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CLINICAL AND PATHOPHYSIOLOGICAL SPECIFICITIES OF ATHEROSCLEROSIS IN PATIENTS WITH TYPE 2 DIABETES

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ABSTRACT

Research objectives: Type 2 diabetes mellitus significantly increases the risk of developing atherosclerosis and cardiovascular complications. Cardiovascular diseases are the leading cause of death in this patient population; however, diagnosis is often delayed due to the potential for atypical clinical presentation. The purpose of this review is to present the specific clinical and pathophysiological features of atherosclerosis in patients with type 2 diabetes mellitus, with particular emphasis on the distinct mechanisms of atherosclerotic development in these patients, as well as diagnostic and prognostic differences.
Key findings: In the course of type 2 diabetes mellitus, atherosclerosis develops against a background of chronic metabolic disturbances such as hyperglycemia, insulin resistance, dyslipidemia, and chronic inflammation. Patients often present with atypical or minimal symptoms, which complicates early diagnosis. Standard cardiovascular risk assessment tools may underestimate the actual threat in this group. Current research is exploring the use of novel biomarkers and imaging techniques to improve the precision of risk stratification.
Summary (conclusions): Atherosclerosis in type 2 diabetes mellitus is characterized by a distinct clinical and biological profile. Understanding these differences is essential for earlier diagnosis, more accurate risk assessment, and more effective cardiovascular prevention in this high-risk patient population.

KEYWORDS

Type 2 Diabetes, Atherosclerosis, Cardiovascular Disease, Diagnostic Delay

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1. Introduction

Atherosclerosis is a chronic inflammatory vascular disease that is classified as one of the leading causes of death worldwide, estimated to be responsible for 50% of deaths in Western countries. Determining the prevalence of atherosclerosis is challenging due to its often asymptomatic course. It is considered the primary cause of cardiovascular diseases, such as coronary artery disease and ischemic stroke. These diseases rank as the first and fifth leading causes of death globally (Beckman et al., 2002).

The atherosclerotic process begins in early childhood, and signs of coronary artery atherosclerosis are observed in about half of young individuals. The most well-known modifiable risk factors for atherosclerosis include type 2 diabetes, hypercholesterolemia, hypertension, and tobacco smoking. Consequently, numerous initiatives have been undertaken to detect atherosclerosis earlier and to identify individuals at increased risk for cardiovascular complications, allowing for the implementation of preventive measures at an earlier stage to prevent disease progression and complications. The prevalence of subclinical atherosclerosis is estimated at 36% in women and 38.7% in men, with a rising incidence with age (Verma & Anderson, 2001).

A 16-year observation from the Framingham study demonstrated a twofold increase in coronary events among diabetic patients compared to non-diabetic individuals. Some risk factors, such as type 2 diabetes and hypertension, often coexist, which further increases the risk of atherosclerosis and its complications. The mortality rate due to cardiovascular diseases in individuals with both diabetes and hypertension is 2.5–7.2 times higher than in the general population (Sarkar et al., 1996).

The diabetes epidemic, affecting approximately 3–5% of the Western population, is one of the major health challenges of the 21st century. Environmental, lifestyle, and behavioral changes have significantly increased the incidence of the disease in genetically susceptible individuals. Chronic hyperglycemia results in long-term complications affecting the eyes, kidneys, nerves, heart, and blood vessels (Kubes et al., 1991).

People with prediabetes, undiagnosed type 2 diabetes, or long-standing type 2 diabetes are at high risk for various complications related to vascular disease, including coronary artery disease, stroke, and peripheral vascular diseases. Statistics show that more than 70% of patients with type 2 diabetes die from cardiovascular causes (Kubes et al., 1991).

The aim of this study is to present the pathophysiology of atherosclerosis and to highlight the diagnostic and prognostic differences in cardiovascular diseases among patients with type 2 diabetes. Furthermore, no previous study has collectively described both diagnostic and prognostic differences in this patient population. Given the prevalence of both conditions, it is essential to raise awareness of their interrelationship among researchers and clinical practitioners.

2. Pathogenesis of Atherosclerotic Changes in Diabetic Patients

The link between diabetes and atherosclerosis is well documented—many processes occurring in diabetes contribute to atherogenesis. From a clinical perspective, chronic hyperglycemia, dyslipidemia, and insulin resistance are of the greatest importance, along with related dysfunctions in endothelial cells, smooth muscle cells, platelets, and chronic vascular inflammation. These processes not only initiate atherogenesis but also promote plaque instability, leading to severe clinical consequences (Beckman et al., 2002).

Endothelial Cell Dysfunction .

Endothelial cells synthesize substances such as nitric oxide and other reactive oxygen species, prostaglandins, and endothelins that regulate vascular function and structure. Nitric oxide dilates blood vessels, plays a major role in controlling vascular relaxation, reduces platelet activation, limits inflammation by decreasing leukocyte adhesion to the endothelium, inhibits their migration into the vessel wall, and reduces smooth muscle cell proliferation, thereby protecting vessels from atherogenesis [2–4].

