ORIGINAL RESEARCH

Prevalence of carotid artery calcifications detected on panoramic radiographs and confirmed by Doppler ultrasonography: Their relationship with systemic conditions

Thalita Queiroz Abreu, Elza Bernardes Ferreira[1], Sebastião Barreto de Brito Filho[2], Kelston Paulo Felice de Sales[3], Fernanda Ferreira Lopes[4], Ana Emília Figueiredo de Oliveira

Departments of Dentistry I and [4]Dentistry II, School of Dentistry, Federal University of Maranhão, [1]Open University of Brazilian National Health System of the Federal University of Maranhão, [2]Department of Medicine II, School of Medicine, Federal University of Maranhão, [3]Member of the Cardiovascular Surgery Sector of the University Hospital of Medicine, Federal University of Maranhão, São Luís, MA, Brazil

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ABSTRACT

Context: Atherosclerosis affects large and medium caliber arteries by forming calcific atheromas, precursors of cerebral vascular disease. Diabetes mellitus, obesity, and hypertension are considered as risk factors of atherosclerosis. Panoramic radiographs can display images suggestive of carotid artery calcifications (CACs).

Aims: To investigate the prevalence of images suggestive of CAC in panoramic radiographs of the jaws (PRJs) and confirm them by Doppler ultrasonography. To evaluate their anatomic locations and relationships between systemic conditions (diabetes, hypertension, and obesity) and the presence of unilateral or bilateral CAC detected on PRJ or by Doppler ultrasonography.

Materials and Methods: Of the 723 routinely performed PRJ in patients over 40 years at the Radiology Center in São Luís, Maranhão, Brazil, 21 PRJ containing images suggestive of CAC were selected in this cross-sectional study. The findings from the PRJ were confirmed by Doppler sonography.

Results: Images suggestive of CAC was detected in 21 (2.9%) of the PRJ evaluated, consisting of 11 (52.4%) hypertensive, 7 (33.3%) diabetics, and 9 (42.9%) obese. There was a higher prevalence of hypertensive patients in the unilateral CAC group (100%) and bilateral CAC (60%) compared to patients without CAC (25%).

Conclusions: CACs can be detected in PRJs, and are more frequent in common carotid arteries. No significant associations were detected between the presence of unilateral or bilateral CAC in PRJ and hypertension, diabetes, or obesity.

Key words: Atherosclerosis, carotid artery diseases, panoramic radiography, ultrasonography

Panoramic radiographs of the jaws (PRJs) are routinely used in dentistry and are of great value in identifying images of pathological changes such as carotid artery calcifications (CACs).[1-3] This fact has attracted considerable attention as findings from PRJ can be used as additional information that may aid in the prevention of cardiovascular and cerebral vascular events.[4,5] Doppler ultrasonography is most commonly used to assess the location and degree of obstruction caused by CAC.[6-8] Diabetes mellitus, obesity, and hypertension are the known risk factors for atherosclerotic disease.[9,10]

This study aimed to investigate the prevalence of images suggestive of CAC, detected by PRJ and confirmed by Doppler ultrasonography. Furthermore, in addition to their anatomic locations, we examined the relationships between the systemic conditions (hypertension, diabetes mellitus, and obesity) and the presence of unilateral or bilateral CAC, detected in PRJ or by Doppler ultrasonography.

Address for correspondence:
Dr. Thalita Queiroz Abreu
E-mail: thalita_abreu@hotmail.com

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MATERIALS AND METHODS

This cross-sectional study was developed in a radiology clinic contracted by the Brazilian National Health System, in São Luís, Maranhão, Brazil, where PRJ were taken for routine dental purposes. The PRJs were obtained using the standard positioning technique and were taken with an X-ray machine (Model ORTHOPHOS 3 Ceph®, Sirona Dental Systems GmbH, Germany) and a 15 cm × 30 cm panoramic film (Eastman Kodak Co.,® Rochester, NY, USA). All films were processed automatically (Xtec-Revell® Ltda., São Paulo, SP, Brazil), with developer and fixer solutions (Kodak® Brazilian Trade and Industry Ltda., São José dos Campos, Brazil).

