Review Article

Therapeutic Potential of Fabaceae-Derived Phytochemicals in Preventing Arterial Thrombosis: A Comprehensive Review

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Abstract

Arterial thrombosis (ATh) has been conventionally observed in distinct circumstances, with alterations in risk factors, pathology and treatment since 17.5 million people got affected by cardiovascular diseases (CVDs) in 2012, with 31% of universal deaths annually. Blood coagulation is a vigorous functional process in the human body that is exaggerated by internal and external factors. Similarly, numerous inherited and acquired defects in the coagulation process are also the causative agent for several health-related problems in humans. Currently, many drugs have been approved and used for the treatment of arterial thrombosis but, those drugs are made of chemicals and result in serious health effects. As a result of problems associated with synthetic drugs, many researchers are focussing on alternative medication and looking for substitute treatments. Plants-based experimental studies have shown their significant role in the alternative treatment of thrombosis. Conversely, traditional medicinal plants-derived novel cardiovascular drugs can be used to prevent blood coagulation and treat ATh through various mechanisms. Recently, a wide range of medicinal plants from the family of Fabaceae were used enormously as antithrombotic agents due to their powerful antithrombotic activity. The current review focuses on ATh and its risk factors, diet and prevention methods using medicinal plants from the family Fabaceae and discovering their latent use in the progress of novel multifunctional medications against thrombosis.

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1. Introduction

Coagulation is the formation of blood clots inside the blood vessels, mainly arterial and intravenous circulatory structures. It plays a vital role in diverse medical circumstance, comprising myocardial infraction, stroke, pulmonary embolism (PE), and limb ischemia **(Miceli *et al.* 2022)**. Thrombus is one of the major causes of cardiovascular disorders that was first examined and postulated over 150 years ago by a German pathologist Rudolf Virchow. In accordance with World Health Organization (WHO), a predictable 17.5 million individuals were affected by cardiovascular diseases (CVDs) in 2012, with 31% of all global deaths and there will be about 23.3 million deaths due to CVD in 2030 **(Leicester 2021)**. In India, nearly a quarter (24.8%) of death occurs annually, as per current publications with 3 huge potential lessons as of India recommend an advanced percentage of death attributable to CVD (30%–42%) and an age-consistent CVD mortality rate (255–525 per 100 000 populaces in males and 225–299 per 100 000 people in females) was increased by 59% from 1990 to 2015 **(Loitongbam and Surin 2024)**. ATh is the fundamental reason of heart attacks and strokes, which are the foremost basis of sickness and death worldwide **(Frak *et al.* 2022)**. ATh generally occurs at the break of an atherosclerotic plaque over platelet-facilitated thrombi, which lead to ischaemic damages, particularly in the terminal vascular bed **(Mlynarska *et al.* 2024)**. Further, platelets gather at the spot of vascular damage and are engaged in various physiological and pathophysiological methods, comprising haemostasis and thrombosis **(Scridon 2022)**. During blood clotting and haemostasis platelet adhesion process, two major events (activation and aggregation) take place to activate platelets through endogenous aspects **(Li *et al.* 2010)**. Hence, platelet-abundant thrombus is consequently moulded in the lumen of the damaged vessel and causes blood clotting **(Periayah *et al.* 2017)**. Consequently, both aggregation and accumulation of platelets at these sites perform an important role in causing thrombotic disorders leading to death **(Badulescu *et al.* 2025)**. Thrombosis is a regulated coagulation of blood that interrupts the arterial or venous flow, which is prompted by variations in the vascular barrier, blood content, and bloodstream **(Litvinov and Weisel 2023)**. Once it occurs in deep vein it is commonly known as deep vein thrombosis (DVT) which is predominantly composed of fibrin and red blood cells (RBCs) **(Aleman *et al.* 2014)**.

Further, the DVT is a foremost curable disease; however, sometimes it causes severe death worldwide, affecting nearly 0.1% of individuals each year. Venous thromboembolism (VTE) is one among the communal vascular diseases subsequent to severe myocardial infraction besides stroke which comprises DVT and pulmonary embolism (PE), and also embraces thrombosis of further vessels, such as the portal or splenic veins **(Kesieme *et al.* 2011)**. VTE is commonly instigated through diverse congenital or developed situations that stimulates clotting, together with congenital coagulopathies, advanced age, overweightness, shock, surgical procedure, contamination and menace or gestation **(Varrias *et al.* 2023)**. The complete typical age and sex-adjusted annual existence of VTE is 117 per 100,000 (DVT, 48 per 100,000; PE, 69 per 100,000), by means of upper age-adjusted rates among males than females **(Heit *et al.* 2016)**. At sites of vascular damage in ATh, platelets come into interaction with uncovered sub-endothelial component collagen form a matrix which inhibits unnecessary blood loss **(Liao *et al.* 2025)**. Yet, this process happens in an unrestrained way, and it might centre to thrombotic events such as myocardial infarction and ischaemic stroke **(Chen *et al.* 2025)**. Epidemic of arterial thrombotic diseases occur due to age factor and cumulative effects such as weak arterial wall, reduced consistent workout, growing illness ensuing in circulatory stasis, and collective systemic activation of blood **(Previtali *et al.* 2011)**. Platelet grip and initiation is a multi-step progression including numerous platelet receptor-ligand relations. Upon vessel wall wound, circulating platelets are quickly broken by fleeting exchanges among the glycoprotein (GP) Ib-VIX complex and von Willebrand factor (VWF) destined to collagen **(Estevez and Du 2017)**.

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Generally, the coagulation process was influenced by numerous inhibitors that regulate the development of clot nearby the damaged vessel wall, thus preventing thrombus propagation. This slight equilibrium can be disturbed at any time as the coagulation factors is increased or decreased, that lead to thrombus formation **(Palta *et al.* 2014).** Molecular docking studies have demonstrated strong interactions of flavonoids, tannins, saponins, and phenolic compounds with thrombosis-related targets such as P2Y12 receptors, cyclooxygenase enzymes, thrombin, and integrin β3. Recent computational workflows integrating virtual screening, molecular docking, MM-GBSA analysis, and molecular dynamics simulations have identified several natural compounds with high binding affinity and stable receptor interactions, supporting their potential as antiplatelet and anticoagulant agents **(Abd Ghani *et al.* 2020)**. Furthermore, artificial intelligence (AI)-guided screening and pharmacokinetic evaluations are also emerging as powerful tools in phytochemical-based antithrombotic research. Machine learning-assisted prediction models, coupled with ADMET (absorption, distribution, metabolism, excretion, and toxicity) profiling, are increasingly being used to assess the drug-likeness, oral bioavailability, gastrointestinal absorption, cytochrome P450 interactions, and toxicity profiles of plant derived compounds before experimental validation. These strategies significantly reduce the time and cost associated with conventional drug discovery while improving the precision of candidate selection **(Santiago *et al.* 2026)**.