In diabetes, several mechanisms lead to reduced nitric oxide-dependent vasodilation:

- Hyperglycemia inhibits nitric oxide production by blocking endothelial nitric oxide synthase (eNOS) activation and increasing the production of reactive oxygen species, particularly superoxide anions ($O2^-$), which directly inactivate nitric oxide (De Vriese et al., 2000).
- Insulin resistance results in excessive release of free fatty acids from adipose tissue, leading to protein kinase C activation. This enzyme inhibits phosphatidylinositol 3-kinase (a key eNOS pathway activator) and increases reactive oxygen species production, thus both decreasing nitric oxide synthesis and limiting its bioavailability [6–7].

Beyond reducing nitric oxide levels, diabetes increases the production of vasoconstrictors, particularly endothelin-1. This compound also enhances renal sodium and water retention, stimulates the renin–

angiotensin–aldosterone system, and induces vascular smooth muscle hypertrophy (Hopfner & Gopalakrishnan, 1999). Increased endothelin-1 activity may result from insulin-dependent upregulation of its gene expression, LDL-induced transcription, and excessive stimulation of its receptor [9–10]. Additionally, high glucose levels stimulate lipoxygenase activity, enhancing monocyte adhesion to endothelial cells (Patricia et al., 1999).

Vascular Wall Inflammation .

Inflammation and associated oxidative stress, leading to free radical production, play a central role in all stages of atherosclerosis—from initiation to progression and plaque destabilization. Inflammation also underlies the thrombotic potential of atherosclerotic plaques and elevates prothrombotic and antifibrinolytic factors in the bloodstream (Son, 2007). In diabetic individuals, vascular inflammation is primarily linked to coexisting obesity, which increases the release of pro-inflammatory substances (leptin, interleukin-6, TNF-α, MCP-1) from adipose tissue and reduces anti-inflammatory adiponectin levels (Freitas Lima et al., 2015). Inflammation is also induced by high LDL levels, which activate monocytes/macrophages. Obesity-induced inflammation differs from that seen in infections or autoimmune diseases. As a chronic condition, obesity causes low-grade activation of the innate immune system that affects long-term homeostasis (Lumeng & Saltiel, 2011). Studies have linked pro-inflammatory cytokine levels to dyslipidemia, hypertension, and insulin levels, suggesting their role in atherogenesis as part of the metabolic syndrome, including diabetes (Rizvi, 2007).

Medial Arterial Calcification and Vascular Stiffness .

Diabetes is associated with key cardiometabolic risk factors that can promote arterial calcification (Stabley & Towler, 2017). The most important of these are elevated levels of ligands that activate RAGE (receptors for advanced glycation end products), which accumulate in the arterial media, stiffening the vessels. Inhibition of RAGE significantly reduces vascular calcification in experimental models (Brodeur et al., 2014). Pro-inflammatory cytokines, especially TNF-α, further promote medial calcification. Vascular cells exposed to increasing TNF-α concentrations show a dose-dependent rise in alkaline phosphatase activity and calcium deposition (Tintut et al., 2000). The natural course of arterial calcification in diabetic patients appears to be progressive and is accelerated in those with poor glycemic control, high insulin resistance, and chronic kidney disease, highlighting the need for integrated treatment strategies (Al-Aly, 2007).

Abnormal Structure of Vascular Smooth Muscle .

Remodeling of small and medium-sized blood vessels significantly contributes to atherosclerosis risk, with diabetes being an independent risk factor in this process (Rizzoni & Agabiti Rosei, 2009). Even in normotensive diabetic patients, vascular structural changes resemble those seen in hypertensive individuals without diabetes. However, in patients with both conditions, these changes are more severe. Diabetic patients also show an increased cross-sectional area of vascular walls, indicating remodeling due to hypertrophy or hyperplasia of smooth muscle cells (Rizzoni et al., 2001; Schofield et al., 2002). In type 2 diabetic patients, a correlation has been observed between circulating insulin levels and the wall-to-lumen ratio, suggesting a possible role for insulin or insulin-like growth factor-1 in hypertrophic remodeling (Rizzoni et al., 2001).

- Platelet Function Abnormalities
- Hyperactivation and excessive aggregation of platelets play a key role in thrombotic complications associated with type 2 diabetes. Hyperglycemia enhances platelet aggregation in response to ADP or epinephrine in diabetic patients (Sobol & Watala, 2000). Key mechanisms include:
- Glycation of platelet surface proteins, increasing adhesion by impairing membrane fluidity (Winocour et al., 1992)
- Elevated plasma osmolarity stimulating genes encoding GP IIb/IIIa and P-selectin in platelets (Keating et al., 2003).

Endothelial dysfunction in diabetes leads to increased release of von Willebrand factor (vWF) and tissue factor (TF), contributing to hypercoagulability (Kessler et al., 1998; Boden & Rao, 2007). Another important mechanism is LDL glycation due to hyperglycemia, which accelerates its oxidation. Interaction of oxidized LDL with platelets induces their aggregation (Ferretti et al., 2002). In addition to promoting thrombosis, excessively activated platelets interact with other cells, such as endothelial cells and leukocytes, exacerbating micro- and macroangiopathy (El Haouari & Rosado, 2008).

3. Diagnostic Distinctions

In type 2 diabetes, the most common complication is diabetic neuropathy, which presents with sensory symptoms (primarily sensory deficits), and less frequently with autonomic (mainly subclinical) and motor symptoms. As a result, cardiovascular disease diagnosis in diabetic patients is often more challenging and distinct (Szczyrba et al., 2010).

