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Plaque distribution in common femoral artery bifurcations, based on multi-slice computed tomography assessment

Abstract

Purpose: The aim of this study was to observe the exact plaque distribution at the common femoral artery bifurcation by multi-slice computed tomography angiography and to examine the relationship between plaque distribution and carina location.

Methods: Symptomatic outpatients who underwent multi-slice computed tomography angiography between May 2013 and February 2015 were enrolled in this study. The presence and distribution of atherosclerotic plaques were assessed in cross section views of vessel lumen. Each vessel lumen cross section was divided into four equal quadrants for the common femoral, superficial femoral and profunda femoral arteries. The quadrant of the superficial femoral artery in which the carina was located was also recorded.

Results: In total, 184 common femoral artery bifurcations in 92 patients were analyzed. Normal arteries were more common in profunda femoral arteries than in common femoral arteries and superficial femoral arteries (both $P < 0.001$). Plaques were found more medial and posterior quadrants in common femoral arteries. In superficial femoral arteries, plaques were found most frequently in anterior quadrants (78.3%, $n=144$) and least frequently in posterior quadrants (49.5%, $n=91$). The carina was located in the posterior quadrant in 160 bifurcations (87.0%) of superficial femoral arteries. Quadrants opposite the carina contained plaque most proportionally (77.2%) and quadrants of carina were affected least proportionally (52.7%) in superficial femoral arteries ($P < 0.001$). Quadrants adjacent to the carina clockwise or anticlockwise also contained a higher proportion than carina quadrants. Significance was found for anticlockwise quadrants ($p=0.002$), but not for clockwise quadrants ($P=0.21$).

Conclusions: The presence and distribution of atherosclerotic plaques were diverse in different artery beds of the common femoral artery bifurcations. Plaque tended to be located in areas opposite the carina in superficial femoral arteries.

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Atherosclerotic cardiovascular disease remains the leading cause of mortality and premature death globally. Most cases occur in low and middle-income countries, according to the most recent statistics from the World Health Organization [1]. Atherosclerosis is associated with genetic predisposition and multiple risk factors, such as sex, age, smoking, dyslipidemia, diabetes mellitus, hypertension and inflammation [2]. Despite its systematic nature, atherosclerosis tends to be localized at inner curvatures and outer walls of branches, which are associated with complex and unsteady patterns of flow [3-6]. Most previous studies have examined atherosclerotic plaque distribution in the coronary and carotid arteries; atherosclerosis distribution in the common femoral artery bifurcation has rarely been assessed. The morphology of atherosclerotic plaques may differ among artery beds [7,8].

Endovascular intervention has emerged as a vital therapy for coronary and peripheral artery disease [9,10]. The femoral artery is a common vascular access site for endovascular procedures; thus, awareness of the exact atherosclerotic plaque distribution at the common femoral artery bifurcation in patients with cardiovascular disease is essential.

Angiography is of great value for visualization of the presence of atherosclerosis in peripheral arteries [10]; however, it provides only a two-dimensional longitudinal view of the lumen and no information about the vessel wall. Multi-slice computed tomography angiography (MSCTA) can be used to evaluate atherosclerosis and to obtain three-dimensional information about artery geometry, with delineation of the lumen as well as the vessel wall [11]. In the present study, we used MSCTA to determine the exact plaque distribution at the common femoral artery bifurcation and examined its relationship with carina location in the superficial femoral artery (SFA).

Materials and Methods

Patient population

We retrospectively analyzed a cohort of symptomatic outpatients with suspected peripheral artery disease who underwent lower-limb computed tomography angiography (CTA) between May 2013 and February 2015. Only patients who had received no previous percutaneous intervention or femoral artery bypass surgery were considered for inclusion. Patients' medical history data, including that on hypertension, dyslipidemia, diabetes, nicotine use, coronary artery disease and cranial artery disease, were collected. Our institutional Human Investigations Committee approved the study protocol, and all patients gave informed consent.

