Styloid and Hyoid Bone Proximity Is a Risk Factor for Cervical Carotid Artery Dissection

Dimitri Renard, MD; Souhayla Azakri, MD; Caroline Arquizan, MD; Bart Swinnen, MD; Pierre Labauge, MD, PhD; Vincent Thijs, MD, PhD

Background and Purpose—Carotid artery dissection (CAD) is more common with increased styloid process length. Our goal was to determine whether proximity of the styloid process and the hyoid bone to the internal carotid artery (ICA) was a risk factor for CAD.

Methods—We studied axial slices on computed tomography angiograms of 88 patients with nonaneurysmal CAD, from 88 age- and sex-matched controls without dissection, and from 32 nonage-/sex-matched nonaneurysmal vertebral artery dissection control patients. We measured the nearest distance between the ICA and both the styloid and the hyoid bones, blinded to clinical information and radiological reports.

Results—Styloid-ICA and hyoid-ICA distances were significantly shorter on the side of the CAD as compared with nondissection control patients (P<0.0001 for the styloid-ICA distance; and P=0.0037 for the hyoid-ICA distance). Styloid-ICA distances, regardless of the side of the dissection, were shorter in CAD patients compared with the nondissection control group. We measured the nearest distance between the ICA and both the styloid and the hyoid bones, blinded to clinical information and radiological reports.

Conclusions—Shorter distances between the styloid and ICA (and possibly also the hyoid and the ICA) are important risk factors for CAD. Further study is needed to determine whether dissections result from direct injury to the outer vessel wall of the carotid artery. (Stroke. 2013;44:2475-2479.)

Key Words: carotid arteries ■ dissection ■ hyoid bone ■ styloid
(ie, the nearest distance between the bone structure and the carotid artery) may be a more important risk factor than the length itself of these bony structures. Longer styloid or hyoid bone structures might indirectly represent a closer anatomic proximity to the carotid arteries, but the distal end of these bony structures does not necessarily represent the area of closest contact to the artery.

Our aim was to analyze the distance between the ICA and both the styloid and the hyoid bones in a large group of patients with CAD, and controls.

Methods

Patient Selection

We performed a retrospective multicenter case–control study of CAD patients and age- and sex-matched controls without dissection and patients with vertebral artery dissection (VAD). Patients and controls were selected from stroke registries of 3 University Hospitals in Belgium and France between 2005 and 2012. Cases and controls had undergone computed tomography angiograms (CTA) as part of their routine workup of suspected cerebral ischemia or workup of local symptoms related to dissection (Horner syndrome, cranial nerve disease, or headache). Known iodine contrast allergy and renal insufficiency were contraindications for CTA in both the CAD and control populations. In all 3 centers, CTA was frequently used in both the initial workup (especially if MRI-MRA and duplex scanning did not lead to definitive diagnosis) and during follow-up. Ethics approval was obtained according to local regulations. Informed consent requirements were waived. Common cardiovascular risk factors were recorded in the CAD, VAD, and nondissection group. Potential risk factors for dissection (coughing, neck movement, minor trauma, etc) were not systematically recorded in the nondissection group and, therefore, not mentioned.

Cases

Cases were defined as patients with a unilateral ICA dissection. We excluded patients with radiological evidence of fibromuscular dysplasia and patients with pseudoaneurysmal forms of dissection. We also excluded patients with dissections of the common carotid artery (because styloid/hyoid bone proximity exists most often above the carotid bifurcation and, therefore, a mechanical role is less likely), patients with concomitant vertebral artery or contralateral ICA dissection, and patients with a history of penetrating trauma, neck surgery, and patients with aortic dissection.

CAD was confirmed in all patients by additional examinations (carotid duplex ultrasound, MR angiography, fat-saturated T1-weighted MRI, and rarely conventional angiography).

Controls

Two control groups were defined: (1) age- and sex-matched controls who underwent CTA and who did not have a history of carotid artery stenting or surgery and no CAD and (2) patients with a nonaneurysmal form of VAD. Age- and sex-matching were not performed in this last group. The VAD group was included because proximity of the bony structures to CAD might be just a bystander phenomenon common to all dissection patients. For anatomic reasons, it is unlikely that styloid and hyoid bone structures play a role in VAD.

Measurements

CTA was performed with different scans with slightly different parameters (Leuven-Belgium: Siemens Somatom Sensation 64, 120 kV, 95 mAS, 250 mm field of view, 512×512 matrix or Siemens Somatom Definition Flash 2011, 100 or 120 kV, 90 mAS, 250 mm field of view, 512×512 matrix; Montpellier-France: General Electric Lightspeed Vinyl Composition Tile 64, 120 kV, 250 mAS, field of view Head, 512×512 matrix), with slice thicknesses of the analyzed axial slices varying between 0.75 and 1.25 mm. CTA was done with the patient in supine and the head in neutral position. A single rater (D.R.) analyzed the nearest distance between the ICA and both the styloid and the hyoid bone on axial slices of CTA. We used the midpoint of the entire artery as a reference point (Figure 1), to avoid potential underestimation of the bone-ICA distance attributable to ICA dilatation resulting from CAD and because we found that even when the ICA was partially or completely occluded, this point could be reliably localized on CTA. When reliable visualization of the ICA was not possible because of severe stenosis or occlusion, subjects were excluded from analysis. Patients with a pseudoaneurysm were excluded from analysis because the distance between the carotid artery and the styloid/hyoid bone could not be assessed reliably.

