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A Comprehensive Review on Cardiovascular Diseases: Pathophysiology, Diagnostics, Therapeutic Advances, and Emerging Herbal Strategies

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Abstract: *Cardiovascular diseases (CVDs) remain the leading contributors to global mortality, affecting millions annually. These conditions involve structural and functional abnormalities of the heart and blood vessels, arising through mechanisms such as atherosclerosis, thrombosis, electrical conduction disturbances, and congenital malformations. Modern clinical care integrates cardiac biomarkers, advanced imaging modalities, pharmacological therapy, surgical interventions, and complementary herbal strategies. This review synthesizes current knowledge on major cardiovascular disorders, diagnostic biomarkers, imaging technologies, pharmacotherapy, and the emerging role of plant-based cardioprotective compounds. The goal is to provide a holistic understanding of CVD management, emphasizing the relevance of multimodal diagnostic tools and integrative therapeutic approaches.*

Keywords: *Cardiovascular diseases*

I. INTRODUCTION

CVDs encompass a wide spectrum of disorders including coronary artery disease, peripheral vascular disease, heart failure, arrhythmias, congenital heart anomalies, and cerebrovascular disease. These conditions impose substantial physical, emotional, and socioeconomic burdens worldwide, particularly in low- and middle-income countries (LMICs) where access to healthcare is often limited[1,2].

Lifestyle-associated risk factors—sedentary behavior, high-fat diets, smoking, alcohol consumption, obesity, hypertension, and diabetes—significantly increase the global CVD burden. Preventive strategies such as regular exercise, stress control, nutritional modification, and risk-factor monitoring are central to reducing disease prevalence. Still, the rising incidence of CVD and its complications underscores the need for improved diagnostics and more effective, personalized management options[2].

Rheumatic Heart Disease represents one of the most persistent cardiovascular complications in the developing world. It commonly affects school-aged children and adolescents following untreated or poorly managed streptococcal pharyngitis infection. Despite improvements in healthcare, RHD remains a leading cause of acquired heart disease among young populations in Asia, Africa, and the Pacific region.

The disease often progresses slowly over years and becomes symptomatic only when irreversible valvular damage has occurred, making early detection and prevention critical. The World Health Organization (WHO) has continuously emphasized RHD control through antibiotic prophylaxis, improved sanitation, and large-scale screening measures[3].

Major Categories of Cardiovascular Diseases

Coronary Artery Disease (CAD)[3,4,16,17,19].
Peripheral Arterial Disease (PAD)[5].
Venous Thromboembolism: DVT and PE[6].
Cardiomyopathies[7,8].

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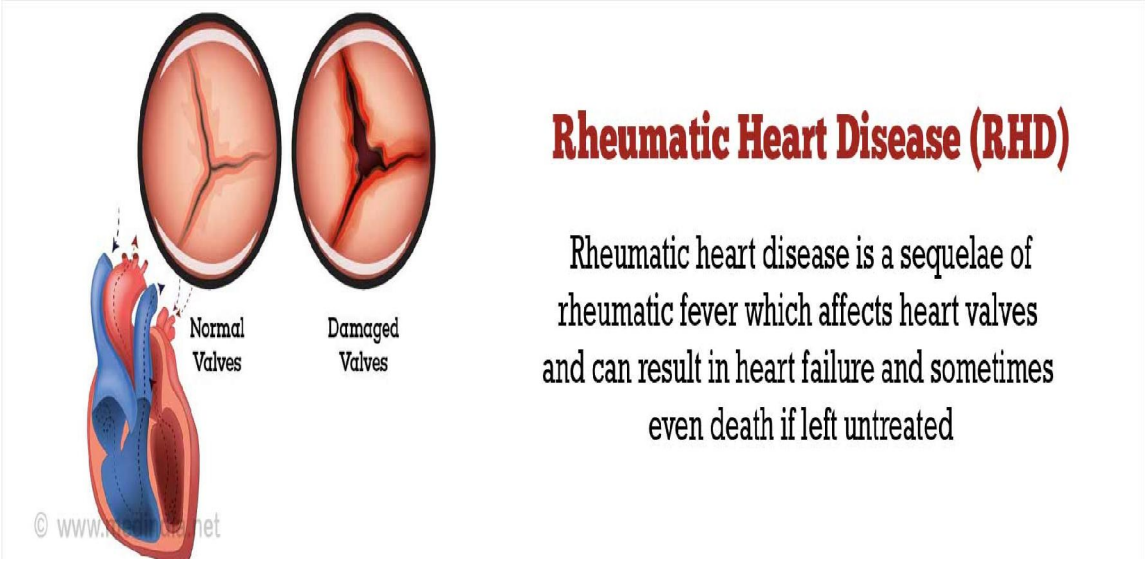
Cerebrovascular Diseases[9].
Rheumatic Heart Disease (RHD)
Congenital Heart Defects (CHDs)[11].
Myocardial Infarction (MI)[4,12].
Cardiac Arrhythmias

