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Triglyceride-glucose index for predicting in-stent restenosis in patients with iliac artery stenosis after percutaneous intervention with stents

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Abstract. – OBJECTIVE: To evaluate the triglyceride-glucose index (TyG index) for predicting in-stent restenosis in patients with iliac artery stenosis after percutaneous intervention with stents.

PATIENTS AND METHODS: Subjects with iliac artery stenosis, who underwent an iliac stent intervention and were followed up for at least 2 years were included in the study. Subjects were grouped according to TyG index (Group A, TyG index ≤8.848; Group B 8.849 ≤TyG index ≤9.382 and Group C TyG index ≥9.383). The subject's baseline characteristics, blood parameters, claudication distance, Transatlantic Intersociety Consensus classification, target lesion localization, stent direction, number of stents that were applied, and stent type were noted. Pre- and 1st and 2nd-year post-procedure Rutherford statuses, ankle-brachial index, and stenosis degree were recorded. To calculate the sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV), Group B and Group C were combined and compared with Group A.

RESULTS: In total, 255 subjects were evaluated (female, n=77-30.2%, male, n=178-69.8%). The mean age of the subjects was 66.00±10.00 years (range from 39 to 90 years). The pre-procedure Rutherford measurements were significantly different among the groups (p=0.001). The rates of mild claudication and resting pain in Group A were higher than those in Groups B and C. The rate of moderate claudication in Group C was higher than that in Groups A and B. The rate of severe claudication in Group B was higher than that in Groups A and C. One year after the procedure, there were more asymptomatic cases in Group A than in Groups B and C (p=0.001). The rate of mild claudication in Group C was lower than that in Groups A and B. The rate of moderate claudication in Group C was higher than that in Group A. The rate of severe claudication in Group C was higher than that in Groups A and B. Two years after the procedure, the Rutherford measurements and the rates of mild claudication in Groups A and B were higher than those in Group C. The rate of severe claudication in Group C was higher than that in Groups A and B (p=0.001). One year after the procedure, the computed tomography angiography (CTA) measurements and the rate of full patency in Group A were higher than that in Groups B and C. The rate of 0-50% stenosis in Group B was higher than that in Groups A and C. The rate of 50-70% stenosis in Group C was higher than that in Group A. Two years after the procedure, the CTA measurements and the rates of 70-99% stenosis and 100% occlusion in Group C were higher than those in Groups A and B. The TyG index has high specificity and NPV. However, specificity and PPV levels were found to be quite low.

CONCLUSIONS: The TyG index was found to be an easy-to-use marker for predicting in-stent restenosis in patients with iliac artery stenosis after percutaneous intervention with stents.

Key Words:
Triglyceride-glucose index, Percutaneous intervention, Stent, Sensitivity, Specificity.

Introduction

Peripheral artery disease (PAD) is a chronic multifactorial disease that is prevalent worldwide. The prevalence of PAD has been reported to be between 2% and 13%[1,2]. It is an important issue for all health systems with regard to its prevention, diagnosis, treatment, and follow-up[3].

Several factors have been studied in the past, including insulin resistance. Insulin resistance (IR) is regarded as one of the main risk factors

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for both PAD and restenosis after appropriate intervention[4-6]. The triglyceride-glucose index (TyG index), which is regarded as a marker for insulin resistance, is calculated based on fasting triglyceride (TG) and fasting blood glucose. The formula is the natural logarithm (Ln) of [fasting triglyceride (mg/dL)×fasting blood glucose (mg/dL)/2][6]. TyG was found[5] to be associated with increased atherosclerosis and arterial stiffness. In the literature, the relationship between the TyG index and coronary artery diseases has been well-studied[6-8]. Individuals with a high TyG index have high risks of cardiovascular diseases and coronary events, as well as all-cause and cardiovascular mortality[9,10].

However, there are few studies on PAD. In the present study, we aimed to assess the TyG indexes of subjects with pure iliac stenosis to evaluate their proneness to restenosis events. We also aimed to detect the sensitivity and specificity of the TyG index for predicting restenosis.

Patients and Methods

A retrospective study was performed at the Tertiary Academic Centre, between June 2022 and February 2023. The study protocol was approved by the Ethical Committee of the Bakirkoy Dr. Sadi Konuk Training and Research Hospital (No.: 2023/132). Subjects with iliac artery stenosis, who underwent iliac stent intervention and were followed up for at least 2 years were included in the study.

Subjects with pure iliac stenosis were included. Subjects with concomitant femoral and/or distal popliteal stenosis were excluded from the study. Subjects under the age of 18 years, with an active infection/ulcer in the affected limb, with a previous history of invasive intervention/surgery in the affected limb, subjects who were lost to follow-up, with malignancy, chronic liver/kidney disease or chronic inflammatory disease were also excluded. Subjects were grouped according to TyG index (Group A, TyG index ≤8.848; Group B 8.849 ≤TyG index ≤9.382 and Group C TyG index ≥9.383).

Propensity Matching

Multivariate logistic regression analysis was performed to calculate propensity scores for the 3 groups using the following covariates: age, sex, body mass index, comorbid diseases, hypertension, medications and tobacco use. The Greedy 5-to-1 digit matching technique was then used to select patients with iliac artery stenosis and occlusion by choosing the patients with the nearest propensity score. The C-statistic for this propensity model was 0.82.

