liver enzymes	3.Liver cancer		2. Severe disease during pregnancy
6.Vomiting	Chronic HBV: 1.Often asymptomatic			

7..Jaundice				
	2.Progressive liver fibrosis			
8.Complete recovery in most patients	3.Cirrhosis			

Complication

- Liver fibrosis
- Liver cirrhosis
- Portal hypertension
- Ascites
- Hepatic encephalopathy
- Hepatocellular carcinoma
- Liver failure • Death

Diagnosis

Early detection is very important in stopping the disease from getting worse and reducing how it spreads.

Diagnosis is based on a combination of clinical assessments, biochemical tests, blood tests, advanced techniques, and imaging scans.

Recent Advances in Diagnosis

Table 3: Clinical Examination

Clinical Assessment	**Parameters Evaluated**
Medical History	Previous liver disease, medications, comorbidities
Travel History	Travel to hepatitis-endemic areas
Blood Transfusion History	Previous blood transfusion or organ transplantation
Drug Abuse	Intravenous drug use or needle sharing
Alcohol Consumption	Quantity and duration of alcohol intake
Vaccination History	Hepatitis A and B vaccination status
Family History	History of hepatitis or liver disease in family
Physical Examination	Jaundice, hepatomegaly, splenomegaly, ascites, peripheral edema

Table 4: Diagnostic Methods

Investigation	**Purpose**
Liver Function Test	Assess liver injury
CBC	General health evaluation
ELISA	Detect viral antibodies
PCR	Detect viral DNA/RNA
Ultrasound	Liver structure
Fibro Scan	Fibrosis assessment
CT Scan	Detect tumours
MRI	Advanced liver evaluation
Liver Biopsy	Histopathology

Recent Advances in Diagnosis

1.Real-time PCR

2.Multiplex PCR

3.Digital PCR

4.CRISPR-based diagnostic methods

5.AI-assisted liver imaging

6.Next-Generation Sequencing (NGS)

7.Point-of-Care diagnostic tools

8.Machine learning for fibrosis prediction

9.These new methods help in early detection, choosing the best treatment, and tracking the disease more effectively.

Liver Health in Hepatitis

Keeping the liver healthy is vital for stopping the disease from getting worse and improving life quality for people with hepatitis.

Chronic hepatitis leads to long-term inflammation of the liver, which may develop into fibrosis, cirrhosis, liver failure, and hepatocellular carcinoma (HCC).Early diagnosis, timely antiviral treatment, getting vaccinated against hepatitis B, eating well, staying active, avoiding alcohol and harmful medicines, and regular checks on liver function are key ways to keep the liver healthy. Making lifestyle changes and educating patients are also important for managing liver disease over the long term.

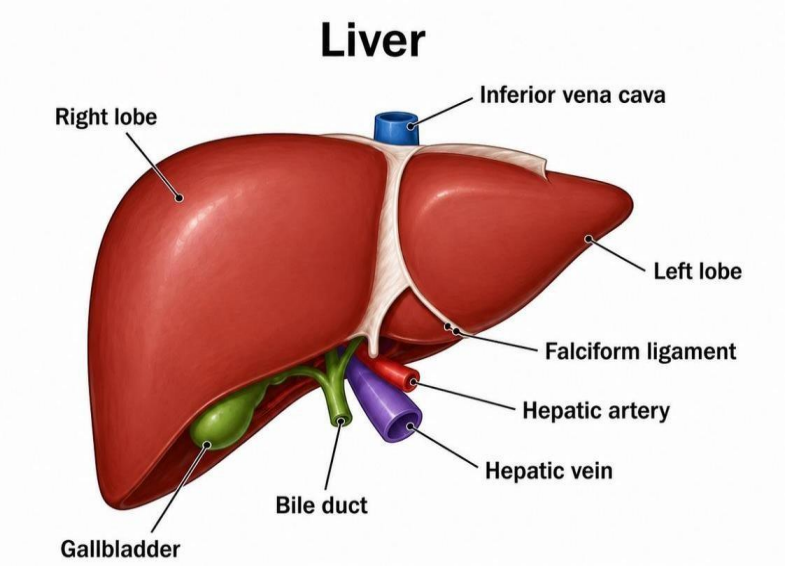


Figure 4

Criteria to Maintain a Healthy Liver

1.Eat a Healthy and Balanced Diet

Eating a healthy diet is one of the best ways to help protect the liver.

