Validation of a method for quantifying carotid artery calcification from panoramic radiographs

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Objective. Carotid artery calcification can be visualized on panoramic radiographs. Incidental observation of these calcifications could identify patients in need of further screening. The purpose of this study was to validate the assessment and quantification of calcification on panoramic radiographs with the stenosis and the calculated resistive index (RI) from Doppler ultrasonography.

Study design. Digital panoramic radiographs were used to assess the area of carotid artery calcification using tools available in NIH's ImageJ. Inpatient and outpatient discharge records were reviewed to identify subjects with a completed carotid Doppler ultrasound exam ($n = 122$).

Results. The quantification of carotid artery calcification was found to correlate well with the degree of stenosis (area under the curve [AUC] 0.81 [95% confidence interval [CI] 0.64, 0.98]) and the RI of the common carotid artery (AUC 0.79 [95% CI 0.59, 0.98]).

Conclusion. This method for quantification of carotid artery calcification could identify patients in need of further evaluation.

(Oral Surg Oral Med Oral Pathol Oral Radiol 2013;116:518-524)

Vascular calcification is common in advanced atherosclerotic lesions.[1,2] The amount of calcification increases with age and is less common in African-Americans compared to other races.[3,4] It also occurs more frequently in individuals with other diseases, such as diabetes and end-stage renal disease.[3] Rigid calcium deposits increase stability within a lesion, but decrease stability in adjacent sections due to compensatory motion and stress at the edges of the mineralized section.[3,5] Calcification results in reduced distensibility of the affected vasculature.[5] This increases pulse pressure, resulting in hypertension, and can lead to congestive heart failure, left ventricular hypertrophy, coronary insufficiency, and death.[3,5-7]

Stroke or cerebral vascular disease is the third leading cause of death in the US.[8] Cerebral vascular disease is often associated with atherosclerosis and calcification of the carotid arteries.[9] About 80% of strokes are ischemic and are caused by atherosclerosis, resulting in turbulent blood flow and clot formation.[8] Of ischemic strokes, about half are caused by a stationary blood clot in the carotid arteries and the other half are caused by stenosis, mostly in the area of the carotid bifurcation.[8]

Carotid calcification has been associated with a subsequent increased stroke risk.[10] The degree of calcification has been shown to be associated with the amount of luminal stenosis.[11] For patients with asymptomatic atherosclerosis in the carotid arteries, the yearly risk of cerebral infarction is between 1% and 3%, and for patients with arterial stenosis or ulcerative lesions the risk increases to between 5% and 7% per year.[9,12-14] The majority of strokes occur without a preceding transient ischemic attack, which results in temporary and brief symptoms stemming from the disruption of the blood supply.[8,12-14] Carotid calcification has been shown to correlate well with past cardiovascular and cerebrovascular disease.[15]

More than 20 years ago, it was determined that carotid artery calcification could be visualized on panoramic radiographs.[16] Calcifications appear as nodular radiopaque masses or vertical lines inferior or posterior to the angle of the mandible.[10] Carotid artery calcification

Statement of Clinical Relevance

Dental providers frequently use panoramic radiographs for routine clinical purposes. The incidental observation of carotid artery calcification and quantification of carotid artery calcification could be used to identify patients that could benefit from further evaluation.

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Received for publication Mar 14, 2013; returned for revision Jun 14, 2013; accepted for publication Jun 21, 2013.

2212-4403/$ - see front matter
http://dx.doi.org/10.1016/j.oooo.2013.06.026

assessed from panoramic radiographs correlate well with carotid stenoses determined by duplex Doppler ultrasonography and carotid digital subtraction angiography.[9,17-20] Sensitivity and specificity (with Doppler ultrasonography or digital subtraction angiography as the gold standard) have been observed to range from 66.6 to 90.0 and 68.8 to 88.2, respectively,[19,21] although some studies have failed to find good correlation between carotid artery calcification and ultrasonography.[21,22] However, the presence of carotid artery calcification on panoramic radiographs may be highly suggestive of a high degree of luminal stenosis,[20,23] particularly in men.[24] Carotid artery calcification assessed from electron beam computed tomography (EBCT) does not appear to correlate well with carotid intima-media thickness (IMT) measurements.[25]