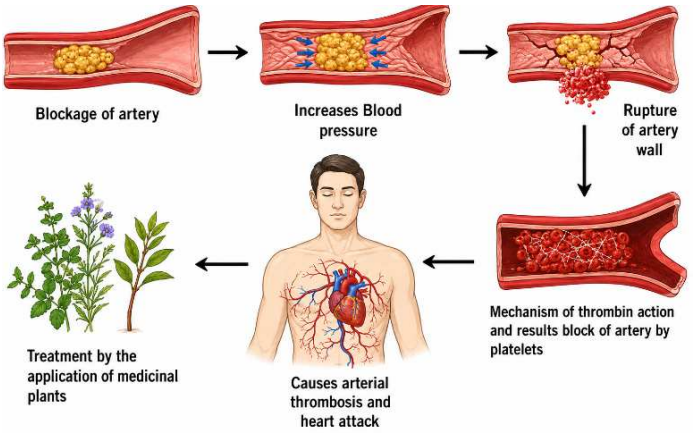

Figure 1. Formation of thrombin and its prevention by fabaceae plants

The treatment of thrombosis uses mediators with thrombolytic, anticoagulant and antiplatelet activities. For instance, the use of antithrombotic drugs specific like chemically made could decrease thrombus formation. Therefore, it is widely used as curative for primary inhibition, secondary prevention, or treatment of an acute thrombus. Anticoagulant drugs comprise of heparins, coumarins, ardeparin etc. and their derivatives are the chief actors in the medical applications. On the other hand, the harmful life-threatening side effects of these drugs have also been well recognized **(Flumignan *et al.* 2022)**. For designing the potential specific drug molecules for cardiovascular diseases in pharma industry, strategic technology is required and also it needs to validate by *in vivo* and *in vitro* assays. Alternative to this chemical, the traditional medicines such as herbal and medicinal plant-derived substances are more desirable alternatives when compare to the chemical drugs due to their convenience, affordability and safeness **(Shaito *et al.* 2020)**. Typically, medicinal plants are a gorgeous source of pharmacologically active compounds and mediators. Flavonoid is a cluster of natural compounds and forms a large class of polyphenols rich in plants belonging to the family Fabaceae. Formation of thrombin and its prevention by fabaceae plants were explained in **figure 1**. Taken together, this review traces about AT and their risk factors, diet, prevention and cure using variety of medicinal plants then discovering their potential effects in the advancement of novel multifunctional treatments against thrombosis in human beings **(Lemanowicz *et al.* 2025)**.

2. Etiology of Arterial Thrombosis

The cause of thrombosis is multifactorial process. ATh is caused by endothelial injury and atherosclerotic plaque that leads to platelet activation, coagulation and thrombus formation in arteries. Its well-known, thrombosis occurs during an inadequate level of endogenic anticoagulant in haemostasis and pathophysiologic mechanisms **(Asada *et al.* 2020)**. In this case, three major common aspects typically influence thrombosis such as injury to the endothelial coating of the vessel wall, hyper coagulable condition, and arterial or venous blood stasis. These three causes are recognized by the term "Virchow's triad." Rudolf Virchow projected Virchow's triad in 1856, and explained how the existence of these tierce issues surges thrombosis **(Wolberg *et al.* 2012)**. The main functions of endothelium are to control universal blood flow and tissue perfusion over variations in vessel diameter and vascular tone, done in aggregation through basic smooth muscle cells and pericytes. Also, flexible systemic blood flow, the endothelium serves as a fence that specifically regulates the undertaking of fluid, ions and other supermolecules between the mixing blood and nearby tissues by managing the inter endothelial adherents and tight junction complexes **(Pluta *et al.* 2025)**. Endothelial wall injury is produced by dissimilar factors, including direct disruption of vessel through tube assignment, upset, or surgical procedure which are the main causes of ATh. Hypercoagulability is noticed in patients with increased risk for thrombosis due to genetic faults in their anticoagulant paths or numerous prejudicing reasons. Patients existing with ATh frequently suffer from their sickness as an impediment of atherosclerosis. Yet, these patients similarly have a type of hypercoagulability, established primarily by high factor I levels and raised factor VII action **(Gimbrone and Garcia-Cardena 2016)**. The third facet Virchow's triad comprises arterial or venous stability of the blood, which could be due to motionlessness, gestation, or reduced blood flow ensuing from earlier thrombosis (e.g., remaining blood clot, remodelling or fibrosis of blood vessels, or atherosclerosis). Long expeditions with imperfect flexibility can also develop a virtual hazard aspect for thrombosis. Several features including oldness, overweightness, smoke, lasting swelling, metabolic disorder as well as others may also one of the primary causes for thrombosis and the secondary cause may due to obesity, high cholesterol, diabetes, high blood pressure, smoking cessation, hypertension, and hypercholesterolemia which subsidize to the hazard of acquiring an AT **(Lowe 2003)**. In addition, ATh occurs for a human with hypertension, type 2 diabetes mellitus, smoking, and hyperlipidemia who presented with sudden chest pain and left arm numbness. Diagnostic angiography revealed thrombotic occlusion of the coronary artery due to rupture of an unstable atherosclerotic plaque. The damaged endothelium exposed collagen and tissue factor, triggering platelet adhesion, aggregation, and fibrin deposition, ultimately causing acute myocardial infarction **(Karakasis *et al.* 2025)**.

3. Risk Factors of Arterial Thrombosis

Several factors responsible for ATh are described below and are explained in **figure 2**.

3.1. Age Factor

In the universal populace, time of life is an eminent menace feature aimed at an exponential increase in arterial thrombotic events. Increasing age is related to cardiovascular diseases. Similarly, sex-specific factors act as a major cause for epidemic arterial thrombosis during the 20th century. The potential mechanism involves damage on the arterial wall, reduced systematic workout, and cumulative motionlessness, subsequent in