The work was approved by the Ethics Committee of the Federal University of Maranhão (Protocol 2311-005753/2009–57) and is in accordance with the Helsinki Declaration. Sample selection was carried out during a period of 1-year, wherein 723 panoramic radiographs from male and female patients, with a minimum age of 40 years, were evaluated by two dental radiologists. The radiographic images were interpreted in low-light conditions, using a negatoscope. The study included only cases where the presence of unilateral or bilateral suggestion of CAC was detected [Figure 1]. From this initial screening, 21 PRJ with images suggestive of CAC were detected. To confirm the presence of stenosis and/or obstruction by atheroma, participants were asked to undergo color Doppler sonography for the neck vessels in Presidente Dutra University Hospital in the City of São Luís, MA, Brazil. A Duplex Scan® (General Electric, NY, USA) was used as it is has good reliability, in showing the blood flow in the studied artery. An angiologist determined if there was stenosis and/or obstruction by atheroma. The anatomical location of the CAC was noted [Figure 2]. Assessment of systemic conditions included the presence or absence of hypertension, obesity, and diabetes mellitus. Patients were classified as hypertensive if they reported the use of antihypertensive drugs or when the systolic blood pressure and/or diastolic blood pressures, measured using a sphygmomanometer, were ≥140 mmHg and/or ≥90 mmHg, respectively, while seated and at rest for 5 min prior to the exam.[11] Obesity was defined as body mass index (BMI) ≥30 kg/m^2, wherein BMI was calculated as the ratio of weight (in kilograms) to the height (in square meters).[12] Weight and height were measured using a mechanical scale with an attached stadiometer (Welmy®). Patients with diabetes mellitus were identified by the reported use of hypoglycemic drugs and/or insulin therapy.

Data were analyzed using the software program SPSS (version 18.0, IBM, Chicago, IL, USA). First, descriptive statistical analysis was performed using frequencies, means, and standard deviations. The Fisher's exact test was used to evaluate differences in frequencies of systemic conditions between patients with unilateral or bilateral CAC detected in the panoramic radiographs and between patients with confirmation of the presence or absence of CAC by Doppler. The level of significance adopted was 5% ($P < 0.05$).

RESULTS

The initial screening of 723 routine PRJs, obtained from individuals over 40 years old, resulted in the detection of 21 (2.9%) radiographs with images suggestive of CAC. The profile of individuals positive for CAC images in PRJ are described in Table 1 and comprises 17 women (81%) and 4 men (19%), with an average age of 54.9 ± 8.8 years. Among them, there were 11 hypertensive (52.4%), 7 diabetic (33.3%), and 9 obese (42.9%) patients. Unilateral CAC images were observed in 13 (61.9%) samples, while bilateral images were observed in 8 (38.1%).

Images suggestive of unilateral CAC were most commonly found in the hypertensive patients (61.5%). Among the patients diagnosed with bilateral CAC, 50% had diabetes mellitus, while 62.5% were obese. Hypertensive patients had a higher prevalence of unilateral atheromas, whereas bilateral atheromas were more common in obese individuals,

Figure 1: Panoramic radiography scanned with an image suggestive of the calcified carotid atheroma

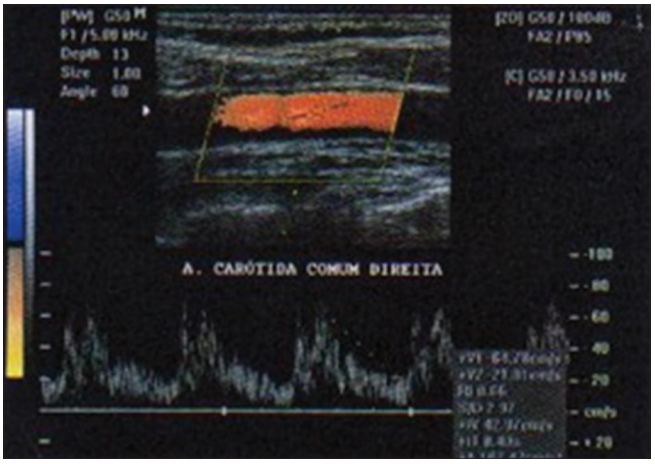

Figure 2: Color Doppler image of the right common carotid artery

although the difference in the percentages between the two groups was not statistically significant [Table 2].

Doppler ultrasonography was used to confirm the diagnosis of CAC in the 21 PRJ, revealing no evidence of carotid calcification in 8 cases, due to overlying anatomical structures (i.e., triticeous cartilage) or other pathological soft tissue calcifications in the head and neck region. The presence and anatomical location of the CACs detected by Doppler are described in Table 3. Higher percentages of CAC were located in the left (57.1%) and right (52.4%) common carotid arteries, followed by the left (14.3%) and right (9.5%) internal carotid arteries.