Scan protocol and image reconstruction

All patients underwent CT with a 64-slice multi-detector scanner (Siemens Somatom Definition Flash; Siemens Medical Solutions, Forchheim, Germany) using a standardized protocol (120 kV, 230 mAs, 0.6-mm collimation, 44-mm/s table feed). The scan range extended from the suprarenal aorta (5cm below the diaphragm) to the bottom of the feet. A bolus of 100 ml contrast material (Iohexol) (Omnipaque; GE, Shanghai, China) was injected intravenously at a 4 ml/s flow rate, followed by a 50-ml saline bolus chaser. A bolus tracking technique was used to synchronize the arrival of contrast in the abdominal aorta at the level of the renal artery. Scanning was triggered automatically when a threshold of 100 HU was reached in a region of interest (ROI) positioned in the abdominal aorta. All images were reconstructed with a field

FIGURE 1. Region of interest for the femoral bifurcation
The ROI selected for analysis comprised three segments of the bifurcations: common femoral artery (CFA; between the inferior border of the inferior epigastric artery and the bifurcation carina), the SFA (to a distance of 2 cm from the bifurcation carina), and the profunda femoral artery (PFA; to a distance of 2 cm from the bifurcation carina or the segment from the carina to the first tributary, whichever was shorter). Abbreviations: CFA, common femoral artery; PFA, profunda femoral artery; SFA, superficial femoral artery

view of 100 mm, matrix size of 512×512, slice thickness of 1.0 mm and increment of 0.7 mm.

Image analysis

Two experienced radiologists who were blinded to patients' identities and clinical conditions interpreted the images. MSCTA images were sent to a workstation (CARESTREAM RIS GC 3.1.S04.0; Carestream) with dedicated three-dimensional analysis software. Multi-planar reformatted images were generated and the lumen and vessel borders were traced longitudinally. Oblique planes were adjusted to evaluate the common femoral artery bifurcations in multiple reformations along the short and long axes with respect to the femoral artery. The common femoral artery bifurcations in both legs were evaluated. The ROI selected for analysis comprised three segments of the bifurcations: the common femoral artery (CFA; between the inferior border of the inferior epigastric artery and the bifurcation carina); the SFA (to a distance of 2 cm from the bifurcation carina); and the profunda femoral artery (PFA; to a distance of 2 cm from the bifurcation carina or the segment from the carina to the first tributary, whichever was shorter) (Figure 1). Measurements were made at each slice in each segment. The window level and width were set to 220 HU and 740 HU, respectively [12].

Plaque identification

Each cross section was divided into four equal quadrants extending from the center of the lumen: the anterior, lateral, posterior and medial quadrants (Figure 2A and B). The quadrants in the SFA in which the carina was located were recorded.

The presence of plaque was evaluated in each quadrant of the cross section. Atherosclerotic plaque was considered to be present when at least one of the following criteria was met: presence of calcification; vessel wall thickness > 1.1 mm [13]; and irregular vessel lumen contour. For occluding lesions, plaque was considered to be present in all four quadrants. The artery was considered to be normal when no plaque was identified.

Statistical analysis

Statistical analysis was performed using SPSS software (ver.20; SPSS Inc., Chicago, IL, USA). Continuous data are expressed as means ± standard deviations, and categorical data are expressed as counts and percentages. The chi-squared test was used for the comparison of categorical variables. Statistical significance was defined as $P < 0.05$.

FIGURE 2. Each cross section was divided into four equal quadrants extending from the center of the lumen: the anterior, lateral, posterior and medial quadrants. The quadrants in the SFA in which the carina was located were recorded.

TABLE 1. Demographic characteristics of the study population

Characteristic	Total (n=92)
Sex (male)	66 (71.7)
Age (years)	67.4±10.5
Hypertension	67 (72.8)
Dyslipidemia	61 (66.3)
Diabetes	62 (67.4)
Nicotine use	37 (40.2)
Coronary artery disease	31 (33.7)
Cranial artery disease	29 (31.5)

Data are presented as *n* (%) or mean±standard deviation.

Results

Patient characteristics

The medical histories and MSCTA images of 92 patients were evaluated. Reasons for exclusion of patients included previous percutaneous intervention or bypass surgery at the common femoral artery bifurcation (*n*=26) and poor image quality due to artifacts (*n*=5). The mean age of the population was 67.4±10.6 years. Most (66/92, 71.7%) of the patients were male. The demographic data are summarized in Table 1.

