Stroke: Emergency Care and Rehabilitation

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Contact hours: 13

Pharmacotherapy hours:4

Course price: $59

Instructions

1. To print everything you need, including the test, evaluation, and registration, click Print This Page at the top right. Study the course, pass the test, and fill out the forms.
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Course Summary

This is an interdisciplinary course intended for nurses, nurse practitioners, advanced practice nurses, physical therapists, and occupational therapists. It presents information about types of stroke and risk factors as well as a review of brain anatomy with emphasis on deficits associated with lesions in different parts of the brain. Treatment regimens, prehospital, ED treatment, and pharmacologic management are described.

Rehabilitation following an acute stroke is discussed in detail, including current information about motor control theories, techniques for regaining the use of the upper and lower extremities, and a discussion of challenges faced by stroke patients and their families following a stroke.

The course is intended to challenge rehabilitation therapists in their understanding of acute management of stroke as well as challenging nurses, nurse practitioners, and advanced practice nurses in their understanding of the efficacy and issues associated with post-stroke rehabilitation.

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Commercial Support
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Criteria for Successful Completions
80% or higher on the post test, a completed evaluation form, and payment where required. No partial credit will be awarded.

Course Objectives

When you finish this course you will be able to:

- Discuss the incidence of stroke in the United States.
- Describe 2 features each of ischemic and hemorrhagic stroke.
- Describe the 4 main structures of the brain.
- State the 2 main arterial systems that supply blood to the brain.
- Identify one aspect each of gender, age, and racial differences in acute stroke.
- Discuss 5 elements addressed in the prevention of stroke.
- Describe the 5 elements of emergency department care of acute stroke patients.
- Summarize 3 therapies for the acute treatment of ischemic stroke.
- Describe the 3 most common destinations for post-stroke rehabilitation.
- Define plasticity and maladaptive plasticity.
- Discuss 3 sensory elements that contribute to balance.
- Define walking adaptability and identify 3 movement strategies important for balance.
- Discuss 3 key points related to bilateral upper limb training.
- Identify 4 screening tools used to assess the presence or absence of dysphagia.
- Describe 4 common cognitive impairments that can occur following a stroke.
- Identify 3 factors that may lead to the development of depression following a stroke.
- Explain why low levels of physical fitness affect recovery following a stroke.
- Describe 3 common mobility devices used following a stroke.
- Describe 3 interventions undertaken to prevent skin breakdown following a stroke.
- Summarize 3 issues with caregiving once a stroke patient is discharged to home.
- Explain the importance of sedentary time in the inpatient rehab setting.
- Summarize the 4 elements associated with treatment burden.
- Define and describe neuroregenerative medicine.

Incidence of Stroke

On average, one American dies from stroke every 4 minutes. Every year, more than 795,000 people in the United States have a stroke. About 610,000 of these are first or new strokes. About 185,000 strokes—nearly 1 of 4—are in people who have had a previous stroke. About 87% of all strokes are ischemic strokes, when blood flow to the brain is blocked. Stroke is a leading cause of serious long-term disability (Go et al., 2014).

In recent years, stroke has declined from the third to fourth leading cause of death in the United States (Go et al., 2014). This change is largely the result of decades of interventions focusing on hypertension, as well as aggressive public campaigns emphasizing early recognition and treatment of stroke symptoms. Despite the progress made in reducing stroke-related deaths, the burden of disability from stroke remains high and continues to be the leading cause of disability in the United States, contributing to poor quality of life and adding billions of dollars to the cost of healthcare (Go et al., 2014).

