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Original Article

Can Development of Diabetic Foot be Predicted Using Aortic, Iliac and Femoral Bifurcation Angles? A Computed Tomography Angiography Study

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Keywords: Aorta; computed tomography angiography; diabetic foot; femoral artery; iliac artery.

ABSTRACT

Objective: The aim of this study was to determine whether aortic, iliac, and femoral artery bifurcation angles were different in diabetic patients with and without diabetic foot, and whether angle differences assessed based on computed tomography angiography (CTA) imaging could predict the development of diabetic foot.

Methods: A total of 111 patients with diabetes mellitus (DM) were included in the study: 61 with diabetic foot and 50 without diabetic foot. The aortic, right and left iliac, and right and left femoral bifurcation angles were measured using CTA images and evaluated retrospectively with the Sectra PACS system (Sectra Medical Systems GmbH, Koln, Germany).

Results: When the values of the control and diabetic foot groups were compared, there was no statistically significant difference between the aortic bifurcation angle (p=0.438), right (p=0.223) and left (p=0.459) iliac bifurcation angles, or the right (p=0.080) and left (p=0.064) femur bifurcation angles.

Conclusion: The results revealed no significant difference in the bifurcation angles of the aorta and lower extremity arteries in diabetic patients with and without diabetic foot, and suggested that the changes in vascular geometry caused by DM may not be a major factor in the development of diabetic foot.

INTRODUCTION

A diabetic foot ulcer is an important cause of morbidity and mortality in diabetes mellitus (DM). Peripheral neuropathy, peripheral vascular disease, and peripheral vascular disease can be responsible for this important complication of DM. Related arterial insufficiency has also been observed in approximately 45% to 50% of diabetic foot cases.[1,2]

It has been established that vascular geometry has an impact on atherosclerotic disease. Local vascular effects influence the arterial geometry and, consequently, arterial hemodynamics.[3] Bifurcation regions are the areas most affected by changes in vascular geometry.[4] One of the most important indicators of vascular changes in bifurcation areas is the bifurcation angle.[5,6] This dynamic structure may also be influenced as a result of DM, which may led to diabetic foot.

Although it has a hemodynamic effect, the relationship between the aortic, iliac, and femoral bifurcation angles and the formation of diabetic foot ulcers has not yet been studied. It was hypothesized that differences in the bifurcation angles between patients with and without diabetic foot could be meaningful and perhaps predict the development of diabetic foot. This study analyzed the aortic and lower extremity arterial bifurcation angles in diabetic patients using computed tomography angiography (CTA) images to determine any differences and the prognostic usefulness for the risk of developing a diabetic foot ulcer.

MATERIALS AND METHODS

This study was approved by local Ethics Committee. Informed consent was obtained from all of the patients included in the study. The records of 111 diabetic patients who underwent CTA of the lower extremity between September 2015 and February 2019 were examined retrospectively. A diabetic foot ulcer was present in 61 patients, who comprised the Diabetic Foot (wDF) group. Fifty patients made up the without Diabetic Foot (woDF) group. Aortic bifurcation angles and lower extremity arterial bifurcation angles were measured using CTA and the values of patients with and without foot ulcers were compared. The initial inclusion criteria for the research were patient age of >18 years and DM. Patients with chronic kidney disease, occlusions, vasculitis or aneurysm in the abdominal aortic artery, the iliac or femoral arteries were excluded.

Computed tomography angiography protocol

CTA was performed with an Aquillon Prime 80 scanner system (Toshiba Medical Systems Corp., Tokyo, Japan). Iohexol (Omnipaque 350 mg/100 mL; GE Healthcare Inc., Chicago, IL, USA) was used as an intravenous contrast agent at a rate of 4-6 mL/second. The CTA parameters were a tube potential of 120 kV, 80 milliamperes per second, 1.25x1.25-mm collimation, pitch value of 1, 20x30-cm field of view, matrix of 512x512, and slice thickness of 0.625 mm. Raw CT images were examined in the axial, coronal, and sagittal oblique planes with multiplanar reconstruction (MPR) using the Sectra PACS system (Sectra Medical Systems GmbH, Koln, Germany). The aortic bifurcation angle (Fig. 1a), right and left iliac bifurcation angles (Fig. 1b), and right and left femoral bifurcation angles (Fig. 1c) were depicted separately on MPR images and measured by an experienced radiologist.

