Cerebral Collateral Circulation

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DOI: https://doi.org/10.52340/spectri.2025.11.01.20

Abstract

Collateral circulation plays a decisive role in the pathophysiology of cerebral ischemia. However, knowledge regarding collateral circulation remains scarce due to the limitations of various assessment methods.

Anatomical descriptions of collateral circulation often focus on the more proximal anastomoses within the Circle of Willis and neglect the secondary pathways of collateral circulation provided by leptomeningeal anastomoses. The final formation of collateral circulation is likely dependent on the operation of multiple compensatory hemodynamic, metabolic, and neural mechanisms, as the subsequent formation of these protective vascular pathways can determine the severity of ischemic damage. Currently, the assessment of collateral circulation is performed using various instrumental studies, most frequently including CT angiography, MRI angiography, and digital angiography.

The assessment of collateral circulation will continue to be refined in the future with various neuroimaging methods, but one thing is clear—it represents one of the most important factors for the outcome of acute ischemic stroke.

Key words: Cerebral infarction, Collateral circulation, Radiological methods of collateral assessment, Normal anatomy of collaterals.

ცერებრალური კოლატერალური ცირკულაცია

თამაზ ჯიოშვილი, ერეკლე გიგიაძე, ნიკოლოზ საინიშვილი

დავით აღმაშენებლის სახელობის საქართველოს უნივერსიტეტი

აბსტრაქტი

კოლატერალური ცირკულაცია გადამწყვეტ როლს ასრულებს ცერებრალური იშემიის პათოფიზიოლოგიაში. თუმცა, კოლატერალური

სისხლის მიმოქცევის შესახებ ცოდნა რჩება მწირი,შეფასების სხვადასხვა მეთოდების ჩატარების შეზღუდვების გამო.

კოლატერალური სისხლის მიმოქცევის ანატომიური აღწერილობები ხშირად ფოკუსირებულია უფრო პროქსიმალურ ანასტომოზებზე ვილიზიის წრეში და უგულებელყოფს კოლატერალური სისხლის მიმოქცევის მეორად გზებს, რომლებიც უზრუნველყოფილია ლეპტომენინგეალური ანასტომოზებით. კოლატერალური სისხლის მიმოქცევის საბოლოო ფორმირება სავარაუდოდ, დამოკიდებულია მრავალი კომპენსატორული ჰემოდინამიკური, მეტაბოლური და ნერვული მექანიზმების მუშაობაზე,ვინაიდან ამ დამცავი სისხლძარღვთა გზების შემდგომმა ფორმირებამ შეიძლება განსაზღვროს იშემიური დაზიანების სიმძიმე. დღესდღეობით კოლატერალური სისხლის მიმოქცევის შეფასება ხორციელდება სხვადასხვა ინსტრუმენტული კვლევებით,მათ შორის ყველაზე ხშირად,კტ ანგიოგრაფიით,მრტ ანგიოგრაფიით და დიგიტალური ანგიოგრაფიით.

კოლატერალური სისხლის მიმოქცევის შეფასება მომავალში კვლავ დაიხვეწება სხვადასხვა ნეიროვიზუალიზაციის მეთოდებათან ერთად,თუმცა ერთი აშკარაა-ის წარმოადგენს, მწვავე იშემიური ინსულტის გამოსავლის, ერთ-ერთ უმნიშვნელოვანეს ფაქტორს.

Through collateral circulation, the brain's blood supply is maintained when central supply channels are somehow obstructed. Obstruction in the brain's blood supply, whether due to hemodynamic or mechanical factors, triggers the activation of collateral circulation, despite the critical importance attributed to it during ischemic infarcts. Even today, this system and its detailed anatomical basis are not well studied in the human brain. Assessment of collateral circulation during normal blood supply is impossible because it is activated only when an obstruction occurs in the main circulatory system, and translating animal experiments in terms of anatomical variations is practically impossible.

Anatomy

The normal anatomy of collateral circulation includes extracranial and intracranial pathways, which, in turn, are divided into primary and secondary collateral pathways. Primary pathways include the vascular collaterals of the Circle of Willis, the anterior and posterior communicating arteries (Fig. 1).