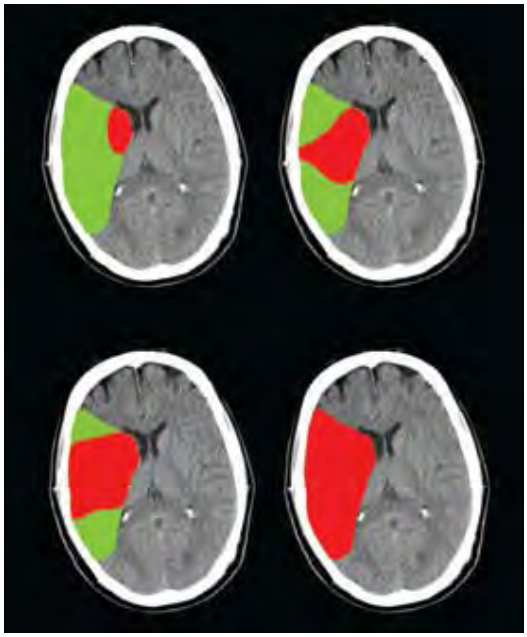
Stroke is the fourth leading cause of death for Americans, but the risk of having a stroke varies with race and ethnicity. Risk of having a first stroke is nearly twice as high for blacks than for whites, and blacks are more likely to die following a stroke than are whites. Hispanics' risk for stroke falls between that of whites and blacks. American Indians, Alaska Natives, and blacks are more likely to have had a stroke than are other groups (CDC, 2014a).

In the United States, African Americans have an age-adjusted risk of death from stroke that is about 1.5 times that of white residents. Hispanics have a lower overall incidence of stroke than whites or blacks, but are more likely to experience stroke at a younger age. Men are at greater risk for stroke than females, with an incidence of about 63 per 100,000 for men and 59 per 100,000 for women. However, females have a higher death rate of 39.3% compared to 26.3% for males (Towfighi & Saver, 2011).

Penumbra Surrounding Damaged Brain Tissue

Although stroke is considered a disease of elders, one-third of strokes occur in individuals younger than 65 years. About 15% to 30% of those suffering an ischemic stroke will die within the first month. The chance of surviving a hemorrhagic stroke is more dire, with a survival rate of only about 20% (Slater, 2014).

After an acute episode, the most common causes of death are pulmonary embolism (within 2–4 weeks), pneumonia (within 2–3 months), and cardiac disease (>3 months) (Slater, 2014).



Immediately after an ischemic stroke (top left), a core of irreversibly damaged brain tissue (red) is surrounded by an area of viable but at-risk tissue called the penumbra (green). Unless blood flow is restored quickly, the tissue within the penumbra will be lost (bottom right). Source: NIH (n.d.).

Types of Stroke

There are two main types of stroke: ischemia and hemorrhage. An **ischemic stroke** is caused by interruption of blood flow and decrease of oxygen to the brain. If not treated rapidly, ischemia ultimately leads to infarction, in which brain cells are replaced by a fluid-filled cavity (or infarct). A **transient ischemic attack (TIA)** is also caused by blockage or interruption of blood flow to the brain. A TIA lasts only a short time but should be treated as a serious neurologic event. **Hemorrhagic stroke** occurs when a blood vessel in the brain leaks or ruptures, spilling blood into adjacent brain tissue.

The loss of oxygen and nutrients following a stroke begins a process that destroys neurons within the brain. Some cells die immediately, while others are damaged and remain at risk for death if treatment is delayed. The damaged neurons surrounding dead cells make up the ischemic **penumbra** (see illustration below) and can linger in a compromised state for several hours. With timely treatment these neurons can be saved (NINDS, 2015a).

Ischemic Stroke

Acute ischemic stroke is characterized by the sudden loss of blood circulation to a location in the brain, typically in a highly vascular area, resulting in a corresponding loss of neurologic function based on the area involved. Individuals having an ischemic stroke experience a sudden onset of neurologic deficit and often have co-morbid hypertension, diabetes mellitus, valvular heart disease, or atherosclerosis. Distinctive neurologic signs typically indicate the region of the brain involved but not necessarily the cause. Strokes are divided into two types: hemorrhagic or ischemic. Acute ischemic stroke is caused by a thrombotic or embolic occlusion of a cerebral artery.