Total occlusion of the aorta was detected in 5 patients in the wDF group and these patients were excluded from the study. Angle measurements could not be performed in the wDF group due to occlusions of the right common iliac artery in 1 patient, the left common iliac artery in 2 patients, the right femoral artery in 5 patients, and the left femoral artery in 2 patients, and these patients were also excluded from the study.

Aortic occlusion was detected in 4 patients in the woDF group and an abdominal aortic aneurysm was detected in 1 patient, and these patients were excluded from the study. In addition, 1 patient had an occlusion in the left internal iliac artery, and 2 patients had a right common femoral artery occlusion in the woDF group and these patients were also excluded.

Statistical analysis

The data were analyzed using SPSS Statistics for Windows, Version 17.0 (SPSS Inc., Chicago, IL, USA). The Kolmogorov-Smirnov test was used to determine whether the distribution of continuous numerical variables was close to normal. Descriptive statistics were expressed as the number of cases, percentage, and mean±SD for continuous numerical variables. The significance of the difference between groups in terms of mean values was examined with Student's t-test, while the significance of the difference in mean values between localizations within the groups was evaluated with a dependent t-test. Categorical variables were analyzed using a continuity-corrected chi-squared test. A p value of <0.05 was accepted as statistically significant.

RESULTS

In all, lower extremity CTA images of 111 patients were analyzed. There were 21 female patients and 90 male patients included in the study. The mean age of the control group participants was 63.9±9.1 years and the mean age was 66.0±8.3 years in the case (wDF) group. The patient demographic characteristics are summarized in Table 1.

When the values between the wDF and woDF groups were compared, no statistically significant difference was found between the aortic bifurcation angle (p=0.438), right (p=0.223) and left (p=0.459) iliac bifurcation angles, or the right (p=0.080) and left (p=0.064) femoral bifurcation angles (Table 2). In the comparison of woDF patients and those with a right diabetic foot ulcer, no statistically significant difference was found in the mean values of aortic bifurcation angle (p=0.923), right (p=0.210) and left (p=0.609) iliac bifurcation angles, or the right (p=0.140) and left (p=0.140) femoral bifurcation angles (Table 3). Similarly, when the woDF group and patients with a left diabetic foot ulcer were compared, no statistically signifi-