No statistical differences ($P > 0.05$) were observed between the presence of positive calcifications, by Doppler, and the systemic conditions, hypertension, diabetes, and obesity, despite there being a borderline association with the hypertension variable ($P = 0.062$). The majority of individuals presenting with unilateral or bilateral calcifications, confirmed by Doppler were also hypertensive [Table 4].

Table 1: Profile of patients with carotid artery calcifications detected in PRJ

Case	Gender	Age	HT	OB	DM	Side of CAC in PRJ	
						Right	Left
1	Female	56	Yes	No	Yes	Yes	Yes
2	Female	69	Yes	No	No	No	Yes
3	Female	64	No	Yes	No	Yes	Yes
4	Female	52	No	No	Yes	Yes	No
5	Male	45	Yes	No	No	Yes	No
6	Female	62	No	No	Yes	Yes	No
7	Female	76	Yes	Yes	Yes	No	Yes
8	Female	57	Yes	No	Yes	Yes	Yes
9	Male	51	No	Yes	No	Yes	Yes
10	Female	58	Yes	No	No	No	Yes
11	Male	43	Yes	Yes	No	No	Yes
12	Male	50	No	No	No	No	Yes
13	Female	50	No	Yes	No	Yes	No
14	Female	47	No	Yes	No	Yes	Yes
15	Female	66	Yes	No	No	Yes	No
16	Female	48	No	No	No	No	Yes
17	Female	61	Yes	Yes	Yes	Yes	Yes
18	Female	55	No	No	Yes	Yes	Yes
19	Female	43	No	Yes	No	Yes	Yes
20	Female	52	Yes	Yes	No	Yes	No
21	Female	49	Yes	No	No	No	Yes

PRJ=Panoramic radiograph of the jaw, CAC=Carotid artery calcification, HT=Hypertension, OB=Obesity, DM=Diabetes mellitus

DISCUSSION

The main findings of this study suggest that CAC can be detected in routine PRJ, and has a higher prevalence in the left and right common carotid arteries. Furthermore, no significant differences were observed in the frequencies of hypertension, diabetes mellitus, and obesity among patients presenting with unilateral or bilateral CAC in PRJ. However, a significantly higher proportion of hypertensive subjects presented with CAC, confirmed by Doppler imaging.

Table 2: Systemic characteristics of individuals, distributed according to the occurrence of unilateral or bilateral CAC in PRJ

Systemic condition	Occurrence of CAC in PRJ *n* (%)		Total *n* (%)	*P**
	Unilateral	Bilateral		
HT				
Yes	8 (61.5)	3 (37.5)	11 (52.4)	0.267
No	5 (38.5)	5 (62.5)	10 (47.6)	
DM				
Yes	3 (23.1)	4 (50.0)	7 (33.3)	0.212
No	10 (76.9)	4 (50.0)	14 (66.6)	
OB				
Yes	4 (30.8)	5 (62.5)	9 (42.9)	0.165
No	9 (69.2)	3 (37.5)	12 (57.1)	

*Comparative analysis of systemic condition and type of CAC (unilateral or bilateral). Fisher's exact test (α=0.05). CAC=Carotid artery calcification, PRJ=Panoramic radiograph of the jaw, DM=Diabetes mellitus, HT=Hypertension, OB=Obesity

The prevalence of CAC images suggestive of CAC on routine panoramic radiographs was 2.9%, in the present study. This is in accordance with previous studies where the prevalence of CAC in PRJ has been reported to range from 0.43% to 5%, depending on variables such as age, gender, ethnicity, and lifestyle.[6,13-18]

The calcified plaques of atheroma can be seen on panoramic radiographs as adjacent nodular radiopacities, not continuous, at the level of the C3 and C4, differing from the usual radiopaque structures of this region. These plaques can also present themselves as radiopaque vertical lines, representing fine calcifications in vascular walls. These calcifications appear separate and distinct from the hyoid bone, being located near or adjacent to it.[4,10,15,19-21] Atheromas found in panoramic radiographs should be differentiated from other anatomical radiopacities located near the carotid artery region, such as calcifications of the styloid process, hyoid bone, epiglottis, calcification of the stylohyoid, and stylomandibular ligaments.[4] Besides these, it must also be differentiated from pathological radiopacities, such as phleboliths, sialoliths, rhinoliths, antroliths, and calcified lymph nodes, in addition to the calcified triticeous cartilage, which are ovoid radiopaque structures located centrally within the free posterior edge of the lateral thyrohyoid ligaments, observed adjacent to the posterior portion of C4.[2,4,9,15,20,22]