Standard Procedure

The procedure was performed by a single vascular surgeon. Before the procedure, a systemic heparin bolus (1 mg/kg) was given. The femoral region was evaluated with a color duplex ultrasound (DUS) system. The common femoral artery (CFA) and vein were identified. The puncture point was marked in the area where the vein and artery separated. After local anesthesia injection with lidocaine hydrochloride 1%, a CFA puncture was performed with an 18 G needle under US guidance. A 6F sheet was replaced with the Seldinger technique. Then, a contrast medium was administered. The vessel was visualized, and the occluded/stenotic segment was detected. The occluded or stenotic segment was passed with a 0.035-inch hydrophilic wire and occlusion catheter (NaviCross™ Catheter, Terumo Interventional Systems, Tokyo, Japan). For pre-dilatation, angioplasty was performed with a drug-free (6-8) mm diameter balloon (Admiral Xtreme PTA Balloon Catheter, Medtronic, Minneapolis, MN, USA) in accordance with the diameter of the vessel. Then, a 6-8 mm balloon expandable stent that was suitable for the diameter of the vessel (Omnlink Elite™, Vascular Balloon-Expandable Stent System, Abbott Laboratories, IL, USA) was applied. Control angiography was performed, and full patency was observed. In cases where a double stent was applied to the same side, the first stent was placed in the proximal part of the occlusion or stenosis. The second stent was placed into the first proximal stent with an overlap of 1 cm, and the distal part was extended to the intact area in the distal region. Then, the process was completed by expanding the balloon inside the stent with the balloon used for pre-dilation, which is suitable for the diameter of the vessel at the intertwined junction. The pre-procedural and post-procedural conventional angiographic measurements of the subjects are presented in Figure 1a and Figure 1b. At the end of the procedure, the sheath was removed. Manual compression of the puncture area achieved hemostasis. A bolus dose of clopidogrel (300 mg) was administered immediately after the procedure. Daily dual antiplatelet therapy with acetylsalicylic acid (100

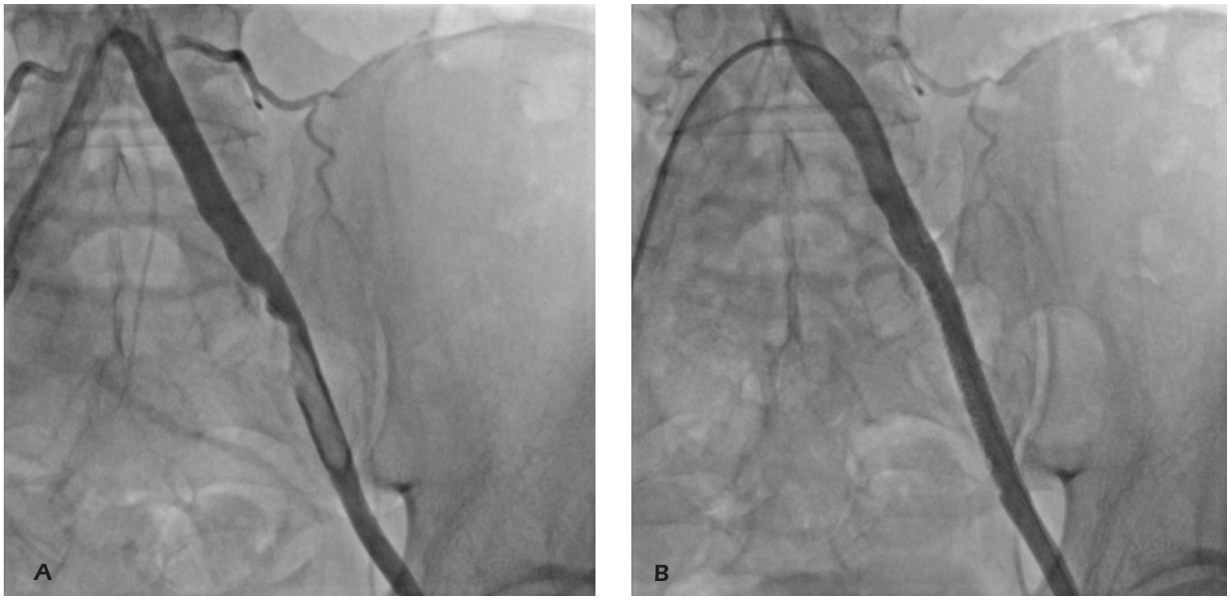

Figure 1. A, Preprocedural conventional angiography of a subject with isolated stenosis and dissection in the left common iliac artery. **B**, Postprocedural conventional angiography of the subject showing full patency after stent application.

mg) and clopidogrel (75 mg) was also given for one year. All subjects received oral statins.

Data Collection

Subjects' baseline characteristics (age, sex, body mass index, comorbid diseases, medications, and tobacco use) were recorded. For blood parameters, hemoglobin A1c (HbA1c), total cholesterol (TC), high-density lipoprotein cholesterol (HDL-C), low-density lipoprotein cholesterol (LDL-C), and hemoglobin levels were noted.

Subjects' claudication distance (0-50 meters, 50 to 100 meters and 100 to 150 meters), TransAtlantic InterSociety Consensus classification (TASC type A, type B, type C or type D), target lesion localization (common iliac, external iliac or common iliac+external iliac), stent direction (right, left or bilateral), number of stents that were applied (1, 2 or 3) and stent type (self-expandable or balloon-expandable) were recorded.

Pre- and 1st and 2nd-year post-procedure Rutherford statuses (asymptomatic, mild claudication, moderate claudication, severe claudication, and rest pain), ankle-brachial index (ABI) and stenosis degree (full patency, 0-50% stenosis, 50-70% stenosis, 70-99% stenosis, 100% occlusion) of the subjects were noted. The stenosis degree was calculated according to the computed tomography angiography (CTA) results.

To detect the sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV), Group B and Group C were combined and compared with Group A.

Statistical Analysis

The Number Cruncher Statistical System (NCSS) 2020 Statistical Software (NCSS LLC, Kaysville, UT, USA) program was used for statistical analysis. Quantitative variables are shown as the mean, standard deviation, median, minimum, and maximum values for evaluating the study data. Qualitative variables such as frequency and percentage were shown with descriptive statistical methods. The Shapiro-Wilks test and box plot graphics were used to evaluate the conformity of the data to a normal distribution.

The one-way ANOVA test was used to compare normally distributed variables across three groups, and the Games-Howell test was used to determine the group that caused the difference. The Kruskal-Wallis test was used to compare nonnormally distributed variables across three groups, and the Dunn test was used to determine the group that caused the difference.