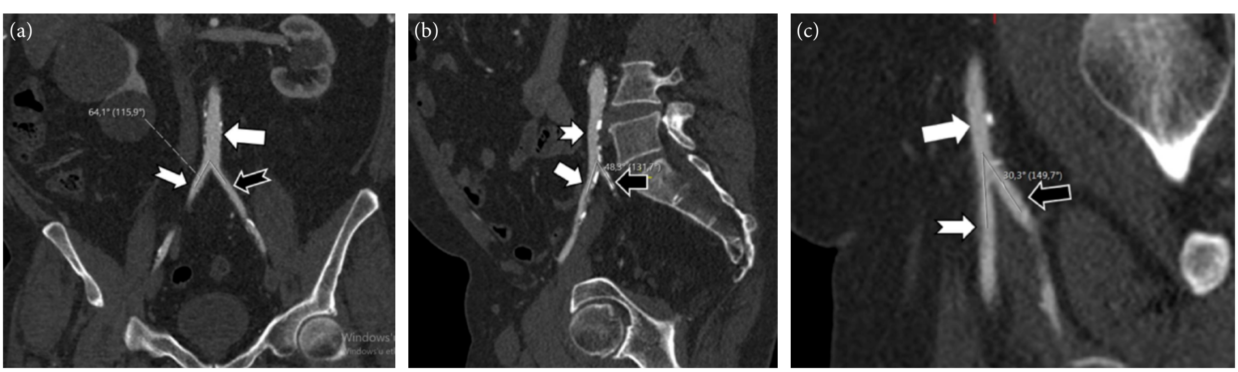

Figure 1. (a) Coronal reformatted computed tomography angiograpy with multiplanar reconstruction shows the aorta (white arrow), right common iliac artery (white tailed arrow), and left common iliac artery (black tailed arrow). The aortic bifurcation angle was 64.1°.
(b) Sagittal oblique reformatted computed tomography angiography illustrates the common iliac artery (white tailed arrow), external iliac artery (white arrow), and internal iliac artery (black arrow). The iliac bifurcation angle was 48.3°. (c) Sagittal oblique reformatted computed tomography angiography depicts the common femoral artery (white arrow), superficial femoral artery (white tailed arrow), and deep femoral artery (black arrow). The femoral bifurcation angle was 30.3°.

Table 1. Demographic characteristics of the patients by group

	woDF (n=50)	wDF (n=61)	p value
Age (years), Mean±SD	63.9±9.1	66.0±8.3	0.209†
Gender, n (%)			>0.999‡
Female	9 (18.0)	12 (19.7)	
Male	41 (82.0)	49 (80.3)	
Localization of diabetic foot, n (%)			–
Right	–	35 (57.4)	
Left	–	23 (37.7)	
Bilateral	–	3 (4.9)	

†Student's t-test; ‡Continuity correction chi-squared test. wDF: With diabetic foot; woDF: Without diabetic foot; SD: Standard deviation.

Table 2. Vascular angular measurements by group

	woDF (n=50)	wDF (n=61)	p value†
Aortic bifurcation angle	38.69±13.71	36.91±9.48	0.438
Iliac bifurcation angle			
Right	31.06±12.91	33.86±11.10	0.223
Left	29.32±13.99	31.31±13.67	0.459
Femoral bifurcation angle			
Right	25.76±10.59	29.47±10.69	0.080
Left	23.99±10.64	27.97±11.36	0.064

Data are shown as mean±standard deviation; †Student's t-test. wDF: With diabetic foot; woDF: Without diabetic foot.

cant difference was seen between the values of the mean aortic bifurcation angle (p=0.135), the mean of the right (p=0.368) and left (p=0.286) iliac bifurcation angles, or the mean of the right (p=0.247) and left (p=0.149) femoral bifurcation angles (Table 4). Furthermore, the right and left side angular measurements of the woDF group revealed no statistically significant difference between the mean iliac (p=0.460) and femoral (p=0.331) bifurcation angles.

In the subgroup of angular measurements of diabetic foot only on the right side, no statistically significant difference between the mean iliac and femoral bifurcation angles (p=0.201 and p=0.542, respectively) was seen. Nor was a statistically significant difference detected in the subgroup angular measurements of iliac and femoral bifurcation angles of those with left side diabetic foot and right side without diabetic foot (p=0.957 and p=0.992, respectively) (Table 5).

Table 3. Bifurcation angle measurements for the woDF group and the patient group with diabetic foot on the right

	woDF (n=50)	Right diabetic foot (n=38)	p value†
Aortic bifurcation angle	38.69±13.71	38.44±9.88	0.923
Iliac bifurcation angle			
Right	31.06±12.91	34.54±12.41	0.210
Left	29.32±13.99	30.89±13.93	0.609
Femoral bifurcation angle			
Right	25.76±10.59	29.38±11.35	0.140
Left	23.99±10.64	27.69±12.64	0.140

Data are shown as mean±standard deviation; †Student's t-test. woDF: Without diabetic foot.