Rheumatic Heart Disease (RHD)



Epidemiology

RHD affects more than 40 million people globally, contributing to over 300,000 deaths annually. The burden is disproportionately high in regions with limited healthcare access, overcrowding, and poor socio-economic conditions. Sub-Saharan Africa, South-East Asia, and some parts of Latin America report the highest incidence. Developed nations have witnessed a marked decline due to better antibiotics, early medical intervention, and improved living standards[10]. Children between 5–15 years are most vulnerable to acute rheumatic fever, while chronic RHD manifests later as progressive valvular stenosis or regurgitation. Mitral valve involvement is most common, followed by the aortic valve[1,2].

Etiology and Risk Factors

RHD arises as a sequel to acute rheumatic fever, triggered by Group A Streptococcus (GAS) throat infection. Autoimmune cross-reactivity leads to inflammatory damage to cardiac tissues.

Key Risk Factors:[13,14].
Recurrent streptococcal throat infection
Overcrowded living conditions
Poor hygiene and sanitation
Limited access to healthcare
Genetic predisposition
Malnutrition and low socio-economic status

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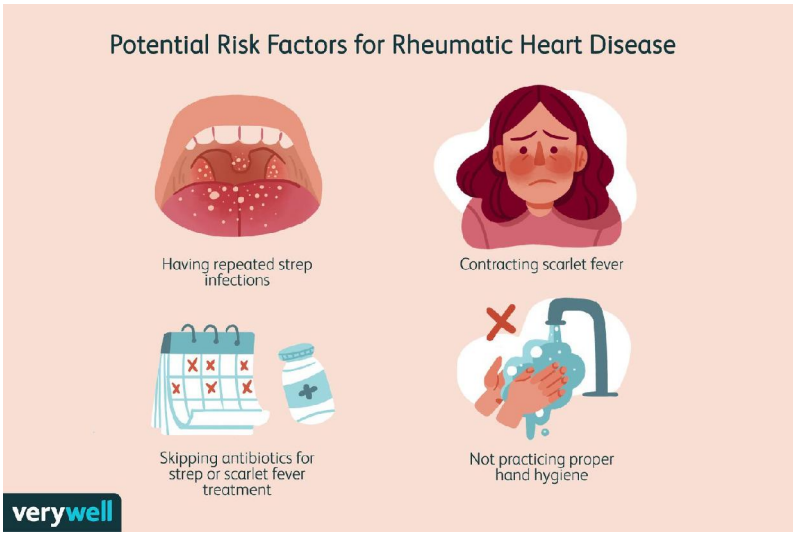

Pathophysiology of Rheumatic Heart Disease (RHD)

Rheumatic heart disease develops as a delayed immune-mediated consequence of infection with Group A β-hemolytic Streptococcus (GAS) affecting genetically susceptible individuals. The disease evolves from acute rheumatic fever (ARF) into chronic, progressive valve damage[15,16,17,19].

1. Initiating Event — Streptococcal Pharyngitis

RHD begins after an episode of untreated or partially treated streptococcal throat infection.