Consuming too much sugar, especially from food and drinks with high-fructose corn syrup and refined carbs, can cause fat build-up in the liver, increasing the risk of Metabolic Dysfunction-Associated Steatotic Liver Disease
(MASLD).Choosing healthy fats such as olive oil, avocados, and nuts and highfibre foods like fruits, vegetables, whole grains, and legumes can help reduce liver fat and support normal liver function. Limiting processed foods and sugary drinks is also helpful.

2.Maintain a Healthy Weight and Stay Active

Being overweight raises the risk of fatty liver disease.

Regular physical activity helps the liver function better by improving insulin sensitivity and reducing fat accumulation. Adults should aim for at least 150 minutes of moderate exercise every week, such as walking, cycling, or swimming. Even a small weight loss of 7 to 10% can make a big difference in liver health for people who are overweight.

3.Limit Alcohol and Avoid Harmful Chemicals

The liver processes alcohol, but drinking too much can damage the liver over time and lead to conditions like alcoholic hepatitis, fibrosis, and cirrhosis.

Therefore, alcohol should be limited or avoided. It is also important to reduce exposure to harmful chemicals such as pesticides, paint thinners, and strong cleaning products by using them in well-ventilated areas and wearing protective gear when needed.

4.Use Medicines and Supplements Carefully

Taking too much paracetamol (acetaminophen) can seriously harm the liver and is one of the main causes of acute liver failure. People should be cautious with herbal supplements and “liver detox” products, as some can be harmful. Some supplements, like high-dose green tea extract and kava, have been linked to liver injury in certain individuals.

5.Protect Yourself from Viral Hepatitis

Vaccination is a great way to prevent Hepatitis A and Hepatitis B.

Good hygiene, drinking clean water, avoiding sharing razors, toothbrushes, or needles, and using sterile equipment during medical procedures, tattoos, and piercings can help stop the spread of hepatitis viruses. Practicing safe sex also lowers the risk of getting viral hepatitis.

6.Have Regular Health Check-ups

Regular health check-ups can help find liver problems before symptoms show up.

Liver Function Tests (LFTs), such as ALT and AST levels, are commonly used to evaluate liver health. People with risk factors like obesity, diabetes, high cholesterol, viral hepatitis, or regular alcohol use should have their liver checked regularly. Early detection allows for timely treatment and helps prevent serious complications.

Vaccination

Vaccination is the most effective way to prevent viral hepatitis, especially Hepatitis A and Hepatitis B.

Widespread immunization programs have greatly reduced the number of cases of acute and chronic hepatitis, liver cirrhosis, and hepatocellular carcinoma. The WHO continues to recommend expanding vaccination coverage as a key part of its strategy to eliminate hepatitis.

