My Approach To: Vascular Ultrasonography in Dolichoarteriopathies of the Carotid Arteries

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Abstract

This article provides step-by-step guidance on how I investigate, classify and evaluate dolichoarteriopathies anatomically and hemodynamically, often found in the carotid and vertebral arteries. Dolichoarteriopathies may be present in children, disappearing during growth and reappearing with increasing age. Previously considered benign anatomic variations (AVs), discussion has arisen on the topic in view of new implications due to associations with cardiovascular events, risk factors, and various pathologies.

Introduction

The internal carotid artery (ICA) usually runs a straight extracranial course in the parapharyngeal space to the base of the skull, without branching. It runs posterolaterally to the pharyngeal wall and the external carotid artery and medial to the internal jugular vein. However, the vessel may elongate to form tortuosity, coils, loops, and kinks. These anatomic variations (AVs), also called dolichoarteriopathies, are frequently found in the general population, ranging from 10% to 45%, with 5% of them being pronounced aberrations.[1-3]

Among AVs, kinking is the most prevalent. Women are predominantly affected by kinking and coiling, while both men and women are equally affected by tortuosity. The incidence rate of AVs increases with age and is particularly high in people over the age of 70 years. The peak prevalence has a bimodal characteristic, occurring in the youngest and oldest extremities, with a lower incidence between 21 and 60 years of age (Table 1).[3,4]

In children, AVs are often the reason for reduced cognitive and neuropsychological capacity, with developmental delay and presence of focal seizures or status epilepticus.[3,5,6] It is a sporadic congenital condition that, apparently, decreases and/or disappears with increasing age and body growth due to stretching of the aorta and supra-aortic trunk. In older people, however, dolichoarteriopathies may manifest due to senile crushing (eg, osteoporotic vertebral compression).[3,4]

Different hypotheses for the development of AVs include embryological and genetic causes and the presence of fibromuscular dysplasia (more closely related to coiling), as well as the process of atherosclerosis in patients with hypertension, diabetes and smokers (more closely related to kinking and tortuosity).[5-8] The ICA is normally coiled during intrauterine development, and straightening occurs as the fetal heart and great vessels descend into the mediastinum. If the descent is incomplete, coiling of the ICA occurs.[9]

There is an increased prevalence of kinking in patients with arterial hypertension, probably due to increased endoluminal pressure and parietal tension, favoring endothelial thickening and deformation. A more severe alteration in vessel wall elasticity may also be related to postmenopause in women due to the hormonal process, without excluding a bias associated with the larger number of comorbidities in men. This might explain the higher overall prevalence of AVs in women than in men aged 60 years or older.[10,11]

The carotid ultrasound study assesses ICA's morphological and atherothrombotic risk by observing alterations in arterial wall thickness and hemodynamic disturbance due to luminal narrowing, which may lead to turbulent blood flow, thus predisposing patients to stroke.[3] However, not all AVs lead to stroke, which occurs in 11% to 33% of cases with AVs.[6] Coiling and tortuosity cannot be considered risk factors for ischemic events due to their weak association

Table 1 – Prevalence of coils and kinks stratified by age decades

Age groups (years)	Patients undergoing ECD of ICA (2856) (n)	Patients with ICCK (284) (n)	Prevalence, % (ratio)	
0–10	208	39	18.8	15.2% (57/374)
11–20	166	18	10.8	
21–30	55	2	3.6	4.4 % (5/113)
31–40	58	3	5.2	
41–50	228	18	7.9	5.3% (36/682)
51–60	454	18	4	
61–70	777	59	7.6	11% (186/1687)
71–80	680	90	13.2	
> 80	230	37	16.1	

ECD : echo-color Doppler; ICA: internal carotid artery; ICCK: internal carotid coiling and kinking.
Table adapted from Luigi Di Pino et al.[3]