The Friedman test was used for intragroup comparisons of the variables that did not show a normal distribution at the follow-up. The Bonferroni-Dunn test was used for post hoc comparisons. Diagnostic screening tests (specificity, sensitivity, NPV, PPV) and Fisher's Freeman Halton test were used to compare qualita-

tive data. The results were evaluated at the 95% confidence interval and a significance level of $p<0.05$.

Results

In total, 255 subjects were evaluated (female, n=77-30.2%, male, n=178-69.8%). A flow chart of the study is presented in Figure 2. The mean age of the subjects was 66.00±10.00 years (range from 39 to 90 years). Groups did not differ in terms of sex or smoking status ($p=0.579$ and $p=0.661$, respectively). The mean age of the patients in Group C was significantly higher than that of Group B ($p=0.02$). The mean BMI of the patients in Group C was significantly higher than that of Group A and Group B ($p=0.001$). The number of patients with hypertension in Group C was significantly higher than that in Group A and Group B ($p=0.001$). The number of patients with diabetes in Groups B and C was significantly higher than that in Group A ($p=0.001$). Oral antidiabetic and acetylsalicylic acid use did not differ between groups ($p>0.05$ for all comparisons). Insulin use differed between groups. The proportion of patients who used insulin was significantly larger in Group C than in Group A ($p=0.008$; $p<0.01$). Statin use differed between groups. The proportion of patients who used statins was significantly larger in Group C than in Group B ($p=0.001$; $p<0.01$). Fenofibrate use differed between groups. The proportion of patients who used fenofibrate was significantly larger in Group C than in Group A ($p=0.001$; $p<0.01$).

For blood parameters, the mean hemoglobin A1c, mean total cholesterol levels, and mean LDL-C levels ($p=0.001$; $p=0.010$; $p<0.05$) in Group C were significantly higher than those in Group A and Group B ($p=0.001$ for all comparisons). In contrast, the mean HDL-C levels in Group C were significantly lower than those in Group A and Group B ($p=0.001$). Hemoglobin levels did not differ between groups ($p=0.200$) (Table I).

The groups did not differ in terms of stent direction, number of stents applied to occlusion, TASC classification, lesion localization, or claudication distance ($p>0.05$ for all comparisons) (Table II).

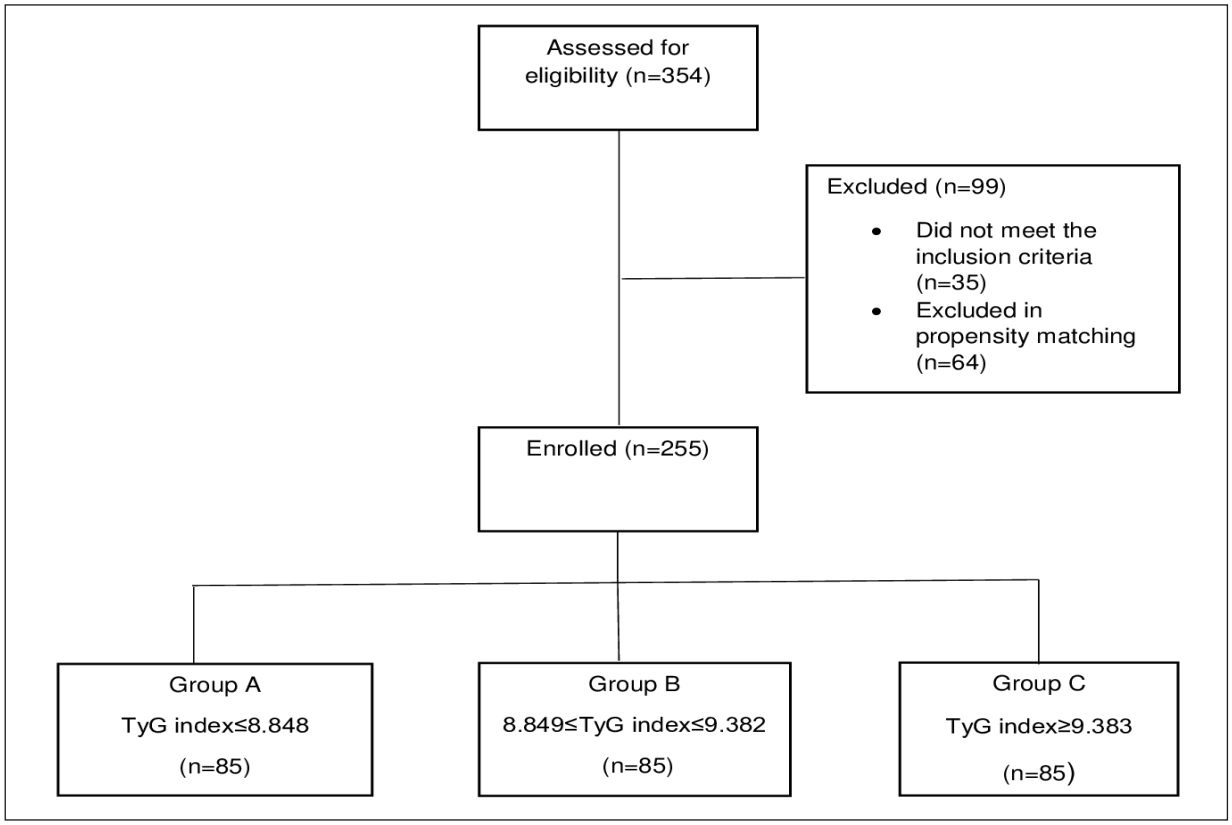

Figure 2. Flowchart of the study.

Table I. Baseline characteristics of the study.