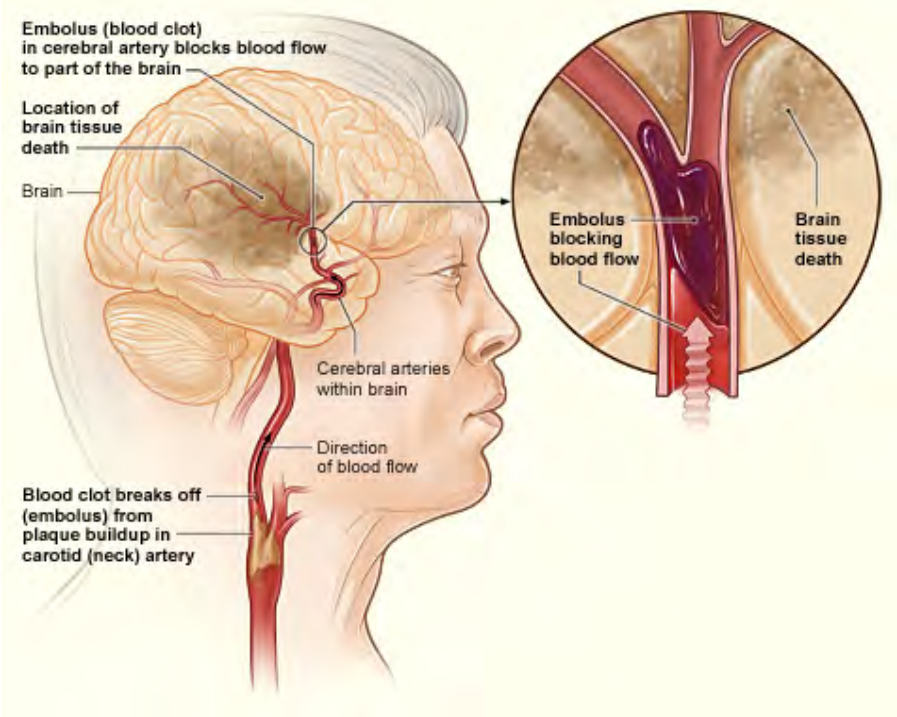
Ischemic strokes occurring in the carotid circulation are the most common type of ischemic stroke, accounting for approximately 70% of all cases (Baird, 2013). They are usually caused by occlusion of one of the major intracranial arteries or one of the small single penetrating arteries.

Depending on the location of the blockage, ischemic stroke can affect sensation, speech, behavior, thoughts, memory, or emotions. One side of the body may become paralyzed or weak. The five most common signs and symptoms of ischemic stroke are acute onset of:

- Numbness or weakness of the face, arm, or leg
- Confusion or trouble speaking or understanding others
- Trouble seeing in one or both eyes
- Dizziness, trouble walking, or loss of balance or coordination
- Severe headache with no known cause (CDC, 2014b)

Blood clots can cause ischemia in two ways. In the first, a clot that forms in a part of the body distant from the brain travels through the blood and becomes wedged in an artery supplying blood to the brain. This free-roaming clot is called an **embolus** and often forms in the heart. An ischemic stroke caused by an embolus is also referred to as an **embolic stroke**.

The Brain During an Embolic Stroke



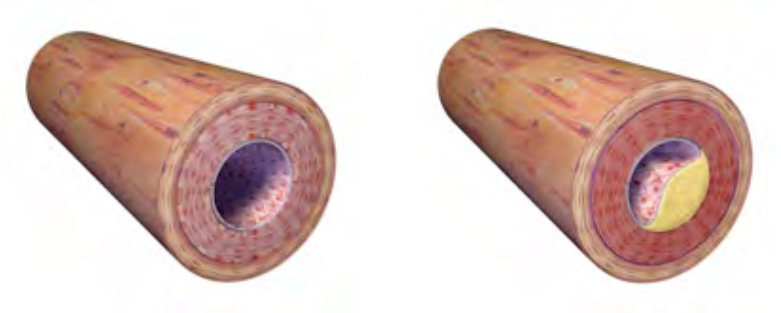
This illustration shows how an ischemic stroke can occur in the brain. If a blood clot breaks away from plaque buildup in a carotid (neck) artery, it can travel to and lodge in an artery in the brain. The clot can block blood flow to part of the brain, causing brain tissue death. Source: NIH, n.d.

