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A Case of Congenital Internal Carotid Artery Hypoplasia and its Influence on Related Anatomy

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Abstract

Congenital hypoplasia of the internal carotid artery (ICA) is a rare vascular anomaly often identified incidentally. This case highlights both local and distant morphological consequences of this anomalous finding and uses reconstruction techniques in parallel with typical angiography to assess the related anatomy. Multimodal imaging, including magnetic resonance angiography (MRA), computed tomographic angiography (CTA), and 3D reconstructions, was used to evaluate an incidentally discovered vascular anomaly in a 49-year-old female presenting with nonspecific neurological symptoms. Imaging revealed congenital hypoplasia of the right ICA with compensatory perfusion via an enlarged posterior communicating artery (PCOM) and anterior communicating artery (ACOM). Pronounced asymmetry between the right and left common carotid arteries (CCA) was observed, along with a small aneurysm-like irregularity along the left ICA. Vascular asymmetry may serve as a clinically valuable indicator of underlying congenital anomalies. High-resolution 3D imaging enhances detection and characterization of collateral flow patterns and supports more informed cerebrovascular risk assessment.

Categories: Neurology, Radiology, Anatomy
Keywords: anatomical variation, circle of willis variation, congenital vascular anomaly, internal carotid artery hypoplasia, vascular asymmetry

Introduction

Congenital hypoplasia of the internal carotid artery (ICA) is a vascular anomaly, with an estimated prevalence ranging from 0.01% to 0.1% of the population [1-4]. It arises from incomplete embryologic development of the third aortic arch and dorsal aorta segment [5]. The condition is typically identified incidentally through imaging performed for unrelated neurological symptoms such as dizziness, vertigo, or ischemia [1]. Although often asymptomatic due to compensatory collateral circulation, ICA hypoplasia has been associated with altered cerebral hemodynamics, increased risk of aneurysms, and anatomical variants in the circle of Willis [1,6]. In this case report, we describe an instance of right ICA hypoplasia with notable vascular asymmetry and compensatory perfusion via the anterior and posterior communicating arteries. Integrated multimodal imaging, including magnetic resonance angiography (MRA), CT angiography (CTA), and three-dimensional (3D) reconstruction, provided detailed visualization of the vascular adaptations and underscored the clinical significance of vascular asymmetries for cerebrovascular anomaly detection and assessment. Stenosis or occlusion of the ICA related to atheroma is far more common than congenital vascular anomalies of the ICA and may result in similar radiological findings [7]. Therefore, we also discuss how this anomaly can be distinguished from acquired ICA narrowing and review its reported associations with concurrent intracranial vascular variants and aneurysm formation.

Case Presentation

A 49-year-old female presented with episodic horizontal vertigo, oscillopsia, and neurological examination findings consistent with cerebellar incoordination. Concern for an underlying cerebrovascular etiology prompted further evaluation with brain MRI with and without contrast, followed by MRA and CTA of the head and neck.

MRA demonstrated hypoplasia of the right ICA, with a diminutive cervical and intracranial ICA segment (Figure *1a*), and an apparent absence of the A1 segment of the right anterior cerebral artery (ACA), consistent with hypoplasia or aplasia (Figure *2b*). The right middle cerebral artery (MCA) was supplied via a prominent right posterior communicating artery (PCOM), while both ACA vessels arose from a common left-sided origin. A head and neck CTA confirmed the hypoplastic right ICA extending from the petrous segment of the temporal bone to the supraclinoid segment, with an associated hypoplastic right carotid canal at the skull base (Figure *1c*). The pronounced asymmetry between the right and left common carotid arteries at their origin was evident on CTA (Figure *1b*). The lack of any significant distal filling of the ICA, no obvious signal from a high-density plaque, the presence of a hypoplastic ipsilateral carotid canal, and a common left-side origin of the ACA were strongly suggestive of a congenital vascular anomaly instead of pathological stenosis [8]. MRA of the brain and neck was subsequently performed to further evaluate vascular anatomy and flow dynamics. It demonstrated a suspected 3-mm irregularity along the inferior margin of the

supraclinoid segment of the left ICA. This finding was not further evaluated with catheter-based digital subtraction angiography and remains of uncertain significance; therefore, it is best described as an indeterminate vascular finding rather than a definitive aneurysm. Imaging demonstrated normal flow-related enhancement in the vertebral, basilar, cerebral, and cerebellar arteries (Figures *2b*, *2c*). A 3D reconstruction of the skull base using CTA provided anatomic correlation of the hypoplastic right ICA and surrounding structures (Figure *2a*). The common carotid arteries were asymmetric, with the right common carotid artery (RCCA) measuring 3.9 mm in diameter and the left common carotid artery (LCCA) measuring 5.4 mm (Figure *1b*).