		Group A	Group B	Group C	p
Sex	Female	22 (25.9)	27 (31.8)	28 (32.9)	[a]**0.579**
	Male	63 (74.1)	58 (68.2)	57 (67.1)	
Age	Mean ± SD	66.00 ± 11.00	65.00 ± 10.00	68.00 ± 7.00	[b]**0.027***
	Median (min-max)	67 (39-90)	65 (41-90)	68 (52-82)	
BMI	Mean ± SD	25.60 ± 1.70	26.60 ± 2.50	28.50 ± 3.40	[b]**0.001****
	Median (min-max)	25.4 (22.1-32.1)	26.1 (22.9-34.3)	27.6 (22.9-35)	
Smoking status	Absent	29 (34.1)	33 (38.8)	35 (41.2)	[a]**0.661**
	Present	56 (65.9)	52 (61.2)	50 (58.8)	
Hypertension	Absent	53 (62.4)	48 (56.5)	30 (35.3)	[a]**0.001****
	Present	32 (37.6)	37 (43.5)	55 (64.7)	
Diabetes	Absent	81 (95.3)	71 (83.5)	62 (72.9)	[a]**0.001****
	Present	4 (4.7)	14 (16.5)	23 (27.1)	
Medications					
Insulin use	Absent	83 (97.6)	77 (90.6)	72 (84.7)	[a]**0.008****
	Present	2 (2.4)	8 (9.4)	13 (15.3)	
OAD use	Absent	83 (97.6)	80 (94.1)	76 (89.4)	[a]**0.094**
	Present	2 (2.4)	5 (5.9)	9 (10.6)	
Statin use	Absent	17 (20.0)	37 (43.5)	2 (2.4)	[a]**0.001****
	Present	68 (80.0)	48 (56.5)	83 (97.6)	
Fenofibrate use	Absent	52 (61.2)	31 (36.5)	4 (4.7)	[a]**0.001****
	Present	33 (38.8)	54 (63.5)	81 (95.3)	
ASA use	Absent	4 (4.7)	6 (7.1)	6 (7.1)	[a]**0.848**
	Present	81 (95.3)	79 (92.9)	79 (92.9)	
Blood parameters					
HbA1c (%)	Mean ± SD	4.90 ± 0.40	5.60 ± 1.00	6.20 ± 1.50	[b]**0.001****
	Median (min-max)	4.9 (4.1-7.1)	5.5 (4-9.5)	5.8 (4.5-9.8)	
TC (mmol/L)	Mean ± SD	165.00 ± 12.00	215.00 ± 14.00	322.00 ± 58.00	[b]**0.001****
	Median (min-max)	165 (142-190)	216 (186-241)	309 (239-490)	
HDL-C (mmol/L)	Mean ± SD	54.00 ± 7.00	47.00 ± 5.00	35.00 ± 4.00	[b]**0.001****
	Median (min-max)	53 (40-66)	47 (38-65)	35 (26-43)	
(LDL-C) (mmol/L)	Mean ± SD	95.00 ± 13.00	140.00 ± 18.00	232.00 ± 57.00	[b]**0.001****
	Median (min-max)	94 (67-128)	140 (91-181)	219 (141-407)	
Haemoglobin (gdl)	Mean ± SD	13.31 ± 1.12	13.36 ± 0.89	13.24 ± 0.84	[c]**0.200**
	Median (min-max)	13.7 (10-15)	13.7 (10.8-14.4)	13.5 (10.4-14.3)	

BMI: body mass index, OAD: oral antidiabetic, ASA: acetylsalicylic acid HbA1c: hemoglobin A1c, TC: total cholesterol HDL-C: high-density lipoprotein cholesterol, LDL-C: low-density lipoprotein cholesterol, [a]Fischer Freeman Halton Test, [b]One-Way ANOVA Test & Games-Howell Test, [c]Kruskal-Wallis Test and Dunn-Bonferroni Test.*$p<0.05$, **$p<0.01$.

There was no statistically significant difference in the pre-procedure ABI measurements between the groups (p=0.335). There was a statistically significant difference in the 1-year post-procedure ABI measurements (p=0.001). As a result of the pairwise comparisons that were made to determine the source of the difference, the 1-year ABI measurements in Group C were significantly lower than those in Groups A and B (p=0.001). The 1-year ABI measurements in Group B were significantly lower than those in Group A (p=0.039). There was a statistically significant difference in the 2-year ABI measurements between the groups (p=0.001). As a result of the pairwise comparisons made to determine the source of the difference, the 2-year ABI measurements of Group C were significantly lower than those in Groups A and B (p=0.001 and p=0.028, respectively). The comparison between Groups A and B did not show a significant difference ($p>0.05$) (Table III).

There was a significant difference in the pre-procedure Rutherford measurements between the groups (p=0.001). The rates of mild claudication and resting pain in Group A were higher than those in Groups B and C. The rate of moderate

Table II. Lesion characteristics and procedural characteristics of the study group.

		Group A	Group B	Group C	*p*
Lesion localization	Common iliac	44 (51.8)	49 (57.6)	55 (64.7)	[a]**0.533**
	External iliac	37 (43.5)	32 (37.6)	27 (31.8)	
	Common+external iliac	4 (4.7)	4 (4.7)	3 (3.5)	
TASC classification	TASC type A	22 (25.9)	24 (28.2)	17 (20)	[a]**0.852**
	TASC type B	58 (68.2)	55 (64.7)	61 (71.8)	
	TASC type C	2 (2.4)	2 (2.4)	4 (4.7)	
	TASC type D	3 (3.5)	4 (4.7)	3 (3.5)	
Claudication distance	0-50 mt	19 (22.4)	16 (18.8)	22 (25.9)	[a]**0.812**
	50-100 mt	48 (56.5)	48 (56.5)	47 (55.3)	
	100-150 mt	18 (21.2)	21 (24.7)	16 (18.8)	
Stent direction	Right	43 (50.6)	39 (45.9)	42 (49.4)	[a]**0.941**
	Left	37 (43.5)	40 (47.1)	36 (42.4)	
	Bilateral	5 (5.9)	6 (7.1)	7 (8.2)	
Number of stents	1	67 (78.8)	66 (77.6)	62 (72.9)	[a]**0.807**
	2	16 (18.8)	15 (17.6)	20 (23.5)	
	3	2 (2.4)	4 (4.7)	3 (3.5)	
Stent type	Self-Expandable	11 (12.9)	14 (16.5)	10 (11.8)	[a]**0.730**
	Balloon Expandable	74 (87.1)	71 (83.5)	75 (88.2)	