The second kind of ischemic stroke, called a thrombotic stroke, is caused by **thrombosis**, the formation of a blood clot in one of the cerebral arteries that stays attached to the artery wall until it grows large enough to block blood flow (NINDS, 2015a).

Ischemic strokes can also be caused by **stenosis**, a narrowing of an artery due to the buildup of plaque and blood clots along the arterial wall. Stenosis can occur in large or small arteries and is referred to as large-vessel disease or small-vessel disease, respectively. When a stroke occurs due to small-vessel disease, a very small infarction results, sometimes called a lacunar infarction (NINDS, 2015a).

Atherosclerosis is the most common blood vessel disease that causes stenosis. In atherosclerosis, deposits of plaque build up along the inner walls of large- and medium-sized arteries, causing thickening, hardening, and loss of elasticity of artery walls along with decreased blood flow (NINDS, 2015a).

Stenosis in a Section of an Artery



Left: A sectioned elastic artery. Elastic arteries are vessels that can handle a great deal of pressure (eg, the aorta, which takes pressure directly from the constant beating of the heart). Right: An atherosclerotic plaque, with the plaque forming on the inside wall. Illustration provided by 3DScience.com. Used with permission.

Stroke recurs in as many as 10% of stroke survivors in the first 12 months after the initial event, with an incidence of 4% per year thereafter (Baird, 2013).

Transient Ischemic Attack (TIA)

The annual incidence of TIA in the United States is estimated to be 200,000 to 500,000. About half of those experiencing TIA don't report it, representing lost opportunities for early intervention and stroke prevention. The actual incidence of TIA is unknown due to under-reporting (Sonni & Thaler, 2013).

A **transient ischemic attack (TIA)** is an ischemic stroke that lasts only a few minutes. Its onset is acute and without warning, and recovery is usually rapid. TIAs occur when the blood supply to part of the brain is briefly interrupted—usually by an embolism. TIA symptoms are similar to those of stroke but do not last as long. Essentials features of TIA include:

- The presence of risk factors for vascular disease

- Focal neurologic deficit of acute onset
- Clinical deficit that resolves completely within 24 hours (Siket & Edlow, 2012)

In the past, TIA was diagnosed solely by the sudden onset of symptoms that resolved spontaneously within 24 hours (Simmons et al., 2012). This definition is now considered inadequate because we now know that even brief periods of ischemia can result in permanent brain injury. Currently the definition is *tissue-based* rather than time-based.

TIA now includes transient episodes of neurologic dysfunction caused by focal brain, spinal cord, or retinal ischemia without infarction (von Weitzel-Mudersbach et al., 2013). This expanded definition is intended to increase opportunities for timely intervention that could prevent a TIA from evolving into a stroke. TIA may be a precursor to stroke because both share the same cerebrovascular disease processes.

Almost 25% of patients experiencing a TIA have resolution of neurologic symptoms within 5 minutes and 50% have resolution within 30 minutes. If the patient's symptoms persist after 1 hour, there is only a 15% chance that neurologic symptoms will disappear within 24 hours (Papadakis et al., 2015).

A number of disorders increase the risk of TIA, including rheumatic heart disease, mitral valve disease, cardiac arrhythmias, infective endocarditis, atrial myxoma, and complications following myocardial infarction. Emboli that break loose from ulcerated atherosclerotic plaques in a major artery may also cause TIA. Patients with AIDS are at increased risk for developing TIAs and stroke (Papadakis et al., 2015).

Aspirin and modification of risk factors such as high cholesterol and hypertension reduce the likelihood of heart attack and stroke (Farina, 2014).

A TIA can occur in either the anterior or the posterior circulation, and symptoms vary depending upon the location of the blockage. If ischemia affects the carotid (anterior) circulation, the symptoms include weakness and heaviness on the contralateral arm, face, or leg. Numbness and sensory changes may also occur, either alone or in combination with motor deficit (Papadakis et al., 2015).

