# Imaging approaches for pediatric ischemic stroke

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Learning objectives

The exhibit will illustrate imaging findings of the pediatric acute ischemic stroke (AIS) on CT, MRI, MR angiography and propose a diagnosis strategy for different clinical presentations.
Background

Pediatric acute ischemic stroke (AIS) differs slightly from adult ischemic stroke with regard to imaging findings and diagnostic algorithm. The response of immature brain parenchyma to ischemia is somewhat different in the pediatric patients, which leads to some imaging findings specific to this age group [1].

The etiological factors show dramatic differences between pediatric and adult stroke, such as diabetes and atherosclerosis, which are most often observed in adults but not in the pediatric AIS [2].

Early diagnosis of pediatric AIS allows rapid neurological consultation and treatment. The usual finding of AIS is hemiplegia observed in 94% of cases. The seizure is another common finding seen in 50% of children with both ischemic and hemorrhagic infarct and not related to any age group or seizure type. AIS constitutes approximately 80-85% of all adult strokes. Nevertheless, this proportion seems to be about 50% in children [3, 4].

In this article, epidemiology and etiology, differential diagnosis and imaging findings of pediatric ischemic stroke will be reviewed.
Findings and procedure details

ETIOLOGIES

The classification of acute ischemic stroke has always been a part of the debate that allows the development of different subtypes. The need to divide patients with AIS into subtypes comes from various reasons. The treatment modality, prognostic and etiologic factors differ among subtypes.

Unlike the adult patients having AIS, degenerative vascular diseases such as atherosclerosis have a minor role in pediatric patients. The most common risk factors for pediatric AIS are congenital heart diseases, infections, and metabolic disorders [5]. However, approximately half of the childhood AIS constitutes unknown risk factors [6].

AIS can be divided into several subtypes according to CASCADE (Childhood AIS Standardized Classification and Diagnostic Evaluation); i- Small vessel arteriopathy of childhood, ii- Unilateral focal cerebral arteriopathy of childhood, iii- Bilateral cerebral arteriopathy of childhood, iv- Aortic cervical arteriopathy, v- Cardioembolic, vi- Other, vii- Multifactorial. The CASCADE criteria is primarily based on anatomic site of the disease [7].

Congenital heart disease (those with right to left-sided shunted) is the most important etiologic factor of AIS especially in infants and young children [8]. The mechanism of the infarction in congenital heart disease is usually embolic in origin. Whereas infection is the most common etiological agent in older children with stroke. The infection usually results in inflammatory changes in the arterial wall [9]. Inflammation of the vessel wall may cause occlusion by causing swelling in the arterial wall, or it can lead to dissection in the weakened part of the vessel wall.

Specific arthritis, such as Moya-Moya disease, is not rare among the primary vascular etiologies of cerebral infarction. Vascular dysplasia is also involved in stroke pathogenesis, especially in patients having neurocutaneous syndrome [10]. Intracranial arteriovenous malformations may cause cardiac insufficiency and cerebral ischemia by creating a steal phenomenon in infants. In uncommon conditions, trauma can be an etiological agent of AIS in the pediatric age group. Infarction can be seen in the case of a direct contusion to the arteries in some specific localizations such as the parapharyngeal space. Ischemic stroke has also been found in children owing closed head trauma or intense exercise [11].

MANAGEMENT
Non-enhanced head CT is the first choice in the diagnosis of AIS. Bland infarcts can be seen as a low-density thrombus in the vessel lumen. Post-AIS CT imaging is usually normal within the first 12 hours of infarction and therefore MRI must be utilized as a sensitive test for the early detection. Additionally, magnetic resonance arteriography (MRA) and magnetic resonance venography (MRV) can be performed to confirm vascular luminal patency or to define the vascular anatomy. MRA gives more information about the arterial structures and MRV can be used more reliably in the diagnosis of cerebral venous sinus thrombosis (CVST) [12].

Catheter angiography (CA) is a method superior to cross-sectional angiographic examinations to visualize intracerebral small vascular structures such as vasculitis or arteriel dissections, which affords a detailed investigation. Also, CA can be combined with endovascular therapy. Nevertheless, an angiography is an invasive procedure in which relatively few physicians have experience for the pediatric patients. CA should be considered strongly in pediatric AIS where no evidence was found on MRA and no further explanation was available.

CT angiography (CTA) is another method to assess the vascular anatomy and cerebral blood flow. It can be utilized to detect arterial dissections causing AIS and vascular lesions requiring urgent surgical operation. Limitations of CTA include higher radiation doses than conventional CT sequences to execute thin-section images required for high-quality images. Furthermore, the amount of contrast used in CT angiography may limit the use of contrast agent, which is required for subsequent angiographic procedures. MRA may be preferable to CTA, especially when the patient is evaluated first with MRI. ECG, chest radiography, and transthoracic or transesophageal echocardiography may provide additional diagnostic utilities as cardiac anomalies which constitute an important risk factor of pediatric AIS [13].

