



RHEOLOGICAL PARAMETERS OF CAROTID CIRCULATION IN METABOLIC SYNDROME WITH OR WITHOUT DIABETES MELLITUS

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SUMMARY – The aim of this research was to examine the rheological parameters of carotid arteries and the frequency of abnormal values in patients with metabolic syndrome (MetS) with and without diabetes mellitus (DM). The sample consisted of 90 subjects and was divided into two equal groups. The first group consisted of patients with MetS but without DM, while the second group had both MetS and DM. We used the values of the peak systolic velocity (PSV) as a reference for pathology. The results showed pathological values of PSV in the right internal carotid artery (ICA) in twelve patients in the MetS + DM group. The study found that the incidence of pathological rheological parameters was higher in subjects with MetS + DM as compared to those with only MetS. Subjects with MetS + DM had higher values of maximum acceleration during systole in various carotid arteries. A subject with MetS + DM also showed total flow obstruction in the left and internal carotid artery (ICA) and a severe narrowing of the right ICA, indicating the presence of carotid artery disease. The study also found that nearly two-thirds of subjects with MetS + DM had pathological values of PSV in the right ICA and slightly fewer in the left ICA. Research on French populations has shown similar results. Eleven patients had pathological values in the left ICA. The frequency of the carotid rheological parameters' abnormalities was significantly higher in the MetS with DM patient group. The frequency of abnormalities in the rheological parameters of carotid circulation was significantly higher in patients with MetS and DM (as compared to non-diabetic patients). In our study, pathological changes were generally more susceptible to ICA. This indicates the importance of screening the rheological parameters of subjects with MetS for the prevention and treatment of cerebrovascular disease.

Keywords: *Rheological parameters; Carotid occlusive disease; Metabolic syndrome; Carotid circulation; Diabetes mellitus type 2*

Introduction

Metabolic syndrome (MetS) is a risk factor for cardiovascular disease and type 2 diabetes due to the existence of abdominal obesity and insulin resistance¹.

Vascular pathologies are very common in patients with MetS, especially in those who also have diabetes

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mellitus (DM). As a result of the vascularization of important organs, the head and neck carotid arteries and their disease are important clinical entities. The criterion for diagnosing MetS varies significantly between various professional societies.

According to the guidelines of the National Cholesterol Education Program – Adult Treatment Panel III (NCEP-ATP III), obesity is defined as the most important criterion for the diagnosis of MetS (defined as waist size >102cm for men and >88cm for women). The other criteria for establishing metabolic syndrome include:

- *hyperlipoproteinemia* (triglycerides ≥ 1.69 mmol/L or high-density lipoprotein concentrations ≤ 1.04 mmol/L for men and ≤ 1.29 mmol/L for women);
- *Hypertension* (systolic ≥ 130 mmHg or diastolic ≥ 85 mmHg); and
- *hyperglycemia* (fasting glucose concentration in blood glucose ≥ 5.6 mmol/L)

The presence of obesity (defined by waist size) and two other components is sufficient for diagnosing MetS. If obesity is not present, all three of the above components must be present for a diagnosis of MetS²⁻⁴.

DM is a systemic metabolic disorder that is characterized by permanently elevated glucose levels in the blood. Hereditary factors causing reduced secretion and/or reduced effects of the hormone insulin are mainly responsible for developing DM. This discrepancy in secretion or acting interferes with the metabolism of carbohydrates, fats, and proteins in the body and, in the long term, affects the structure and function of blood vessels, nerves, and other vital organ systems^{5,6}.

Carotid disease in patients with MetS usually manifests as atherosclerotic stenosis and occlusion⁷.

Subjects and Methods

This study sought to determine the rheological parameters of carotid arteries in subjects with MetS, diagnosed within the past five years, with or without DM.

The study was approved by the Ethics Committee of the University Clinical Center Tuzla, Bosnia and Herzegovina. This prospective observational-comparative study was performed at the Department for Cardiovascular Diseases – University Clinical Center Tuzla, and 90 patients were enrolled.