venous stasis, and growing systemic stimulation of blood clotting (Esmon 2009). With the gradual increase in age, the plasma concentration of some coagulation factors like proaccelerin (Labile factor), proconvertin (stable factor), antihaemophilic factor A and antihaemophilic globulin, antihaemophilic factor B and plasma thromboplastin component, christmas factor and fibrinogen may also increase simultaneously, since fibrinogen increases beginning a mean value of 280 mg Dl^{-1} in persons aged 47-54 years to further than 300 mg dL^{-1} in those elderly 65-79 years. Chains of variations happen in the body of aged persons, which cause local haemorrhage and release of exogenous coagulation elements from wounded soft tissues, which collectively trigger the clotting mechanism and cause hypercoagulable state which results in thrombosis (Mari *et al.* 2008). Similarly, the principal causative agent in the occurrence of cardiovascular events in ageing people is the high plasma levels of fibrinogen, possibly by increasing the association of platelets via their glycoprotein IIb-IIIa receptor, by acting as a straight substratum of the lump and collective blood viscidness. The foremost inhibitor of fibrinolysis increases simultaneously with plasminogen activator inhibitor type 1 (PAI-1) that corresponds to an age-dependent reduction in fibrinolytic movement and an upsurge in platelet responsiveness with aging has also been established, and stimulated platelets significantly quicken thrombin cluster (Schneider *et al.* 1999). Deprived of straight contribution to the risk, increased fibrinogen levels may be acting as simply an indicator of the prolonged provocative state characteristic of maturing where tissue factor act as a major component of blood coagulation. In answer to adenosine diphosphate (ADP) and collagen platelets of 60-yearold or older persons aggregate rapidly in regards than platelets since minor persons (Luyendyk *et al.* 2019). Besides, an optimistic constructive association has been experiential among phase and indicators of platelet initiation such as plasma β thromboglobulin (a protein stored in the α granules of platelets) and platelet membrane phospholipids. More often thrombosis is unnoticed in older patients, who tend to exhibit different signs and symptoms (Kreidy 2014).

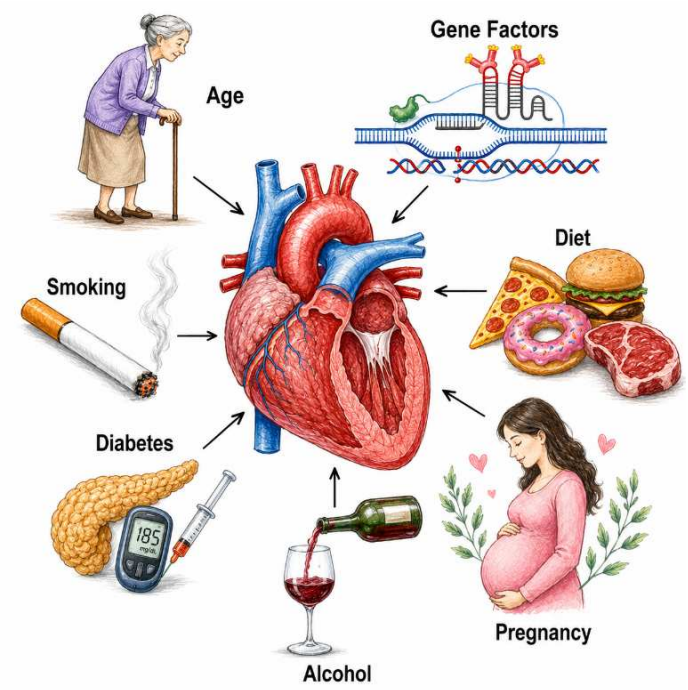

Figure 2. Factors responsible for the formation of arterial thrombosis leading to lethal effects

3.2. Immobility

Upon growing age (and partly because of it), motionlessness has augmented significantly in the subsequent half of the twentieth century. Socio-economic modifications stimulating stillness comprise inactive in cars or in front of television or computer screens, and reduced leisure-time activity (Yang *et al.* 2019). The cardiovascular disease increases with persistent bed rest and immobility, as blood from the lower limbs to the thoracic cavity, which increased venous return leading to the elongation of the right atrium, and release of atrial natriuretic peptide, a dominant diuretic that creates improved urine production, decreasing blood volume leading to arterial thrombosis (Barbic *et al.* 2019). Epidemiological readings have shown it is linked to the risk of arterial thrombosis in cooperation with universal initiation of haemostasis and inflammation. Previous studies reported that, the consequence of lengthy hold on thrombin cohort and on the fibrinolytic system has generated contradictory results (Howard *et al.* 2013).

3.3. Obesity and Metabolic Syndrome

Increased fat diet such as 'junk foods' are the major reason for immobility which leads to global widespread of obesity, metabolic syndrome (hypertension, dyslipidaemia, hyperglycaemia, and hyper insulinaemia) and type 2 diabetes mellitus. In addition to food, ecological and social influences enhance the risk for obesity which alters metabolic features (glucose, insulin, fatty acids, and gut microbiome) and act as a key factor for arterial thrombosis (Abbasi and Khodadadi 2025). Elevated abdomen perimeter (abdominal obesity), higher triglycerides, condensed high density lipid (HDL) cholesterol, high blood pressure and raised abstaining glucose are considered as potential metabolic syndromes by National Cholesterol Education Program Adult Treatment Panel III (NCEP ATP III) in 2001. Currently, several shreds of evidences have proved to demonstrate the relationship between ATh and the metabolic syndrome (Rezaianzadeh *et al.* 2012). The inter heart experimentation recognized nine risk issues that collectively reported for extra 90% of the danger of acute myocardial infraction. Obesity and metabolic syndrome raise the hazard of ATh perhaps of numerous contrary possessions on the principal wall and general belongings on inflammation, coagulation and fibrinolysis. Major variation among studies was noticed for obesity hence, precaution is compulsory for this; though the assessed virtual risk of thromboembolism in obese individuals at current seems similar to the relative risk of arterial thromboembolism (Ajay and Prabhakaran 2010). In general, obesity is considered with amplified adipose tissue and reduction in adiponectin stages in the body, and it cause imbalance of body homeostasis and mechanisms, which promote obesity-induced metabolic problems and vascular interruption leading to thrombotic variations. Furthermore, obesity centrals to insulin confrontation and endothelial disfunction owing to the development of metabolic goods resulting from lipids, hormones and proinflammatory cytokines and promotes the risk of cardiac diseases (Fuster *et al.* 2016). Similarly, obesity has been exposed to increase the risk of increased blood pressure, hypertension and is one of the major hazard features for stroke, myocardial infarction, heart failure, and AT. Rise in arterial blood pressure upsurges the risk of heart disease. The foreseeable risk of thromboembolism at present-day seems to be about half as robust as the relative hazard of stroke. This inconsistency may replicate the principal belongings of obesity on the arterial wall which array from endothelial disfunction to widespread atherosclerosis (Landsberg *et al.* 2013).

