**KEY CLINICAL CONCEPT**

**10.1 CLINICAL SYNDROMES OF THE THREE CEREBRAL ARTERIES**

Recognition of the classic syndromes produced by infarcts of the middle cerebral artery (MCA), anterior cerebral artery (ACA), and posterior cerebral artery (PCA) territories remains a cornerstone of neurologic assessment and continues to play an important role in evaluating patients with acute stroke. We discuss localization of these syndromes here; stroke pathophysiology and clinical management are discussed in KCC 10.3 and KCC 10.4.

**Middle Cerebral Artery (MCA)**

Infarcts and ischemic events are more common in the middle cerebral artery than in the anterior or posterior cerebral arteries, at least in part because of the relatively large territory supplied by the middle cerebral artery. MCA infarcts occur in the following three general regions (see Figures 10.6, 10.7, and 10.9):

1. Superior division
2. Inferior division
3. Deep territory

Proximal MCA occlusions affecting all three of these regions are called MCA stem infarcts. The most common deficits seen with infarcts of left or right MCA territories are summarized in Table 10.1. Knowledge of the deficits associated with each of these territories is clinically useful since

<table>
<thead>
<tr>
<th>LOCATION OF INFARCT</th>
<th>AFFECTED TERRITORY</th>
<th>DEFICITS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Left MCA superior division</strong></td>
<td><img src="image1.png" alt="Image of brain" /></td>
<td>Right face and arm weakness of the upper motor neuron type and a nonfluent, or Broca’s, aphasia. In some cases there may also be some right face and arm cortical-type sensory loss.</td>
</tr>
<tr>
<td><strong>Left MCA inferior division</strong></td>
<td><img src="image2.png" alt="Image of brain" /></td>
<td>Fluent, or Wernicke’s, aphasia and a right visual field deficit. There may also be some right face and arm cortical-type sensory loss. Motor findings are usually absent, and patients may initially seem confused or crazy but otherwise intact, unless carefully examined. Some mild right-sided weakness may be present, especially at the onset of symptoms.</td>
</tr>
<tr>
<td><strong>Left MCA deep territory</strong></td>
<td><img src="image3.png" alt="Image of brain" /></td>
<td>Right pure motor hemiparesis of the upper motor neuron type. Larger infarcts may produce “cortical” deficits, such as aphasia as well.</td>
</tr>
<tr>
<td><strong>Left MCA stem</strong></td>
<td><img src="image4.png" alt="Image of brain" /></td>
<td>Combination of the above, with right hemiplegia, right hemianesthesia, right homonymous hemianopia, and global aphasia. There is often a left gaze preference, especially at the onset, caused by damage to left hemisphere cortical areas important for driving the eyes to the right.</td>
</tr>
<tr>
<td>LOCATION OF INFARCT</td>
<td>AFFECTED TERRITORY</td>
<td>DEFICITS</td>
</tr>
<tr>
<td>---------------------</td>
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</tr>
<tr>
<td>Right MCA superior division</td>
<td>Left face and arm weakness of the upper motor neuron type. Left hemineglect is present to a variable extent. In some cases, there may also be some left face and arm cortical-type sensory loss.</td>
<td></td>
</tr>
<tr>
<td>Right MCA inferior division</td>
<td>Profound left hemineglect. Left visual field and somatosensory deficits are often present; however, these may be difficult to test convincingly because of the neglect. Motor neglect with decreased voluntary or spontaneous initiation of movements on the left side can also occur. However, even patients with left motor neglect usually have normal strength on the left side, as evidenced by occasional spontaneous movements or purposeful withdrawal from pain. Some mild, left-sided weakness may be present. There is often a right gaze preference, especially at onset.</td>
<td></td>
</tr>
<tr>
<td>Right MCA deep territory</td>
<td>Left pure motor hemiparesis of the upper motor neuron type. Larger infarcts may produce “cortical” deficits, such as left hemineglect as well.</td>
<td></td>
</tr>
<tr>
<td>Right MCA stem</td>
<td>Combination of the above, with left hemiplegia, left hemianesthesia, left homonymous hemianopia, and profound left hemineglect. There is usually a right gaze preference, especially at the onset, caused by damage to right hemisphere cortical areas important for driving the eyes to the left.</td>
<td></td>
</tr>
<tr>
<td>Left ACA</td>
<td>Right leg weakness of the upper motor neuron type and right leg cortical-type sensory loss. Grasp reflex, frontal lobe behavioral abnormalities, and transcortical aphasia can also be seen. Larger infarcts may cause right hemiplegia.</td>
<td></td>
</tr>
<tr>
<td>Right ACA</td>
<td>Left leg weakness of the upper motor neuron type and left leg cortical-type sensory loss. Grasp reflex, frontal lobe behavioral abnormalities, and left hemineglect can also be seen. Larger infarcts may cause left hemiplegia.</td>
<td></td>
</tr>
<tr>
<td>Left PCA</td>
<td>Right homonymous hemianopia. Extension to the splenium of the corpus callosum can cause alexia without agraphia. Larger infarcts, including the thalamus and internal capsule, may cause aphasia, right hemisensory loss, and right hemiparesis.</td>
<td></td>
</tr>
<tr>
<td>Right PCA</td>
<td>Left homonymous hemianopia. Larger infarcts including the thalamus and internal capsule may cause left hemisensory loss and left hemiparesis.</td>
<td></td>
</tr>
</tbody>
</table>