TASC: The TransAtlantic InterSociety Consensus. [a]Fisher Freeman Halton Test.

claudication in Group C was higher than that in Groups A and B. The rate of severe claudication in Group B was higher than that in Groups A and C. There was a significant difference in the 1-year Rutherford measurements between the groups (p=0.001). The proportion of asymptomatic patients in Group A was higher than that in Groups B and C. The rate of mild claudication in Group C was lower than that in Groups A and B. The rate of moderate claudication in Group C was higher than that in Group A. The rate of severe claudication in Group C was higher than that in Groups A and B (Figure 3a). There was a significant difference in the 2-year Rutherford measurements between the groups (p=0.001). The rate of mild claudication in Groups A and B was higher than that in Group C. The rate of severe claudication in Group C was higher than that in Groups A and B (Figure 3b).

Table III. Lesion characteristics and procedural characteristics of the study group.

		Group A	Group B	Group C	*p*
Pre-procedure ABI	Mean ± SD	0.58 ± 0.12	0.60 ± 0.09	0.57 ± 0.11	[c]**0.335**
	Median (min-max)	0.6 (0.4-0.7)	0.6 (0.4-0.7)	0.6 (0.4-0.7)	
1-year postprocedure ABI	Mean ± SD	0.97 ± 0.09	0.93 ± 0.12	0.86 ± 0.13	[b]**0.001****
	Median (min-max)	1 (0.7-1.2)	0.9 (0.6-1.2)	0.9 (0.6-1)	
2-year post-procedure ABI	Mean ± SD	0.92 ± 0.10	0.89 ± 0.13	0.83 ± 0.17	[b]**0.001****
	Median (min-max)	0.9 (0.6-1.1)	0.9 (0.4-1.1)	0.9 (0.5-1)	
	p	[d]**0.001****	[d]**0.001****	[d]**0.001****	
		Change Δ			
1-year pre-procedure	Mean ± SD	0.39 ± 0.11	0.33 ± 0.14	0.28±0.10	[c]**0.001****
	p	[d]**0.001****	[d]**0.001****	[d]**0.001****	
2-year pre-procedure	Mean ± SD	0.34 ± 0.12	0.29 ± 0.14	0.26 ± 0.15	[c]**0.003****
	p	[d]**0.001****	[d]**0.001****	[d]**0.001****	
	Mean ± SD	-0.06 ±0.07	-0.04 ± 0.09	-0.03 ± 0.08	[c]**0.102**
	p	[d]**0.004****	[d]**0.038***	[d]**0.084**	

[b]One-way ANOVA Test and Games-Howell Test. [c]Kruskal-Wallis Test and Dunn-Bonferroni Test. [d]Friedman Test & Dunn-Bonferroni Test. *$p < 0.05$, **$p < 0.01$.