Quantitative plaque characteristics

In six (6.5%) patients, both common femoral artery bifurcations were free of atherosclerosis. Plaques were found in only one common femoral artery bifurcation in six (6.5%) patients (right, *n* = 2; left, *n* = 4). Both common femoral artery bifurcations showed atherosclerosis in the majority (*n*=80, 87.0%) of patients.

Of the 552 arteries inspected, 124 (22.5%) were normal without plaques, 162 (29.3%) were atherosclerotic in one or two quadrants and 256 (46.4%) had plaques in three or more quadrants (Table 2). The percentage of normality was greater in PFAs (35.3%) than in CFAs (15.7%) and SFAs (16.3%; both *P*<0.001). Plaque was present in three or four quadrants in a smaller percentage of PFAs (34.2%) compared with CFAs (48.4%; *P*=0.006) and SFAs (56.5%; *P*<0.001). The difference between CFAs and SFAs was not significant.

Plaque location and relationship to the carina

Plaques were found in posterior and medial quadrants in 76.6% (*n*=141) and 77.2% (*n*=142) of CFAs, respectively. Anterior and lateral quadrants were less often affected (44.0% and 42.9%, *P*<0.001 for comparison between anterior and posterior quadrants). In SFAs, plaques were found most frequently in anterior quadrants (78.3%, *n*=144) and least frequently in posterior quadrants (49.5%, *n*=91, *P*<0.001). In contrast, plaques were identified with similar frequencies in the four quadrants in PFAs (Table 3).

The carina was in the posterior quadrant in 160 (87.0%) bifurcations and in the lateral quadrant in 22 (12.0%) bifurcations in SFAs. Quadrants opposite the carina contained plaque most proportionally (77.2%) and quadrants of carina were affected least proportionally (52.7%) in SFAs, *P*<0.001. Quadrants adjacent to the carina clockwise or anticlockwise also contained a higher proportion of atherosclerosis than carina quadrants. Significance was found for anticlockwise quadrants (*P*=0.002), but not for clockwise quadrants (*P*=0.21), as is shown in Table 4.

Discussion

Few studies have focused on the exact plaque distribution at the common femoral artery bifurcation. Although the prevalence and predictive value for cardiovascular diseases of femoral artery atherosclerosis have long been investigated [14-18], no previous study has emphasized the presence of plaques at the bifurcation. One study, in which plaque was assessed in the femoral artery in hypertensive patients using ultrasonography, showed that most plaques were localized in the CFA and that the SFA contained large plaques [13]. Atherosclerosis distribution in coronary bifurcations has been investigated previously. One study explored plaque burden in different segments of the left main bifurcation using multi detector CT, and showed that atherosclerotic plaques were commonly located at the ostial left anterior descending (LAD) artery (main branch), whereas the left main coronary artery (LMCA, parent vessel) and the ostial left circumflex coronary (LCX) artery (side branch) were affected less frequently. In another study, intravascular ultrasound demonstrated that plaque burden was ≥40% lesser in LCX arteries (69.3%) than in LMCA (82.1%) and LAD (92.9%) arteries [19]. In this study, most (87%) patients had bilateral atherosclerotic plaques. Plaques were found more frequently in CFAs and SFAs than in PFAs, which is similar with the results of coronary arteries.

TABLE 2. Numbers of quadrants with plaques

Quadrants	Right bifurcation (n=92)			Left bifurcation (n=92)		
	CFA	SFA	PFA	CFA	SFA	PFA
0	14 (15.2)	17 (18.5)	31 (33.7)	15 (16.3)	13 (14.1)	34 (37.0)
1	3 (3.3)	2 (2.2)	11 (12.0)	6 (6.5)	8 (8.7)	8 (8.7)
2	27 (29.3)	21 (22.8)	16 (17.4)	30 (32.6)	19 (20.7)	21 (22.8)
3	20 (21.7)	20 (21.7)	16 (17.4)	16 (17.4)	19 (20.7)	9 (9.8)
4	28 (30.4)	32 (34.8)	18 (19.6)	25 (27.2)	33 (35.9)	20 (21.7)

Data are presented as n (%) or mean $\pm$ standard deviation.