During this infection, the bacterial M protein acts as the major antigen that triggers an abnormal immune response.

2. Molecular Mimicry

The structure of streptococcal antigens resembles proteins present in human tissues.

Because of this similarity, the immune system generates:

- Antibodies

T-cells that mistakenly react with host tissues, especially:

- Cardiac valves
- Myocardium
- Synovium
- Skin
- Central nervous system

This phenomenon is known as molecular mimicry.

3. Autoimmune Inflammation in the Heart (Pancarditis)

During acute rheumatic fever, the immune attack leads to inflammation of all three cardiac layers:

A. Endocardium (Valves)

Inflammatory cells infiltrate valve leaflets

Edema and small vegetations (verrucae) form along the lines of closure

With repeated inflammation, valves undergo fibrosis, thickening, and calcification

This is the foundation for long-term RHD

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B. Myocardium

Formation of Aschoff bodies (foci of macrophages, lymphocytes, and fibrinoid necrosis)

Myocardial swelling leads to reduced contractility in severe cases

C. Pericardium

Fibrinous inflammation (bread-and-butter pericarditis) may occur

Less common but contributes to chest pain.

4. Chronic Structural Changes of Valves

Repeated episodes of ARF—or persistent autoimmune activity—cause progressive scarring of valves.

- Mitral Valve (most affected)
- Leaflet thickening
- Commisural fusion
- Chordae tendineae shortening and fusion
- Leads to mitral stenosis or mitral regurgitation
- Aortic Valve
- Cusp retraction and thickening
- Results in aortic regurgitation and later stenosis

These changes are permanent and produce the characteristic lesions of RHD.

5. Hemodynamic Consequences

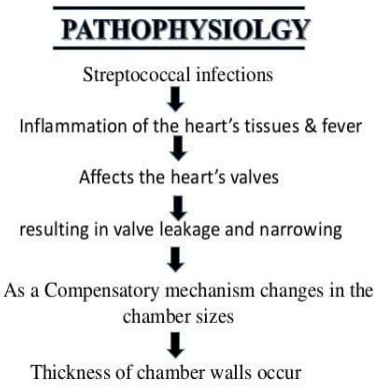
The structural damage causes:

- Pressure overload (mitral/aortic stenosis)
- Volume overload (mitral/aortic regurgitation)
- Atrial dilation → atrial fibrillation
- Pulmonary hypertension
- Right-sided heart failure in advanced stages

6. Progression to Chronic RHD

Over years, persistent hemodynamic stress and recurrent inflammation lead to:

- Valve deformity
- Calcification
- Reduced mobility
- Heart failure symptoms
- Increased risk of thromboembolic events (especially in AF)



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The pathogenesis of RHD is immune-mediated. Molecular mimicry occurs when antibodies produced against streptococcal antigens cross-react with cardiac myosin and valvular endothelium. This triggers inflammatory infiltration, Aschoff body formation, and progressive fibrosis. Chronic inflammation leads to valve thickening, stenosis, and regurgitation—most frequently affecting the mitral valve.

Over time, these changes cause altered hemodynamics, pulmonary hypertension, atrial fibrillation, and eventual heart failure.

Herbal Drugs with Potential Benefits in Rheumatic Heart Disease

Sr.No	Herbal Drug	Botanical Name	Key Active Constituents	Reported Actions Relevant to RHD	Common Dosage Forms
1	Turmeric	Curcuma longa	Curcumin,volatile oils	Anti-inflammatory, antioxidant, reduces cardiac inflammation	Powder, capsules, decoction, extracts
2	Garlic	Allium sativum	Allicin, organosulfur compounds	Cholesterol-lowering, antithrombotic, improves blood circulation	Raw, tablets, oil, extract
3	Ginger	Zingiber officinale	Gingerols, shogaols	Anti-inflammatory, analgesic, reduces oxidative stress	Tea, powder, capsules
4	Ashwagandha	Withania somnifera	Withanolides, alkaloids	Reduces stress on heart, improves cardiac endurance	Powder, tablets, extract
5	Neem	Azadirachta indica	Nimbidin, quercetin	Anti-inflammatory, antibacterial (helpful in throat infections leading to RF)	Leaves, juice, capsules
6	Amla	Emblica officinalis	Vitamin C, tannins, flavonoids	Antioxidant, strengthens immunity	Enhances cardiovascular health Juice, powder, tablets