Other symptoms may include monocular visual loss, dysphagia, and slowness of movement. Examination during a TIA may reveal sensory changes, hyper-reflexia, extensor plantar response, and flaccid weakness. Once the symptoms pass, examination will reveal no neurologic deficits, but carotid bruit or cardiac abnormalities may be present (Papadakis et al., 2015).

Because there is no way to tell whether symptoms are from a TIA or an acute stroke, people should assume that all stroke-like symptoms signal an emergency and should not wait to see if they go away. A prompt evaluation is necessary to identify the cause of the TIA and determine appropriate therapy (Papadakis et al., 2015).

Key Points About TIAs

TIA produces some or all of these symptoms:

- Numbness or weakness in the face, arm, or leg, especially on one side of the body
- Confusion or difficulty talking or understanding speech
- Trouble seeing in one or both eyes
- Difficulty walking, dizziness, or loss of balance and coordination
- Numbness/sensory changes

Source: NINDS, 2015b.

The occurrence of a TIA is a major indicator of the overall health of the cardiovascular system, and many strokes can be prevented by heeding warning signs and treating underlying risk factors. Drug therapy or surgery to reduce the risk of stroke may be indicated. The use of antiplatelet agents, particularly aspirin, is a standard treatment for patients at risk for stroke, and people with atrial fibrillation may be prescribed anticoagulants (NINDS, 2015b).The American Heart Association/American Stroke Association (AHA/ASA) support treatment with aspirin alone as monotherapy, or combined therapy which includes clopidogrel or dipyridamole as first-line interventions for prevention of secondary ischemic events (AHA/ASA, 2014).

People who have suffered a TIA are at increased risk for stroke, especially in the first year after the event. In the first 3 months, stroke risk is more than 10%, with the highest risk in the 2 days following the TIA (NINDS, 2015b). After the first year, the risk of a subsequent stroke decreases to about 8% per year. Patients with TIA who are considered at high risk for a stroke include those over the age of 60, diabetics, or those with TIAs lasting longer than 10 minutes and with weakness or speech impairment (JAHA, 2011).

Post-TIA stroke risk is based on assessment of both modifiable (hypertension, diabetes, abnormal lipid profile, smoking, sedentary lifestyle and obesity) and non-modifiable (age, gender, race/ethnicity and heredity) risk factors. Again, the goal is for intervention and prevention of progression to stroke with permanent neurologic deficits (Rhoney, 2011; Sonni & Thaler, 2013).

Hemorrhagic Stroke

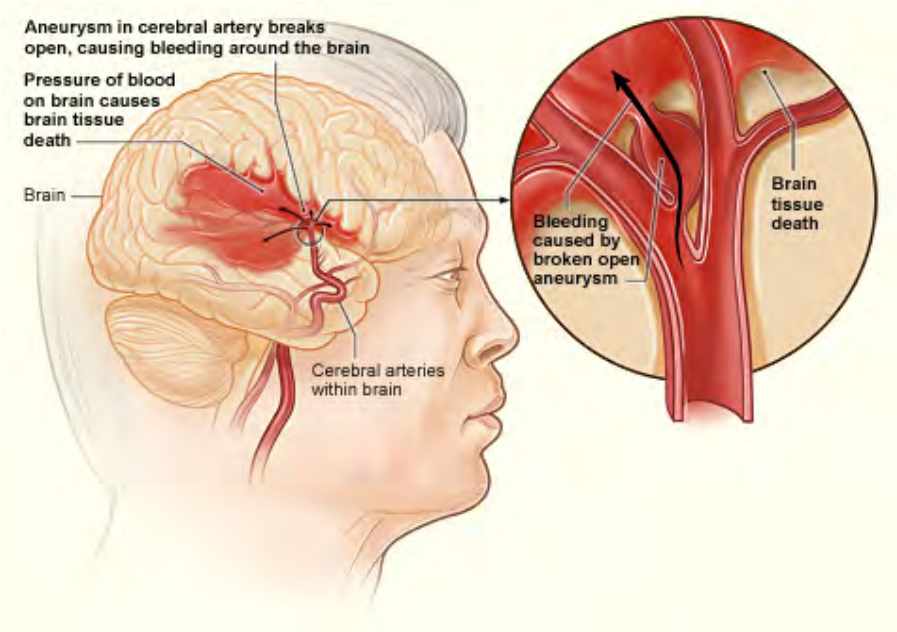
There are two types of hemorrhagic strokes—intracerebral and subarachnoid hemorrhages. Bleeding from ruptured brain arteries can either go into the substance of the brain or into the various spaces surrounding it.