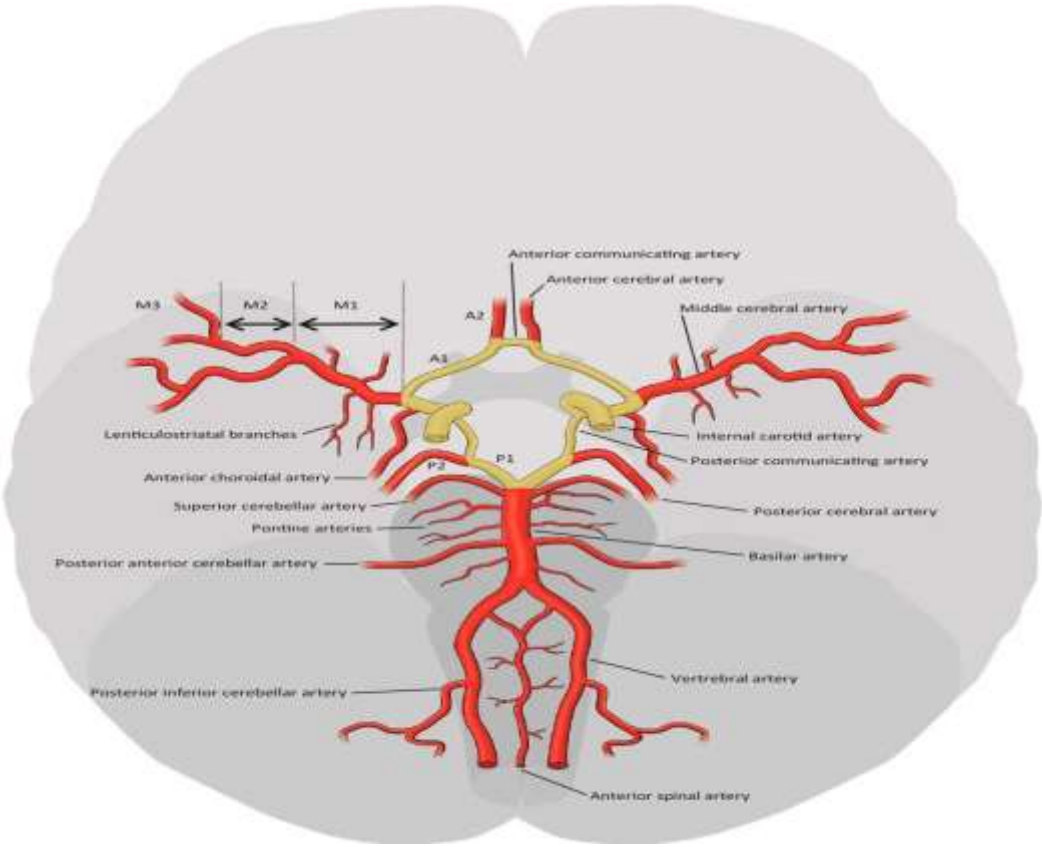

Fig. 1. Normal anatomy of the circle of Willis

Secondary pathways include branches of the ophthalmic and leptomeningeal arteries. The anterior communicating artery provides collateral support to the brain structures proximal to it, while the posterior communicating arteries ensure collateral connection between the anterior and posterior circulations of the brain. It is important to consider that the anatomy of the Circle of Willis is often variable: Aplasia of the anterior communicating artery (1%), hypoplasia or aplasia of the A1 segment of the anterior cerebral artery (10%), hypoplasia or aplasia of the P1 segment of the posterior cerebral artery (30%).