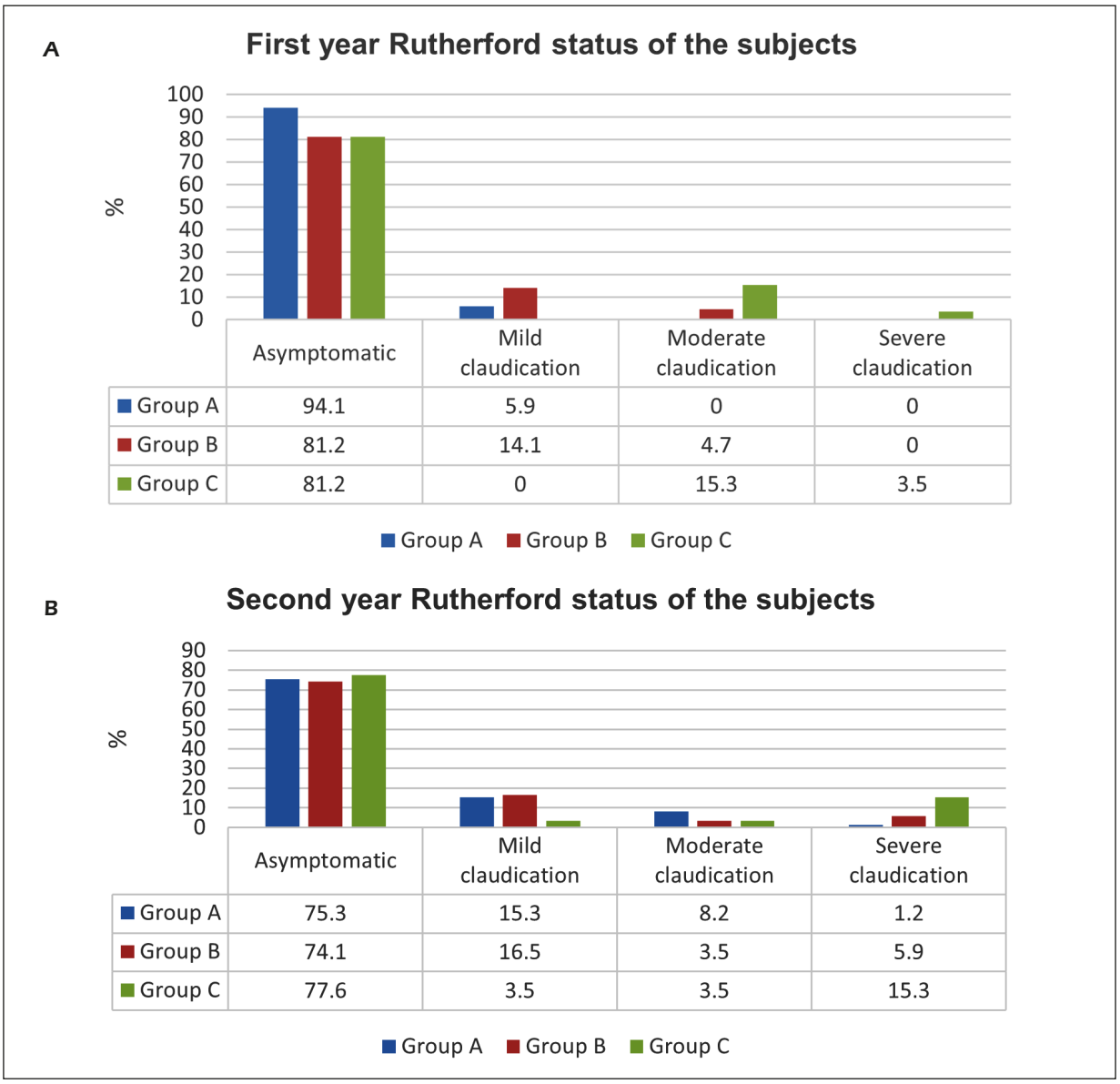

Figure 3. **A**, First-year Rutherford status of the subjects. **B**, Second-year Rutherford status of the subjects.

There was no statistically significant difference in the pre-procedure lower extremity CTA measurements between the groups (p>0.05). There was a significant difference in the 1st year lower extremity CTA measurements between the groups (p=0.001). The rate of full patency in Group A was higher than that in Groups B and C. The rate of 0-50% stenosis in Group B was higher than that in Groups A and C. The rate of 50-70% stenosis in Group C was higher than that in Group A (Figure 4a). A statistically significant difference was found in the 2nd year lower extremity CTA measurements between the groups (p=0.037). The rates of 70-99% stenosis and 100% occlusion in Group C were higher than those in Groups A and B (Figure 4b) (Table IV).

Group B and Group C were combined and compared with Group A to detect sensitivity (Table V). In estimating 0-70% stenosis at 1 year postoperatively, the sensitivity, specificity, PPV, and NPV of the TyG index were 85.71%, 36.36%, 17.65%, and 94.12%, respectively. In estimating 0-70% stenosis at 2 years postoperatively, the

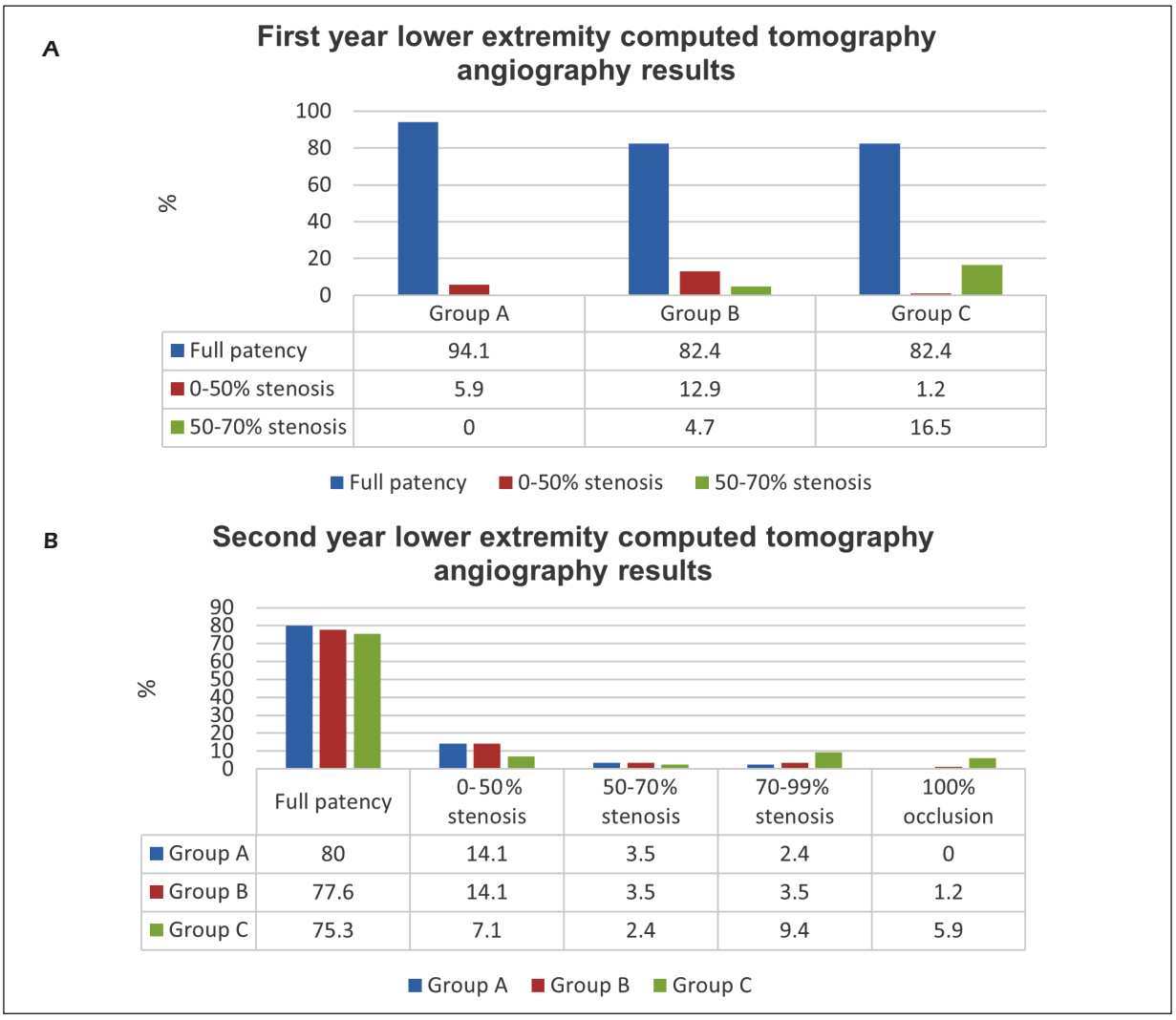

Figure 4. **A**, First-year lower extremity computed tomography angiography results of the subjects. **B**, Second-year lower extremity computed tomography angiography results of the subjects.

sensitivity, specificity, PPV, and NPV of the TyG index were 60.53%, 34.34%, 15.03%, and 81.93%, respectively. In estimating 70-100% stenosis/occlusion at 2 years postoperatively, the sensitivity, specificity, PPV, and NPV of the TyG index were 89.47%, 34.34%, 11.56%, and 97.14%, respectively (Table V).