A **hemorrhagic stroke** occurs when a blood vessel in the brain bursts or leaks, causing blood to accumulate, compressing the surrounding brain tissue, and killing neurons. Blood also irritates delicate brain tissue and causes cerebral edema. Tissue swelling—along with the hematoma from the leaking blood—increases the mass effect, causing further damage and a general increase in intracranial pressure. Brain cells beyond the rupture are deprived of blood and are also damaged (Mayo Clinic, 2014).

Symptoms of hemorrhagic stroke include those of ischemic stroke, but may also include nausea, vomiting, headache, and altered level of consciousness. These symptoms may indicate increased intracranial pressure and are more common with hemorrhagic strokes or large ischemic strokes. Seizures occur in up to 28% of hemorrhagic strokes (Liebeskind, 2015).

Hemorrhage can occur in several ways. One common cause of hemorrhage is a bleeding **aneurysm**—a weak or thin spot on an artery wall. Over time, these weak spots stretch or balloon out under high arterial pressure and their thin walls can rupture and spill blood into the surrounding brain cells (NINDS, 2015b). Aneurysms affect as much as 1% of the population and are sometimes hereditary. Studies have shown that the risk an aneurysm will rupture is related to its size and shape, its location, and the person's age (NINDS, 2009).

Ruptured Aneurysm with Associated Bleeding in the Brain



This shows how a hemorrhagic stroke can occur in the brain. An aneurysm in a cerebral artery breaks open, which causes bleeding in the brain. The pressure of the blood causes brain tissue death. Source: NIH, n.d.

Hemorrhage also occurs when an arterial wall breaks open. Plaque-encrusted arteries eventually lose their elasticity and become brittle, thin, and prone to cracking. Hypertension increases the risk that a brittle artery wall will give way and release blood into the surrounding brain tissue (NINDS, 2015b).

An **arteriovenous malformation** can also cause a hemorrhagic stroke. A cerebral arteriovenous malformation is an abnormal connection between the arteries and veins in the brain that forms during embryonic development or soon after birth. This tangle of defective, thin-walled blood vessels and capillaries may bleed when subjected to pressure or damage. Although hemorrhage from an arteriovenous malformation can occur at any age, it is most common between the ages of 15 and 20 years. Arteriovenous malformations may develop in many different sites but those located in the brain or spinal cord can have especially widespread effects on the body (NINDS, 2014a).

Intracerebral Hemorrhage

Intracerebral hemorrhage is the most common type of hemorrhagic stroke and the second most common cause of strokes after ischemic strokes. An intracerebral hemorrhage occurs when an artery in the brain bursts, flooding the surrounding tissue with blood (CDC, 2013a). The 30-day mortality rate from intracerebral hemorrhage ranges from 35% to 52%, and half of these deaths occur within the first 2 days. Only a small number of patients who survive an intracerebral hemorrhage function independently after the event (Rordorf & McDonald, 2013).

In the absence of neurovascular abnormalities such as aneurysm or angioma, nontraumatic intracerebral hemorrhage is most commonly caused by hypertensive damage to blood vessel walls (Liebeskind, 2014). A significant increase in blood pressure over time can cause hemorrhage, which often occurs after activity.

Hypertensive intracerebral hemorrhage occurs most often in the basal ganglia and less frequently in the pons, cerebellum, thalamus, and white matter. Nontraumatic cerebral hemorrhage is also associated with bleeding disorders, anticoagulant therapy, liver disease, and brain tumors (Papadakis et al., 2015).