Table 4. Bifurcation angle measurements according to the woDF group and the patient group with diabetic foot on the left

	woDF (n=50)	Left diabetic foot (n=26)	p value†
Aortic bifurcation angle	38.69±13.71	34.87±8.23	0.135
Iliac bifurcation angle			
Right	31.06±12.91	33.28±8.34	0.368
Left	29.32±13.99	33.08±14.69	0.286
Femoral bifurcation angle			
Right	25.76±10.59	28.79±9.98	0.247
Left	23.99±10.64	27.64±8.68	0.149

Data are shown as mean±standard deviation; †Student's t-test. woDF: Without diabetic foot.

Table 5. Right and left iliac and femoral bifurcation angles in the woDF group and wDF subgroups

	n	Right	Left	p-value†
Iliac bifurcation angle				
Without diabetic foot	49	30.83±12.93	29.32±13.99	0.460
Right diabetic foot	36	34.34±12.53	31.08±14.07	0.201
Left diabetic foot	25	33.26±8.51	33.08±14.69	0.957
Femoral bifurcation angle				
Without diabetic foot	48	25.76±10.59	24.15±10.72	0.331
Right diabetic foot	35	29.38±11.35	27.99±12.91	0.542

Data are shown as mean; †Dependent t-test. wDF: With diabetic foot.

DISCUSSION

Our study results indicated that bifurcation angles, one of the morphological measurements in the aorta and lower extremities, were not major factors in diabetic foot development. The bifurcation angle is altered as the aorta changes position during and after the gestational period.[7] Arterial bifurcation angles measure important areas where the atherosclerotic process can develop due to wall shear stress.[4] Local vascular geometric changes have been defined as a major cause of atherosclerotic changes. For instance, a left aortic orientation leads to a longer right common iliac artery, a smaller left common iliac take-off angle, and a larger left radius of curvature at the aortic-common iliac bifurcation, which changes the aortic bifurcation.[8] The femoral artery curvature has also been defined as a local geometric risk factor for atherogenesis.[9] This anatomical change speeds the process of atherosclerosis.

Accelerated atherosclerotic processes caused by DM increase wall thickness and vascular calcification of the aortic and main vascular structures, which lead to hemodynamic changes.[10] Aortic bifurcation angles have been shown to be an important risk factor for aortoiliac occlusive disease.[5] Our study appears to be the first in the literature to evaluate aortic bifurcation angles in the diabetic process.

Peripheral arterial disease occurs in approximately half of patients with a diabetic foot ulcer.[11] Foot perfusion disorder can occur due to peripheral arterial disease, and as a result, the wound may open easily, wound healing might be delayed, and infection may develop more easily. In addition, antibiotherapy penetration of this area becomes more difficult and infection treatment is insufficient.[12] Amputation is necessary in more than 25% of diabetic patients due to peripheral arterial disease.[13]

Diabetic foot ulcer is a common and important complication of DM. The prevalence of diabetic foot ulcers is approximately 6.3% and is more common in men (4.5%) than women (3.5%).[14] Diabetic foot ulcers can be a result of neuropathy and peripheral vascular disease due to DM. Peripheral vascular disease can manifest as major vascular disease or microvascular disease in cases of DM.[15] Although DM is known to cause accelerate arterial disease the atherosclerotic process and cause vascular calcification, DM also can cause microvascular disease by disrupting endothelial function.[16] Akcay et al.[17] demonstrated a strong relationship between diabetic retinopathy and the diabetic foot process. This study emphasized the importance of diabetic neuropathy in the development of diabetic foot.