We used the axial slice where the smallest distance was observed between the closest bone edge of the styloid or the hyoid bone and the midpoint of the entire artery. In cases where the carotid bifurcation was located above the level of the hyoid bone, the distance between the hyoid bone and the common instead of the ICA was measured. We obtained 4 distances for cases and controls (ie, right styloid-right ICA distance, left styloid-left ICA distance, right hyoid-right ICA distance, and left hyoid-left ICA distance).

We also recorded how frequently direct mechanical contact between the bony structure with deformation of the ICA was observed (Figure 2). If patients had undergone several CTA as part of their clinical follow-up, measurements were determined on the CTA that was performed most remotely in time from the initial clinical event. We recorded the time between symptom onset and the analyzed CTA.

Measurements were performed blinded to the clinical information and radiology reports. However, complete blinding was impossible because dissection-related radiological CTA abnormalities could be observed by the rater. To study consistency of the rater, 60 measurements were repeated after several weeks. The concordance coefficient, a measure of intrarater agreement proposed by Lin et al 3, was 0.92 (95% confidence interval, 0.88–0.96).

Statistics

We used ANOVA or the Student t test to detect statistical significant differences in distances between the styloid/hyoid bone and the ICA between the different groups, and Pearson’s χ² test to detect significant differences between the occurrence
Variables & Control Group & P Value From ANOVA or χ² Test
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<table>
<thead>
<tr>
<th>Variables</th>
<th>CAD</th>
<th>VAD</th>
<th>Control Group</th>
<th>P Value From ANOVA or χ² Test</th>
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<td>Mean age (SD)</td>
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<td>0.002</td>
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<td>Hypercholesterolemia, n (%)</td>
<td>18 (20) †</td>
<td>8 (25)</td>
<td>35 (40)</td>
<td>0.016</td>
</tr>
<tr>
<td>Diabetes mellitus, n (%)</td>
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<td>8 (10)</td>
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<td>Active smokers, n (%)</td>
<td>23 (26)</td>
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CAD indicates carotid artery dissection; and VAD, vertebral artery dissection.

*VAD group is significantly younger than control group.

†Hypertension, hypercholesterolemia, and diabetes mellitus are significantly more frequent in control group compared with CAD. No significant differences between VAD and control groups in terms of risk factors.
Discussion

Our study lends support to the hypothesis that anatomic factors predispose to the occurrence of CAD. Our results are in line with a previous study, which showed smaller styloid-ICA distances contralateral to the CAD side. In that study, direct measurement of the distance between the bone structure and the affected vessel was not performed because the authors considered this unreliable. We confirmed the finding of a shorter distance opposite to the site of the dissection in a larger study population, but also showed that the styloid and hyoid bone were closer to the dissected artery. Our findings were specific to patients with CAD and not a general feature of patients with dissection because distances in patients with VAD did not differ from controls. The fact that both the previous study and our study point to the same conclusions despite the use of a different methodology reinforces the idea of a potential true mechanical role of the styloid process in, at least some, patients with CAD.

We consider our measurement method to be reliable. In the majority of our patients with CAD, the analyzed CTA was performed late after the acute phase of CAD. Therefore, intramural hematoma, stenosis, and occlusion were unfrequent, and reliable measurement of the styloid-ICA and the hyoid-ICA distances could be performed. We moreover excluded patients with pseudoaneurysmal forms of CAD or fibromuscular dysplasia in which measurements would be more difficult. We did not measure the distance to the outer wall of the CAD but instead the distance to the midpoint of the carotid artery, which is less likely to be displaced. The intrarater consistency was very high. Our findings, however, may have been influenced by the few patients with associated mural hematoma, which may alter carotid-styloid/hyoid distances. Further longitudinal study is needed to determine whether distances between the carotid and styloid/hyoid evolve over time.

If anatomic factors contribute so strongly to CAD risk, one could wonder why CAD recurrence is so rare. This could be partly attributable to underestimation of the true rate of (asymptomatic) CAD recurrences because studies with long-term imaging follow-up are scarce. Because cervical artery dissection seems to be associated with a multitude of potential risk factors (including underlying connective tissue disorder, infection, migraine, hyperhomocysteinemia, genetic factors, and other environmental factors), styloid/hyoid proximity may be just one of several environmental factors playing a role in CAD. Potentially, only the temporal co-occurrence of certain head positions, movements, and head or cervical trauma in patients with pre-existing proximate styloid/hyoid bones create the unfavorable mechanical conditions leading to direct ICA injury provoked by the styloid/hyoid.

Our study has some limitations: we did not include a consecutive series of patients with dissections because CTA was not performed systematically in the 3 participating centers. Complete blinded measurements are impossible and might

Figure 3. Comparison of the mean distances between the styloid/hyoid and the internal carotid artery in the 3 different groups. All ANOVA comparisons were significant. There were no significant differences between the vertebral artery dissection (VAD) groups and controls. Post hoc Bonferroni-corrected P values are shown. CAD indicates carotid artery dissection.

Figure 4. Distances of the styloid and hyoid at the side of the carotid artery dissection (CAD) and at the side opposite to the CAD in patients with CAD and in the control group.
have influenced the rater. Therefore, our findings need to be replicated in other cohorts.

Our study implies that the anatomic relationship between the stylohyoid complex in relation to the carotid artery should be examined more carefully in patients with CAD. Whether there is a role for surgery on the styloid or hyoid bone in management of CAD requires further study and cannot be recommended at present.

Acknowledgments
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Disclosures
None.

References
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