Discussion

The present study on 255 subjects with iliac artery stenosis indicated that a normal TyG index is associated with low in-stent restenosis rates. The normal TyG index also has a high sensitivity for predicting low in-stent restenosis rates. Our study highlights the importance of lower triglyceride and glucose levels for decreasing the in-stent re-stenosis rates. This point also shows the importance of effective medical treatment and regular follow-up.

Peripheral artery disease is an important issue for related comorbidities. Due to its multifactorial etiology, several prognostic measures have been studied in the past. In the pathogenesis of PAD, environmental and genetic factors play an important role. Age, sex, smoking status, body mass index, presence of diabetes, hypertension, dyslipidemia, etc., were the traditional risk factors for PAD[1].

Insulin resistance is a well-known cause of PAD. Insulin resistance results in several changes

Table IV. Pre- and 1- and 2-year post-procedure Rutherford statuses and computed tomography angiography (CTA) results.

		Group A	Group B	Group C	
Rutherford-Pre-procedure	Mild claudication	10 (11.8)	0 (0.0)	0 (0.0)	[a]**0.001****
	Moderate claudication	55 (64.7)	43 (50.6)	61 (71.8)	
	Severe claudication	18 (21.2)	42 (49.4)	24 (28.2)	
	Rest pain	2 (2.4)	0 (0.0)	0 (0.0)	
Rutherford-Post-procedure (1st year)	Asymptomatic	80 (94.1)	69 (81.2)	69 (81.2)	[a]**0.001****
	Mild claudication	5 (5.9)	12 (14.1)	0 (0.0)	
	Moderate claudication	0 (0.0)	4 (4.7)	13 (15.3)	
	Severe claudication	0 (0.0)	0 (0.0)	3 (3.5)	
Rutherford-Post-procedure (2nd year)	Asymptomatic	64 (75.3)	63 (74.1)	66 (77.6)	[a]**0.001****
	Mild claudication	13 (15.3)	14 (16.5)	3 (3.5)	
	Moderate claudication	7 (8.2)	3 (3.5)	3 (3.5)	
	Severe claudication	1 (1.2)	5 (5.9)	13 (15.3)	
CTA-Pre-procedure	70-99% stenosis	76 (89.4)	74 (87.1)	74 (87.1)	[a]**0.916**
	100% occlusion	9 (10.6)	11 (12.9)	11 (12.9)	
CTA-Post-procedure (1st year)	Full patency	80 (94.1)	70 (82.4)	70 (82.4)	[a]**0.001****
	0-50% stenosis	5 (5.9)	11 (12.9)	1 (1.2)	
	50-70% stenosis	0 (0.0)	4 (4.7)	14 (16.5)	
CTA-Post-procedure (2nd year)	Full patency	68 (80.0)	66 (77.6)	64 (75.3)	[a]**0.037***
	0-50% stenosis	12 (14.1)	12 (14.1)	6 (7.1)	
	50-70% stenosis	3 (3.5)	3 (3.5)	2 (2.4)	
	70-99% stenosis	2 (2.4)	3 (3.5)	8 (9.4)	
	100% occlusion	0 (0)	1 (1.2)	5 (5.9)	

[a]Fisher Freeman Halton Test. ** $p < 0.01$.

that can facilitate the development of PAD. The release of nitric oxide decreases, and the levels of endothelin-1, fibrinogen, thromboxane, and platelet aggregation increase as a result of insulin resistance[2]. There are several measurement methods that can be used to diagnose IR. Among these methods, the hyperinsulinaemic-euglycaemic clamp and homeostasis model assessment are powerful for determining IR; however, the complexity of these procedures and related costs make them not widely used[11]. Noninsulin-based insulin resistance indices (triglyceride and glucose index, triglyceride to high-density lipoprotein cholesterol ratio, triglyceride glucose-body mass index, and metabolic score for insulin resistance) are simple and reliable tools that can be used for the diagnosis of IR[12].

The TyG index is the most studied noninsulin-based insulin resistance index[10]. The TyG index is also one of the markers that have been studied and considered for predicting long-term restenosis rates. These studies[6,7] mostly included areas such as the cardiovascular system and metabolic diseases. In a recent meta-analysis[11], it was reported that subjects with a high TyG index were 1.85 times more likely to develop arterial stiffness than subjects with a low TyG index. In terms of the development of PAD, Liu et al[13] found that compared with a lower TyG, a high TyG was associated with a 1.27-fold (after adjusting for

Table V. The sensitivity, specificity, positive predictive value and negative predictive value of the abnormal triglyceride-glucose index (TyG) index for detecting in-stent restenosis.

	Sensitivity	Specificity	PPV	NPV
Abnormal TyG index for predicting 0-70% stenosis at 1 year postoperatively	85.71	36.36	17.65	94.12
Abnormal TyG index for predicting 0-70% stenosis at 2 years postoperatively	60.53	34.34	15.03	81.93
Abnormal TyG index for predicting 70-100% stenosis/occlusion at 2 years postoperatively	89.47	34.34	11.56	97.14

PPV: Positive predictive value, NPV: Negative predictive value. Groups B and C, which reflect subjects with an abnormal TyG index, were combined and compared with Group A (which reflects normal TyG values) to calculate the sensitivity, specificity, PPV and NPV of the TyG index.

sociodemographic factors, lifestyle differences, and cardiometabolic factors) increased risk for PAD. In 211 subjects with PAD, Calıskan and Boyuk[2] reported that the TyG index is one of the predictors for PAD. For predicting PAD, the cut-off value of TyG is reported to be 9.06 (sensitivity of 57.8% and specificity of 70%). In 723 subjects with lower extremity PAD, Tasbulak et al[14] found that a high TyG index was an independent risk factor related to long-term mortality. In a recent meta-analysis[15] including 26 observational studies, it was found that each 1-unit increase in the TyG index was associated with increased arterial stiffness and coronary artery calcification risk (OR 1.51 and 1.73, respectively).