Keywords

Anatomic Variation; Carotid Arteries; Ultrasonography, Carotid Arteries

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with cerebrovascular events. Kinking, however, even in the absence of atherosclerotic plaques, is more closely associated with the onset of events, being aggravated when combined with carotid stenosis.[4]

Cerebral ischemia occurs by two mechanisms: thromboembolic mechanism, resulting from endothelial lesions associated with blood flow stasis at the kink level and the occurrence of microembolization; and hemodynamic mechanism, which plays a role in both neutral and dynamic conditions. The smaller the angle formed between the kinked carotid segments, the greater the resistance to blood flow, which can worsen in conditions such as hypotension during sleep or flexion and/or extension of the head. Altogether, these situations may lead to vessel collapse at the point of greatest narrowing.[3,5,6]

Dolichoarteriopathies can be classified into 3 types, as shown in Figure 1:[2,6]

- Type 1: S- or C-shaped tortuosity of a non-rectilinear artery segment with an angulation > 90°;
- Type 2: a 360° angulation of an artery on its transverse axis in a circular or spiral shape (coil);
- Type 3: torsion of the inflection of 2 or more segments of an artery with an internal angle of ≤ 90° (kinking).

While Type 2 or coiling is attributed to embryological causes, the other two types are generally caused by the aging process with progression of atherosclerosis or by fibromuscular dysplasia.[11-13]

The anatomic classification of kinks using the Metz criteria is performed as follows (Figure 2):[6,8,13]

- Mild kinking: acute ICA angle between the two segments forming the kink, ≥ 60°;
- Moderate kinking: acute ICA angle between the two segments forming the kink, between 30° and 60°;
- Severe kinking: acute ICA angle between the two segments forming the kink, < 30°.

Kinks are common among patients with ischemic stroke, affecting both the intracranial and extracranial vasculature. The unfavorable anatomy of these vessels has been identified as an impediment to several types of endovascular treatment, such as ICA catheterization, leading to worse outcomes with increased revascularization time during thrombectomy. Alternative procedures include vessel resection and bypass grafting. Carotid stenting may also have its outcome quite impaired, since this device will further stretch the carotid artery, making a distal kink to become even more kinked. Twists and spirals are a contraindication to endovascular interventions because of the danger associated with passing a wire through an angled segment.[3,9,12,14] Carotid ultrasound is the gold standard for assessing extracranial circulation, has replaced carotid arteriography as a screening test for carotid artery occlusive disease, and has low cost, minimal risk, and good diagnostic accuracy.[4]

The use of intraoperative duplex ultrasonography in carotid endarterectomy has allowed the identification and repair of intraluminal residual defects, which may arise from the arterial reconstruction at the distal end of the repair and

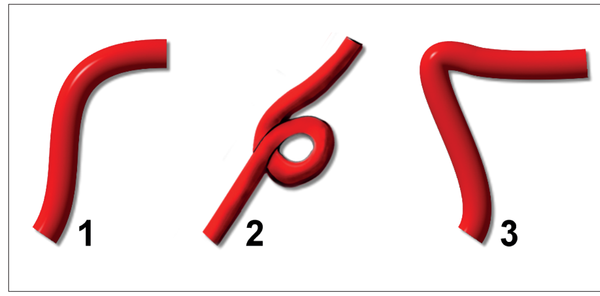

Figure 1 – *Classification of dolichoarteriopathies: Type 1, Type 2, and Type 3.*

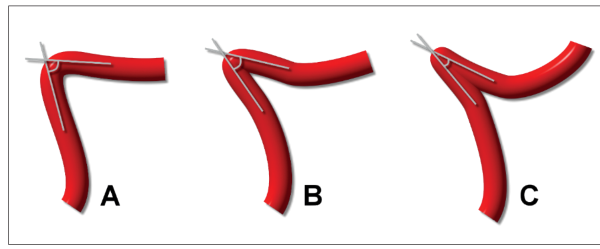

Figure 2 – *Anatomic classification of kinks. Mild kinking, angle between 60° and 90° (A); moderate kinking, angle between 30° and 60° (B); severe kinking, angle <30° (C).*

appear to result from hydrodynamic forces seen after primary closure of the arteriotomy.[15] The specificity of the method for predicting small ICA diameter, high carotid bifurcation, and a coiled or kinked carotid artery was 56%, 100%, and 100%, respectively. The presence of severe tortuosity of an artery, high carotid bifurcation, obesity or arterial calcification will reduce the accuracy of the ultrasound. This method can be improved with the use of high-frequency combined with low-frequency probes. This combination can provide an intuitive interface with a complete anatomic image of the artery for surgeons.

