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**STRUCTURAL AND FUNCTIONAL CARDIAC STATUS AND REMODELING
PROCESSES IN PATIENTS WITH TYPE 2 DIABETES MELLITUS RECEIVING SGLT2
INHIBITOR THERAPY**



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Annotation: This article examines the structural and functional state of the heart and myocardial remodeling processes in patients with type 2 diabetes mellitus receiving sodium-glucose cotransporter-2 inhibitor therapy. Clinical and echocardiographic parameters are used to assess left ventricular structure, myocardial thickness, cardiac function, and remodeling characteristics. The study focuses on the relationship between diabetes-associated metabolic disturbances and cardiac structural and functional changes. The findings emphasize the importance of comprehensive clinical and echocardiographic assessment for evaluating cardiovascular status in patients with type 2 diabetes mellitus receiving sodium-glucose cotransporter-2 inhibitor therapy.

Keywords: Type 2 diabetes mellitus, sodium-glucose cotransporter-2 inhibitors, cardiac remodeling, left ventricle, cardiac function, echocardiography, myocardial remodeling, cardiovascular system.

**СТРУКТУРНО-ФУНКЦИОНАЛЬНОЕ СОСТОЯНИЕ СЕРДЦА И ПРОЦЕССЫ
РЕМОДЕЛИРОВАНИЯ У ПАЦИЕНТОВ С САХАРНЫМ ДИАБЕТОМ 2-ГО ТИПА,
ПОЛУЧАЮЩИХ ТЕРАПИЮ ИНГИБИТОРАМИ SGLT2**

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Аннотация: В статье рассматриваются структурно-функциональное состояние сердца и процессы ремоделирования миокарда у пациентов с сахарным диабетом 2-го типа, получающих терапию ингибиторами натрий-глюкозного котранспортера 2-го типа. Для оценки состояния левого желудочка, толщины миокарда, сердечной функции и признаков ремоделирования используются клинические и эхокардиографические показатели. Особое внимание уделяется взаимосвязи метаболических нарушений, связанных с сахарным диабетом, со структурными и функциональными изменениями сердца. Полученные данные подчеркивают важность комплексной клинико-эхокардиографической оценки сердечно-сосудистого состояния пациентов с сахарным диабетом 2-го типа, получающих терапию ингибиторами натрий-глюкозного котранспортера 2-го типа.

Ключевые слова: Сахарный диабет 2-го типа, ингибиторы натрий-глюкозного котранспортера 2-го типа, ремоделирование сердца, левый желудочек, функция сердца, эхокардиография, ремоделирование миокарда, сердечно-сосудистая система.

SGLT2 INGIBITORLARI QABUL QILUVCHI 2-TUR QANDLI DIABETLI BEMORLARDA YURAKNING STRUKTURAVIY-FUNKSIONAL HOLATI VA REMODELLANISH JARAYONLARI

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Annotatsiya: Ushbu maqolada 2-tur qandli diabet bilan og'rig'an va natriy-glyukoza kotransporteri 2-tur ingibitorlari bilan davolanayotgan bemorlarda yurakning strukturaviy-funksional holati hamda miokard remodelanish jarayonlari yoritilgan. Chap qorincha tuzilishi, miokard qalinligi, yurak funksiyasi va remodelanish belgilarini baholashda klinik hamda exokardiografik ko'rsatkichlardan foydalanilgan. Tadqiqotda qandli diabet bilan bog'liq etabolic buzilishlarning yurakdagi strukturaviy va funksional o'zgarishlar bilan bog'liqligiga e'tibor qaratilgan. Olingan ma'lumotlar 2-tur qandli diabetli, natriy-glyukoza kotransporteri 2-tur ingibitorlari bilan davolanayotgan bemorlarda yurak-qon tomir holatini kompleks klinik va exokardiografik baholash muhimligini ko'rsatadi.

Kalit so'zlar: 2-tur qandli diabet, natriy-glyukoza kotransporteri 2-tur ingibitorlari, yurak remodelanishi, chap qorincha, yurak funksiyasi, exokardiografiya, miokard remodelanishi, yurak-qon tomir tizimi.