Assessment of carotid artery calcification from panoramic radiographs varies from simply acknowledging it's presence to using complex methods of image analysis to attempt to quantify the amount of calcification present. With the use of readily available image analysis software, such as NIH's ImageJ (NIH, Bethesda, MD; http://imagej.nih.gov/ij/), a quantitative measure of carotid artery calcification can be obtained from panoramic radiographs. This can be accomplished by manually tracing around the calcification using draw tools available in ImageJ, and then using the area measurement tool to determine the area within the tracing.[26] Another method involves creating a rectangular selection around the calcification and using the threshold tools to highlight a range of gray-level values to select the calcification from the background.[27] The thresholded area is then measured using the measurement tools on the Analyze menu. These methods are relatively simple and easy to perform, and provide a quantitative measure of carotid artery calcification. Unfortunately, there are no published studies utilizing these techniques in quantifying carotid artery calcification. Consequently, there are also no published articles correlating these methods of carotid artery calcification quantification with more established methods for assessing carotid artery disease. The purpose of this study was to validate the assessment and quantification of vascular calcification from panoramic radiographs with the stenosis and the calculated resistive index (RI) from Doppler ultrasonography. The resistive indices of the common carotid artery (CCA) and the internal carotid artery (ICA), measures of vascular resistance, have been previously shown to correlate well with the carotid IMT and generalized atherosclerosis.[28] The ICA RI, in particular, has been shown to be a predictor of future cardiovascular events.[29]

MATERIALS AND METHODS

This study involved medical record review at the VA Medical Center in Denver, Colorado. Digital panoramic radiographs were used to assess the area of carotid artery calcification. Inpatient and outpatient discharge records were reviewed to identify subjects with a completed carotid Doppler ultrasound exam and to obtain demographic information. No names, phone numbers, or other identifying information was collected. Information was collected from all VA medical centers available for each subject. The assessment of carotid artery calcification was performed within a larger study examining the association between alveolar bone loss and cardiovascular disease.[30] This validation study was performed on the subset of subjects with an available carotid ultrasound ($n = 121$).

This study was reviewed and approved by the appropriate institutional review boards and adheres to the guidelines of the Helsinki Declaration. A waiver of consent was obtained since only existing records were utilized for this study.

Assessment of the carotid artery calcification

Carotid artery calcifications on panoramic radiographs appear as nodular or dual vertical line radiopacities at the approximate level of the hyoid bone, epiglottis, or the lower margin of the third cervical vertebra (C3).[8,31] Calcification of other structures in the same area, including calcification of the triticeous cartilage, greater horn of the hyoid bone, and the superior horn of the thyroid cartilage, may confound the identification of arterial calcification.[8,32-34] While it may be difficult to differentiate these structures, Ahmad, et al.[32] showed that some differentiation is possible based on shape, as calcified atheromas appear as mostly linear structures with irregular borders while calcified triticeous cartilages appear as mostly oval with well-defined borders. Carter et al.,[34] have identified calcifications of the superior horn of the thyroid cartilage as appearing at the lower edge of the panoramic radiograph medial to the C4 vertebra, that are approximately 4 mm wide. We used these additional definitions to exclude oval to round appearing structures with regular borders, and identified radiopacities as calcification only when it exhibited a mostly verticolinear, heterogeneous appearance separate from the hyoid bone. The presence of radiopacities meeting this description was recorded for both the right and left sides.

The procedure described in Mitsuyama et al.,[27] was used to measure the area of calcification. All image analyses were performed using NIH's ImageJ. The image was zoomed to the region of interest involving the carotid bifurcation (area around the lower margin of C3 vertebra). The contrast and brightness of the image were adjusted to better reveal any radiopacities in the region of interest (Image → Adjust → Brightness/Contrast). For any radiopacities meeting the description of carotid artery calcification a rectangular selection was drawn around the calcification (Figure 1*A*). The range of gray-level values to select the calcification from the