As it is a simple method that does not add risk or increase cost or discomfort for patients, the use of a convex probe is suggested as a complement to conventional ultrasound if necessary.[6,16,17] It is a noninvasive and effective method to easily detect vascular dysfunctions that allows us to assess the presence of AV-related submucosal masses in the posterior pharyngeal wall, which may be at risk for surgical injury to the oropharynx and laryngopharynx. Thus, it is possible try to predict cardiovascular events and complications during surgical procedures, both vascular and non-vascular, such as tonsillectomy, treatment of peritonsillar abscess, and adenoid surgery. Hence the great importance of careful and accurate examination prior to the procedure.[5,6,18]

Vascular ultrasound image acquisition technique with color flow mapping – "how I do it" step by step

1. Use a device with a multifrequency linear array transducer with frequencies greater than 7 MHz and color and power Doppler capability. Not infrequently, we need to use of a convex probe with frequencies ranging from 2 to 5 MHz in order to obtain an image

of the complete extent of the carotid alteration and reach a greater depth;

2. Lay the patient in the supine position with the head slightly hyperextended and rotated 45° away from the side to be examined;
3. Perform an axial and longitudinal scan from the origin of the common carotid artery to the most distal visible portion of the ICA, looking for any tortuosity;
4. Using pulse Doppler, color Doppler and power Doppler, detect blood flow and determine its direction, velocity, spectral waveform, and morphology;
5. Using spectral or pulse Doppler, record the peak systolic velocity (PSV), end-diastolic velocity (EDV), and resistance index in the common carotid artery, proximal ICA, and proximal external carotid artery;
6. Once an AV is identified, still using pulse Doppler, record the velocities before, inside, and after the curved portion, keeping the angle correction at 0° (Figures 3 and 4):
   a) PSV > 140 cm/s – hemodynamically significant parameter, suggestive of an approximately 50% diameter stenosis;
   b) PSV > 140 cm/s with EDV < 70 cm/s – hemodynamically significant parameters, suggestive of 50% to 69% diameter stenosis;
   c) PSV > 140 cm/s with EDV > 70 cm/s – parameter suggestive of 70% to 99% diameter stenosis.
7. Calculate the PSV ratio between two carotid segments (velocity at the kinking level divided by the velocity obtained at 2 cm proximal to the internal branch before the lesion).[3]

   If:

   a) Ratio < 1.5 → physiological or stenosis < 50%
   b) Ratio > 3.2 → stenosis > 60%
   c) Ratio > 3.3 → stenosis > 70%