3.4. Smoking, Blood pressure and Cholesterol

The typical risk factors for ATh determined were due to tobacco smoking, arterial blood pressure and serum cholesterol. During 2020, the age-standardised occurrence of day-to-day smoking was 25.5% for men and 5.4% for women universal and is a significant danger to public health, existence accountable for approximately 6.3 million demises which is a foremost hazard issue for numerous diseases, comprising lung cancer, coronary heart disease, and stroke (Li *et al.* 2017). The British Regional Heart Study is clearly noted that increase in chronic heart diseases among

persons have severe blood pressure with increased cholesterol of the same age and sex was estimated to be about 80 - 90% risk. Meta-analyses of arbitrary measured trials of blood pressure drop (Blood Pressure Lowering Treatment Trialists' Collaborators, 2003) cholesterol reduction (Cholesterol Trialists' Treatment Collaborators, 2005) and observational studies of smoking termination confirmed that these three risk factors play fundamental parts in arterial disease **(Prospective Studies *et al.* 2007)**. This may be partially over atherogenesis, and somewhat over universal stimulation of coagulation and inflammation. Currently, the relationship of serum cholesterol with risk of thromboembolism is indistinct. Whereas experimental reports propose that treatment with strains (which decrease low density-lipoprotein cholesterol and hence total cholesterol) might be linked with reduced comparative hazard of thromboembolism, the interconnection of this relationship remnants to be recognised by randomized skilful trials **(Gusev and Sarapultsev 2023)**. It is reported that the relative risk of thromboembolism in relation to smoking and blood pressure may result in stroke and severe cardiac diseases.

3.5. Cancer

Cancer is renowned as a hazard factor for both arterial and venous thrombosis. Effects of rock-hard tumours on blood vessels (firmness and invasion), stillness for venous thrombosis, and universal hypercoagulability encouraged by the cancer or by actions for instance chemotherapy were considered to be the potential mechanism of inducing thromboembolism **(Blann and Dunmore 2011)**. There is important connection in the epidemiology and risk issues for the increase of cardiovascular disease and tumour since, they combine to account for 50% of deaths annually and emergent suggestion validates a major improved risk of arterial thromboembolism. Cardiac disease kills more than 1 in 10 cancer patients due to thrombosis related diseases but not due to cancer **(Wilcox *et al.* 2024)**. Among 3,234,256 cancer patients, 38% (1,228,328) perished from cancer and 11% (365,689) perishing from CVDs in which almost 76% were due to cardiac disease. In this case, it is reported that the pathophysiology of thromboembolism in patients with cancer is even more multifarious than that in patients depressed of three groups of issues have been related to the augmented risk of thromboembolism in the patients: persons associated to cancer, individuals correlated to the host, and persons receiving psychotherapies **(Khalil *et al.* 2015)**. Cancer cells might stimulate the relief of tissue factor from the damaged organs through development and the metastatic procedures. Significantly, tumour compartments themselves may discharge tissue feature rich micro atoms. These micro particles can then stick to (and be combined into) monocytes and supplementary cells, in specific individuals triggered by hypoxia, and stimulate fibrin formation. Bearing in mind the healing features that impact cancer-related risk of thromboembolism, it partaken exposed that patient role with cancer express dual the hazard of evolving thromboembolism due to oncological operation, associated with the risk in patients lacking cancer experiencing comparable surgical procedure **(Versteeg *et al.* 2004)**. The occurrence of factor V Leiden in cancer patient's upsurges the danger of thromboembolism almost 12-fold related to those individuals deprived of cancer and who have the wild-type issue V Leiden; analogous effects have been detected in cancer patients resounding the prothrombin G20210A optional **(Heraudeau *et al.* 2018)**.

3.6. Pregnancy

One of the foremost reasons of maternal demise is, complication of cardiovascular diseases during pregnancy which includes hypertensive disorders owing to changes in maternal physiology and also the compounds of foetus since, the management or treatment may affect the development of the foetus and induce maternal death. Oral contraceptives (OCs) and oral hormone replacement therapy (HRT) increases the dangers of AT during pregnancy most likely owing to general hypercoagulability (particularly in females with thrombophilias). Prolonged intakes of OCs proliferate the comparative risk of thromboembolism nearly twofold, and increase virtual hazard of ATh (MI, ischaemic stroke and marginal arterial disease) approximately three-fold **(Gongora and Wenger 2015)**. The foremost hazard issues intended for thromboembolism through gestation comprise the occurrence of thrombophilic irregularities, Caesarean section, advanced maternal age, obesity and pre-eclampsia, that are determined in approximately 70% of females with pregnancy- or puerperium-related thromboembolism. Mostly, regular gestation is categorized by a hypercoagulable condition. Pregnancy is related with haemostatic variations that comprise amplified concentrations of maximum procoagulant issues, reduced absorptions of certain ordinary anticoagulants and condensed fibrinolytic activity. These variations aid to preserve placental activity for the period of pregnancy and reduce blood loss at delivery **(Kearsley and Stocks 2021)**. Plasma concentrations of coagulation factors Proaccelerin (Labile factor), proconvertin (stable factor), Antihaemophilic factor A and Antihaemophilic globulin, Antihaemophilic factor B and Plasma thromboplastin constituent, Christmas factor, fibrinogen and vWF rise considerably throughout gestation, whereas factor XI stages tend to decline. Completely unrestricted protein S level was decreased, whereas protein C and antithrombin remains considerably unaffected. Such variations may happen throughout pregnancy period **(Kontovazainitis *et al.* 2024)**.

3.7. Trauma and Surgery

Annually, about 4% of people globally will go through a surgical practice, with 30% of persons having foremost surgical treatment in this situation several individuals may die due to alternation in their body which leads to thrombosis. Shock and operation are entrenched danger features for coagulation owing to motionlessness and general hypercoagulability. There is a cumulative risk of ATh surgery, particularly in patients having an arterial disease. The risk of thrombosis related to surgical treatment differs beginning 15% to 60% in the instance of a laparotomy method though the hazard accompanying through laparoscopic and arthroscopic surgical procedure is fewer distinct **(Meara *et al.* 2016)**. Surgery may lead to blood flow moderately in the pouches of intravenous regulators, mostly mediocre limbs which are emphasized by immobilization. Stability locally focuses haemostasis initiation aspects (cytokines and other intermediaries of swelling), favours cellular margination and communication of mixing lifeblood cells with endothelium, besides accountable for local hypoxia which is one of the main pathways of endothelial instigation **(Thomas and Roberts 1997)**. Physical disturbance of the endothelium, as happens in shock or surgical treatment, might result exposure of blood to extravascular muscle factor. Yet, massive intravenous thrombi happen in the situation of a complete endothelium which cause thromboembolism. Furthermore, subordinate to surgical procedure ATh characterize chief indicator of heparin-persuaded thrombocytopenia, an autoimmune illness generated by contact to the heparin that is usually specified as antithrombotic prophylaxis of post-operative thrombosis patients **(Yau *et al.* 2015)**.