Patients

MetS diagnosis was made utilizing NCEP-ATP III criteria². The recruitment of patients was based on the following available medical history data: information on DM, the results of anthropometric measurements (waist size), values of blood pressure, and laboratory tests (serum triglycerides and high-density lipoproteins).

In addition to history, we used an oral glucose tolerance test to surely differentiate whether a patient with MetS also suffers from DM. Afterward, we divided the patients into two groups: 1) patients with MetS and normal glucoregulation and 2) patients with MetS and abnormal glucoregulation (Table 1).

The exclusion criteria were as follows: patients with diabetes mellitus type 1; patients who had surgery or injury to deeper tissues and/or who had a tumor process localized in the areas of carotid arterial delivery; and patients with hereditary or autoimmune disease with vascular symptoms.

Outcome measure

The extent of atherosclerotic disease on the carotid artery was determined by color Doppler ultrasonography, and stenosis was primarily diagnosed using pulse wave section measuring values of peak systolic velocity (PSV) on the common carotid artery (CCA), external carotid artery (ECA), and internal carotid artery (ICA). When there was no flow and no PSV, we considered this to be an occlusion and confirmed it secondarily by the morphological characteristics of the blood vessels. Doppler ultrasonography was performed according to standard procedure: at room temperature, in a horizontal position by the side of the patient, and with Siemens (SONOLINE G60S, 2003) linear probes (7.5 MHz).

Statistics

In addition to standard descriptive statistical methods, the statistical analysis was conducted using the Mann-Whitney U test⁸. The normality of the data was assessed using the Kolmogorov-Smirnov goodness-of-fit test. We conducted a chi-square test to determine if there was a statistical difference between the two groups.

A significance level of 5% was applied, while the analyses were performed using Microsoft Office Excel 2007 and the Arcus Quickstat Biomedical program for statistical data processing.

Table 1. Study groups

	First group (MetS with normal glucoregulation)	Second group (MetS with abnormal glucoregulation)
Sex	45 patients: 27 male, 18 female	45 patients: 35 male, 10 female
Age (Years)	63.4 (44-77) ± 8.7	64.2 (52-76) ± 6.2
Blood sugar measured fasting (mmol/L)	5.7 (9.2-4.1)	8.2 (14.2- 5.1)
Waist circumference (cm)	90.1 (121-76)	100.3 (135-81)
Blood pressure (mmHg)	125.8 (170-95) / 80 (100-55)	133.7 (170-110) / 82.6 (100-55)
High-density lipoproteins (mg/dL)	1.1 (1.5-0.8)	0.9 (1.4-0.7)
Triglycerides (mmol/L)	2.6 (4.9-1.5)	2.5 (4.5-1.3)

MetS = metabolic syndrome

Table 2. PSV parameters of CCA, ICA and ECA in the two study groups

Artery	MetS only			MetS+DM			p
	Median	Min	Max	Median	Min	Max	
ACC dex	60	40	90	70	40	80	0.1918
ACI dex	80	50	240	110	60	270	0.0015
ACE dex	80	50	180	80	60	170	0.3089
ACC sin	60	40	90	60	40	90	0.6553
ACI sin	90	60	220	110	0	240	0.4137
ACE sin	70	60	200	80	60	120	0.3399

PSV = peak systolic velocity – values are expressed in cm/s; CCA = common carotid artery; ICA = internal carotid artery; ECA = external carotid artery; MetS = metabolic syndrome; DM = diabetes mellitus; ACC dex = right common carotid artery (Latin: *arteria carotis communis dextra*); ICA dex = right internal carotid artery (Latin: *arteria carotis interna dextra*); ACE dex = right external carotid artery (Latin: *arteria carotis externa dexter*); ACC sin = left common carotid artery (Latin: *arteria carotis communis sinistra*); ICA sin = left internal carotid artery (Latin: *arteria carotis interna sinistra*); ACE sin = left external carotid artery (Latin: *arteria carotis externa sinistra*); Min = minimum; Max = maximum;

Results

Table 2 shows the measured PSV of carotid arteries at all sites (CCA, ICA, ECA) for both groups, a total of 90 patients, and includes calculated median values.