Bleeding into the deep portions of the brain causes visual loss of conjugate lateral gaze, loss of upward gaze, downward deviation of the eyes, lateral gaze palsies, and unequal pupils. If hemorrhage is in the cerebellum, there may be sudden onset of nausea and vomiting, headache, disequilibrium, and loss of consciousness. Treatment for hemorrhage is generally conservative and supportive. Surgical intervention may be indicated in the presence of a hematoma, especially in the cerebellum. The incidence of intracerebral hemorrhage has increased by 18% in the past 10 years, possibly because of increase in the number of elders who may lack adequate blood pressure control, as well as the increasing use of anticoagulants, thrombolytics, and antiplatelet agents (JAHA, 2011a).

Subarachnoid Hemorrhage

Subarachnoid hemorrhage is caused by bleeding under the meninges into the thin fluid-filled space that surrounds the brain (NINDS, 2015b). Trauma is the most common cause of subarachnoid hemorrhage (Papadakis et al., 2015). About 10% of patients who have subarachnoid hemorrhage die immediately, and up to 60% die within the first 30 days. Rebleeding is a major complication, with a mortality rate of 50% to 80% (Becske, 2014).

The first sign of subarachnoid hemorrhage is typically a severe headache with a split-second onset and no known cause. Neurologists call this a thunderclap headache and it demands immediate medical attention. About one-half of patients lose consciousness, and vomiting can present (Papdakis et al., 2015). The rupture may occur in an arteriovenous malformation, but typically it is caused by an aneurysm.

Hemorrhagic Transformation of Ischemic Stroke

Hemorrhagic transformation represents conversion of a previously ischemic infarction into an area of hemorrhage. This is estimated to occur in 5% of uncomplicated ischemic strokes in the absence of fibrinolytic treatment. Furthermore, this hemorrhagic transformation may not be associated with additional neurologic decline, as the conversions can range from small petechial hemorrhages to large hematomas that may require surgical evacuation. Hemorrhagic transformation generally occurs 2 to 14 days post event. It is also more likely to occur following administration of rt-PA in patients thought to have had an ischemic stroke (Nighoghossian et al., 2002).

Risk Factors for Stroke

Risk factors for both ischemic stroke and intracerebral hemorrhage increase with age. The risk of both types of stroke doubles for each successive decade after age 55 years (JAHA, 2011b). Some risks factors can be modified while others cannot. Risk factors that cannot be modified include age, gender, race/ethnicity, and family history of stroke. In contrast, other risk factors for stroke (eg, high blood pressure, cigarette smoking) can be changed or controlled by the person at risk.

The most important risk factors for stroke are age, hypertension (HTN), diabetes, heart disease, and cigarette smoking. Others include heavy alcohol consumption, high blood cholesterol levels, and illicit drug use. When someone has more than one risk factor their overall risk of stroke is amplified. This means that the multiple risk factors compound their destructive effects and create an overall risk greater than the simple cumulative effect of the individual risk factors.