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Introduction

Cardiac structural and functional alterations represent an important aspect of the long-term cardiovascular consequences of type 2 diabetes mellitus. Persistent metabolic disturbances may influence myocardial tissue, ventricular geometry, and cardiac performance, resulting in progressive remodeling of the heart. These changes may develop gradually and can be detected through clinical and echocardiographic assessment before the appearance of pronounced cardiovascular symptoms. Sodium-glucose cotransporter-2 inhibitors are increasingly used in patients with type 2 diabetes mellitus, and their potential effects on cardiovascular function have become an important area of clinical research. Evaluation of myocardial structure, left ventricular geometry, and functional parameters in patients receiving these medications may provide valuable information regarding cardiac remodeling. Echocardiography enables the assessment of ventricular dimensions, wall thickness, myocardial function, and other structural characteristics, making it an important method for studying cardiac changes in diabetes. Therefore, investigation of the structural and functional state of the heart and remodeling processes in patients with type 2 diabetes mellitus receiving sodium-glucose cotransporter-2 inhibitor therapy is relevant for a comprehensive assessment of cardiovascular involvement in this patient population.

Relevance

Cardiovascular complications are a major concern in patients with type 2 diabetes mellitus. Persistent metabolic disturbances may affect myocardial structure, left ventricular geometry, and cardiac function, leading to progressive remodeling of the heart. Early structural and functional changes may occur without pronounced clinical manifestations, making their timely assessment clinically important. Sodium-glucose cotransporter-2 inhibitors are increasingly used in the management of type 2 diabetes mellitus, and their potential cardiovascular effects have become an important area of clinical research. Evaluation of cardiac remodeling and functional parameters in patients receiving these medications may provide valuable information about changes in myocardial status. Echocardiographic assessment of left ventricular dimensions, wall thickness, ventricular geometry, and functional parameters can help identify structural and functional abnormalities.

Aim

The aim of the study is to assess the structural and functional state of the heart and characterize myocardial remodeling processes in patients with type 2 diabetes mellitus receiving sodium-glucose cotransporter-2 inhibitor therapy using clinical and echocardiographic parameters.

Main part

Type 2 diabetes mellitus is associated with progressive structural changes in the cardiovascular system. Persistent hyperglycemia can contribute to metabolic disturbances that affect myocardial tissue and vascular function. Insulin resistance, oxidative stress, chronic inflammation, and endothelial dysfunction may influence the structure and mechanical properties of the myocardium. These processes can lead to changes in left ventricular geometry, myocardial thickness, and ventricular compliance. Structural alterations may develop gradually and can occur before the appearance of clinically significant cardiovascular symptoms. Increased myocardial stiffness may impair ventricular relaxation and subsequently affect cardiac filling. Changes in left ventricular dimensions may also reflect the progression of diabetic cardiovascular involvement. In some patients, structural remodeling can be accompanied by changes in systolic and diastolic performance. The severity of these changes may depend on the duration of diabetes, metabolic control, associated cardiovascular risk factors, and the presence of other complications. Echocardiography provides an important method for assessing cardiac morphology and detecting changes in ventricular structure. Measurements of ventricular dimensions, wall thickness, and myocardial geometry can provide information about structural cardiac status. Assessment of these parameters is particularly relevant in patients with long-standing type 2 diabetes mellitus. Early recognition of structural abnormalities may allow closer cardiovascular monitoring and more comprehensive clinical assessment. Thus, cardiac



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structural changes represent an important component of diabetic cardiovascular involvement and should be considered when evaluating patients with type 2 diabetes mellitus.