4. Diet for Arterial thrombotic Patients

During past 70 years, a revealing and association among diet and cardiovascular disease has occupied a numerous curls and cracks, with the attention of ever-changing dietary patterns to particular nutrients and foods and back again. An unwell nourishment besides inadequate bodily activity stand as foremost worldwide threats to well-being says the World Health Organization (WHO) since, they root changes in internal mechanism of body by obesity, lipid blood profile, blood pressure,

glucose-insulin homeostasis, endothelial health, adipocyte metabolism, cardiac function, metabolic disbursement, weight parameter, visceral adiposeness, and microbiome **(Gao *et al.* 2021)**. A healthy diet is a typically recommended for cardiac patients by the cardiologist **(figure 3)**. Numerous studies have associated healthy nutritional diet arrangements with minor plasmatic concentrations of pro-inflammatory indications whereas a Western-type diet (meat-based dietary pattern) is related to advanced stages of low-quality inflammation. Currently, much evidence illustrates about healthy nutritional dietary system including high consumption of fiber, antioxidants, vitamins, minerals, polyphenols, monounsaturated fatty acids (MUFA) and polyunsaturated fatty acids (PUFA); little intake of salt, polished sugar, saturated, and Tran's fats; and carbohydrates, fruits, vegetables, legumes, fish and seafood, nuts, seeds, whole grains, vegetable oils and low intake of pastries, soft drinks, and red and processed meat which makes our heart healthy **(Diab *et al.* 2023)**.

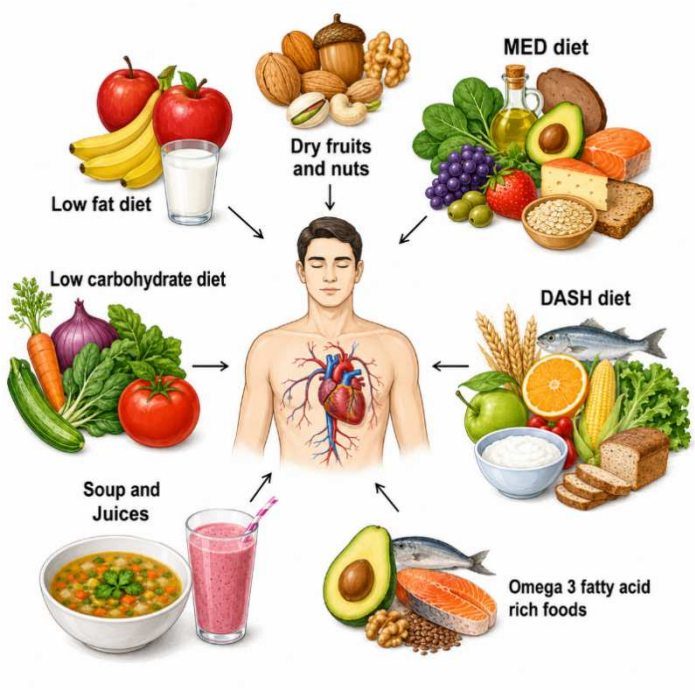

Figure 3. Diet for deep vein thrombosis comprising best foods to eat to prevent DVT

4.1. Low fat Diet

Ingesting low-fat food stays normally recognized in entire medical guidelines to prevent cardiac diseases **(Lamarche *et al.* 2025)**. Concisely, the diet of cardiac patients is based on the complete fat intake of 25% - 35% of whole calories, of which, saturated fat must remain not at all extra than 7% - 10%, trans fat fewer than 1%, unsaturated fats, chiefly MUFA and omega-3 PUFA would signify the remaining of the calories from fat and cholesterol, for a whole of less than 300 mg day^{-1}. For example, the low-fat meats, vegetables, dairy foodstuffs and 1% milk, and fat dropping food comprising TFA are commonly used as low-fat diet **(Eilat-Adar *et al.* 2013)**.

4.2. Low carbohydrate Diet

Lower carbohydrate regime such as intake of 30 - 130 g of carbohydrate per day or up to 45% of total calories is enough for a cardiac patient. Further, low-carbohydrate diets result in positive effects on body weight and chief cardio vascular risk factors; though, the effects on long-term health are still unknown **(Hu and Bazzano 2014)**. Intake of low-carbohydrate diet results effectively in weight loss, decreasing triglycerides and increasing high density lipopolysaccharide-C levels. Hence, collectively, the low carbohydrate diets may reduce the risk of cardiac diseases, and problems **(Dong *et al.* 2020)**.

4.3. Mediterranean Diet

The Mediterranean (Med) nourishment was first termed in the country Crete and Italy, which stands described as increased fat consumption (40% – 50% of total day-to-day calories), of that SFA covers ≤ 8% and MUFA gives 15% – 25% of calories. Med diet is related with a superior regulator of menace aspects to recover blood pressure (BP), lipid profile, glucose metabolism, arrhythmic risk, or gut micro biome and anti-inflammatory effect **(Abenavoli *et al.* 2026)**. Med diet is categorized by high omega-3 fatty acid consumption from fish and plant sources like fresh vegetables, fruits, PUFA, MUFA, vitamins, minerals, fibre, whole bread and grains, legumes, nuts and olive oil along with modest feeding of dairy foodstuffs (low-fat), in addition to eggs, fish, and chicken are permitted, whereas red meat is circumvented **(Davis *et al.* 2015)**. It's said that having a Med diet exerts a significant immune modulatory influence, dropping pro-inflammatory biomarkers, particularly individuals associated with atheroma constancy plaque, and shows its effect on vascular endothelial development aspect and maintains blood serum phospholipid fatty acid configuration. In relation to this, it's experimentally proved that the Med diet was enhanced with additional ingredients of olive oil and nut given to persons significantly reduced the tendency of cardiac diseases **(Casas *et al.* 2014)**. Hence, the Med diet is most widely preferred for cardiac patients.

4.4. Dietary Approach to Stop Hypertension (DASH) Diet

Dietary tactic is commonly followed on the way to reduce the high blood pressure. DASH regime which is described in the 1990s with a key goal to lower the risk of cardiac disease in terms of blood pressure, body weight glucose-insulin homeostasis, endothelial function, blood lipids and lipoproteins, inflammation status, the gut microbiome, and overall mortality through proper nutritional diet **(Chiu *et al.* 2016)**. DASH diet affords extra calcium, potassium, magnesium, dietary fibre and a reduced amount of fat, saturated fatty acid, cholesterol, and sodium which are abundant in vegetables and fruits. Further, whole grains, chicken, fish, nuts, sweets, and sodas also contain low-fat products. It is experimentally evaluated that DASH diet reduces systolic and diastolic blood pressure by 11.4 and 5.5 mmHg, correspondingly, and by 7.2 and 2.8 mmHg, correspondingly, in patients with high blood pressure. Similarly, it's reported that the reduction of sodium in the DASH food decrease the hypertension and enhance autonomic and vascular function among overweight patients and reduce the risk of cardiac diseases **(Suri *et al.* 2020)**.