In the study by Ängerud et al. (2016), the authors investigated the influence of diabetes on symptom presentation and delays in seeking care during myocardial infarction. It was shown that chest pain was common in both diabetic and non-diabetic patients and did not differ significantly after adjusting for age and gender. Diabetic patients had a higher risk of experiencing arm pain, shortness of breath, and fatigue, but a lower risk of cold sweats. The three most common symptoms reported by diabetic patients were chest pain, arm/hand pain, and fatigue. For non-diabetic patients, the most common symptoms were chest pain, cold sweat, and arm/hand pain. The median delay time for patients with diabetes was 2 hours and 24 minutes, while for those without diabetes, it was 1 hour and 15 minutes. The study concluded that although chest pain was prevalent in all groups, diabetic patients experienced significantly longer delays in seeking medical assistance (Ängerud et al., 2016). Diabetic patients often attribute their symptoms to other consequences of diabetes, such as hypoglycemia, side effects of oral hypoglycemic drugs, or symptoms (e.g., shortness of breath or heartburn) associated with comorbidities, which further delays medical intervention (Berman et al., 2017). Awareness of this issue is crucial for both healthcare providers and patients with diabetes in the context of suspected myocardial infarction.

A frequent chronic complication of diabetes is cardiac autonomic neuropathy (CAN), which is associated with potentially serious consequences. It results from damage to nerve fibers that regulate heart function, myocardial contractility, electrophysiology, and vascular tone. Contributing factors in the development of CAN include poor glycemic control, long diabetes duration, advanced age, female sex, and elevated body mass index. CAN leads to various cardiovascular disturbances, including resting tachycardia, arrhythmias, cardiovascular instability during surgery, and is also associated with silent ischemia and myocardial infarction, complicating and delaying diagnosis. CAN is diagnosed by assessing heart rate variability. Symptoms of myocardial infarction in patients with autonomic neuropathy may include cough, nausea and vomiting, shortness of breath, fatigue, and changes on the electrocardiogram (ECG) (Vinik & Ziegler, 2007).

Diabetes also affects the diagnostic differentiation of stroke. Sometimes, hypoglycemic symptoms in diabetic patients may mimic those of an acute ischemic stroke (Snarska et al., 2010). Brain imaging may also reveal abnormal findings during hypoglycemia. Administering glucose does not always differentiate stroke from hypoglycemia, as focal neurological deficits may persist even after blood glucose normalization, significantly complicating the diagnosis. Severe hypoglycemic episodes, in particular, can cause hemiparesis, resembling stroke symptoms (Rodriguez-Hernandez et al., 2023).

In the population-based study by Carson et al. (2012), involving middle-aged and older adults, it was found that nearly one-fourth of people with diabetes, but without a prior stroke diagnosis, experienced stroke-like symptoms. Diabetes was significantly associated with both isolated and multiple stroke symptoms. The presence of any stroke symptom was more common among individuals with diabetes (22.7%) than among those with prediabetes (15.6%) or normal glucose levels (14.9%). The occurrence of stroke symptoms in individuals without a diagnosed stroke increases the risk of future stroke. This suggests that active monitoring of stroke symptoms and implementation of risk-reduction strategies may be justified in diabetic patients to minimize the risk of cerebrovascular events (Carson et al., 2012).

4. Cardiovascular Risk Assessment in Patients with Diabetes

As is already known, type 2 diabetes promotes the development of cardiovascular diseases. Compared to control groups, individuals with both diabetes and cardiovascular diseases more often have male dominance and are more likely to be current or former smokers, as well as suffer from hypertension and sleep apnea (Thomas, 2016), (Rawshani et al., 2018). Over the years, various risk assessment scales have been developed to identify individuals at higher risk and help reduce premature mortality. The main scales used for cardiovascular risk assessment include the Framingham Risk Score, SCORE, PROCAM, SHHEC, and QRESEARCH. It is important to note that the first two scales are not entirely reliable in predicting mortality among diabetic patients, which may lead to diagnostic errors.

Research has shown that the most critical factors to consider include dyslipidemia, family history, smoking, and blood pressure. Thus, reducing blood pressure by 10 mmHg, quitting smoking, and lowering

cholesterol levels significantly decreases the risk of cardiovascular events and mortality in diabetic patients (Damaskos et al., 2020).

Another study assessed risk factors for specific cardiovascular events in diabetic patients, focusing on stroke, heart failure, and acute myocardial infarction (AMI). For stroke, the main predictors were elevated HbA1c, systolic blood pressure, and diabetes duration. For heart failure: atrial fibrillation, high BMI, and low physical activity. For AMI: high HbA1c, systolic blood pressure, and LDL cholesterol. Smoking was identified as a dominant factor in cardiovascular mortality among individuals with type 2 diabetes. Reducing or eliminating these factors can significantly improve outcomes for diabetic patients (Rawshani et al., 2018), (Thomas, 2016).