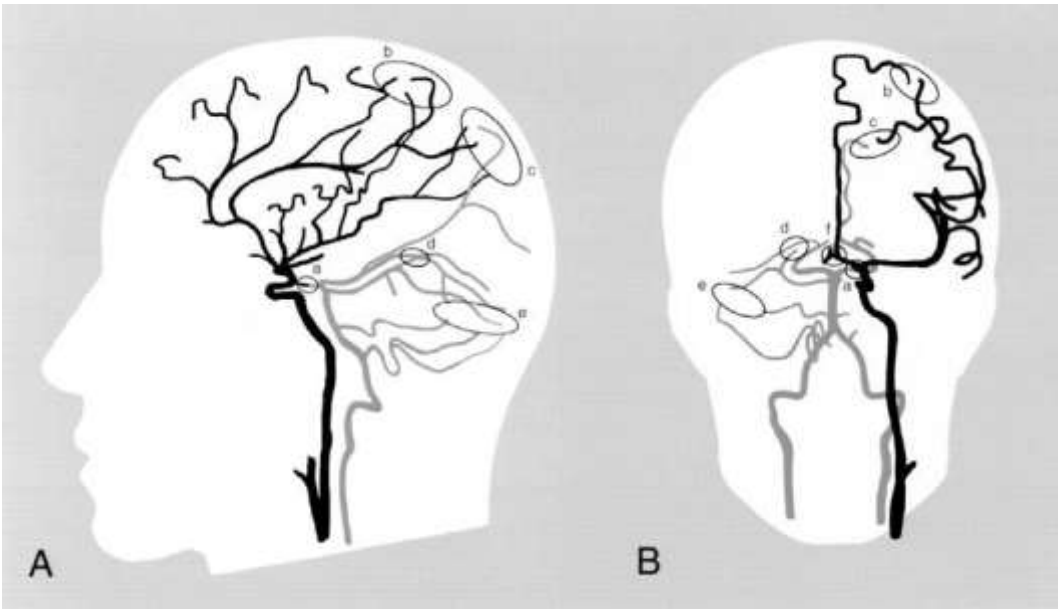

Fig. 2. Intracranial arterial collateral circulation in lateral (A) and frontal (B) views. Shown are posterior communicating artery (a); leptomeningeal anastomoses between anterior and middle cerebral arteries (b) and between posterior and middle cerebral arteries (c); tectal plexus between posterior cerebral and superior cerebellar arteries (d); anastomoses of distal cerebellar arteries (e); and anterior communicating artery (f).

Reversed blood flow in the ophthalmic arteries provides second-order collateral support. Additionally, the collateral network existing between the terminal branches of the main arteries provides supplementary collateral support. These anastomoses are most prominent between the Middle and Anterior Cerebral Arteries, less so between the Middle and Posterior Cerebral Arteries, and least so between the Anterior and Posterior Cerebral Arteries. Arterial anastomoses of the leptomeningeal and dural arteries further enhance collateral circulation. Other collateral pathways, such as the tectal plexus connecting the supratentorial Posterior Cerebral Artery branches to the infratentorial branches of the Superior Cerebellar Artery; the orbital plexus connecting the ophthalmic artery branches to the facial, middle meningeal, maxillary, and ethmoidal artery branches; and the carotid network connecting the Internal and External Carotid Artery branches, play a comparatively lesser role in the formation of collateral circulation during acute ischemic infarction. The anatomy and direction of the collateral network are highly variable (Fig. 3).