*Compare regions of infarcts to Figure 10.1.*
MCA infarcts are relatively common. Deficits such as aphasia, hemineglect, hemianopia, and face–arm or face–arm–leg sensorimotor loss are described further in KCC 6.3, 7.3, 11.2, 19.4, 19.5, and 19.9. Large MCA territory infarcts often have a gaze preference toward the side of the lesion (see Figures 13.14 and 13.15), especially in the acute period, shortly after onset. Other combinations not listed in Table 10.1, such as superior plus inferior division infarcts sparing deep territories, or superior division plus deep territories, can occasionally occur. In addition, there are sometimes partial or overlapping syndromes. Smaller cortical infarcts can also occur within one territory, producing more focal deficits, such as monoparesis (see KCC 6.3; Figure 6.14E,F).

Small, deep infarcts involving penetrating branches of the MCA or other vessels are called lacunes, as we will discuss in KCC 10.4. Certain characteristic lacunar syndromes (see Table 10.3) can often be distinguished on clinical grounds from infarcts involving large blood vessel territories (see Table 10.1).

**Anterior Cerebral Artery (ACA)**

ACA infarcts typically produce upper motor neuron-type weakness and cortical-type sensory loss (see KCC 7.3) affecting the contralateral leg more than the arm or face (see Table 10.1; Figure 10.1B). Larger ACA strokes may cause contralateral hemiplegia, at least initially. Dominant ACA strokes sometimes are associated with transcortical motor aphasia (see KCC 19.6), and non-dominant ACA strokes can produce contralateral neglect (see KCC 19.9). There may also be a variable degree of frontal lobe dysfunction depending, in part, on the size of the infarct. Such dysfunction may include a grasp reflex, impaired judgment, flat affect, apraxia, abulia, and incontinence (see KCC 19.11). Sometimes damage to the supplementary motor area and other regions in the frontal lobe leads to an unusual “alien hand syndrome” characterized by semiautomatic movements of the contralateral arm that are not under voluntary control.

**Posterior Cerebral Artery (PCA)**

PCA infarcts typically cause a contralateral homonymous hemianopia (see Table 10.1; Figure 11.15). Smaller infarcts that do not involve the whole PCA territory may cause smaller homonymous visual field defects. Sometimes the small, penetrating vessels that come off the proximal PCA are involved, leading to infarcts in the thalamus or posterior limb of the internal capsule. The result can be a contralateral sensory loss; contralateral hemiparesis; or even thalamic aphasia (see KCC 19.6) if the infarct is in the dominant (usually left) hemisphere, thereby mimicking features of MCA infarcts. PCA infarcts that involve the left occipital cortex and the splenium of the corpus callosum can produce alexia without agraphia (see KCC 19.7).

Small, perforating vessels arising from the proximal PCAs at the top of the basilar artery (see Figure 4.17B) supply the midbrain. Vascular syndromes of this region of the brainstem will be discussed in Chapter 14 (see KCC 14.3).

**KEY CLINICAL CONCEPT**

**10.2 WATERSHED INFARCTS**

When a cerebral artery is occluded, ischemia or infarction occurs in the territory supplied by that vessel, with regions near other vessels relatively spared. In contrast, when the blood supply to two adjacent cerebral arteries...
is compromised, the regions between the two vessels are most susceptible to ischemia and infarction. These regions between cerebral arteries are called watershed zones (Figure 10.10). Bilateral watershed infarcts in both the ACA–MCA and MCA–PCA watershed zones can occur with severe drops in systemic blood pressure. A sudden occlusion of an internal carotid artery or a drop in blood pressure in a patient with carotid stenosis (KCC 10.5) can cause an ACA–MCA watershed infarct, since the MCA and ACA are both fed by the carotid (see Figure 10.2).