Myocardial remodeling in type 2 diabetes mellitus develops as a result of complex metabolic, molecular, and hemodynamic mechanisms. Chronic hyperglycemia promotes the formation of advanced glycation products, which can alter the properties of myocardial proteins and extracellular matrix components. Insulin resistance may modify cardiac energy metabolism and affect the ability of cardiomyocytes to efficiently utilize available energy substrates. Increased oxidative stress can contribute to cellular injury and disturbances in myocardial function. Chronic low-grade inflammation may additionally influence myocardial tissue and promote structural remodeling. Changes in the extracellular matrix and increased deposition of collagen can contribute to myocardial stiffness. These processes may reduce ventricular compliance and impair normal relaxation of the left ventricle. At the same time, changes in vascular resistance and blood pressure may increase the hemodynamic load on the myocardium. The combined effects of metabolic and hemodynamic abnormalities can gradually modify ventricular geometry and cardiac performance. Myocardial remodeling may initially occur without severe clinical manifestations, making instrumental assessment particularly important. Echocardiographic parameters can help identify structural and functional consequences of these processes. The evaluation of ventricular wall thickness, chamber dimensions, and functional characteristics can provide information about the degree of remodeling. Understanding the mechanisms of diabetic myocardial remodeling is important for interpreting cardiac changes in patients with type 2 diabetes mellitus.

Sodium-glucose cotransporter-2 inhibitors are an important class of glucose-lowering medications used in the management of type 2 diabetes mellitus. Their primary pharmacological action is associated with inhibition of glucose reabsorption in the renal proximal tubules, resulting in increased urinary glucose excretion. This mechanism contributes to improved glycemic control and may also influence several metabolic and hemodynamic parameters. Patients receiving sodium-glucose cotransporter-2 inhibitor therapy may differ in age, duration of diabetes, metabolic control, cardiovascular risk profile, and concomitant treatment. These characteristics should be considered when evaluating cardiac structure and function. Clinical assessment may include evaluation of diabetes duration, blood pressure, body mass index, glycemic parameters, and the presence of cardiovascular complications. The cardiovascular relevance of this therapeutic class has generated considerable interest because changes in fluid balance and metabolic conditions may influence cardiac workload. Assessment of patients before and during therapy can therefore provide useful information about changes in their clinical status. The evaluation of symptoms associated with cardiac dysfunction is also important when studying diabetic patients receiving these medications. Clinical information should be interpreted together with instrumental findings to obtain a comprehensive assessment of cardiovascular status. In this context, echocardiographic evaluation provides additional information about myocardial structure and ventricular function. The combination of clinical and instrumental assessment allows more detailed characterization of patients receiving sodium-glucose cotransporter-2 inhibitor therapy. Such an approach is particularly relevant when investigating cardiac remodeling and functional changes associated with type 2 diabetes mellitus. Therefore, clinical characterization represents an essential component of studies evaluating the cardiovascular aspects of sodium-glucose cotransporter-2 inhibitor therapy.

Echocardiography is one of the principal non-invasive methods used to evaluate cardiac structure and function. In patients with type 2 diabetes mellitus, echocardiographic examination can provide important information about changes in left ventricular morphology and performance. Assessment of left ventricular dimensions allows evaluation of ventricular geometry and chamber characteristics. Measurement of interventricular septal and posterior wall thickness can provide information about myocardial structural changes. Left ventricular mass and related parameters may also be useful for characterizing ventricular remodeling. Functional assessment includes evaluation



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of systolic performance as well as parameters associated with ventricular relaxation and filling. The combination of structural and functional measurements provides a comprehensive description of the cardiac state. Echocardiographic findings can be interpreted together with clinical characteristics and metabolic parameters. This approach makes it possible to identify relationships between diabetes-related metabolic abnormalities and cardiac changes. Repeated echocardiographic assessment can also be used to evaluate changes in cardiac parameters over time. In patients receiving sodium-glucose cotransporter-2 inhibitor therapy, echocardiographic evaluation may help characterize structural and functional cardiac changes during treatment. Particular attention can be given to left ventricular geometry, myocardial thickness, ventricular dimensions, and functional indices. The use of standardized echocardiographic measurements improves the comparability of findings between patients and observation periods. Therefore, echocardiography represents an important methodological component in the assessment of myocardial remodeling in patients with type 2 diabetes mellitus. Its clinical application allows structural abnormalities to be detected and functional cardiac status to be characterized without invasive procedures.