Diagnosis

Clinical Evaluation:-

Rheumatic Heart Disease (RHD) is a chronic cardiovascular condition that develops following Acute Rheumatic Fever (ARF), leading to progressive and permanent damage to the heart valves, most commonly the mitral valve, followed by the aortic valve. Clinical evaluation aims to diagnose the condition, assess severity, identify complications, and determine the approach to management.

Steps in Clinical Evaluation of RHD

Medical History & Physical Examination

The doctor asks about past history of throat infections, suspected or confirmed episodes of Acute Rheumatic Fever (ARF), recurrent sore throats, fevers, joint pains, etc.

On cardiovascular exam, a stethoscope is used to listen for heart murmurs (due to regurgitation or stenosis), abnormal heart sounds — which may point toward valvular damage.

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Symptoms like breathlessness, palpitations, fatigue, swelling (if heart failure) are noted.

Physical Examination:-

- General Examination
- Pallor (anemia due to chronic disease)
- Cyanosis (if severe hypoxia)
- Peripheral edema in late stage
- Elevated JVP (in right-sided failure)
- Clubbing (rare but in long-standing valvular disease)
- Detailed history of recurrent sore throat
- Physical examination for murmurs or cardiac enlargement

Cardiovascular Examination

Auscultation using a stethoscope is key:[15,16,17,19].

Lesion	Auscultatory Finding
Mitral Stenosis (MS)	Opening snap + mid-diastolic murmur at apex
Mitral Regurgitation (MR)	Pan-systolic murmur at apex radiating to axilla
Aortic Stenosis (AS)	Ejection systolic murmur in aortic area
Aortic Regurgitation (AR)	Early diastolic murmur along left sternal border

Management

- Acute Rheumatic Fever Treatment
- Bed rest and aspirin for inflammation
- Corticosteroids for severe carditis
- Antibiotic therapy (Benzathine Penicillin G recommended)
- Chronic RHD Management
- Long-term secondary prophylaxis with penicillin to prevent recurrence
- Medical management of heart failure using diuretics, beta-blockers, ACE inhibitors
- Anticoagulants in atrial fibrillation
- Surgical options
- Valve repair
- Valve replacement (mechanical/bioprosthetic)
- Percutaneous balloon valvotomy for mitral stenosis