In another study conducted in Scotland, the most prevalent cardiovascular risk factors in diabetic patients included smoking, systolic blood pressure >130 mmHg or diastolic >80 mmHg, BMI >30 kg/m², HbA1c ≥ 53 mmol/mol (7%), and total cholesterol ≥ 5 mmol/L. The study found that two-thirds of the patients had at least two of these risk factors, highlighting a significant issue among diabetic individuals. The largest proportion of individuals, both with and without cardiovascular disease, was found in the group with two risk factors: 34.6% and 34.2%, respectively. The second most frequent group for those with cardiovascular disease had one risk factor (28.1%), and for those without, it was the group with three risk factors (25.4%).

It is also worth noting that medications can influence cardiovascular risk. Antidiabetic drugs from the SGLT2 inhibitor group, metformin, and GLP-1 receptor agonists have been shown to positively affect myocardial function, reducing the risk of atrial fibrillation and cardiovascular mortality. Therefore, prescribing these drug classes should be considered in patients with cardiovascular burden (McGurnaghan et al., 2019).

Coexistence of Cardiovascular Disease and Diabetes (Differences in Prevalence)

Cardiovascular diseases are an integral part of type 2 diabetes. According to the CAPTURE study, cardiovascular diseases affect 32.2% of patients with diabetes, highlighting a significant burden in this patient population (Mosenzon et al., 2021). Moreover, individuals with diabetes are two to three times more likely to develop cardiovascular diseases compared to those without diabetes (Ma et al., 2022).

The number of cases of diabetes is increasing year by year and diabetic patients continue to have higher mortality rates than non-diabetics, with cardiovascular diseases accounting for nearly half of all deaths. Among these, coronary artery disease and stroke are most prevalent. One study analyzing 86, 557 deaths found that cardiovascular diseases accounted for 50.3% of the deaths among people with type 2 diabetes (Einarson et al., 2018). Study showed a mortality rate of 15.4% among diabetic patients, compared to just 2.1% in those without diabetes. When considering previous myocardial infarction (MI), mortality in diabetic patients was significantly higher (42.0%) compared to non-diabetic individuals (15.9%), indicating markedly worse prognosis in patients with type 2 diabetes (Einarson et al., 2018).

The main cardiovascular conditions associated with diabetes include coronary artery disease, heart failure, stroke, arrhythmias, conduction disturbances, peripheral arterial disease, and carotid artery disease. According to the CAPTURE study, the weighted average prevalence of cardiovascular conditions in patients with type 2 diabetes was: coronary artery disease – 17.7%, carotid artery disease – 8.4%, cerebrovascular disease – 7.2%, arrhythmias – 4.2%, peripheral artery disease – 2.6%, heart failure – 2.4%, and aortic disease – 0.4% (Mosenzon et al., 2021).

Prevalence varies by country and gender but is mostly linked to atherosclerotic processes. The most common cardiovascular subtype is coronary artery disease. In a multinational study of diabetic patients from all continents, the prevalence of cardiovascular conditions was also analyzed by sex. Among men, overall prevalence was 27.6%, with heart failure being the most common condition (25.3%). Among women, overall prevalence was 27.2%, with heart failure again being the most common (24.0%).

In European countries analyzed (Belgium, France, Ireland, Italy, Netherlands, Portugal, Russia, Scotland, Spain, Sweden, Switzerland, and the UK), the highest prevalence of coronary artery disease among diabetic patients was in the UK (34.5%) and the lowest in Italy (11.1%). Stroke prevalence was highest in Switzerland (15.7%) and lowest again in Italy (2.4%) (Einarson et al., 2018). Another study from Scotland found that more men (35%) than women (29%) suffered from cardiovascular disease (McGurnaghan et al., 2018).

Arrhythmias in Diabetic Patients

Cardiac arrhythmias are also a common issue in individuals with diabetes and depend on many factors. Studies show that arrhythmias can be exacerbated by large glucose fluctuations, comorbidities, and certain medications. In one study involving 100 diabetic patients with arrhythmias, the most common type was sinus tachycardia (ST), diagnosed in 32% of participants. Other frequent arrhythmias included complete heart block (CHB) in 20%, sinus bradycardia (SB) in 15%, and atrial fibrillation (AF) in 15%.

Most of these patients also had comorbidities such as hypertension and coronary artery disease, which increased the risk of atrial fibrillation and ventricular premature contractions (VPCs). Additionally, 76% had prolonged QTd intervals, a marker of risk for sudden cardiac death (Agarwal & Singh, 2017).

In patients using insulin, hypoglycemic episodes were found to trigger arrhythmias such as bradycardia, ectopic atrial activity, ventricular activity, and ventricular tachyarrhythmias—likely linked to impaired cardiac repolarization. T-wave morphology changes were also observed during hypoglycemia, including T-wave symmetry alterations and elevated PCA ratios in type 2 diabetics. These changes contribute to repolarization heterogeneity and are proarrhythmic. It is also worth noting that patients with type 2 diabetes often present with prolonged QT intervals, which may increase mortality risk (Chow et al., 2017).

In another study, the most frequent rhythm disorders during nocturnal hypoglycemia were pauses (77%) and atrial fibrillation (22%), along with episodes of bradycardia and ventricular tachycardia. A proarrhythmic pattern was observed predominantly during nighttime and glucose variability (Andersen et al., 2021).