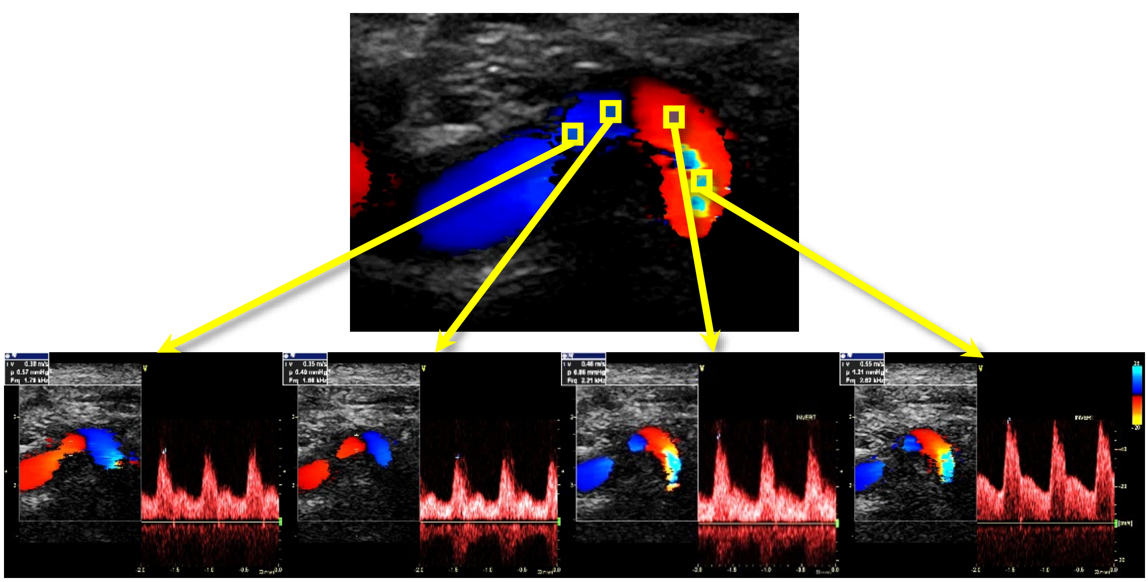

Figure 3 – *Mapping of velocities along the kinked segment, without angle correction in the region of kinking.*

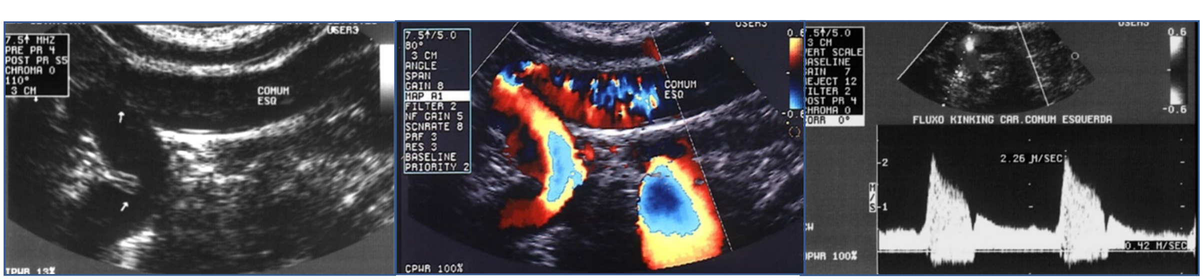

Figure 4 – *Stenotic kinking with a peak velocity of 2.26 m/s. The common carotid artery velocity before the kinked segment was 0.68 m/s. Ratio = 3.3.*

Technical pitfalls

In our service, we usually use a ratio of 2.5 for kinks with significant stenosis (above 60%), a criterion used for the serial assessment of the severity of peripheral arterial occlusion. It is important to note that a kink is considered occlusive only when it presents a significant increase in pulse Doppler velocities. The degree of kinking is not necessarily related to major occlusion (even with angles close to 0°). Also, the presence of turbulent flow on Doppler does not reflect the degree of stenosis, as it is found in all kinks, whether occlusive or not.

Dolichoarteriopathies can be located at the very beginning of the common carotid artery or at a great distance from the carotid bifurcation in the internal branch, requiring a scan of the entire length of the carotid artery from the base of the neck until it is no longer visible in the skull vault. Approximately 75% of the abnormalities are found at 2-4 cm proximal to the carotid bifurcation, but they are also seen more distally, as shown in Figure 5.[5,6] A possible presence of distal kinking in the internal branch should be considered when the opening angle between the internal and external carotid arteries is greater than 60° (Figure 6).

Coils can be found in different planes, requiring a "3D mental" map, with image acquisition in different axes, planes and angles of the neck for their composition and evaluation (Figure 7).