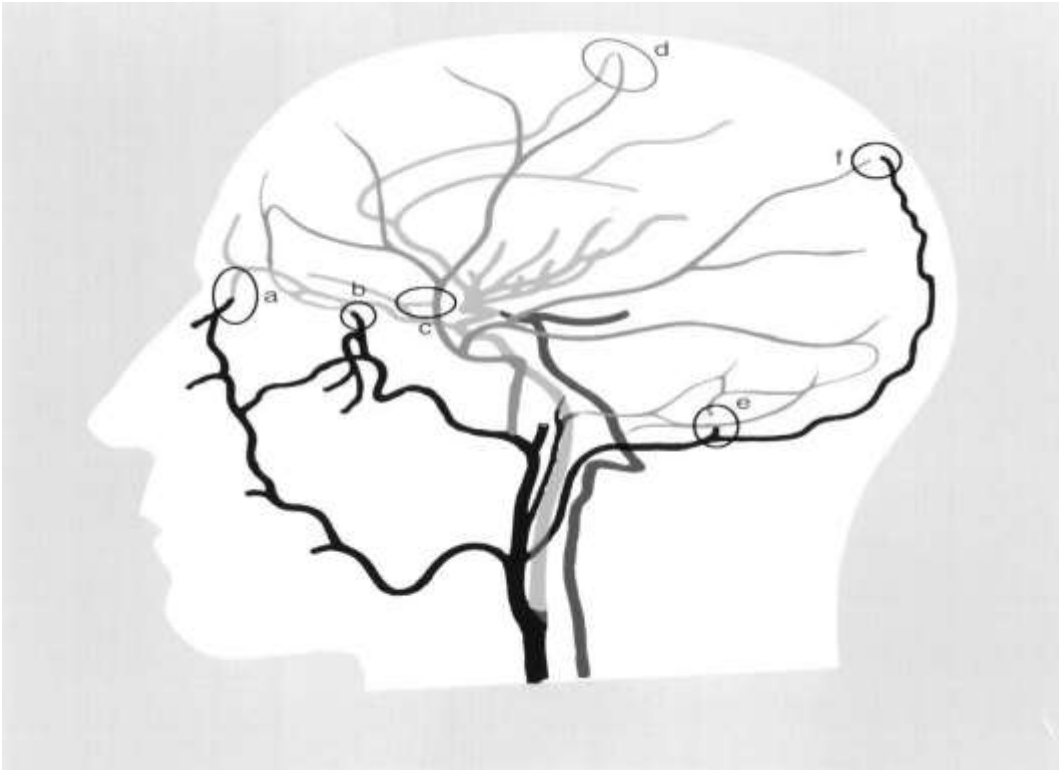

fig. 3. Extracranial arterial collateral circulation. Shown are anastomoses from the facial (a), maxillary (b), and middle meningeal (c) arteries to the ophthalmic artery and dural arteriolar anastomoses from the middle meningeal artery (d) and occipital artery through the mastoid foramen (e) and parietal foramen (f).

Pathophysiology

The process of collateral circulation development is dependent on the size and patency of the primary pathways, which can quickly compensate for the decrease in blood flow, and the patency of secondary collateral pathways.Primary pathways ensure the immediate diversion of cerebral blood flow to the ischemic regions via existing anastomoses. Secondary pathways, such as leptomeningeal anastomoses, may exist anatomically, but the passage of cerebral blood flow through these alternative routes requires time [4]. The specific pathophysiological factors causing the development of collaterals are unclear, but a drop in arterial pressure in the proximal vessels can be considered one of the important factors. Several compensatory-hemodynamic, metabolic, and neural mechanisms must also be considered. Patient age, duration of ischemia, collateral anatomy, as well as other co-morbidities, including heart failure, diffuse cerebral atherosclerosis, tobacco use, dehydration, hyperglycemia, uric acid levels, and blood-inhibiting drugs, high blood pressure, etc. (Table 1).

Table 1: Factors Responsible for the Development of Collateral Circulation
1. Decrease in arterial pressure in proximal vessels
2. Patient age
3. Duration of ischemia
4. Collateral anatomy
5. Heart failure
6. Cerebral atherosclerosis
7. Tobacco use
8. Dehydration
9. Hyperglycemia
10. Uric acid levels
11. Blood-inhibiting drugs

Also, the involvement of angiogenic processes following the ischemic event in the development of collateral circulation has been confirmed, influenced by specific peptides released during this time, which participate in the formation/development of blood vessels.

Various Methods for Assessing Collateral Circulation

With the development of radiological investigations, various methods for assessing collateral circulation have increased. However, the most frequently used in routine practice to check collateral status include Head Computed Tomography Angiography (CTA), Head Magnetic Resonance Angiography (MRA), Digital Subtraction Angiography (DSA), Head Computed Tomography Perfusion (CTP), Head Magnetic Resonance Perfusion (MRP), Single-Photon Emission Computed Tomography (SPECT), and Positron Emission Tomography (PET) (Fig. 4, 5) .