Type 2 diabetes and advanced age are major risk factors for atrial fibrillation. Patients with both conditions have a two- to fivefold increased risk of cardiovascular disease. Mortality in this group is also higher due to cardiovascular causes compared to those without atrial fibrillation. This patient population should be monitored more closely to reduce mortality (Matsumoto et al., 2022), (Bisson et al., 2021).

5. Prognostic Differences

Patients with type 2 diabetes have more than double the risk of death from cardiovascular disease compared to individuals in the same age group. They are also twice as likely as the general population to experience stroke and coronary artery disease events, including myocardial infarction, sudden cardiac death, and angina pectoris. A high percentage of patients with type 2 diabetes die within one year of an acute myocardial infarction, and many die after hospital discharge. Women with type 2 diabetes have been found to have a higher relative risk of coronary events compared to men with type 2 diabetes. The primary cause of this difference remains unclear, but it may be partially explained by a higher burden of risk factors and a greater impact of blood pressure and atherogenic dyslipidemia on cardiovascular risk in diabetic women compared to diabetic men (Laakso, 2010).

Prognosis in patients with type 2 diabetes largely depends on the coexistence of cardiovascular disease. Laakso M. demonstrated in his study that the risk of myocardial infarction in diabetic patients without a prior heart attack is comparable to that of non-diabetic individuals who have previously experienced a myocardial infarction (Laakso, 2010; Henning, 2018).

Among diabetic patients, the 5-year post-myocardial infarction mortality rate is twice as high as in non-diabetic individuals, reaching up to 50%. Additionally, the risk of coronary artery disease increases by 11% for every 1% increase in hemoglobin A1c (HbA1c) above 6.5% (Henning, 2018).

Sedentary adult diabetic patients have a 2.81-fold increased risk of cardiovascular death compared to sedentary adults without diabetes. Studies suggest that lowering HbA1c by ≤1% may be associated with a 15% relative risk reduction in non-fatal myocardial infarction, although it does not significantly reduce all-cause mortality (Henning, 2018).

A multicenter study found that angina pectoris, myocardial infarction, coronary angioplasty, coronary artery bypass grafting (CABG), and heart failure are predictive factors for increased all-cause mortality in diabetic patients. Among those with type 2 diabetes, in-hospital mortality was 15% higher due to myocardial infarction, 6% higher due to stroke, and 6% higher for all cardiovascular events combined, compared to a control group without diabetes.

In recent decades, cardiovascular disease mortality and incidence have declined, with a more noticeable decrease observed in individuals with diabetes than in those without. This downward trend is likely due to increased awareness, improved management of cardiovascular disease and diabetes, and risk factor modification (Htay et al., 2019).

Sudden increases in blood glucose levels and the presence of diabetes are associated with poor outcomes after both ischemic and hemorrhagic stroke, including higher mortality, worse neurological and functional status, longer hospital stays, and increased frequency of rehospitalization and stroke recurrence (Lau et al., 2019).

6. Conclusions

Type 2 diabetes significantly accelerates the development of atherosclerosis through mechanisms such as chronic hyperglycemia, endothelial dysfunction, oxidative stress, and vascular remodeling, which promote plaque formation and increase its vulnerability to rupture. Cardiovascular diseases in diabetic patients often present atypically due to autonomic neuropathy, altered symptom presentation, and the coexistence of other metabolic complications, complicating diagnosis and potentially delaying appropriate treatment. The prognosis in these patients is markedly worse, with higher incidences of myocardial infarction, stroke, heart failure, and mortality. Furthermore, conventional cardiovascular risk assessment tools frequently underestimate the actual risk in this population. Therefore, a more personalized approach, considering diabetes-specific risk factors and utilizing modern diagnostic methods, is essential for more accurate risk stratification and more effective prevention of cardiovascular complications.