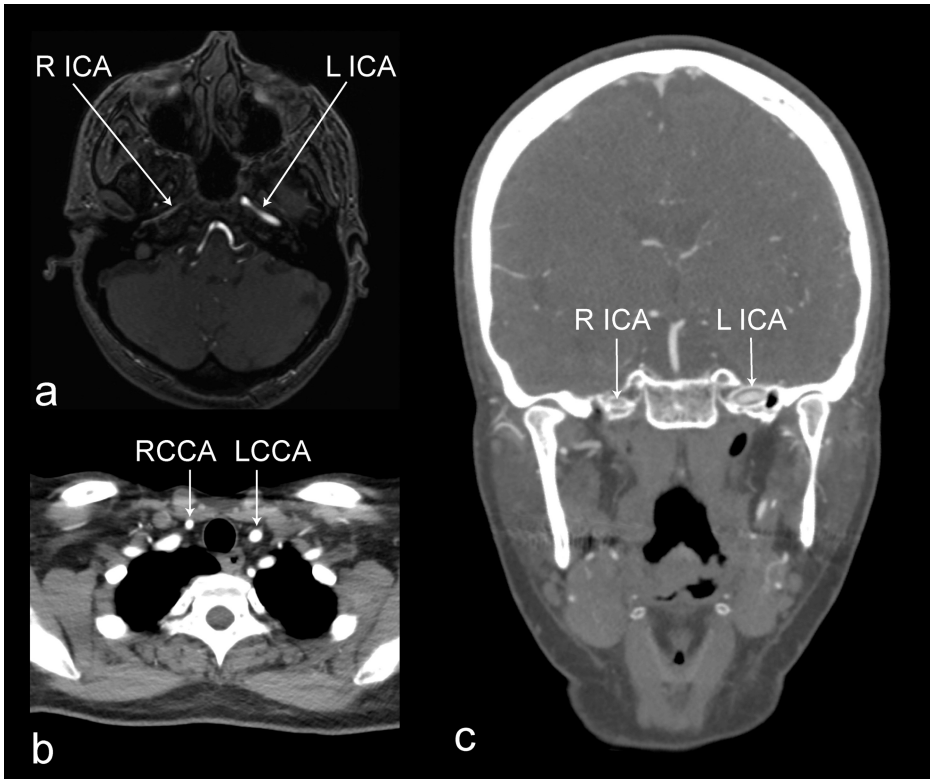


FIGURE 1: Multimodal imaging of hypoplastic right internal carotid artery (ICA).

(a) Axial magnetic resonance angiography at the skull base demonstrating pronounced asymmetry of the petrous ICAs, with the right ICA diminutive compared to the normal left ICA. (b) Axial CT angiography (CTA) at the thoracic inlet showing caliber discrepancy between the common carotid arteries. (c) Coronal CTA at the skull base further delineates the hypoplastic right ICA and narrowed right carotid canal.

R ICA: right internal carotid artery; L ICA: left internal carotid artery; RCCA: right common carotid artery; LCCA: left common carotid artery