In our study, aortic and lower extremity arterial bifurcation angles were measured using CTA imaging. CTA is a non-invasive diagnostic method used to view peripheral vessels via a contrast agent injection and has become a diagnostic alternative to invasive digital subtraction angiography (DSA). With the development of the MPR technique in multidetector computed tomography, CTA can now be used to provide more accurate and realistic images. In their study, Catalano et al.[18] reported accurate diagnostic performance of CTA compared with DSA, citing a high level of sensitivity (96%) and specificity (93%). In meta-analysis studies, the sensitivity and specificity of the CTA method for detecting more than 50% stenosis was 90% to 95% and 92% to 96%, respectively.[19,20]

Ali et al.[21] found in their CTA study that evaluated the aortic and femoral artery diameters in diabetic, hypertensive, and normal individuals that there was a significant difference in the diameters seen in diabetic and hypertensive patients compared with the normal population.[21] To the best of our knowledge, there is no previous study in the literature that has evaluated the possible relationship between vascular bifurcation angles and the development of diabetic foot. We found that the CTA measurements indicated that major vascular geometry was similarly affected in diabetic patients with or without diabetic foot. Our study results suggest that the development of diabetic foot is not just related to the deterioration of the major vascular anatomy Diabetic foot, which is a special complication of DM, should be analyzed for diabetic neuropathy, vascular endothelial dysfunction, and microvascular damage in the angiosomes.[22]

The limitations of our study include the small number of patients and the retrospective study design. The lack of intra- and interobserver reliability data is also a limitation. The pathophysiology of diabetic foot may be better understood with additional studies conducted using a larger patient series.

CONCLUSION

Our study of CTA images revealed that the development of diabetic foot in diabetic patients is related to more than wall shear stress due anatomical changes, such as bifurcation angles. The findings in our study suggest that diabetic foot is a complex disorder associated with macro- and microvascular disease, and that macrovascular changes, such as bifurcation angles, may not predict the development of diabetic foot.

Ethics Committee Approval

Approved by the local ethics committee.

Informed Consent

Retrospective study.

Peer-review

Internally peer-reviewed.

Authorship Contributions

Concept: O.O.; Design: O.O., T.I.K.O.; Supervision: T.I.K.O.; Fundings: O.O., T.I.K.O.; Materials: O.O., T.I.K.O.; Data: O.O.; Analysis: O.O.; Literture search: O.O., T.I.K.O.; Writing: O.O.; Critical revision: O.O., T.I.K.O.

Conflict of Interest

None declared.

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Aort, İliak ve Femur Bifurkasyon Açıları İle Diyabetik Hastalarda Diyabetik Ayak Gelişimi Öngörülebilir mi? Bilgisayarlı Tomografi Anjiografi Çalışması

Amaç: Bu çalışmanın amacı aort, iliak ve femoral arter açılarının diabetik ayaklı ve diabetik ayağı olmayan diabetik hastalarda farklı olup olmadığını ve bu açı farklılıkları ile diabetik ayak gelişiminin öngörülüp görülemeyeceğini bilgisayarlı tomografi anjiografi (BTA) kılavuzluğunda belirlemekti.

Gereç ve Yöntem: Çalışmaya 61 diabetik ayaklı, 50 diabetik ayağı olmayan toplam 111 diabetes mellitus (DM) hastası dahil edildi. Bu hastaların çekilmiş BTA'larında ölçülen aort, sağ ve sol iliak ve sağ ve sol femoral bifurkasyon açıları ayrı ayrı olarak PACS sistemi üzerinden geriye dönük olarak değerlendirildi.

Bulgular: Kontrol grubu ile olgu grupları arasındaki değerler karşılaştırıldığında, aort bifurkasyon açısı (p=0.438); sağ (p=0.223) ve sol (p=0.459) iliak bifurkasyon açıları; sağ (p=0.080) ve sol (p=0.064) femur bifurkasyon açıları arasında istatistiksel olarak anlamlı bir fark bulunmadı.

Sonuç: Çalışmamız Aort ve alt ekstremite bifurkasyon açıları diabetik ayağı olan ve olmayan diabetik hastalarda farklılık olmadığını göstermiş olup diabetik ayak gelişiminde DM'nin (DM) neden olduğu vasküler geometrideki bozulmanın majör bir etken olmadığını göstermiştir.

Anahtar Sözcükler: Aorta; bilgisayarlı tomografi anjiografi; diabetik ayak; femoral arter; iliak arter.