5. Prevention and Treatment of Arterial Thrombosis

In recent years, many artificial and chemical antithrombotic agents are extensively used to prevent thrombosis. Among them, currently available antithrombotic agents such as aspirin, streptokinase etc. shows severe side effects including inadequate fibrin specificity associated with a severe bleeding tendency **(Smola-Dmochowska *et al.* 2026)**. For overcome these problems, varieties of steps are taken to develop better recombinant alternates of these drugs to diminish the insufficiencies of the existing thrombolytic drugs. Heparin is the greatest frequently utilised drug in thromboembolic illnesses; however, it grants frequent difficulties comprising high haemorrhagic risks **(Hale and Medina 2022)**. Therefore, the expansion of further operative and harmless anticoagulant/antithrombotic drugs remains a long-desired goal in the present day. Taking this into consideration currently, many researchers has been focussing on the use of medicinal plants and their products as an antithrombotic agent since they produce less or no side effects (non-toxic nature). Many investigations have been demonstrated towards determining the antithrombotic effect (anticoagulant and antiplatelet) of plants, natural food sources and their complements **(Subramani and Sathiyarajeswaran 2022)**. Hence, there is a suggestion that taking such

nourishment centrals to anticipation of coronary thrombosis events and stroke. The situation is predictable that around 80% of the population of developing countries meet their chief health care needs principally over plant-based traditional therapeutic remedies as different parts of plants including leaves, root, bark, stem, flower; fruit and seeds which play a vital role in the discovery of pharmacologically active plant-derived drugs. Nowadays, phyto-pharmacological exploration has produced a novel field to discover plant derived drugs, which are active and effective for certain ailments, and improved the consideration of herbal medicines **(Bays *et al.* 2021)**. It is estimated that about 30% of the medications are largely sourced from vegetal byproducts. Excitingly many plants displayed cardiovascular activities and prevent the risk of cardiac diseases via significant pathways such as calcium resentment, ACE-inhibition, antiarrhythmic, decoagulant and fibrinolytic activities, and reduction of cardiac fibrosis as their phenoplast complexes such as luteolin, rosmarinic acid, salvianolic acid A, cardamonin, cinnamic acid, punicalagin, punicalin, strictinin A, granatin B, ellagitannins and anthocyanins. These findings can be possible for developing novel cardiovascular drugs **(Kaur and Kumar 2025)**. Generally, in *vitro* thrombolytic activity of three medicinal plants namely *Averrhoa bilimbi* (Oxalidiaceae), *Clerodendrum viscosum* (Verbenaceae) and *Drynaria quercifolia* (Polypodiaceae) which were significantly reduced the clot formation. Numerous observational and experimental clinical studies have drastically investigated the potential efficacy of wide variety of medicinal plants for the treatment of cardiac diseases in humans with positive results **(Ramjan *et al.* 2014)**. Hence, it suggests that the medicinal plants and their compounds can be largely used to prevent blood coagulation by various mechanisms and their chemical structure were given in **figure 4**.

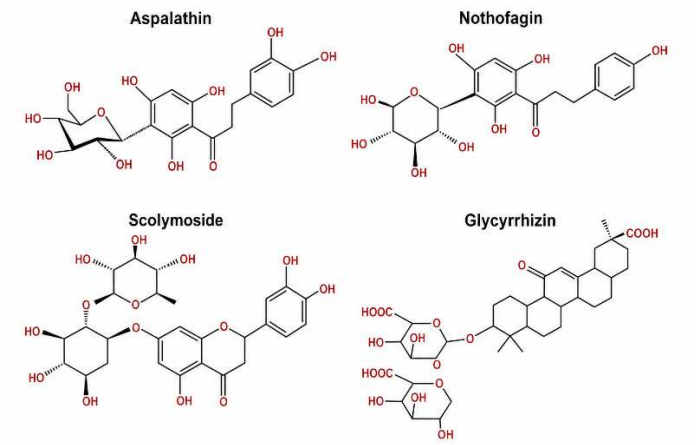

Figure 4. Representative chemical structures of bioactive secondary metabolites derived from medicinal plants, thoroughly categorized for treating Ath

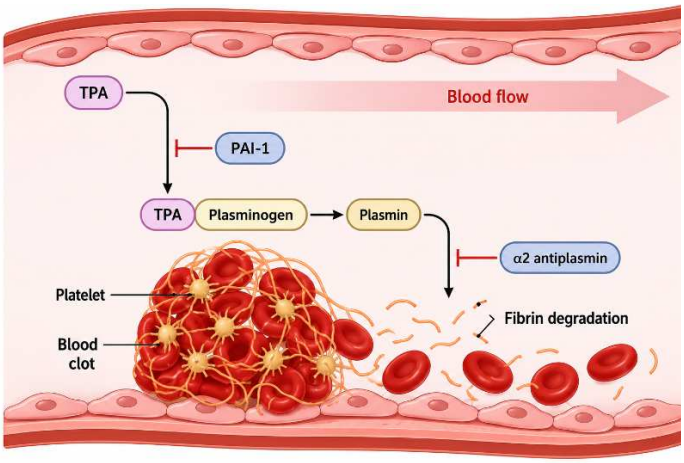

Figure 5. Mechanism of blood clot formation

Table1. Fabaceae family plant parts with antithrombotic activity

Scientific name	Common name	Parts used
Aspalathus linearis	Green rooibos tea	Active dihydrochalcones Aspalathin and nothofagin
Bauhinia forticata	Brazilian orchid tree	Aerial parts
Bauhinia rufa	Mountain ebony	Leaves
Bauhinia variegata	Mountain ebony	Leaves
Cyclopiasub ternata	Honeybush Tea	Active compound scolymoside
Cyamopsis tetragonoloba	Cluster beans	Seed
Dalbergia odorifera	Rosewood	Essential oil
Dalbergia sissoo	Rosewood	Bark
Desmodium gyrans	Dancing Grass	Leaves
Glycyrrhiza glabra	Licorice	Active compound Glycyrrhizin
Geoffroea spinosa	Almendon	Bark
Melilotus officinalis	Yellow sweet clover	Active compound coumarin
Stryphnodendron adstringens	Barbatimao	Leaves and stem bark
Sutherlandia frutescens	Cancer bush	Leaf
Trifolium pallidum	Trefoil	Aerial parts

5.1. Fabaceae Plants as Antithrombotic Agent

Globally, wide range of traditional herbal medicines has been extensively used to reduce thrombin **(Table 1)**. However, more particularly, most of the plants belongs to the family Fabaceae are more preferred as good antithrombotic agent due to the presence of active phytochemicals **(Kubatka *et al.* 2022)**. For example, seeds of *Cyamopsis tetragonoloba*, essential oils from *Dalbergia odorifera*, various bioactive components from *Cyclopia subternata, Aspalathus lineari*, *Glycyrrhiza glabra*, leaves of *Bauhinia variegate*, *Bauhinia rufa*, *Stryphnodendron adstringens* and *Sutherlandia frutescens*, are used as active antithrombotic agents. In the future, medicinal herbs can be transformed into drugs, which despite having numerous and novel materials require a very little manufacture cost and additional benefits comprising low side effects **(Ekor 2014)**.