Table 2 compares the median, minimum, and maximum values of rheological parameters (ACC dex., ICA dex., ACE dex., ACC sin., ICA sin., and ACE sin.). This comparison is made for the two groups of patients: those with MetS only and those with both MetS and DM. The p-values are also given for each

rheological parameter to indicate the level of significance between the two groups.

For example, for the rheological parameter ACC dex., the median value for the group with MetS only is 60, and the minimum value is 40. The maximum value is 90. The median value for the group with MetS + DM is 70, and the minimum value is 40. The maximum value is 80. The p-value for this parameter is 0.1918, indicating that the difference between the two groups is not significant ($p > 0.05$).

Similarly, for ICA dex., the median value for the group with MetS only is 80, and the minimum value

is 50. The maximum value is 240. The median value for the group with MetS + DM is 110, with a percentile range of 90 to 140, and a minimum value of 60. The maximum value is 270. The p-value for this parameter is 0.0015, indicating that the difference between the two groups is significant ($p < 0.05$).

Distribution of pathological results in the groups

A distribution of pathological results refers to the distribution or spread of abnormal or pathological values found in different groups. In this context, the groups are patients with MetS only and patients with both MetS and DM. By analyzing the distribution of pathological results, we can understand the frequency and pattern of abnormality in each group and determine whether there are any significant differences between the two groups. By comparing the distributions, we draw conclusions about the relationship between MetS, DM, and the pathological results of the rheological parameters of the carotid arteries. There are significant differences between MetS and MetS + DM (chi-square test, see Table 3).

Table 3. Distribution of PSV pathologic findings in subjects with MetS only and subjects with MetS + DM

Parameter of variable		χ^2
Maximum speed flow of blood in systole (PSV)	Right internal carotid artery	<0.0001
	Right external carotid artery	0.2941
	Left internal carotid artery	0.1405
	Left external carotid artery	0.2235

PSV = peak systolic velocity; MetS = metabolic syndrome; DM = diabetes mellitus

As we can see from Table 2, there is a significant difference between the ICA on the right side ($\chi^2 < 0.0001$), while the same cannot be said for the ECA on the right side ($\chi^2 = 0.2941$). We cannot say that there is a significant difference in the carotid arteries on the left side.

Rheological parameters in subjects with non-diabetic metabolic syndrome

The results of the MetS-only subjects have shown the presence of some pathological values of PSV of the right ICA in almost one-third of cases (30.0%),

while the same group of thirteen subjects (43.3%) had abnormal values of PSV in the left ICA.

Five subjects with MetS were found to have some pathological values of PSV in the right ACE (16.6%). Three respondents (10.0%) in the same group had pathological values in the left ACE.

As a result of the pathological measurements obtained at the ICA and ACE in subjects with MetS alone, we extrapolate the significant impact of MetS on cardiovascular disease. Several studies have established the connection between MetS and an increased risk of cardiovascular disease^{8,9}.

Hence, there is an association between MetS and disorders of carotid circulation. Of course, we cannot exclude age as an independent factor contributing to this disorder. This study, however, was unable to estimate this, due to limited number of cases.

In the prospective Bruneck study, subjects with MetS had a more rapid progression of carotid artery disease by forming atherosclerotic plaques and consequent luminal narrowing⁹.

The study found that the incidence of pathological rheological parameters was higher in subjects with MetS + DM compared to those with only MetS. Subjects with MetS + DM had higher values of maximum acceleration during systole in various carotid arteries. A subject with MetS + DM also showed total flow obstruction in the left ICA and a severe narrowing of the right ICA, indicating the presence of carotid artery disease. The study also found that nearly two-thirds of subjects with MetS + DM had pathological values of PSV in the right ICA and slightly fewer in the left ICA. Research of French populations has shown similar results.