Evaluation of cardiac remodeling during sodium-glucose cotransporter-2 inhibitor therapy requires a comprehensive assessment of both structural and functional cardiac parameters. The analysis can include clinical characteristics together with echocardiographic measurements of the left ventricle. Structural parameters such as ventricular dimensions, myocardial wall thickness, and ventricular geometry provide information about the morphological state of the heart. Functional parameters complement these findings by describing the mechanical performance of the myocardium. Comparison of clinical and echocardiographic characteristics can help identify changes associated with the treatment period. In patients with type 2 diabetes mellitus, such evaluation is particularly important because cardiovascular changes may develop gradually and remain clinically silent. Assessment of cardiac remodeling may therefore provide additional information beyond routine evaluation of glycemic control. Changes in ventricular structure can be considered together with metabolic and clinical characteristics of the patient. Echocardiographic monitoring may also help determine whether functional abnormalities accompany structural remodeling. The interpretation of these findings requires consideration of diabetes duration, cardiovascular risk factors, concomitant diseases, and other medications. A comprehensive approach reduces the possibility of interpreting an isolated cardiac parameter without appropriate clinical context. Evaluation of cardiac structure and function can contribute to a better understanding of cardiovascular involvement in type 2 diabetes mellitus. It also provides a basis for characterizing the cardiac status of patients receiving sodium-glucose cotransporter-2 inhibitors. The combination of clinical examination and echocardiographic assessment is therefore valuable for studying myocardial remodeling. Such an approach can provide clinically relevant information about structural and functional cardiac changes during therapy.

Results

A total of 60 patients with type 2 diabetes mellitus were included in the study. The patients were divided into two groups: 30 patients (50.0%) received sodium-glucose cotransporter-2 inhibitor therapy, while 30 patients (50.0%) received standard antidiabetic treatment. The mean age of the study population was 56.8 ± 7.4 years. The SGLT2 inhibitor group included 17 men (56.7%) and 13 women (43.3%), whereas the comparison group consisted of 16 men (53.3%) and 14 women (46.7%). The mean duration of type 2 diabetes mellitus was 8.2 ± 3.1 years in the treatment group and 8.5 ± 3.4 years in the comparison group.

Echocardiographic assessment demonstrated differences in several structural and functional parameters between the groups. The mean left ventricular ejection fraction was $58.7 \pm 4.2\%$ in patients receiving SGLT2 inhibitors compared with $55.9 \pm 4.8\%$ in the comparison group. Increased left ventricular wall thickness was observed in 8 patients (26.7%) in the SGLT2 inhibitor group and 12 patients (40.0%) in the comparison group. Signs of left ventricular structural remodeling were identified in 9 patients (30.0%) receiving SGLT2 inhibitors and in 15 patients (50.0%) receiving



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standard therapy. Analysis of diastolic functional parameters showed that impaired relaxation was detected in 10 patients (33.3%) in the SGLT2 inhibitor group compared with 16 patients (53.3%) in the comparison group. The mean E/e' ratio was 9.8 ± 2.1 and 11.6 ± 2.7 , respectively. The average left ventricular mass index was 101.4 ± 15.6 g/m² in the treatment group and 110.8 ± 17.2 g/m² in the comparison group. These findings indicate differences in structural and functional cardiac characteristics between patients receiving SGLT2 inhibitor therapy and those receiving standard treatment.

Clinical signs suggestive of heart failure were recorded in 7 patients (23.3%) in the SGLT2 inhibitor group and 13 patients (43.3%) in the comparison group. The proportion of patients with peripheral edema was 10.0% and 23.3%, respectively, while exertional dyspnea was reported by 20.0% of patients in the treatment group and 36.7% in the comparison group. Overall, the observed clinical and echocardiographic parameters demonstrated differences in cardiac structural and functional characteristics between the study groups. These results suggest that patients with type 2 diabetes mellitus receiving sodium-glucose cotransporter-2 inhibitor therapy may demonstrate more favorable structural and functional cardiac characteristics compared with patients receiving standard antidiabetic treatment. The differences were particularly observed in parameters reflecting left ventricular remodeling, myocardial function, and clinical manifestations associated with cardiac dysfunction. Further assessment using standardized echocardiographic parameters and appropriate statistical analysis is necessary to determine the significance of these differences.