When associated with aneurysms, dilations, atheromatous plaques or thrombi in dolichoarteriopathies, the quantification of possible stenosis is even more difficult (Figure 8).

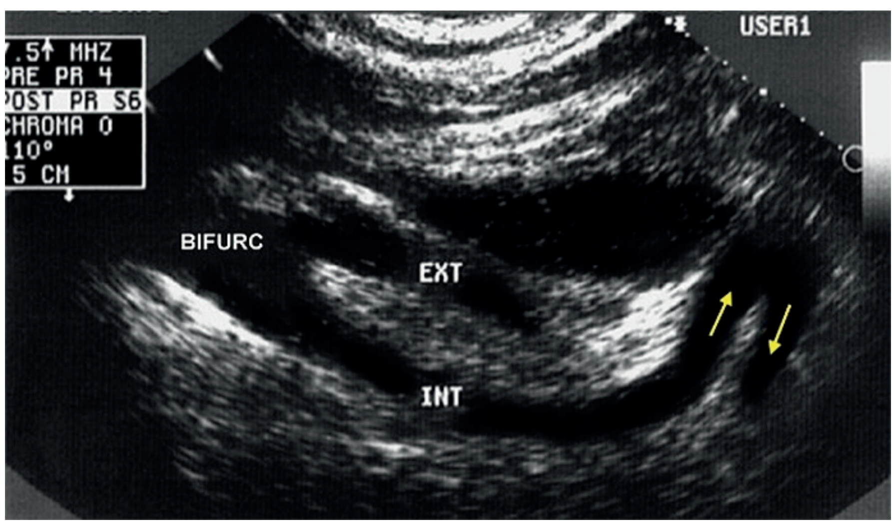

Figure 5 – *Kinking far from the bifurcation. Bifurc: carotid bifurcation; Ext: external carotid artery; Int: internal carotid.*

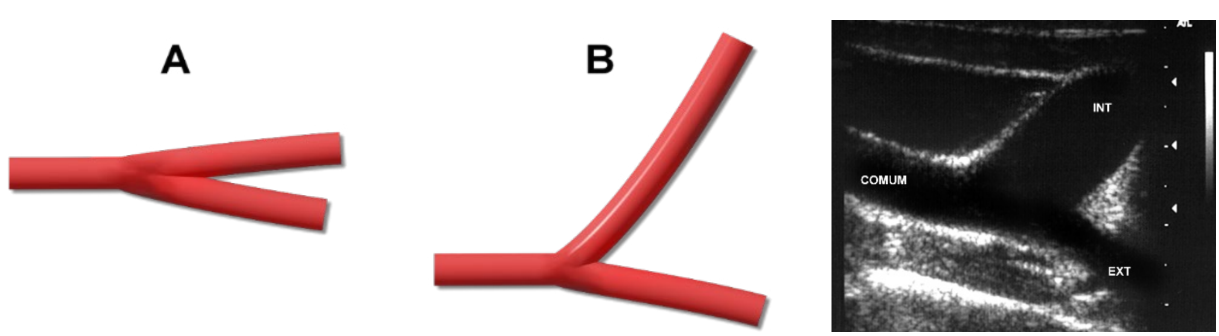

Figure 6 – *In the illustration, the angle formed between the carotid branches. A: small angle between the branches, which is more common; B: there is a greater probability of kinking, as the angle between them is >60°, as shown in the image on the right. Comun: common carotid; Ext: external carotid artery; Int: internal carotid.*