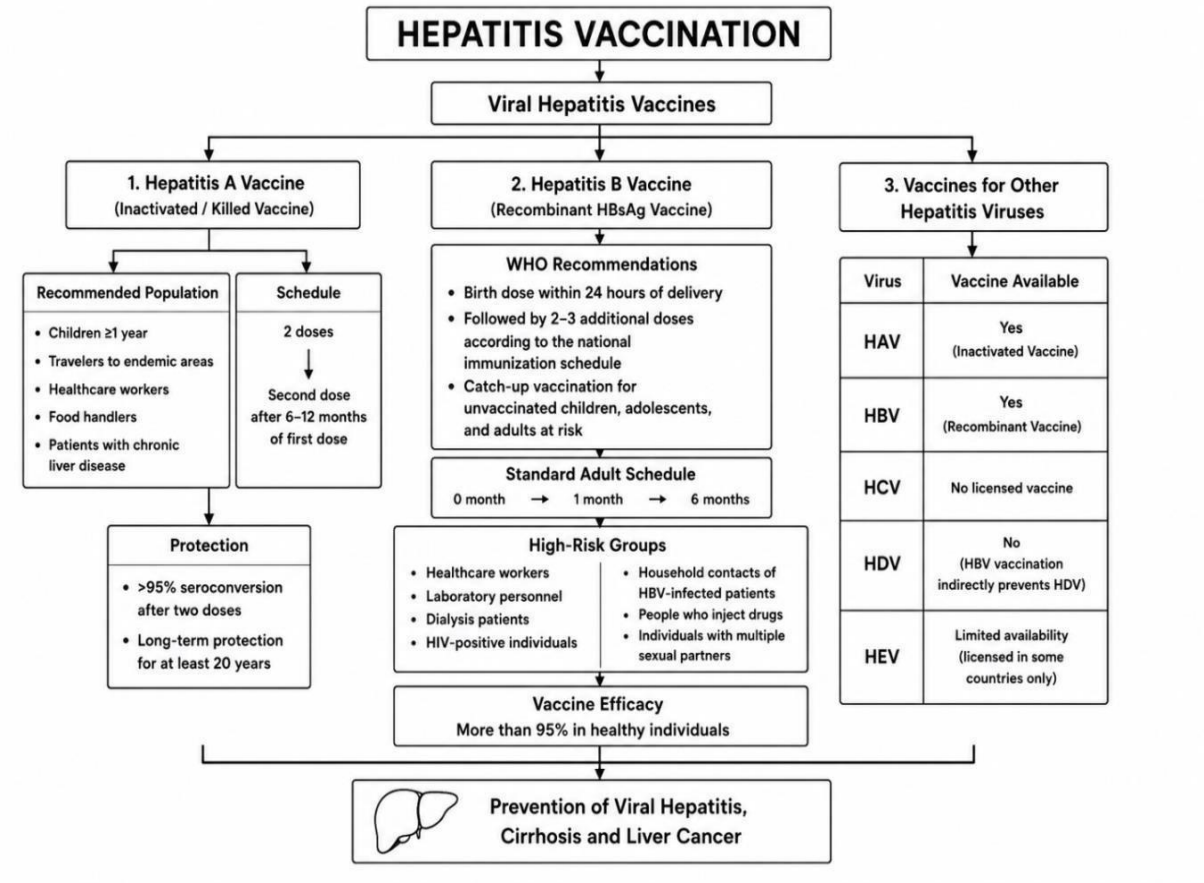


Table 5: Latest Treatment of Hepatitis (2023–2026)

Hepatitis Type	**Recommended Treatment (2023–2026)**	**First-Line Drugs / Regimen**	**Recent Advances (2023–2026)**

Hepatitis A	Supportive care	Bed rest, adequate hydration, nutritional support, avoidance of alcohol and hepatotoxic drug	No specific antiviral therapy available
Chronic Hepatitis B (HBV)	Long-term antiviral therapy	Tenofovir Disoproxil Fumarate , Tenofovir Alafenamide, Entecavir	Functional cure research, siRNA therapies, antisense oligonucleotides, therapeutic vaccines, immune modulators, capsid assembly modulators, biomarker-guided therapy, combination antiviral regimens
Hepatitis C	Direct-Acting Antiviral therapy	Sofosbuvir + Velpatasvir**,** Glecaprevir + Pibrentasvir	Highly effective pangenotypic regimens with simplified treatment protocols
Hepatitis D	Antiviral therapy with HBV treatment	Pegylated Interferon-α + HBV antiviral therapy	New antiviral agents are under evaluation in clinical trials

Hepatitis E	Supportive care	Oral/IV fluids, electrolyte correction, nutritional support; Ribavirin in selected chronic cases	Improved management of chronic HEV in immunocompromised patients