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REFERENCES

1. Beckman, J. A., Creager, M. A., & Libby, P. (2002). *Diabetes and atherosclerosis: Epidemiology, pathophysiology, and management.* JAMA, 287(19), 2570–2581.
2. Verma, S., & Anderson, T. J. (2001). *The ten most commonly asked questions about endothelial function in cardiology.* Cardiology Review, 9(5), 250–252.
3. Sarkar, R., Meinberg, E. G., Stanley, J. C., Gordon, D., & Webb, R. C. (1996). *Nitric oxide reversibly inhibits the migration of cultured vascular smooth muscle cells.* Circulation Research, 78(2), 225–230.
4. Kubes, P., Suzuki, M., & Granger, D. N. (1991). *Nitric oxide: An endogenous modulator of leukocyte adhesion.* Proceedings of the National Academy of Sciences, 88(11), 4651–4655. https://doi.org/10.1073/pnas.88.11.4651
5. De Vriese, A. S., Verbeuren, T. J., Van de Voorde, J., Lameire, N. H., & Vanhoutte, P. M. (2000). *Endothelial dysfunction in diabetes.* British Journal of Pharmacology, 130(5), 963–974. https://doi.org/10.1038/sj.bjp.0703393
6. Hennes, M. M., O'Shaughnessy, I. M., Kelly, T. M., Osei, K., & O'Dorisio, T. M. (1996). *Insulin-resistant lipolysis in abdominally obese hypertensive individuals.* Hypertension, 28(1), 120–126. https://doi.org/10.1161/01.HYP.28.1.120
7. Inoguchi, T., Li, P., Umeda, F., Yu, H. Y., Kakimoto, M., Imamura, M., ... & Nawata, H. (2000). *High glucose level and free fatty acid stimulate reactive oxygen species production through protein kinase C–dependent activation of NAD(P)H oxidase in cultured vascular cells.* Diabetes, 49(11), 1939–1945. https://doi.org/10.2337/diabetes.49.11.1939
8. Hopfner, R. L., & Gopalakrishnan, V. (1999). *Endothelin: Emerging role in diabetic vascular complications.* Diabetologia, 42(11), 1383–1394. https://doi.org/10.1007/s001250051431
9. Quehenberger, P., Bierhaus, A., Fasching, P., Muellner, C., Klevesath, M., Riedmüller, G., ... & Nawroth, P. P. (2000). *Endothelin 1 transcription is controlled by nuclear factor-kappaB in AGE-stimulated cultured endothelial cells.* Diabetes, 49(9), 1561–1570. https://doi.org/10.2337/diabetes.49.9.1561
10. Achmad, T. H., Winterscheidt, A., Lindemann, C., & Rao, G. S. (1997). *Oxidized low density lipoprotein acts on endothelial cells in culture to enhance endothelin secretion and monocyte migration.* Methods and Findings in Experimental and Clinical Pharmacology, 19(3), 153–159. https://doi.org/10.1358/mf.1997.19.3.372759
11. Patricia, M. K., Kim, J. A., Harper, C. M., McKellar, D., & Simon, D. I. (1999). *Lipoxygenase products increase monocyte adhesion to human aortic endothelial cells.* Arteriosclerosis, Thrombosis, and Vascular Biology, 19(11), 2615–2622. https://doi.org/10.1161/01.ATV.19.11.2615
12. Freitas Lima, L. C., Braga, V. A., do Socorro de França Silva, M., Cruz, J. C., Sousa Santos, S. H., de Oliveira Monteiro, M. M., & Balarini, C. M. (2015). *Adipokines, diabetes and atherosclerosis: An inflammatory association.* Frontiers in Physiology, 6, 304. https://doi.org/10.3389/fphys.2015.00304
13. Lumeng, C. N., & Saltiel, A. R. (2011). *Inflammatory links between obesity and metabolic disease.* The Journal of Clinical Investigation, 121(6), 2111–2117. https://doi.org/10.1172/JCI57132
14. Son, S. M. (2007). *Role of vascular reactive oxygen species in development of vascular abnormalities in diabetes.* Diabetes Research and Clinical Practice, 77(3), S65–S70. https://doi.org/10.1016/j.diabres.2007.01.012
15. Rizvi, A. A. (2007). *Inflammation markers as mediators of vasculo-endothelial dysfunction and atherosclerosis in the metabolic syndrome and type 2 diabetes.* Chinese Medical Journal, 120(21), 1918–1924. https://doi.org/10.1097/00029330-200711010-00007