Imaging is usually the first choice to evaluate a pediatric ill patient. Two common imaging modalities to investigate a pediatric AIS in the emergency department are CT or MRI, particularly diffusion-weighted (DWI) and perfusion-weighted (PWI) imaging sequences. DWI is the most sensitive method to diagnose AIS owing unremarkable conventional CT and MRI findings.

The low diagnostic capability of CT is the main limiting factor to identify a pediatric AIS. Identification of stroke may alter depending on the affected brain parenchyma and vascular structures. The development rate of cytotoxic edema may vary whether the affected brain parenchyma consists of end arterial or collateral blood supply. For
instance, CT findings of infarction could be seen within 6 to 7 hours after ACA (Anterior Cerebral Artery) infarction and could be detected in the basal ganglia infarction within 1 to 2 hours due to end arterial blood supply of the affected region [14].

Furthermore, perfusion imaging can offer valuable informations on the predictive aspect of the AIS. It allows to determine vascular territories or ischemic areas at risk for acute stroke. The ratio of perfused to ischemic tissues can also serve to specify the gain-loss statement of a particular treatment. Indeed, the perfusion / diffusion "mismatch" reflects the conflict between the ischemic core and the surrounding penumbra; abnormal DWI areas accompanied by low ADC values point us irreversibly damaged brain tissue. Therefore, low PWI and normal DAG areas represent penumbrae or potentially reversible ischemic tissue [15].

The utilization of MRA helps to characterize intracerebral vascular lesions non-invasively. Nevertheless, the extensive examination of the intracerebral arterial lesions (intimal flap or intraluminal thrombus) is the primary restraining factor of MRA. In whole instances, imaging of the cervical and proximal intracranial arteries should be reckoned within the first 48 hours to exclude arterial dissection in children presenting with AIS [16].

Diagnostic sensitivity of the imaging methods can be increased by combining MRA and DWI sequences for the pediatric AIS. According to the guidelines, cross-sectional head imaging is necessary for AIS. Brain MRI should be performed as soon as possible. CT is an acceptable alternative imaging method in cases where brain MRI is not available within 48 hours. CT should be performed immediately in clinical signs of stroke, decreased consciousness, or worsening clinical conditions [17].

More specific sequences to visualize venous structures may be preferred if there is an unusual feature of the AIS. Initially, noninvasive diagnostic methods such as MR venography (MRV) or CT venography (CTV) may be favored to the invasive imaging methods such as intra-arterial digital subtraction angiography (IADSA) [18].

The MR imaging has some restrictive features; the procedure lasts for a long time, but this can easily be overcome by using "fast protocols". Other determining factor is the low sensitivity of MRI to detect acute bleeding, but different studies [19] demonstrate that MRI can identify acute hemorrhage with high sensitivity as well. Moreover, even if intracranial hemorrhage can easily diagnosed by CT, the cause of hemorrhage is really difficult to identify without the role of MR imaging. In fact, MRI can quickly distinguish the cause of hemorrhage and detect the presence of lesions such as vascular malformation which are suitable to surgical or interventional treatment. The "real" limitation of magnetic resonance imaging is likely due to the need for patients to be cooperated or sedated. In most events, anesthesia support is needed to sedate and monitor the patients. CT,
however, is a lot faster than MRI and can be easily applied even in noncooperative patients.

The gold standard method for definitive diagnosis of cerebral vascular lesions is IADSA and it should be preferred for children with stroke who are supposed to possess a small intracerebral arterial pathology. For instance, IADSA can diagnose moyamoya disease by showing bilateral stenosis in the internal carotid arteries and vascular collateral supplies known as "puff of smoke". MRI, MRA, and in some cases IADSA should be repeated to evaluate the condition of vasculopathy in cases with new onset of stroke and to investigate arteriopathies as a part of the routine algorithm [20].
Fig. 1: AIS caused by craniopharyngioma on T2 weighted MRI

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**Fig. 2:** AIS caused by craniopharyngioma on ADC map

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Fig. 3: Iatrogenic AIS on T2 weighted MRI

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Fig. 4: Iatrogenic AIS on DWI

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Conclusion

The diagnosis of AIS has been often difficult because of unknown mechanisms and confusing clinical picture.

Instructions should be contributed to doctors with regard to recognizing neurological symptoms in patients having high risk of stroke, such as children with sickle cell disease. It is important to use the extraordinary treatment approach without a delay to investigate detailed diagnosis in these patient group.

Our experience suggests that MRI should be regarded as the first diagnostic method to provide a complete set of data in the identification of pediatric AIS. In instances which MRI is not available or if the patient is not cooperative, it is urged to perform a CT scan as a first diagnostic step.
References