In contrast to studies found in the literature on the coronary arterial system, the effect of the TyG index on the major arterial system has been less frequently reported. Chen et al[16] reported that each 1-unit increase in the TyG index also increases the odds of extensive abdominal aortic calcification by 41%. Chen et al[16] also reported that this association was irrespective of age, sex, smoking status, and the presence of metabolic diseases (hypertension, diabetes, hypercholesteremia, etc.).

Few studies in the literature have evaluated the association between TyG and lower extremity PAD. In one study involving iliac and femoral arteries (n=71), Karaduman et al[17] reported that the TyG index was correlated with lesion complexity (TASC-II), Rutherford status, HbA1c and HDL-C levels. Pala and Urcun[18] reported that chronic limb-threatening ischemia could be predicted by a high TyG index (cut-off value 9.13, sensitivity 70.8%, and specificity 65.2%). The index was also found to be correlated with Rutherford status and HDL-C levels.

Endovascular stenting of iliac artery occlusive disease is a preferred treatment method that has favorable outcomes[19,20]. Of 616 subjects, RECCORD Investigators[21] reported the use of only balloon angioplasty, stenting and drug-coated balloon in 8.3%, 82.3% and 11.2% of patients, respectively. Different stents were used and showed variable success rates. For CIA, Bekken et al[22] reported that 174 subjects who underwent CIA stenting had excellent outcomes with both covered and bare metal stents regardless of the stent type. Of 93 subjects, Squizzato et al[23] also reported favorable early and mid-term results. The rate of in-stent restenosis after successful treatment[21,24] was reported to be 10% for TASC C and D complex lesions at the one-year follow-up, which steadily increased over time. This percentage makes in-stent restenosis an important issue. A reliable, easy-to-use marker will be useful for detecting in-stent restenosis.

In the present study, the overall full patency rates after the 1st year and 2nd year were 86.3% (n=220/255) and 77.6% (n=198/255), respectively. One year after the procedure, the full patency rates of Groups A, B, and C were 94.1%, 82.4%, and 82.4%, respectively. Two years after the procedure, the full patency rates of Groups A, B, and C were 80.0%, 77.6%, and 75.3%, respectively. Our findings for the 1st and 2nd year follow-ups were consistent with the literature.

One year after the procedure, the lower extremity CTA measurements indicated that the rate of full patency in Group A was higher than in Groups B and C. The rate of 0-50% stenosis in Group B was higher than in Groups A and C. The rate of 50-70% stenosis in Group C was higher than in Group A. Two years after the procedure, the rate of 70-100% stenosis in Group C was higher than in Groups A and B. These results indicate that a high TyG index has an effect on the in-stent restenosis rates. The CTA measurements were also supported by ABI and Rutherford status, and both measurements were worsened in the presence of a high TyG index.

In our study, Groups B and C, which reflect subjects with an abnormal TyG index, were combined and compared with Group A (which reflects normal TyG values) to calculate the sensitivity, specificity, PPV and NPV of the TyG index. Our results indicate that the TyG index has a high specificity. However, specificity and PPV values were found to be quite low. The TyG index also has a high NPV. The index was found to be useful for subjects with a normal TyG index, who have lower risks of restenosis. However, low specificity and PPV indicate that a high TyG index may not be useful for patients with a medium to high TyG index and a high risk of restenosis. Restenosis is a multifactorial issue, which means that a high TyG index is not the only factor that is related to its development.

Practical measurements were needed to predict PAD restenosis rates[25]. For this purpose, different measurements (e.g., monocyte to high-density lipoprotein ratio, neutrophil to high-density lipoprotein ratio) were studied previously[25,26]. Different practical measurements' diagnostic value in predicting in-stent restenosis in patients with PAD will be addressed in future studies. Future head-to-head comparisons will also clarify which measurement is better for predicting in-stent restenosis.

Limitations

The limitations of the present study included its retrospective design. The development of PAD is a multifactorial process in which many parameters will be assessed. Our results are limited to the factors that we studied.

Conclusions

The TyG index was useful for subjects with a normal TyG index and a lower risk of restenosis. However, low specificity and PPV indicate that a high TyG index may not be useful for patients with a medium to high TyG index and a high restenosis risk. The TyG index was found to be an easy-to-use marker for predicting in-stent restenosis in patients with iliac artery stenosis after percutaneous intervention with stents.

Conflict of Interest

The authors declare that they have no conflict of interests.

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Informed Consent

An informed consent form was obtained from the participants before participating in the study.

Ethics Approval

The study was approved by the Ethical Committee of the Bakirkoy Dr. Sadi Konuk Training and Research Hospital (No.: 2023/132).

Availability of Data and Materials

The datasets generated during and/or analyzed during the current study are available from the corresponding author upon reasonable request

Authors' Contributions

Conception and design: S. Turkyilmaz, G. Turkyilmaz and AA. Kavala; Acquisition of data: S. Turkyilmaz, H. Toz and G. Turkyilmaz; Analysis and interpretation of data: S. Turkyilmaz, G. Turkyilmaz, AA. Kavala and H. Toz; Drafting the article: S. Turkyilmaz, G. Turkyilmaz, H. Toz and Y. Kuserli; Supervision: S. Turkyilmaz, AA. Kavala and Y. Kuserli; Validation and final approval: all authors..

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All the data shown in the manuscript further queries can be communicated through the corresponding author by email..

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