A study by Tofangchiha *et al.*[23] involving 158 patients with diabetes mellitus type 2 showed that the frequency of calcified carotid atheromas on panoramic radiographs is higher in diabetic patients than in normal individuals. Thirty-eight (82.6%) of the 46 diabetic patients diagnosed with calcification, in the afore-mentioned study, presented with unilateral calcifications, while 8 (17.4%) of them had bilateral calcifications ($P < 0.001$). Therefore, dentists should be informed of the possibility of observing calcifications in PRJ, and patients (particularly those in the high-risk category) withlinear and nodular opacities in the space

Table 3: Distribution of the location of carotid artery calcifications detected on the Doppler

Case	Branches of the right carotid artery				Branches of the left carotid artery			
	CCA	ICA	ECA	VA	CCA	ICA	ECA	VA
1	Yes	No	No	No	Yes	No	No	Yes
2	Yes	No	No	No	Yes	No	No	No
3	Yes	No	No	No	Yes	No	No	No
4	Yes	No	No	No	Yes	No	No	No
5	Yes	No	No	No	Yes	No	No	No
6	Yes	Yes	No	No	Yes	Yes	No	No
7	Yes	No	No	No	Yes	No	No	No
8	Yes	No	No	No	No	No	No	No
9	No	No	No	No	No	No	No	No
10	No	No	No	No	Yes	No	No	No
11	No	No	No	No	No	No	No	No
12	No	No	No	No	No	No	No	No
13	No	No	No	No	No	No	No	No
14	Yes	No	No	No	Yes	No	No	No
15	No	No	No	No	Yes	Yes	No	No
16	No	No	No	No	No	No	No	No
17	Yes	No	No	No	Yes	No	No	No
18	No	No	No	No	No	No	No	No
19	No	No	No	No	No	No	No	No
20	Yes	Yes	Yes	No	Yes	Yes	Yes	No
21	No	No	No	No	No	No	No	No
Total (%)	11 (52.4)	2 (9.5)	1 (4.8)	0 (0)	12 (57.1)	3 (14.3)	1 (4.8)	1 (4.8)

CCA=Common carotid artery, ICA=Internal carotid artery, ECA=External carotid artery, VA=Vertebral artery

Table 4: Systemic characteristics of individuals, distributed according to the presence of unilateral or bilateral CAC confirmed by Doppler examination

Systemic condition	Occurrence of CAC in Doppler *n* (%)			*P**
	Absent	Present		
		Unilateral	Bilateral	
HT				
Yes	2 (25.0)	3 (100)	6 (60.0)	0.062
No	6 (75.0)	0 (0)	4 (40.0)	
DM				
Yes	1 (12.5)	1 (33.3)	5 (50.0)	0.207
No	7 (87.5)	2 (66.7)	5 (50.0)	
OB				
Yes	4 (50.0)	1 (33.3)	5 (50.0)	0.359
No	4 (50.0)	2 (66.7)	5 (50.0)	

*Comparative analysis of systemic condition and type of CAC (absent or unilateral or bilateral). Freeman-Halton extension of the Fisher's exact probability test (α=0.05). CAC=Carotid artery calcification, HT=Hypertension, DM=Diabetes mellitus, OB=Obesity

between the third and fourth cervical vertebrae should be referred to specialists for further, more accurate, medical examinations.[23]

Tamura *et al.*[24] evaluated the prevalence of carotid calcifications in 2568 panoramic radiographs, and assessed their relationship with the risk factors for vascular diseases. They found that individuals with carotid calcifications had medical histories that included hypertension (27.6%), obesity (21.1%), hyperlipidemia (14.5%), and cardiovascular diseases (13.2%), all of which are recognized risk factors for atheromas and showed that the detectection of carotid calcifications on panoramic radiographs may help prevent stroke.

Obesity is reported as a risk factor for atherosclerosis. In the present study, 9 (42.9%) of the 21 participants with atheromas on panoramic radiographs, were obese. Among the subjects with CAC, confirmed by Doppler, 38.5% were obese, although no statistically significant diferrences were observed in between the frequencies of obese patients with or without artery calcification ($P = 0.472$).

Some areas of the body, such as those with low pressure, flow separation and blood stasis, are at a higher risk in developing plaques, due to decreased blood flow velocity and increased exposure to atherogenic particles, which, in the presence of hyperlipidemia, increases the risk of plaque formation.[5] In the present study, a major portion of the calcifications were detected in the common carotid arteries, before the bifurcation into internal and external carotid, representing an area of reduced blood flow with increased risk of atheroma formation.