Table 1.6 General Treatment Principles for Hepatitis

Treatment Goal	**Purpose**
Eliminate or suppress viral replication	Reduce viral load and prevent disease progression
Prevent liver fibrosis and cirrhosis	Protect liver structure and function
Reduce hepatocellular carcinoma (HCC) risk	Lower the risk of liver cancer
Improve survival and quality of life	Enhance long-term patient outcomes
Prevent transmission	Reduce spread of hepatitis viruses
Early diagnosis and treatment	Improve treatment success through timely intervention
Simplified treatment pathways	Increase accessibility and treatment adherence
Broader access to antiviral therapy	Ensure effective treatment for more patients

Future Treatment Directions (2023–2026) Drug Development in Hepatitis Drug development is essential for reducing the global impact of viral hepatitis.

Ongoing research has led to the discovery of highly effective antiviral drugs for hepatitis B and C. Modern drug development focuses on finding new antiviral targets, improving drug effectiveness, minimizing side effects, and preventing drug resistance. Recent advances include direct-acting antivirals (DAAs) for HCV, long-acting antiviral drugs, RNA-based therapies, therapeutic vaccines, gene-editing technologies like CRISPR/Cas9, and nanotechnology for drug delivery. Artificial intelligence is also being used to speed up drug discovery by identifying potential drug candidates and predicting their behaviour

Table 7

Emerging Therapy	Purpose / Potential Benefit
Small interfering RNA (siRNA) therapies	Suppress HBV gene expression and viral replication
Antisense oligonucleotides	Inhibit viral RNA and protein synthesis
Therapeutic HBV vaccines	Stimulate immune response to achieve functional cure
Immune modulators	Enhance host immune control of HBV infection
Capsid assembly modulators	Prevent proper formation of HBV viral particles
Gene-editing approaches	Target and eliminate viral DNA from Infected cells
CRISPR-based antiviral strategies	Precisely disrupt HBV genome

Biomarker-guided personalized medicine	Individualize treatment based on patientspecific biomarkers

Clinical Studies in Hepatitis

Clinical studies are conducted to assess the safety, effectiveness, and long-term outcomes of new drugs, vaccines, diagnostic meods, and treatment approaches for viral hepatitis.

These studies provide scientific proof that supports clinical practice and the approval of new therapies by regulatory bodies. Currently, research is focused on developing a functional cure for chronic hepatitis B, improving antiviral treatments, creating therapeutic vaccines, using AI for diagnosis, applying nanotechnology for drug delivery, and offering personalized treatment strategies. Well-designed clinical trials are essential for improving patient outcomes and achieving the (WHO) goal of eliminating viral hepatitis as a public health threat by 2030.

Herbal Therapy in Hepatitis

Introduction

Herbal medicines have been used for centuries to support liver health and manage liver conditions.

Many medicinal plants contain compounds like polyphenols, flavonoids, terpenoids, alkaloids, saponins, and antioxidants that have liver-protecting, antiviral, anti-inflammatory, and immune-modulating properties. These herbs are considered complementary therapies and are being studied as potential additions to standard antiviral treatment. Current research suggests they may help improve liver function and decrease oxidative stress, but they should not replace WHO-recommended antiviral treatment for chronic hepatitis.

1.Milk Thistle (Silybum marianum)

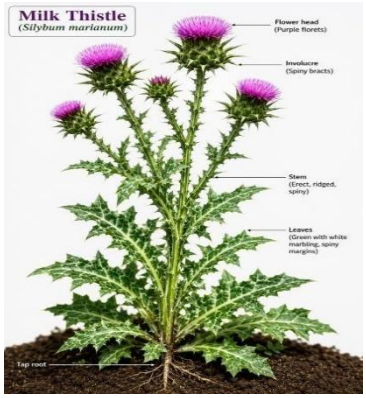


Figure 5

Active constituent: Silymarin

Pharmacological Effects:

Antioxidant

Liver-protective Anti-inflammatory

Membrane stabilizer

Protects liver cells from toxin damage

Reduces oxidative stress

Supports liver regeneration

2.Turmeric (Curcuma longa)



Figure 6

Active constituent: Curcumin Mechanism of Action:

Inhibits inflammatory cytokines

Reduces oxidative damage

Protects liver tissue

3.Licorice (Glycyrrhiza glabra)



Figure 7

Active constituent: Glycyrrhizin

Therapeutic Effects:

Antiviral properties

Anti-inflammatory action

Liver-protective effects

4.Phyllanthus amarus



Figure 8

Reported Biological Activities:

Anti-HBV activity Immune-modulating effects

Antioxidant properties

5.Green Tea (Camellia sinensis)



Figure 9

Contains catechins (especially EGCG), which may:

Reduce oxidative stress

Improve liver function

Decrease inflammation

Table 8: Herbal Medicines Used in Hepatitis

Herb	**Active Compound**	**Major Action**
Milk Thistle	Silymarin	Hepatoprotective
Turmeric	Curcumin	Anti-inflammatory
Licorice	Glycyrrhizin	Antiviral
Phyllanthus amarus	Lignans	Anti-HBV (investigational)
Green Tea	EGCG	Antioxidant

Nanotechnology in Hepatitis

Introduction

Nanotechnology is becoming an advanced approach to improve hepatitis diagnosis, drug delivery, vaccine development, and gene therapy.

Nanocarriers can increase drug stability, deliver medicines more effectively to the liver, lower systemic toxicity, and enhance therapeutic effectiveness. Research is also exploring nanoparticle-based delivery of siRNA and CRISPR systems for chronic hepatitis B.

Types of Nanocarriers

1.Lipid nanoparticles (LNPs) – for mRNA vaccines and siRNA delivery

2.Polymeric nanoparticles – for controlled drug delivery

3.Solid lipid nanoparticles – for sustained drug release

4.Liposomes – for drug and vaccine delivery

5.Metallic nanoparticles – for drug and vaccine delivery

6.Dendrimers – for gene and drug delivery

Advantages

1.Targeted delivery to the liver

2.Reduced toxicity

3.Sustained drug release

4.Better patient compliance

5.Potential for combination treatment

Limitations

1.High manufacturing cost

2.Challenges in scaling up production

3.Need for long-term safety evaluation

4.Regulatory issues

Artificial Intelligence (AI) in Hepatitis

Introduction

Artificial Intelligence (AI) is transforming healthcare, providing innovative solutions for the prevention, diagnosis, treatment, and management of viral hepatitis.

AI uses machine learning (ML), deep learning (DL), and advanced data analysis to process large volumes of clinical, lab, and imaging data.These technologies help clinicians improve diagnostic accuracy, predict disease progression, optimize treatment plans, and enhance public health monitoring.AI is increasingly recognized as a key tool for achieving the WHO's goal of eliminating viral hepatitis by 2030.

Applications of AI in Hepatitis

1.Early Diagnosis

AI algorithms analyse lab results, medical records, and imaging data to detect hepatitis early.

Machine learning models can find subtle abnormalities that conventional methods may miss, enabling early intervention and preventing complications. **2.Disease Progression Prediction**

AI-based models evaluate the risk of liver fibrosis, cirrhosis, liver failure, and hepatocellular carcinoma (HCC).

By combining patient demographics, viral load, liver function tests, and imaging data, AI helps clinicians identify high-risk patients and develop personalized follow-up plans.

3.Medical Imaging Analysis

Deep learning improves the interpretation of ultrasound, CT scans, and MRI by detecting liver fibrosis, cirrhosis, and tumours accurately.

AI-assisted imaging reduces diagnostic inconsistency and helps detect liver issues early.

4.Drug Discovery and Development

Artificial intelligence speeds up the process of finding new antiviral drugs by discovering new targets for treatment, predicting how drugs will interact with these targets, and improving potential drug candidates.