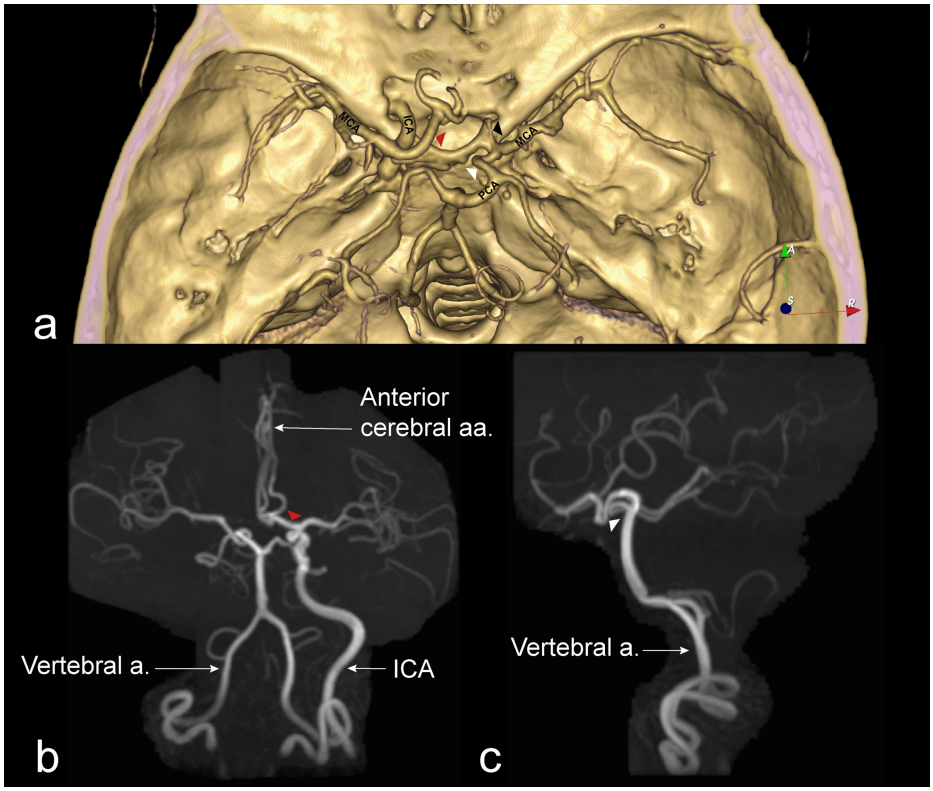


FIGURE 2: Vascular and bony three-dimensional (3D) reconstructions highlighting compensatory circulation and anatomical variation.

(a) 3D reconstruction of the skull base and vasculature from CT angiography (CTA), illustrating bony asymmetry and vascular alterations. (b) Anterior magnetic resonance angiography (MRA) maximum intensity projection (MIP) demonstrating absent right internal carotid artery (ICA) and both anterior cerebral arteries arising from the left ICA (red arrowhead). (c) Lateral MRA MIP emphasizing the enlarged right posterior communicating artery (PCOM) (white arrowhead), which supplies the right middle cerebral artery (MCA). The hypoplastic right ICA is indicated with a black arrowhead (a).

No surgical intervention was initiated. Pravastatin, part of the patient's pre-existing medication regimen for hyperlipidemia, was continued to optimize vascular risk factors. Propranolol was initiated at 40 mg twice daily for anxiety and palpitations, while ondansetron 4 mg as needed was prescribed for nausea associated with vertigo. The patient had previously been on estrogen hormone replacement therapy for menopausal symptoms, which was discontinued due to increased vascular risk. She was referred to neuro-ophthalmology for further evaluation of oscillopsia.

At follow-up, the patient reported partial improvement of vertigo-associated nausea with ondansetron and reduction of anxiety and palpitations after starting propranolol. No endovascular or surgical treatment was indicated, as the anomaly was well-compensated by collateral circulation. Neuro-ophthalmology evaluation confirmed persistent oscillopsia and nystagmus, for which prism therapy was recommended. She was additionally referred to cardiology for echocardiographic assessment and vascular risk stratification. Longitudinal neurovascular surveillance was recommended to monitor the hypoplastic right ICA and the indeterminate left ICA irregularity.

Discussion

This case presents a rare instance of congenital hypoplasia of the right ICA, accompanied by compensatory vascular mechanisms involving the PCOM and ACOM. Three-dimensional reconstruction using external imaging software (3D Slicer) was helpful in visualization, specifically in confirming the presence of a very low-caliber ICA emerging from the cavernous sinus, which was otherwise difficult to visualize. Three-dimensional imaging may improve the assessment of vascular anatomy, particularly in cases of ICA hypoplasia, by allowing for a more accurate depiction of compensatory circulation pathways [2,9].