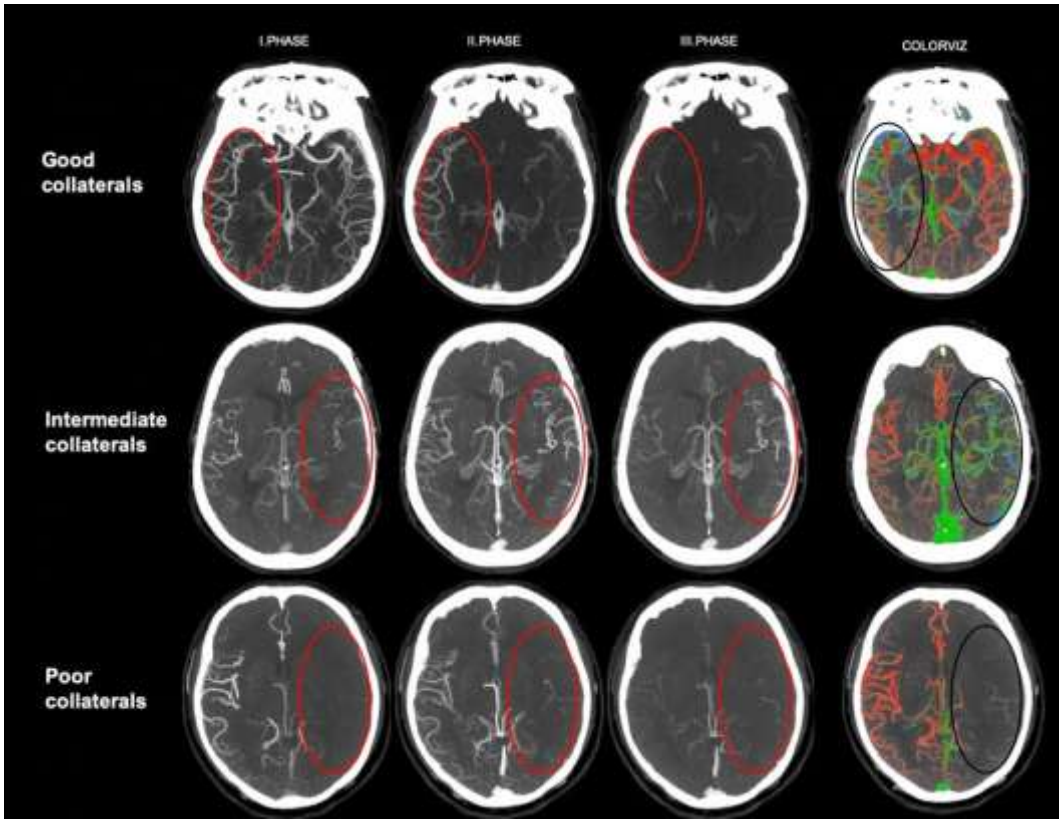

FIG. 4. Assessment of collateral circulation with CTA

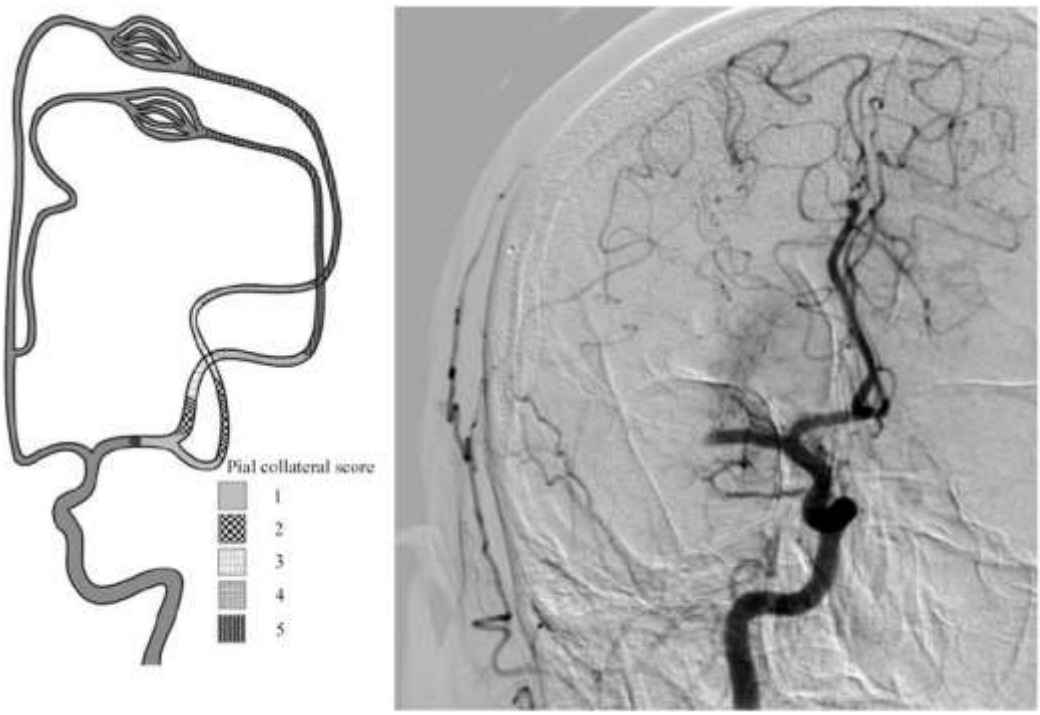

FIG. 5. Assessment of collateral circulation with DSA

Conclusion

Collateral circulation plays a crucial role in the final outcome of cerebral ischemia. Accordingly, knowledge of the normal anatomy and physiology of collateral circulation, as well as its various radiological assessment methods, represents a key factor for choosing the treatment strategy, which, in turn, determines the final outcome.

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