Of the 21 participants who had atheromas detected by panoramic radiography, 11 were hypertensive and 7 were diabetics. Although the results of this study show no dependence of the presence of positive calcification, confirmed by Doppler, with the variable hypertension, a close association was noted ($P = 0.063$). Chronic elevation of blood pressure damages the lining of the arteries and accelerates the development of atheromas by endothelial dysfunctions. Over time, there is increased expression of adhesion molecules on the endothelium along with susceptibility to endothelial infiltration of some cells, initiating the process of atherogenic inflammatory changes. The endothelial lining secretes substances, such as, nitric oxide, prostacyclin, and endothelium-derived hyperpolarizing factor, which protect against the development of vascular lesions. The endothelium also secretes contractile factors, such as endothelin,

angiotensin II, prostaglandins and reactive oxygen species. In pathological conditions, like arterial hypertension and diabetes mellitus, a metabolic imbalance followed by the reduction of the effects of vasodilation occurs, resulting in a process known as endothelial dysfunction, leading to the development of atheroma plaques.[5]

Diabetes mellitus is a common systemic disease and can be of two types: Type 1 (insulin dependent) and type 2 (noninsulin-dependent), with approximately 85–90% of patients having type 2 diabetes. Due to increased serum glucose and lipid levels as well as high blood pressure, diabetic patients have a higher risk of cerebral vascular accident stroke.[20] Studies have shown that about 80% of the strokes are induced by atherosclerotic plaques detected on the main bifurcations of the carotid artery.[18,23,25]

In our study, there were no differences in the frequencies of diabetes mellitus between patients with unilateral or bilateral atheromas in PRJ, confirmed by Doppler. Kataoka *et al.*[26] (2013) however demonstrated that the improvement of glycemic status and of multiple risk factors in early stage diabetic patients, provides benefits in the progression of atheroma plaques in individuals with coronary artery disease. In another study, panoramic radiographs revealed the prevalence of carotid arteries calcifications in 24% of the diabetic patients treated without insulin, and in 36% of the diabetics treated with insulin. This demonstrates the high-risk of stroke in diabetic patients regardless of the treatment modality used.[7] The inconsistency of results between the two afore-mentioned studies may be explained by the stage of diabetes in patients who made up the samples.

The rate of detection of calcified carotid atheromas in hypertensive, diabetic, and/or obese patients, in the present study, were similar between panoramic radiography and Doppler sonography. Nevertheless, there is controversy in the literature as to the accuracy of panoramic radiography in detecting carotid calcifications. A study conducted in 2007 showed that PRJ presented low sensitivity and accuracy for detecting calcifications,[1] although TT is worthy to note that radiographs were interpreted by a single dental radiologist and two different X-ray equipment had been used for image acquisition. On the other hand, as indicated in the same study, Doppler images of calcifications were obtained from several locations and interpreted by different radiologists.

Romano-Sousa *et al.*[2] had also investigated the accuracy of Doppler color and panoramic radiographs images in the diagnoses of calcified atheroma, in a study conducted at the city of Valença, RJ, Brazil and found a substantial agreement between the two techniques (kappa value of 0.78).

Regardless of the presence of systemic factors such as obesity, hypertension, and diabetes, if the panoramic radiograph suggests a diagnosis of carotid atheroma, the patient should be referred to a neurologist to confirm the diagnosis. This is performed by Doppler ultrasonography, which allows for the visualization of the walls and lumen of the vessels, blood flow and the location and size of atheroma in the carotid artery. In addition to being cost-effective, Doppler ultrasonography is a more sophisticated method that reproduces detailed images, without the use of ionizing radiation.[6,9,27]

It is important to emphasize that lifestyle changes such as diet, physical activity, and reduced stress are important strategies for the prevention of atherosclerosis and the associated systemic conditions, obesity, hypertension, and diabetes. It is the prerogative of the dentists to guide and refer patients with suspected carotid artery atheromas indicated on the panoramic radiographs, for appropriate medical treatment, thereby helping to save many lives.[10]

CONCLUSIONS

CACs can be detected using panoramic radiographs, which are more prevalent in the left and right common carotid arteries. There were no differences in the frequencies of hypertension, diabetes mellitus and obesity between patients with unilateral or bilateral CAC in PRJ. However, hypertensive patients presented with a higher percentage of CAC confirmed by Doppler ultrasonography.

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Conflicts of interest
There are no conflicts of interest.

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