5.1.1. Dalbergia sissoo

Its traditionally known as Sisu, Shisham, Tahli, Jag, Indian rose wood at different parts of world. Their bark rich in antithrombotic activity are about 3-5 cm long, either curved or flat, and fibrous. It shows anti-coagulant activity including antiplatelets that decrease the rate of blood clotting in the body **(Mannan *et al.* 2017)**. These are precisely specified for stroke and deep vein thrombosis. It is mentioned that the presence of alkaloids, phenolic compounds/tannins and flavonoids are responsible for its antithrombotic activity **(Vazhappilly *et al.* 2019).**

5.1.2. Cyamopsis tetragonoloba

The seeds of *Cyamopsis tetragonoloba* are rich in bioactive constituents, including guar gum residues, saponins, low-molecular-weight polyphenols, flavonoids, and other phenolic compounds, which contribute to their diverse pharmacological activities. These phytochemicals exhibit significant antioxidant, anti-inflammatory, and antithrombotic properties by modulating multiple pathways involved in hemostasis and vascular function. In particular, saponins and polyphenols have been reported to inhibit platelet activation, suppress thromboxane A_2 synthesis, reduce oxidative stress, and improve endothelial function, thereby lowering the risk of thrombus formation. To evaluate the

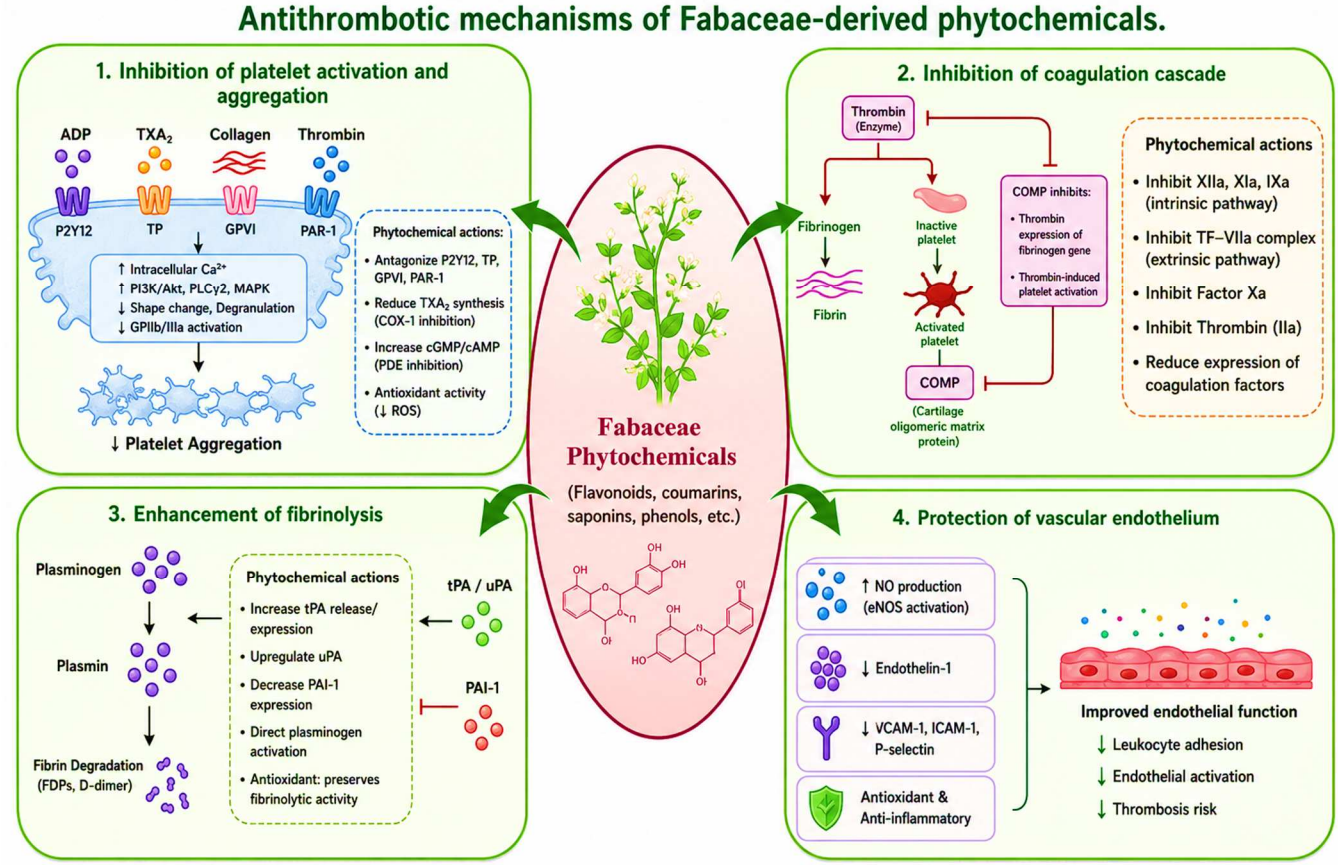

Figure 6. Antithrombotic mechanisms of Fabaceae-derived phytochemicals

antithrombotic potential of *C. tetragonoloba* seeds, platelet aggregation assays were performed, as platelet hyperactivity is a critical event in arterial thrombosis. The ability of the seed-derived bioactive compounds to inhibit platelet aggregation indicates their potential to enhance anticoagulant activity and reduce thrombotic events. These findings suggest that *C. tetragonoloba* seeds may serve as a promising natural source of antithrombotic agents with potential applications in the prevention and management of cardiovascular diseases associated with abnormal platelet activation and coagulation. **(Joshi *et al.* 2023)**.

5.1.3. Aspalathus lineari

A healthy beverage the herb tea, rooibos prepared from the fynbos plant *A. linearis* as they are rich in flavonoids chiefly, Aspalathin (Asp) and nothofagin (Not). They take part in the activation of coagulation and provides a foundation for growth of a new decoagulant drug **(Afrifa *et al.* 2023; Ku *et al.* 2015)**.

5.1.4. Desmodium gyrans

This plant is generally found in the forest of Kerala, India; commonly called as dancing grass by the local villagers. It partakes an elongated past of usage in Indian and Chinese traditional medicines to treat various ailments. Leaves of this plant are rich in phenolic compounds and flavonoids. They can be used antithrombotic and anticoagulant agents **(Sahu *et al.* 2024)**.