Watershed infarcts can produce proximal arm and leg weakness ("man in the barrel" syndrome) because the regions of homunculus involved often include the trunk and proximal limbs (see Figure 10.1A). In the dominant hemisphere, watershed infarcts can cause transcortical aphasias syndromes (see KCC 19.6). MCA–PCA watershed infarcts can cause disturbances of higher-order visual processing (see KCC 19.12). In addition to watershed infarcts between the superficial territories of different cerebral vessels, watershed infarcts can also occasionally occur between the superficial and deep territories of the MCA (see Figure 10.9).

**KEY CLINICAL CONCEPT
10.3 TRANSIENT ISCHEMIC ATTACK AND OTHER TRANSIENT NEUROLOGIC EPISODES**

Transient neurologic episodes are a common diagnostic problem. Symptoms and signs may be positive or negative, and they can be motor, somatosensory, visual, auditory, olfactory, kinesthetic, emotional, or cognitive in nature. Some causes of transient neurologic episodes are listed in Table 10.2. Of these, the most common causes are transient ischemic attack, migraine, seizures, and other non-neurologic conditions such as cardiac arrhythmia or hypoglycemia.
In this chapter we will be concerned primarily with transient neurologic episodes caused by cerebrovascular disease. A transient ischemic attack, or TIA, was classically defined as a neurologic deficit lasting less than 24 hours, caused by temporary brain ischemia. This concept has been revised in recent years for several reasons. First, although some transient ischemic deficits last longer, the more typical duration for a TIA is about 10 minutes. Second, improved imaging technology and animal studies suggest that ischemic deficits lasting more than about 10 minutes probably produce at least some permanent cell death in the involved region of the brain. TIAs lasting more than an hour, in fact, are usually small infarcts. On the other hand, despite the appearance of a small infarct on an MRI scan, complete functional recovery can sometimes occur within 1 day. The concept of a TIA remains useful, at the very least, as an important warning sign for a potentially larger ischemic injury to the brain.

TIAs are a neurological emergency akin to acute coronary disease or unstable angina. Approximately 15% of patients with TIAs will have a stroke causing persistent deficits within 3 months, and about half of these strokes occur within the first 48 hours. Therefore, all patients who experience a TIA should be urgently admitted and evaluated for treatable causes of ischemic cerebrovascular disease (see next section).

Several mechanisms for TIAs have been proposed, each of which may occur in different situations. One possibility is that an embolus temporarily occludes the blood vessel but then dissolves, allowing return of blood flow before permanent damage occurs. Other possibilities include in situ thrombus formation on the blood vessel wall and/or vasospasm leading to temporary narrowing of the blood vessel lumen.

TIAs must be distinguished clinically from the other kinds of transient episodes listed in Table 10.2. When transient deficits occur in a typical vascular pattern (see KCC 10.1; see also Chapter 14), especially in a patient with stroke risk factors (see KCC 10.4), TIA must be high on the list of possible diagnoses, and an appropriate workup should be pursued. Other diagnoses that can commonly mimic TIAs include focal seizures (see KCC 18.2) and migraine (see KCC 5.1). Interestingly, episodes of hypoglycemia can sometimes produce transient focal neurologic deficits, especially in the elderly.

**Transient loss of consciousness without other focal features** is a special case of transient neurologic dysfunction. The most common cause by far is cardiogenic **syncpe** including vasovagal transient episodes of hypotension (“fainting”), arrhythmias, and other non-neurologic causes. Neurologic causes are responsible for less than 5 to 10% of cases of syncpe and include seizures (see KCC 18.2), other causes of coma listed in Table 14.4, and rarely, TIA of the posterior circulation affecting the brainstem reticular activating systems (see KCC 14.3).
KEY CLINICAL CONCEPT

10.4 ISCHEMIC STROKE: MECHANISMS AND TREATMENT

Stroke is the third leading cause of death in the United States and a major cause of permanent disability. Recent improvements in the acute diagnostic and therapeutic management of stroke have made it clear that stroke should be handled as an emergency along lines similar to cardiac emergencies. **Stroke** refers to both hemorrhagic events, such as intracerebral or subarachnoid hemorrhage, and to ischemic infarction of the brain. Sometimes ischemic strokes can cause blood vessels to become fragile and rupture, leading to secondary **hemorrhagic conversion**. Ischemic stroke is discussed in this section, and nontraumatic intracranial hemorrhage is discussed in KCC 5.6.