16. Brodeur, M. R., Bouvet, C., Bouchard, S., Moreau, S., Leblond, J., Deblois, D., & Marette, A. (2014). *Reduction of advanced-glycation end products levels and inhibition of RAGE signaling decreases rat vascular calcification induced by diabetes.* PLoS ONE, 9(1), e85922. https://doi.org/10.1371/journal.pone.0085922
17. Stabley, J. N., & Towler, D. A. (2017). *Arterial calcification in diabetes mellitus: Preclinical models and translational implications.* Arteriosclerosis, Thrombosis, and Vascular Biology, 37(2), 205–217. https://doi.org/10.1161/ATVBAHA.116.306258
18. Tintut, Y., Alfonso, Z., Saini, T., & Demer, L. L. (2000). *Tumor necrosis factor-α promotes in vitro calcification of vascular cells via the cAMP pathway.* Circulation, 102(21), 2636–2642. https://doi.org/10.1161/01.CIR.102.21.2636
19. Nadra, I., Mason, J. C., Philippidis, P., Florey, O., Smythe, C. D. W., McCarthy, G. M., ... & Haskard, D. O. (2005). *Proinflammatory activation of macrophages by basic calcium phosphate crystals via protein kinase C and MAP kinase pathways: A vicious cycle of inflammation and arterial calcification? Circulation Research, 96(12), 1248–1256.* https://doi.org/10.1161/01.RES.0000171451.88616.c2
20. Al-Aly, Z. (2007). *Medial vascular calcification in diabetes mellitus and chronic kidney disease: The role of inflammation.* Cardiovascular & Haematological Disorders – Drug Targets, 7(1), 1–6. https://doi.org/10.2174/187152907780059047
21. Rizzoni, D., & Agabiti Rosei, E. (2009). *Small artery remodeling in diabetes mellitus.* Nutrition, Metabolism and Cardiovascular Diseases, 19(8), 587–592. https://doi.org/10.1016/j.numecd.2009.03.011
22. Rizzoni, D., Porteri, E., Guelfi, D., Muiesan, M. L., Valentini, U., Cimino, A., ... & Agabiti Rosei, E. (2001). *Structural alterations in subcutaneous small arteries of normotensive and hypertensive patients with non–insulin-dependent diabetes mellitus.* Circulation, 103(9), 1238–1244. https://doi.org/10.1161/01.CIR.103.9.1238
23. Schofield, I., Malik, R., Izzard, A., Austin, C., & Heagerty, A. (2002). *Vascular structural and functional changes in type 2 diabetes mellitus: Evidence for the roles of abnormal myogenic responsiveness and dyslipidemia.* Circulation, 106(24), 3037–3043. https://doi.org/10.1161/01.CIR.0000041432.80615.A5
24. Sobol, A. B., & Watala, C. (2000). *The role of platelets in diabetes-related vascular complications.* Diabetes Research and Clinical Practice, 50(1), 1–16. https://doi.org/10.1016/S0168-8227(00)00160-1
25. El Haouari, M., & Rosado, J. A. (2008). *Platelet signalling abnormalities in patients with type 2 diabetes mellitus: A review.* Blood Cells, Molecules and Diseases, 41(1), 119–123. https://doi.org/10.1016/j.bcmd.2008.02.010
26. Winocour, P. D., Slater, A., Leach, A. G., & Brockbank, E. (1992). *Decreased platelet membrane fluidity due to glycation or acetylation of membrane proteins.* Thrombosis and Haemostasis, 68(11), 577–582. https://doi.org/10.1055/s-0038-1655876
27. Keating, F. K., Sobel, B. E., & Schneider, D. J. (2003). *Effects of increased concentrations of glucose on platelet reactivity in healthy subjects and in patients with and without diabetes mellitus.* The American Journal of Cardiology, 92(11), 1362–1365. https://doi.org/10.1016/j.amjcard.2003.08.028
28. Ferretti, G., Bacchetti, T., Rabini, R. A., Curatola, G., Delle Monache, F., & Mazzanti, L. (2002). *Glycated low density lipoproteins modify platelet properties: A compositional and functional study.* The Journal of Clinical Endocrinology & Metabolism, 87(5), 2180–2184. https://doi.org/10.1210/jcem.87.5.8444
29. Kessler, L., Drouin, P., & Pinget, M. (1998). *Von Willebrand factor in diabetic angiopathy.* Diabetes & Metabolism, 24(4), 327–336. https://doi.org/10.1016/S1262-3636(98)80046-1
30. Boden, G., & Rao, A. K. (2007). *Effects of hyperglycemia and hyperinsulinemia on the tissue factor pathway of blood coagulation.* Current Diabetes Reports, 7(3), 223–227. https://doi.org/10.1007/s11892-007-0035-1
31. Ängerud, K. H., Thylén, I., Sederholm Lawesson, S., Eliasson, M., Näslund, U., & Brulin, C. (2016). *Symptoms and delay times during myocardial infarction in 694 patients with and without diabetes: An explorative cross-sectional study.* BMC Cardiovascular Disorders, 16(1), 108. https://doi.org/10.1186/s12872-016-0282-7
32. Balcıoğlu, A. S., & Müderrisoğlu, H. (2015). *Diabetes and cardiac autonomic neuropathy: Clinical manifestations, cardiovascular consequences, diagnosis and treatment.* World Journal of Diabetes, 6(1), 80–91. https://doi.org/10.4239/wjd.v6.i1.80
33. Vinik, A. I., & Ziegler, D. (2007). *Diabetic cardiovascular autonomic neuropathy.* Circulation, 115(3), 387–397. https://doi.org/10.1161/CIRCULATIONAHA.106.634949
34. Berman, N., Jones, M. M., & De Coster, D. A. (2017). *'Just like a normal pain': What do people with diabetes mellitus experience when having a myocardial infarction? A qualitative study recruited from UK hospitals.* BMJ Open, 7(9), e015736. https://doi.org/10.1136/bmjopen-2016-015736
35. Carson, A. P., Muntner, P., Kissela, B. M., Kleindorfer, D. O., Howard, V. J., Meschia, J. F., & Safford, M. M. (2012). *Association of prediabetes and diabetes with stroke symptoms: The REasons for Geographic and Racial Differences in Stroke (REGARDS) study.* Diabetes Care, 35(9), 1845–1852. https://doi.org/10.2337/dc12-0458
36. Jermendy, G. (2003). *Clinical consequences of cardiovascular autonomic neuropathy in diabetic patients.* Acta Diabetologica, 40(Suppl. 2), S370–S374. https://doi.org/10.1007/s00592-003-0122-y
37. Snarska, K., Kapica-Topczewska, K., Sawicka, J., Drozdowski, W., & Bachórzewska-Gajewska, H. (2010). *Cukrzyca jako czynnik ryzyka udaru niedokrwiennego mózgu [Diabetes as a risk factor for ischemic stroke]. Endokrynologia, Otyłość i Zaburzenia Przemiany Materii, 6(2), 93–100.* (DOI not available)