Discussion

The present findings demonstrate that cardiac structural and functional alterations are relevant components of cardiovascular involvement in patients with type 2 diabetes mellitus. In the presented sample of 60 patients, differences were observed between those receiving sodium-glucose cotransporter-2 inhibitor therapy and those receiving standard antidiabetic treatment. The mean left ventricular ejection fraction was higher in the treatment group ($58.7 \pm 4.2\%$) than in the comparison group ($55.9 \pm 4.8\%$), indicating a more preserved systolic functional profile among patients receiving sodium-glucose cotransporter-2 inhibitors. Structural assessment also revealed differences in the frequency of left ventricular remodeling. Structural remodeling was identified in 9 patients (30.0%) in the sodium-glucose cotransporter-2 inhibitor group compared with 15 patients (50.0%) in the comparison group. Similarly, increased left ventricular wall thickness was observed less frequently in the treatment group, occurring in 8 patients (26.7%), compared with 12 patients (40.0%) in the standard-treatment group. These findings indicate that structural characteristics of the left ventricle should be considered when evaluating cardiovascular status in patients with long-standing type 2 diabetes mellitus.

The assessment of diastolic function demonstrated clinically relevant differences between the groups. Impaired relaxation was identified in 10 patients (33.3%) receiving sodium-glucose cotransporter-2 inhibitors, whereas it was observed in 16 patients (53.3%) receiving standard therapy. The mean E/e' ratio was also lower in the treatment group (9.8 ± 2.1) than in the comparison group (11.6 ± 2.7). Since this parameter is used in the assessment of left ventricular filling conditions, the observed difference may indicate a more favorable diastolic functional profile among patients receiving sodium-glucose cotransporter-2 inhibitor therapy. The clinical findings were consistent with the echocardiographic observations. Clinical signs suggestive of heart failure were recorded in 7 patients (23.3%) in the treatment group and in 13 patients (43.3%) in the comparison group. Exertional dyspnea was reported by 20.0% and 36.7% of patients, respectively, while peripheral edema was observed in 10.0% and 23.3%. The lower frequency of these manifestations in the sodium-glucose cotransporter-2 inhibitor group corresponds to the differences observed in selected echocardiographic parameters.

The left ventricular mass index was also lower among patients receiving sodium-glucose cotransporter-2 inhibitors, with values of 101.4 ± 15.6 g/m² compared with 110.8 ± 17.2 g/m² in the



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comparison group. This difference, together with the lower frequency of structural remodeling, suggests that assessment of ventricular geometry may provide additional information when characterizing cardiac changes in patients with type 2 diabetes mellitus. The presented clinical and echocardiographic findings indicate differences in cardiac structural and functional characteristics between patients receiving sodium-glucose cotransporter-2 inhibitor therapy and those receiving standard treatment. However, these observations should be interpreted cautiously because the presented data do not include statistical significance values, confidence intervals, or adjustment for potential confounding factors. Therefore, the observed differences should be considered as descriptive findings rather than definitive evidence of a causal treatment effect. Further studies with larger patient populations, standardized follow-up periods, and appropriate statistical analysis are required to clarify the relationship between sodium-glucose cotransporter-2 inhibitor therapy and cardiac remodeling in patients with type 2 diabetes mellitus.

Conclusion

The presented findings indicate that cardiac structural and functional changes are important manifestations of cardiovascular involvement in patients with type 2 diabetes mellitus. Patients receiving sodium-glucose cotransporter-2 inhibitor therapy demonstrated more favorable values of several echocardiographic and clinical parameters compared with the standard-treatment group. The mean left ventricular ejection fraction was higher, while the frequency of left ventricular remodeling and impaired relaxation was lower among patients receiving sodium-glucose cotransporter-2 inhibitors. The lower E/e' ratio and left ventricular mass index also indicate differences in diastolic and structural cardiac characteristics between the groups. Clinical manifestations associated with heart failure were observed less frequently in the treatment group. These findings support the importance of comprehensive clinical and echocardiographic assessment of patients with type 2 diabetes mellitus. However, the presented results should be interpreted as descriptive findings because statistical significance and adjustment for potential confounding factors were not provided. Further studies involving larger patient populations and longer observation periods are needed to clarify the relationship between sodium-glucose cotransporter-2 inhibitor therapy and cardiac remodeling.

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