Prevention Strategies

Primary Prevention

Early diagnosis and complete treatment of streptococcal pharyngitis

Public awareness and school-based screening

Secondary Prevention

Continuous penicillin prophylaxis to prevent recurrent ARF attacks

Tertiary Prevention

Regular monitoring, echocardiography, timely surgery to prevent complications

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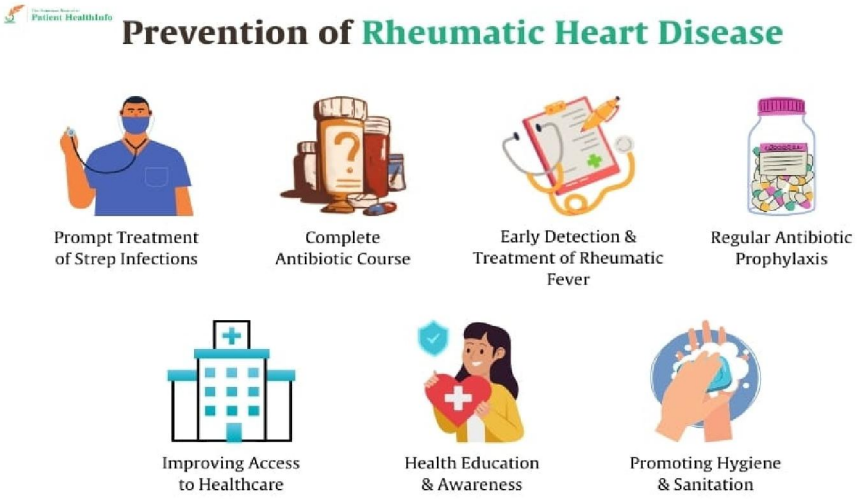
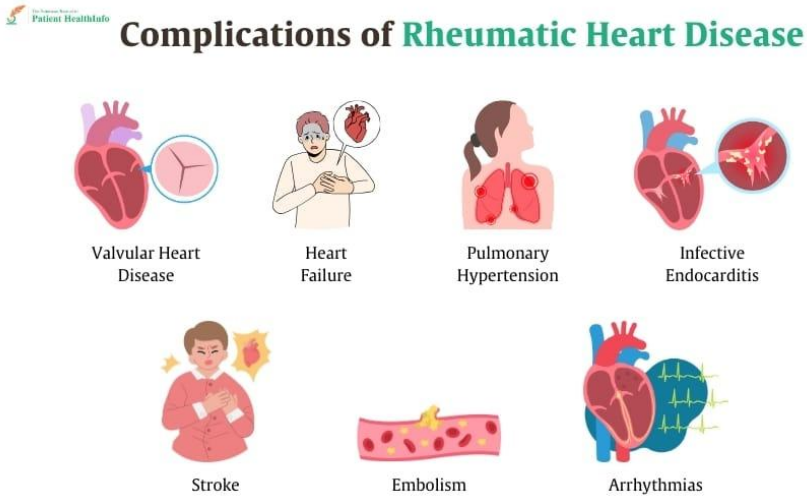


Complications



Chronic heart failure
Infective endocarditis
Pulmonary hypertension
Atrial fibrillation and thromboembolism
Stroke in severe cases

Current Research and Future Perspectives

Recent advances include vaccine development targeting GAS antigens, improved echocardiographic screening programs, and novel anti-inflammatory therapies. Digital health tools and AI-based early detection systems may play a critical role in future RHD control programs. Research on gene–environment interaction and molecular biomarkers is ongoing to better understand susceptibility and progression.

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Public health strategies integrating community awareness, routine prophylaxis, and access to pediatric cardiology services hold promise for reducing global RHD burden.

Advanced Imaging Techniques

Modern cardiovascular imaging significantly improves diagnostic precision:[15,16]

Imaging Modality	Key Role
ECG	Detects arrhythmias and ischemic patterns
Chest X-Ray	Structural and functional assessment
Echocardiography	Structural and functional assessment
CT Angiography	High-resolution coronary visualization
SPECT/PET	Myocardial perfusion and viability
Cardiac MRI	Gold standard for tissue characterization, fibrosis, cardiomyopathy assessment

Therapeutic Approaches[17,18].

Pharmacological Treatments

Common drug classes include:

Statins: lipid-lowering agents

ACE inhibitors & ARBs: reduce afterload and ventricular remodeling

Beta Blockers: hypertension, arrhythmias, heart failure management

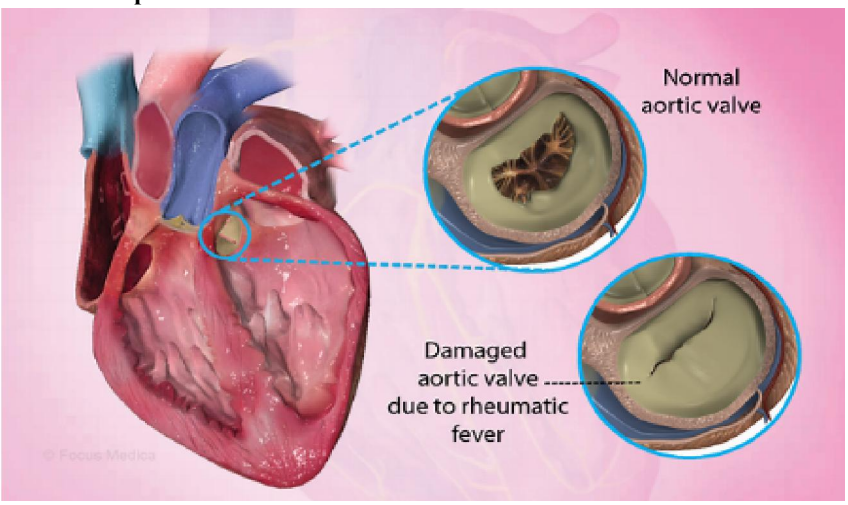
Calcium Channel Blockers: vasodilation, arrhythmia control