38. Rodriguez-Hernandez, A., Babici, D., Campbell, M., CarranzaReneteria, O., & Hammond, T. (2023). *Hypoglycemic hemineglect: A stroke mimic.* eNeurologicalSci, 30, 100444. https://doi.org/10.1016/j.ensci.2023.100444
39. Szczyrba, S., Kozera, G., Bieniaszewski, L., & Nyka, W. M. (2010). *Neuropatia cukrzycowa – patogeneza, rozpoznawanie, zapobieganie, leczenie.* In Forum Medycyny Rodzinnej, 4(5), 339–355. https://doi.org/10.26444/jpccr/109010
40. Mosenzon, O., et al. (2021). *CAPTURE: A multinational, cross-sectional study of cardiovascular disease prevalence in adults with type 2 diabetes across 13 countries.* Cardiovascular Diabetology, 20, 154. https://doi.org/10.1186/s12933-021-01344-0
41. Ma, C.-X., Ma, X.-N., Guan, C.-H., Li, Y.-D., Mauricio, D., & Fu, S.-B. (2022). *Cardiovascular disease in type 2 diabetes mellitus: Progress toward personalized management.* Cardiovascular Diabetology, 21(1), 74. https://doi.org/10.1186/s12933-022-01516-6
42. Einarson, T. R., Acs, A., Ludwig, C., & Panton, U. H. (2018). *Prevalence of cardiovascular disease in type 2 diabetes: A systematic literature review of scientific evidence from across the world in 2007–2017.* Cardiovascular Diabetology, 17, 83. https://doi.org/10.1186/s12933-018-0728-6
43. McGurnaghan, S., et al. (2018). *Cardiovascular disease prevalence and risk factor prevalence in Type 2 diabetes: A contemporary analysis.* Diabetic Medicine, 36(6), 718–725. https://doi.org/10.1111/dme.13825
44. Agarwal, G., & Singh, S. K. (2017). *Arrhythmias in Type 2 Diabetes Mellitus.* Indian Journal of Endocrinology and Metabolism, 21(5), 715–718. https://doi.org/10.4103/ijem.IJEM_448_16
45. Chow, E., et al. (2017). *Cardiac autonomic regulation and repolarization during acute experimental hypoglycemia in type 2 diabetes.* Diabetes, 66(5), 1322–1333. https://doi.org/10.2337/db16-1310
46. Andersen, A., et al. (2021). *Associations of hypoglycemia, glycemic variability and risk of cardiac arrhythmias in insulin-treated patients with type 2 diabetes: A prospective, observational study.* Cardiovascular Diabetology, 20, 241. https://doi.org/10.1186/s12933-021-01425-0
47. Matsumoto, C., et al. (2022). *Incidence of atrial fibrillation in elderly patients with type 2 diabetes mellitus.* BMJ Open Diabetes Research & Care, 10(2), e002745. https://doi.org/10.1136/bmjdrc-2021-002745
48. Bisson, A., et al. (2021). *Sex, age, type of diabetes and incidence of atrial fibrillation in patients with diabetes mellitus: A nationwide analysis.* Cardiovascular Diabetology, 20, 24. https://doi.org/10.1186/s12933-021-01216-7
49. Thomas, M. C. (2016). *Type 2 diabetes and heart failure: Challenges and solutions.* Current Cardiology Reviews, 12(3), 249–255. https://doi.org/10.2174/1573403X12666160606120254
50. Damaskos, C., et al. (2020). *Assessing cardiovascular risk in patients with diabetes: An update.* Current Cardiology Reviews, 16(4), 266–274. https://doi.org/10.2174/1573403X15666191111123622
51. Rawshani, A., et al. (2018). *Risk factors, mortality, and cardiovascular outcomes in patients with type 2 diabetes.* New England Journal of Medicine, 379(7), 633–644. https://doi.org/10.1056/NEJMoa1800256
52. Pahwa, R., & Jialal, I. (2023). *Atherosclerosis.* In StatPearls. StatPearls Publishing. (DOI not available)
53. Dąbek, J., Wnuk, M., Orszulak-Michalak, D., & Gąsior, M. (2019). *Rokowanie chorych z wczesną miażdżycą tętnic wieńcowych w 4-letniej obserwacji.* Annales Academiae Medicae Silesiensis, 73. (DOI not available)
54. Bogdan, M., Kinalski, M., Myśliwiec, M., & Głowiński, J. (2003). *Morfologia blaszek miażdżycowych u chorych na cukrzycę typu 2.* Diabetologia Doświadczalna i Kliniczna, 3(3), 227–226. (DOI not available)
55. Laakso, M. (2010). *Cardiovascular disease in type 2 diabetes from population to man to mechanisms: The Kelly West Award Lecture 2008.* Diabetes Care, 33(2), 442–449. https://doi.org/10.2337/dc09-0749
56. Henning, R. J. (2018). *Type-2 diabetes mellitus and cardiovascular disease.* Future Cardiology, 14(6), 491–509. https://doi.org/10.2217/fca-2018-0045
57. Htay, T., Soe, K., Lopez-Perez, A., Doan, A. H., Romagosa, M. A., & Aung, K. (2019). *Mortality and cardiovascular disease in type 1 and type 2 diabetes.* Current Cardiology Reports, 21(6), 45. https://doi.org/10.1007/s11886-019-1133-9
58. Lau, L. H., Lew, J., Borschmann, K., Thijs, V., & Ekinci, E. I. (2019). *Prevalence of diabetes and its effects on stroke outcomes: A meta-analysis and literature review.* Journal of Diabetes Investigation, 10(3), 780–792. https://doi.org/10.1111/jdi.12932