It also helps in developing new vaccines and tailored treatment methods, which lowers the time and cost involved in research and development.

5.Clinical Decision Support

Systems powered by AI help medical professionals choose the right antiviral treatments, predict how patients will respond to therapy, track any harmful side effects of medications, and manage patient care based on their personal health information.

6.Public Health Surveillance

AI allows for real-time tracking of hepatitis outbreaks by analyzing data from epidemiological studies, electronic health records, and population-based monitoring systems.

These tools help in forecasting disease spread, distributing resources effectively, and planning public health responses.

Advantages of AI in Hepatitis

1.Early and accurate diagnosis

2.Prediction of how the disease will progress

3.Better interpretation of medical images

4.Faster development of drugs and vaccines

5.Customized treatment plans

6.Ongoing monitoring of patients

7.Improved public health surveillance

8.Lower healthcare costs and better patient outcomes

9.Challenges and Limitations

Although AI has significant potential, there are several obstacles to its use in hepatitis care. These include a lack of high-quality data, concerns about patient privacy and data security, biased algorithms, the absence of standard validation processes, regulatory hurdles, and limited access in under-resourced healthcare environments.

Innovative Public Health Awareness and Elimination Strategies

To speed up the elimination of viral hepatitis, it is important to combine new, technology-based, and community-focused public health methods with the current healthcare system.

These strategies can help raise awareness, detect the disease early, make treatment more available, ensure patients follow their medication, and improve overall control of the disease, especially among those in rural or underserved areas.

Proposed Strategies

1.QR Code-Based Health Education

QR codes can be placed in hospitals, primary health centers, colleges, pharmacies, and community health camps.

When people scan these codes, they can get information about hepatitis symptoms, prevention methods, vaccination schedules, nearby screening centres, and treatment facilities. **2.Online Health Counselling**

Using telemedicine and online counselling services, patients can connect with specialists like hepatologists, physicians, pharmacists, and trained healthcare workers. This method is especially helpful for people living in rural and hard-toreach areas.

3.Medication Home Delivery

Government and health organizations can provide home delivery of medicines for elderly people, disabled individuals, and those living in remote villages.This helps improve patient adherence to treatment.

4.Digital Health Information Portal

A multilingual digital platform can offer information on hepatitis, vaccination, treatment guidelines, hospital locations, and frequently asked questions.

5.College Awareness Programs

Working with pharmacy, medical, nursing, and allied health colleges can help spread awareness about hepatitis. Activities like seminars, poster competitions, screening camps, and vaccination drives can be organized.

6.Hospital Collaboration

Government hospitals, private hospitals, and diagnostic labs can work together to offer integrated services for hepatitis screening, diagnosis, counselling, and treatment.

7.Community Health Volunteers

Trained community health workers, such as ASHA workers, Anganwadi workers, and volunteers, can conduct door-to-door awareness campaigns. These efforts focus on educating uneducated and underserved communities through simple educational materials in local languages.

8.Local Language Education

Educational materials like pamphlets, posters, and videos should be made available in regional languages. This helps improve understanding among the public and encourages early healthcare seeking.

9.Affordable and Accessible Healthcare

Governments should ensure that vaccinations are low-cost, screening programs are free, antiviral medicines are affordable, and healthcare facilities are easily accessible.

10.Public–Private Partnerships

Collaboration between government agencies, NGOs, hospitals, academic institutions, and pharmaceutical companies can help make hepatitis elimination programs more effective.

World Health Organization Programs

- Global Health Sector Strategies (GHSS) 2022–2030
- World Hepatitis Day (28 July) awareness campaign
- Universal hepatitis B vaccination
- Prevention of mother-to-child transmission (PMTCT)
- Universal access to hepatitis testing and treatment
- Strengthening blood safety and infection control
- Monitoring and surveillance of hepatitis cases
- These initiatives aim to reduce illness and death caused by hepatitis through coordinated public health actions.