5.1.5. Glycyrrhiza glabra

It is a small 1 m high herbaceous shrub that contains 9–17 leaflets and 7–15 cm long pinnate leaves, with light ashen blue to purple flowers with a distance extending from 0.8 to 1.2 cm. The fruits are 2–3 cm long oblong pods, comprising numerous kernels with stoloniferous roots. The *G. glabra* generally recognized by way of licorice, sweetened timber, or mulaithi **(Pastorino *et al.* 2018)**. The active compound namely glycyrrhizin is isolated from this plant, which has rich anticoagulant properties. Aggregation and accumulation of platelets in the circulatory system cause severe thrombotic disorders and cardiovascular risks, and these could lead to death **(figure 5)**. Moreover, universal variations in a population inherited coagulopathy, progressive oldness, overweightness, suffering, surgical procedure, contagion, enmity, gestation and the cumulative effects are mainly due to the feeble arterial wall, reduced consistent workout, cumulative stillness ensuing in intravenous inertia and collective systemic instigation of blood thickening **(Mendes-Silva *et al.* 2003)**. They were clearly described as most important reason for the present epidemic of ATh and are growing the probable hazard issues. Most of the artificial and chemical antithrombotic agents have been used to prevent thrombosis; however, they were induced adverse effects. The recent scientific advancement performs numerous on-going medical trials that may deliver novel treatments for thrombotic diseases **(Heestermans *et al.* 2022)**. Many herbal plants belong to the family Fabaceae are mostly preferred for the production of natural medicines (without side effects) due to their bioactive components. In recent years, many research activities are going on this family plant worldwide as they significantly displayed cardiovascular and anti-coagulation activities **(Maroyi 2023)**. Collectively, in this field, furthermore research is need to be carried out to explore the efficacy of its medicinal values in management of the thrombotic disorders and finding more beneficial drug compounds **(figure 6)**.

6. Conclusion

Arterial thrombosis remains one of the leading causes of cardiovascular morbidity and mortality worldwide despite substantial advances in preventive strategies and pharmacological interventions. Although conventional antiplatelet and anticoagulant drugs have significantly reduced thrombotic events, their long-term administration is frequently associated with bleeding complications, drug resistance, narrow therapeutic windows, and multiple adverse effects. These limitations have intensified the search for safer, multi-targeted, and naturally derived

therapeutic alternatives. In this context, medicinal plants belonging to the Fabaceae family have emerged as an exceptionally promising source of bioactive phytochemicals with considerable antithrombotic potential. The evidence summarized in this review demonstrates that numerous Fabaceae species possess diverse classes of bioactive constituents, including flavonoids, isoflavones, saponins, tannins, alkaloids, phenolic acids, terpenoids, and other polyphenolic compounds that collectively contribute to cardiovascular protection. These phytochemicals exert their antithrombotic activities through multiple complementary mechanisms, such as inhibition of platelet aggregation, suppression of thromboxane synthesis, modulation of coagulation pathways, enhancement of fibrinolysis, attenuation of oxidative stress, regulation of endothelial function, and reduction of inflammatory responses associated with thrombus formation. Such multi-target pharmacological actions distinguish plant-derived compounds from many single-target synthetic drugs and make them attractive candidates for the prevention and management of arterial thrombosis. In addition to their direct antithrombotic properties, several Fabaceae-derived phytochemicals exhibit antioxidant, anti-inflammatory, antihyperlipidemic, antihypertensive, and antidiabetic activities, thereby simultaneously targeting major cardiovascular risk factors that contribute to thrombus development. This broad spectrum of biological activities supports the concept that these natural products may provide comprehensive cardiovascular protection rather than merely inhibiting coagulation. Consequently, Fabaceae plants represent an important reservoir for the discovery of multifunctional therapeutic agents capable of addressing the complex pathophysiology of arterial thrombosis. Nevertheless, despite encouraging findings from in vitro experiments, animal studies, and limited clinical investigations, the clinical translation of Fabaceae-derived phytochemicals remains incomplete. Most available studies vary considerably in plant species, extraction methods, phytochemical composition, dosage, and experimental design, making direct comparisons difficult and limiting reproducibility. Furthermore, many investigations rely on crude extracts without identifying the precise bioactive constituents responsible for the observed pharmacological effects. Additional challenges include poor bioavailability of certain phytochemicals, variability caused by geographical origin and cultivation conditions, lack of standardized formulations, insufficient pharmacokinetic and pharmacodynamic data, potential herb-drug interactions, and inadequate long-term safety evaluations. Future research should therefore focus on systematic phytochemical characterization, isolation of active compounds, elucidation of molecular mechanisms, and validation of therapeutic targets using advanced technologies such as metabolomics, transcriptomics, proteomics, network pharmacology, molecular docking, molecular dynamics simulations, and artificial intelligence-assisted drug discovery. Well-designed preclinical investigations should be complemented by large-scale, randomized, multicentre clinical trials to establish efficacy, optimal dosage, pharmacokinetics, toxicity profiles, and long-term safety. Standardization of plant materials, quality control procedures, and regulatory guidelines will also be essential for translating these promising phytochemicals into clinically approved botanical therapeutics or lead molecules for novel drug development. Overall, the Fabaceae family represents a rich and largely underexploited source of natural antithrombotic agents with significant therapeutic promise for preventing and managing arterial thrombosis. Continued interdisciplinary research integrating ethnopharmacology, natural product chemistry, molecular pharmacology, computational biology, and clinical medicine will accelerate the identification and development of next-generation cardiovascular therapeutics. With rigorous scientific validation and appropriate clinical evaluation, Fabaceae-derived phytochemicals have the potential to complement or even inspire safer, more effective, and multifunctional therapeutic strategies for reducing the global burden of arterial thrombosis and cardiovascular disease.

7. Disclosure Statements

7.1. Author Contribution

AS: Conceptualization, study design, supervision, data interpretation, manuscript writing and revision. **IPD:** Data collection, manuscript drafting, Data curation, literature review. The corresponding author have read and approved the final manuscript.

7.2. Declaration of Generative AI

During the preparation of this manuscript, artificial intelligence (AI)-assisted tools were used solely for language editing, grammar correction, improvement of sentence clarity, and figure editing/enhancement. AI tools were not used to generate scientific content, analyze or interpret data, formulate scientific conclusions, or make decisions regarding the study findings. The authors independently reviewed and verified all AI-assisted modifications and take full responsibility for the accuracy, originality, integrity, and scientific content of the manuscript and figures.

7.3. Ethics approval (for clinical/animal studies)

Not applicable. This manuscript is a review article based solely on the critical analysis and synthesis of previously published literature and did not involve any studies with human participants, animals, or identifiable human data performed by the authors.

7.4. Informed Consent Statement

Informed consent was not required for this study, as it is a review of published literature and does not involve human participants, patient data, or identifiable personal information.

7.5. Data Availability Statement

This review article is based exclusively on previously published studies. No primary datasets were generated or analyzed during the preparation of this manuscript. All relevant information supporting the findings of this review is available in the cited references.

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The authors declare that they have no known financial, personal, academic, or other relationships that could inappropriately influence, or be perceived to influence, the work reported in this manuscript. The authors confirm that there are no competing interests to declare.

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7.10. Supplementary Information

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