Discussion

Detecting vascular pathologies at an early stage via color Doppler ultrasonography can significantly contribute to the treatment and prevention of their complications, especially if recent reports indicate that there is no significant difference in the results obtained using CDUs and CTAs¹¹. The progression of these complications has negative repercussions on the quality of life of patients and highlights the importance of their early detection and treatment.

When determining disease severity, the role of fast and inexpensive ultrasound diagnostics should not be underestimated. Some studies on color duplex ultrasonography have shown sensitivity of 90-96% and specificity of 86-93%⁸.

MetS is a common condition that is associated with an increased risk of developing cardiovascular disease¹². In our study of 90 patients with MetS, we found that males were predominant, accounting for 68.3% of the sample. This is consistent with previous studies of French and German populations, which also found a higher prevalence of MetS in men.

We also found that the highest median values of PSV were recorded in the right and left ICAs. This suggests that these arteries may be particularly affected by the vascular complications associated with MetS.

Interestingly, we found that the prevalence of MetS in female patients was similar to that in Spain and Italy, countries with populations at high cardiovascular risk. This highlights the need for early detection and treatment of MetS in both men and women, to prevent the negative consequences of this condition on cardiovascular health.

Conclusion

In conclusion, our study shows that the presence of both MetS and DM results in a higher incidence of pathological rheological parameters compared to having MetS alone. These findings emphasize the importance of early detection and monitoring of cardiovascular risk factors in individuals with MetS and DM. The use of ultrasound as a diagnostic tool in such cases can provide valuable information for the management of these conditions and help prevent their progression towards more severe stages.

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Sažetak

REOLOŠKI PARAMETRI CIRKULACIJE KAROTIDNIH ARTERIJA U METABOLIČKOM SINDROMU S ILI BEZ DIJABETESA MELITUSA

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Cilj je ovog istraživanja bio ispitati reološke parametre karotidnih arterija i učestalost abnormalnih vrijednosti kod pacijenata s metaboličkim sindromom (MetS) s i bez diabetesa melitusa (DM). Uzorak se sastojao od 90 ispitanika i bio je podijeljen u dvije jednake skupine. Prvu skupinu činili su pacijenti s MetS-om, ali bez DM-a, dok je druga skupina imala i MetS i DM. Kao referentnu vrijednost za patologiju koristili smo vrijednosti vršne sistoličke brzine (VSB). Rezultati su pokazali patološke vrijednosti VSB-a u desnoj unutarnjoj karotidnoj arteriji (UKA) kod dvanaest pacijenata u skupini MetS + DM. Studija je utvrdila da je incidencija patoloških reoloških parametara bila veća kod ispitanika s MetS + DM-om u usporedbi s onima koji su imali samo MetS. Ispitanici s MetS + DM-om imali su veće vrijednosti maksimalnog ubrzanja tijekom sistole u različitim karotidnim arterijama. Jedan ispitanik s MetS + DM-om također je pokazao potpunu opstrukciju protoka u lijevoj UKA-i i teško suženje desne UKA-e, što ukazuje na prisutnost bolesti karotidnih arterija. Studija je također utvrdila da je gotovo dvije trećine ispitanika s MetS + DM-om imalo patološke vrijednosti VSB-a u desnoj UKA-i, a nešto manji broj u lijevoj UKA-i. Istraživanja na francuskim populacijama pokazala su slične rezultate. Jedanaest pacijenata imalo je patološke vrijednosti u lijevoj UKA-i. Učestalost abnormalnosti karotidnih reoloških parametara bila je značajno veća u skupini pacijenata s MetS-om i DM-om. Učestalost abnormalnosti reoloških parametara karotidne cirkulacije bila je značajno veća u pacijenata s MetS-om i DM-om (u usporedbi s nedijabetičnim pacijentima). U našem istraživanju, patološke promjene bile su općenito osjetljivije na UKA-e. Ovo ukazuje na važnost probira reoloških parametara kod ispitanika s MetS-om radi prevencije i liječenja cerebrovaskularnih bolesti.

Ključne riječi: Reološki parametri; Karotidna okluzivna bolest; Metabolički sindrom; Cirkulacija karotidnih arterija; Dijabetes melitus tip 2