**Mechanisms of Ischemic Stroke**

Ischemic stroke occurs when inadequate blood supply to a region of the brain lasts for enough time to cause infarction (death) of brain tissue. There are numerous mechanisms for ischemic stroke. In clinical practice, a distinction is often made between embolic and thrombotic infarcts. In an **embolic infarct**, a piece of material (usually a blood clot) is formed in one place and then travels through the bloodstream to suddenly lodge in and occlude a blood vessel supplying the brain. In a **thrombotic infarct**, a blood clot is formed locally on the blood vessel wall, usually at the site of an underlying atherosclerotic plaque, causing the vessel to occlude. Embolic infarcts are considered to occur suddenly, with maximal deficits at onset, while thrombotic infarcts may have a more stuttering course. In reality, this distinction is not often easy to make on clinical grounds alone.

Another important distinction is between large-vessel and small-vessel infarcts. **Large-vessel infarcts** involve the major blood vessels on the surface of the brain, such as the middle cerebral artery and its main branches (see KCC 10.1). Large-vessel infarcts are most often caused by emboli, although thrombosis can also occasionally occur, especially in large proximal vessels such as the vertebral, basilar (see KCC 14.3), and carotid arteries. **Small-vessel infarcts** involve the small, penetrating vessels that supply deep structures. In the cerebral hemispheres these include the basal ganglia, thalamus, and internal capsule (see Figures 10.7 and 10.8), while in the brainstem these include the medial portions of the midbrain, pons, and medulla (see Figures 14.18 and 14.20). Small-vessel infarcts are sometimes also called **lacunar infarcts** because they resemble small lakes or cavities when the brain is examined on pathologic section.

In embolic infarcts, the goal is to determine the **source of the embolus** so that future strokes may be prevented. Emboli are most commonly composed of thrombotic (blood clot) material. In **cardioembolic infarcts**, the embolus originates in the heart. Cardioembolic infarcts occur in conditions such as **atrial fibrillation**, in which thrombi form in the fibrillating left atrial appendage; **myocardial infarction**, in which thrombi form on hypokinetic or akinetic regions of infarcted myocardium; and **valvular disease** or mechanical prostheses, in which thrombi form on the valve leaflets or prosthetic parts. **Artery-to-artery emboli** can also occur. These include emboli arising from a stenosed segment of the internal carotid artery (see KCC 10.5), vertebral stenosis, or an ectatic dilated basilar artery. **Dissection** of the carotid or vertebral arteries (see KCC 10.6) often results in thrombus formation, which can embolize to the brain. In addition, atherosclerotic disease of the aortic arch is increasingly being recognized as an important potential source of artery-to-artery thromboembolic material. Occasionally, a **patent foramen ovale** can allow a thromboembolus formed in the venous system to bypass the lungs and pass directly from the right to the left side of the heart, reaching the brain.
Aside from thrombus, emboli composed of other materials can, less commonly, lead to stroke. Examples include air emboli in deep-sea divers or iatrogenic introduction of air into the circulation; septic emboli in bacterial endocarditis, which can lead to mycotic aneurysms and hemorrhage; fat or cholesterol emboli in trauma to long bones or to arterial walls; proteinaceous emboli in marantic endocarditis; disc emboli in cervical trauma; amniotic fluid emboli during childbirth; platelet aggregates; and foreign materials introduced into the circulation (such as talc or other contaminants of illicit intravenous drugs).

Lacunar infarcts are usually associated with small-vessel disease caused by chronic hypertension. In hypertension, small penetrating vessels can become occluded by a several pathologic processes. Atherosclerotic disease, in situ thrombosis, small emboli, or hypertension-related changes in the vessel wall, known as lipohyalinosis, can lead to occlusion of small intracranial blood vessels. In addition, abnormalities of the parent vessel wall such as thrombosis, atheroma formation, or dissection can occlude the openings to one or more small vessels. Numerous characteristic lacunar syndromes have been described, and some of the more common ones are listed in Table 10.3. The clinical features of these lacunar syndromes can help localize infarcts and can help distinguish them from large-vessel infarcts (see Table 10.1).