Abbreviations: CFA, common femoral artery; PFA, profunda femoral artery; SFA, superficial femoral artery

TABLE 3. Distribution of plaques and carinas

Quadrant	CFA	SFA	PFA	SFA carina
Anterior	81 (44.0)	144 (78.3)	82 (44.6)	1 (0.5)
Lateral	79 (42.9)	105 (57.1)	85 (46.2)	22 (12.0)
Posterior	141 (76.6)	91 (49.5)	85 (46.2)	160 (87.0)
Medial	142 (77.2)	128 (69.6)	68 (37.0)	1 (0.5)

Data are presented as n (%) or mean $\pm$ standard deviation.

Abbreviations: CFA, common femoral artery; PFA, profunda femoral artery; SFA, superficial femoral artery

TABLE 4. Proportion of patients with plaque in relation to the carina

	Same	Clockwise	Anticlockwise	Opposite
Right	58.7% (54)	59.8% (55)	66.3% (61)	73.9% (68)*
Left	46.7% (43)	58.7% (54)	70.7% (65)*	80.4% (74)**
Total	52.7% (97)	59.2% (109)	68.5% (126)*	77.2% (142)**

* P (vs. same) < 0.05 ** P (vs. same) < 0.001

Definitions: Same means patients with plaque in the same quadrant as the carina;

clockwise means patients with plaque in the quadrant adjacent to the carina clockwise; anticlockwise means patients with plaque in the quadrant adjacent to the carina anticlockwise; and opposite means patients with plaque in the quadrant opposite the carina.

In the present study, atherosclerosis appeared at anterior walls less than posterior walls of CFAs. This distribution pattern was reversed in SFAs, in which most plaques located in anterior quadrants and fewest located in posterior quadrants. Awareness of this distribution pattern is important for clinicians because CFA is an important access site for endovascular procedures. Femoral access should be performed with image guidance to ensure that the vessel is accessed at the appropriate level. Puncture of the external iliac artery predisposes patients to higher rates of retroperitoneal hemorrhage [20], whereas puncture below the bifurcation is associated with pseudoaneurysm, hematoma, arterio-venous fistula and ischemic limb complications [2,22].

Quadrants nearer to the carina were found to be burdened with less plaque in SFA in this study. The proportion of atherosclerosis was lowest in carina quadrants and highest in opposite quadrants. This could be explained by the wall shear stress (WSS) distribution at the bifurcation. Atherosclerosis distribution at the bifurcation and the role of WSS in plaque development have been investigated in the carotid and coronary arteries [5,19,23-29]. Lower WSS at outer walls of vascular bifurcations was associated with localization of atherosclerosis and pathologic lesions were absent from the flow dividers and inner wall where WSS is higher [24]. Cross-sectional studies of the carotid artery have demonstrated that WSS was lower in areas with plaque than those in the absence of plaque [26]. An MSCT study of the coronary artery demonstrated that plaque was present most commonly in low WSS regions, whereas plaque in high WSS regions was accompanied by plaque in adjacent low-WSS regions [29]. WSS has been shown to affect endothelial phenotype, endothelial cell signaling, low-density lipoprotein uptake, redox state and proinflammatory pathways, and thus to promote the development of atherosclerosis [30]. In the

present study, plaque in common femoral artery bifurcations tended to locate in quadrant opposite the carina in SFA, where WSS was lower according to existing literature of carotid and coronary arteries [5,19,23-29].

Limitations

As the present study was based on data from a single center, the generalizability of the results is restricted. In addition, the criteria for the presence of plaque are controversial, as the determination of vessel wall thickness and irregularity of the vessel lumen contour can be subjective. The PFA segment of the common femoral artery bifurcation is considered to be located 2 cm to the bifurcation carina or to be the segment from the carina to the first tributary, whichever is shorter; thus, PFA length varies among bifurcations, which may cause bias in the identification of atherosclerosis. Further investigations could emphasize the use of novel non-invasive methods and modalities for the detection of atherosclerotic plaques. Relationships of plaque constitution and morphology with the remodeling patterns of femoral arteries should also be investigated.

Conclusions

The presence and distribution of atherosclerotic plaques were diverse in different artery beds of the common femoral artery bifurcations. Plaque tended to be located in areas opposite the carina in superficial femoral arteries.

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