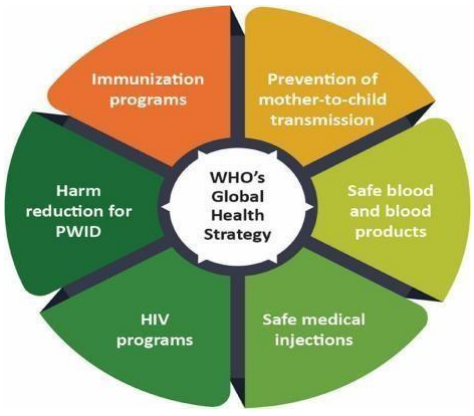


Figure 10

Table.10: WHO 2030 Targets

Target	Goal by 2030

Reduction in new hepatitis infections	90%
Reduction in hepatitis-related mortality	65%
Hepatitis B birth-dose vaccination	≥90% coverage
Three-dose HBV vaccination	≥90% coverage
Blood donation screening	100%
Safe injections	90%
Diagnosis of HBV/HCV	90% of infected people
Treatment of eligible HBV/HCV patients	80%
Prevention of mother-to-child HBV transmission	Universal implementation

Future Prospects

Future developments in the prevention, diagnosis, and treatment of hepatitis are expected to greatly decrease the disease's impact around the world. The creation of new antiviral treatments, therapeutic vaccines, gene-editing tools like CRISPR/Cas9, and RNA-based medicines offers hope for a functional cure of chronic hepatitis B virus (HBV) infection. Additionally, ongoing improvements in direct-acting antiviral (DAA) treatments are likely to result in better outcomes for people living with hepatitis C virus (HCV) infection. The use of artificial intelligence (AI) in hepatitis care is expected to change how the disease is managed.AI can help with early diagnosis, predict how the disease may progress, assist in interpreting medical images, and speed up the discovery of new drugs.AI tools can also support tailored treatment plans, leading to better health results for patients.

Nanotechnology is expected to become more important in delivering medications precisely, developing vaccines, and creating treatments that target the liver specifically. Nanocarriers may increase how well drugs work in the body, lower harmful effects on other parts of the body, and make antiviral treatments more effective.

The use of omics technologies—such as genomics, proteomics, transcriptomics, and metabolomics—could provide a deeper understanding of how the virus causes disease and how the body's immune system responds. This knowledge can help create more personalized treatment options.

From a public health angle, improving universal hepatitis B vaccination, expanding screening and testing programs, making antiviral treatments more affordable, and increasing awareness are essential for achieving the WHO goal of eliminating viral hepatitis as a major health issue by 2030.

Although significant progress has been made, continued teamwork among scientists, healthcare professionals, governments, public health groups, and the pharmaceutical industry will be needed to address ongoing issues such as limited access to healthcare, late diagnosis, drug resistance, and health inequalities.

Maintaining support for research, innovation, and global health efforts is vital for reducing the illness and death caused by hepatitis worldwide.

Key Future Directions

- Development of a functional cure for chronic HBV infection
- Discovery of an effective vaccine to prevent HCV
- Expansion of AI-supported diagnosis and personalized medicine
- Wider use of nanotechnology in drug delivery systems
- Translation of gene-editing and RNA-based treatments into clinical use
- Identification of new biomarkers for early diagnosis
- Improved global vaccination and screening coverage
- Meeting the WHO 2030 hepatitis elimination goals
- Strengthening international research partnerships
- Ensuring fair access to diagnosis and treatment in low- and middle-income countries

Conclusion

Viral hepatitis remains a major global health challenge, causing significant liver disease and mortality. Despite advances in vaccination, diagnosis, and antiviral treatment, challenges such as delayed diagnosis, limited awareness, and unequal healthcare access persist. Emerging technologies, including artificial intelligence and nanotechnology, along with strong public health efforts, offer promising solutions. Continued research and global collaboration are essential to achieve the World Health Organization's goal of eliminating viral hepatitis as a public health threat by 2030.

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