A central consideration in this case is whether the diminutive right ICA is congenital or acquired. The presence of a correspondingly hypoplastic right bony carotid canal supports a congenital etiology because the canal develops in association with the ICA during embryogenesis [10]. However, carotid canal hypoplasia is not independently diagnostic of a congenital anomaly, as acquired reductions in ICA caliber can also be

accompanied by canal narrowing [2,11,12]. In this patient, the combination of a hypoplastic ICA extending along its course, a correspondingly hypoplastic carotid canal, and the absence of a reported history or imaging evidence suggesting an acquired occlusive process favors a congenital origin. Taken together, these findings support congenital right ICA hypoplasia as the most likely explanation.

While the findings in this case are most closely aligned with hypoplasia of the right ICA, it is worth noting that some studies question whether the term "hypoplasia" is always appropriate, as the degree of underdevelopment can vary. Whitley et al. note that the terms aplasia and hypoplasia are often used interchangeably, reflecting the difficulty in drawing clear distinctions between the two and underscoring the need for further standardization in classification [2,4]. Such ambiguity is important to recognize, as this case offers an opportunity to consider how these distinctions influence the interpretation of compensatory vascular adaptations observed through advanced imaging.

A key element of this case was the pronounced asymmetry between the right and left CCA, demonstrated in both the CTA and MRA imaging. Side-to-side differences in the carotid arteries are clinically relevant beyond congenital anomalies; for instance, Larson et al. reported a higher prevalence of intraplaque hemorrhage in left-sided than right-sided carotid arteries [13]. In the present case, the smaller RCCA is consistent with reduced flow demand from the hypoplastic right ICA. Recognizing a marked CCA caliber discrepancy may therefore prompt evaluation for a downstream anomaly such as ICA hypoplasia or stenosis.

In this case, the hypoplastic right ICA was compensated by robust perfusion through the PCOM and ACOM (Figures *2b*, *2c*). The right MCA receives blood supply from the right PCOM, while the right ACA is perfused via the ACOM. These compensatory mechanisms are critical in maintaining cerebral blood flow despite the absence or underdevelopment of the right ICA. This compensatory perfusion aligns with collateral circulation patterns sometimes observed in ICA hypoplasia, as documented in case series, individual case reports, and systematic reviews [1,2,14]. Congenital ICA hypoplasia and agenesis have also been associated with intracranial aneurysms, potentially related to altered hemodynamic stress in collateral vessels [2,4]. However, the aneurysm prevalence reported in the literature should not be interpreted as an individualized risk estimate for this patient, and the left ICA irregularity in this case remains indeterminate rather than a confirmed aneurysm. In this case, 3D reconstruction facilitated visualization of the spatial relationships among the hypoplastic ICA, skull base, and collateral vessels. A dedicated venographic study was not performed; accordingly, associated venous developmental anomalies cannot be excluded, and our conclusions are limited to the arterial findings demonstrated.

Conclusions

This case not only highlights the rare occurrence of congenital ICA hypoplasia but also provides a detailed examination of the vascular system's adaptive response to such anomalies. The observed asymmetries between the RCCA and LCCA, combined with the compensatory circulation via the PCOM and ACOM, offer valuable insights into cerebral blood flow dynamics. These findings underscore the clinical importance of recognizing vascular asymmetries as potential indicators of underlying pathology. Advanced imaging techniques such as CTA and MRA are essential for accurately characterizing vascular anomalies and understanding compensatory flow patterns in cases of ICA hypoplasia. Contrast enhancement allows for more careful scrutiny of vascular patterns; in this case, allowing visualization of the extremely narrow ICA, thereby discriminating it from complete aplasia. Future studies aimed at establishing patterns of concurrent anatomical anomalies may inform risk stratification, although an outcome benefit cannot be established from a single case report.

Additional Information

Author Contributions

All authors have reviewed the final version to be published and agreed to be accountable for all aspects of the work.

Concept and design: Jonathan Millard, Laura Soares

Acquisition, analysis, or interpretation of data: Jonathan Millard, Laura Soares

Critical review of the manuscript for important intellectual content: Jonathan Millard, Laura Soares

Supervision: Jonathan Millard

Drafting of the manuscript: Laura Soares

Disclosures

Human subjects: Informed consent for treatment and open access publication was obtained or waived by all participants in this study. Edward Via College of Osteopathic Medicine Institutional Review Board issued

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