### Table 10.3 Common Lacunar Syndromes

<table>
<thead>
<tr>
<th>SYNDROME</th>
<th>CLINICAL FEATURES</th>
<th>POSSIBLE LOCATIONS FOR INFARCT</th>
<th>POSSIBLE VESSELS INVOLVED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pure motor hemiparesis or dysarthria hemiparesis</td>
<td>Unilateral face, arm, and leg upper motor neuron–type weakness, with dysarthria</td>
<td>Posterior limb of internal capsule (common)</td>
<td>Lenticulostriate arteries (common), anterior choroidal artery, or perforating branches of posterior cerebral artery</td>
</tr>
<tr>
<td>Ataxic hemiparesis</td>
<td>Same as pure motor hemiparesis, but with ataxia on same side as weakness</td>
<td>Same as pure motor hemiparesis</td>
<td>Same as pure motor hemiparesis</td>
</tr>
<tr>
<td>Pure sensory stroke (thalamic lacune)</td>
<td>Sensory loss to all primary modalities in the contralateral face and body</td>
<td>Ventral posterior lateral nucleus of the thalamus (VPL)</td>
<td>Thalamoperforator branches of the posterior cerebral artery</td>
</tr>
<tr>
<td>Sensorimotor stroke (thalamocapsular lacune)</td>
<td>Combination of thalamic lacune and pure motor hemiparesis</td>
<td>Posterior limb of the internal capsule, and either thalamic VPL or thalamic somatosensory radiation</td>
<td>Thalamoperforator branches of the posterior cerebral artery, or lenticulostriate arteries</td>
</tr>
<tr>
<td>Basal ganglia lacune</td>
<td>Usually asymptomatic, but may cause hemiballismus (see KCC 16.1)</td>
<td>Caudate, putamen, globus pallidus, or subthalamic nucleus</td>
<td>Lenticulostriate, anterior choroidal, or Heubner’s arteries</td>
</tr>
</tbody>
</table>
Cerebral Hemispheres and Vascular Supply

Cortical vs. subcortical lesions can sometimes be differentiated clinically based on the absence or presence of so called cortical signs, including aphasia (see KCC 19.6), neglect (see KCC 19.9), homonymous visual field defects (see KCC 11.2), and cortical sensory loss (see KCC 7.3). However, each of these deficits can be seen in some cases of subcortical lesions as well. Presence of a typical lacunar syndrome (see Table 10.3), such as pure motor hemiparesis, suggests that a subcortical lesion is present. Clinical differentiation between hemispheric vs. brainstem lesions will be discussed in KCC 14.3.

In addition to focal neurological deficits (see KCC 10.1, 10.2, 11.3, and 14.3), ischemic stroke can be associated with headache or, less commonly, seizures. Headache (see KCC 5.1) occurs in 25% to 30% of ischemic strokes. When headache is unilateral, it is more commonly on the side of the infarct, although exceptions do occur. Headache may be more common for posterior than for anterior circulation infarcts. In addition, headaches or neck pain are often seen in dissection of the carotid or vertebral arteries (see KCC 10.6). Seizures (see KCC 18.2) occur in 3% to 10% of stroke patients, usually sometime after the stroke but occasionally as the presenting abnormality.

To summarize:

- Emboli usually cause large-vessel infarcts involving cerebral or (less commonly) cerebellar cortex, with sudden onset of maximal deficits.
- Lacunes are small-vessel infarcts usually seen in chronic hypertension, commonly affecting the deep white matter and nuclei of the cerebral hemispheres and brainstem.
- Thrombosis occasionally occurs in large proximal vessels, such as vertebral, basilar, and carotid arteries, and may also contribute to large or small vessel infarction.

Stroke Risk Factors

Certain patients are at increased risk for vascular disease, including ischemic stroke. When the history is being taken, patients should be asked if they have the following common vascular risk factors: hypertension, diabetes, hypercholesterolemia, cigarette smoking, family history, or prior history of stroke or other vascular disease (Table 10.4). In addition, certain cardiac disorders are important risk factors for stroke, especially atrial fibrillation, mechanical valves or other valvular abnormalities, patent foramen ovale (mentioned in the preceding section), and a severely decreased ejection fraction.

Less commonly, several other systemic medical conditions may affect the coagulation pathways or work through other mechanisms to increase both thrombotic and embolic infarcts (Table 10.5). These hypercoagulable states also increase the risk for venous thrombosis (see KCC 10.7).

Ischemic stroke is relatively uncommon in young individuals because the cumulative effects of the major stroke risk factors (see Table 10.4) tend to worsen with age. When stroke does occur in a young patient, conditions such as arterial dissection (see KCC 10.6), patent foramen ovale, or the disorders listed in Table 10.5 should be considered in addition to the usual causes.

Treatment and Diagnostic Workup of Ischemic Stroke and TIA

ACUTE MANAGEMENT

Not for this LO

Treating stroke or TIA as an acute medical emergency, similar to treating a heart attack. Prompt