Anticoagulants & Antiplatelets: thrombosis prevention

Antiarrhythmics: rhythm control

Side effects—hepatic dysfunction, renal impairment, hypotension, and bleeding—necessitate careful monitoring.

Surgical and Interventional Options[19,20].



Percutaneous Coronary Intervention (PCI)

Coronary Artery Bypass Grafting (CABG)

Valve Repair/Replacement

Ventricular Assist Devices (VADs)

Ablation and Device Implantation

These strategies are essential for advanced or refractory disease[19,20].

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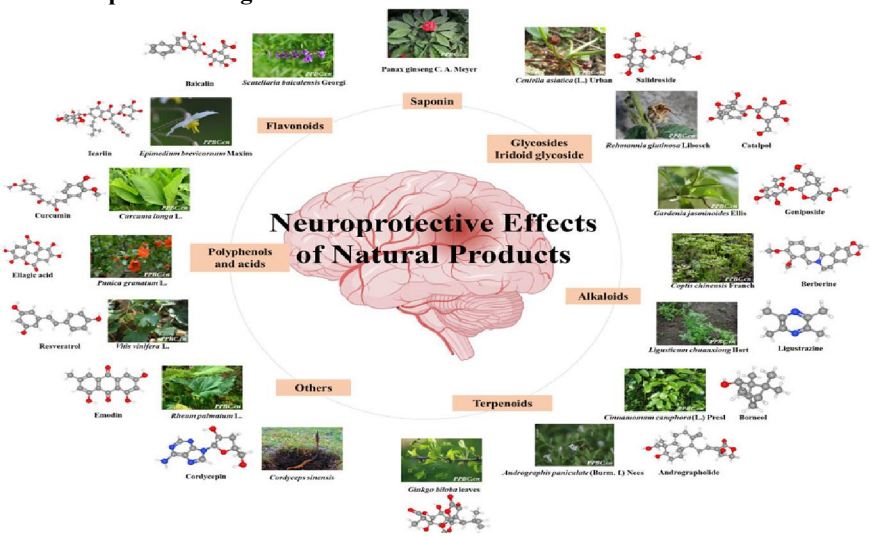
Herbal and Natural Cardioprotective Agents



Growing evidence supports the therapeutic potential of bioactive phytochemicalsKey groups include:[21,22,23,24]

Flavonoids

Antioxidant and anti-inflammatory effects; found in green tea, berries, citrus.

Phenolic Acids

Reduce oxidative stress and inhibit LDL oxidation.

Saponins

Improve lipid profiles and exhibit antihypertensive effects.

Alkaloids

Some exhibit vasodilatory and antiarrhythmic actions.

Herbal formulations may offer complementary benefits when combined with standard therapies; however, dosage standardization and safety validation remain essential.

II. CONCLUSION

Rheumatic Heart Disease remains a preventable yet highly prevalent cardiovascular disorder, especially in resource-limited settings. Early treatment of streptococcal infections, appropriate prophylaxis, and timely medical or surgical management are essential to improving patient outcomes. Strengthening healthcare infrastructure, conducting large-scale screening, and enhancing research into vaccines and diagnostic tools can significantly reduce the global impact of RHD. Collaborative efforts between healthcare systems, governments, and educational institutions are fundamental to achieving long-term control and eventual eradication of this disease.

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