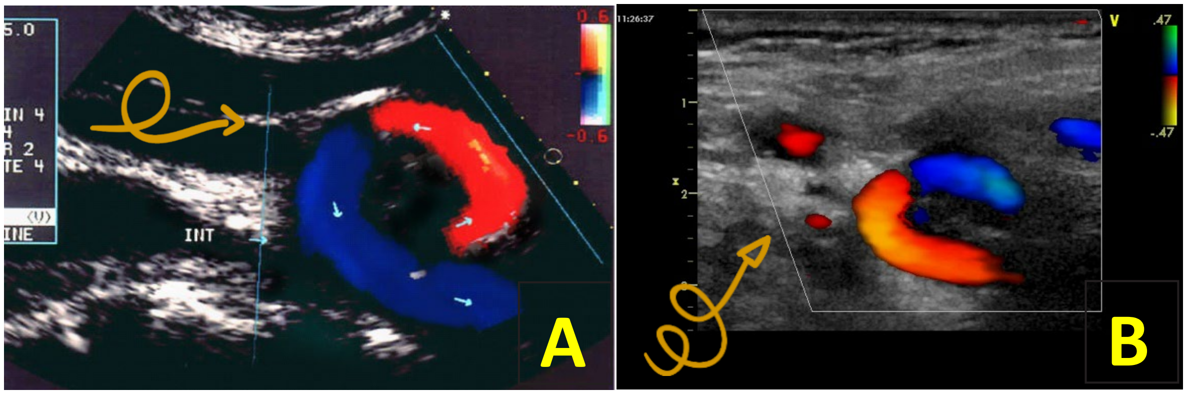

Figure 7 – Coil being built in two ways. A) circular, it appears entirely in the same plane; B) spiral, where its complete tracing is observed in several planes, requiring a scan with the transducer. Int: internal carotid.

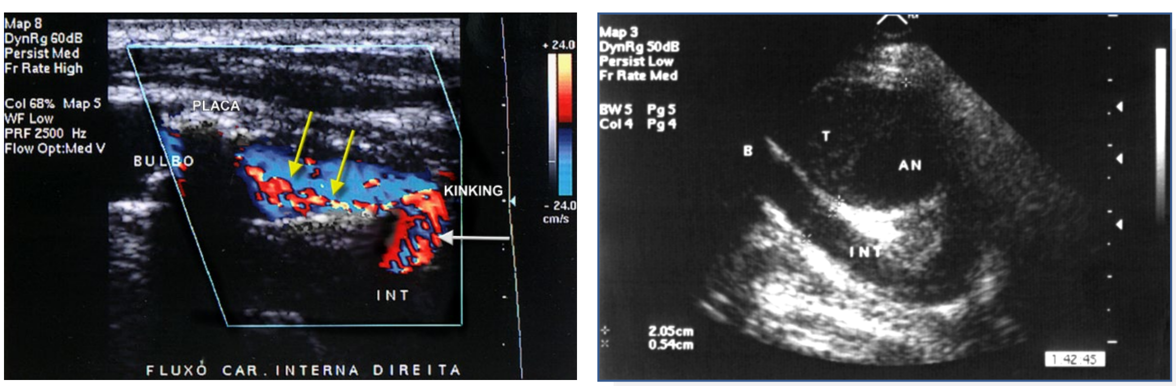

Figure 8 – *Associated conditions. A) occlusive atheromatous plaque preceding kinking (plaque turbulence, yellow arrows, mixes with kinking, white arrow); B) large internal branch aneurysm after kinking. Int: internal carotid artery; B: carotid bifurcation; T: thrombus; An: Aneurysm.*

Conclusion

Dolichoarteriopathies are frequently found in our clinical practice, whether in preoperative patients with non-vascular or vascular diseases, patients with stroke, and those with genetic diseases or in children with seizures, who require a detailed study of the entire course of the vessel in the search for anatomic abnormalities with turbulent flows and increased velocities.

Faced with a patient with a cerebrovascular condition, using the appropriate technique, we must actively search for these abnormalities, which may be responsible for the event and, thus, guide our decision on the optimal approach and treatment.

Author Contributions

Conception and design of the research, acquisition of data and critical revision of the manuscript for intellectual content: Cantisano AL; analysis and interpretation of the data and writing of the manuscript: Cantisano AL, Grubert CS.

Potential Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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Ethics Approval and Consent to Participate

This article does not contain any studies with human participants or animals performed by any of the authors.

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