Important Risk Factors for Stroke	
Risk factor	**Comments**
Age	Risk of stroke doubles each decade after the age of 55 (AHA, 2012).
High blood pressure (HTN)	Stroke risk is 4–6 times higher than for those without HTN. One-third of the adult U.S. population (including 40–70% of those over age 65) has HTN. Forty percent to 90% of stroke patients have high blood pressure before their stroke event. Treatment of HTN can decrease stroke incidence rate by 38% and stroke fatality rate by 40% (NINDS, 2015a).
Diabetes	Stroke risk is 3 times higher than for those without diabetes. Contributing risk factors can amplify the overall risk for stroke—the prevalence of HTN is 40% higher in the diabetic population than the general population (NINDS 2015a).
Cigarette Smoking	Doubles a person's risk for ischemic stroke and increases risk for subarachnoid hemorrhage by up to 3.5%. Promotes atherosclerosis and increases the levels of blood clotting factors such as fibrinogen. Weakens the endothelial lining of the cerebrovascular system, which leads to greater damage to the brain from events that occur in the secondary stage of stroke (NINDS 2015a).
Atrial fibrillation	Raises the risk for stroke because the upper chambers of the heart beat ineffectively and allow blood to pool and clot. If a clot breaks off it can lodge in the brain and cause a stroke (AHA, 2012).
High cholesterol	Contributes to stroke in the same way that it contributes to heart disease. Low-density lipoprotein (LDL or bad cholesterol) circulates in the blood, picks up excess cholesterol, and deposits it where it is needed. Excess LDL cholesterol builds up in the arteries, leading to stenosis and atherosclerosis. High density lipoprotein (HDL, good cholesterol) delivers cholesterol to the liver, where the excess is then sent to the kidneys and eliminated (NINDS, 2015a).
High alcohol consumption	Leads to an increase in blood pressure and also may deplete platelets and compromise blood clotting. Although heavy drinking is a risk for both hemorrhagic and ischemic stroke, daily consumption of smaller amounts of alcohol may provide a protective influence against ischemic stroke by decreasing the clotting ability of platelets in the blood (NINDS, 2015a).

Important Risk Factors for Stroke	
Risk factor	**Comments**
Illicit drugs	Use of illicit drugs can cause stroke by acting on other risk factors, such as HTN, heart disease, and vascular disease. Decreases relative blood flow by up to 30%, causes vascular constriction, and inhibits vascular relaxation, leading to narrowing of the arteries. Drugs such as cocaine affect the heart, causing arrhythmias and rapid heart rate that can lead to blood clots. Marijuana decreases blood pressure and may interact with other risk factors, such as HTN and cigarette smoking, to cause rapidly fluctuating blood pressure levels, damaging blood vessels (NINDS 2015a).

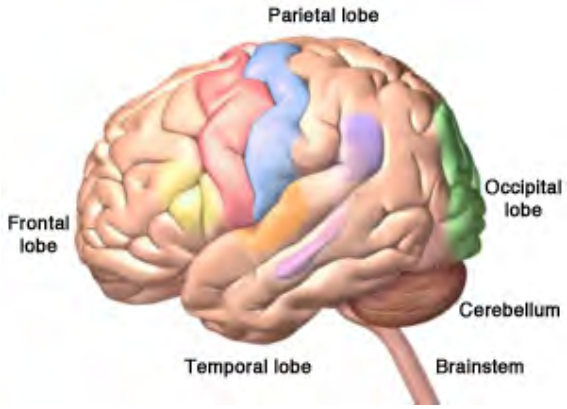
In 2014 the AHA/ASA issued guidelines for the reduction of stroke risk aimed specifically at **women**. These gender-specific recommendations include the following

- A stroke risk score should be developed specifically for women.
- Women with a history of high blood pressure before pregnancy should be considered for low-dose aspirin and/or calcium supplement treatment to reduce the risk of pre-eclampsia.
- Blood pressure medication may be considered for pregnant women with moderately high blood pressure (150–159 mmHg/100–109 mmHg), and pregnant women with severe high blood pressure (160/110 mmHg or above) should be treated.
- Women should be screened for high blood pressure before they start using birth control pills due to increased risk of stroke.
- Women with migraine headache with aura should be encouraged to stop smoking to reduce the risk of stroke.
- Women over age 75 should be screened for atrial fibrillation. (Bushnell et al., 2014)

Brain Anatomy

The brain is made up of the cerebrum, cerebellum, and the brainstem. The **cerebrum** has two hemispheres, each divided into four lobes: the frontal, parietal, temporal, and occipital lobes. The lobes are named for the bones of the skull overlying them. Each lobe has extensive interaction with other lobes, although specific lobes have regions that are responsible for certain cognitive functions. The nerve cells within each region are highly interconnected with other neurons in the same region, to related areas in other lobes, to areas deep in the cerebrum, and to the brainstem and spinal cord.

The Anatomy of the Brain



The cerebrum is made up of the parietal, frontal, occipital, and temporal lobes. Source: 3Dscience.com. Used with permission.

Cerebral Cortex

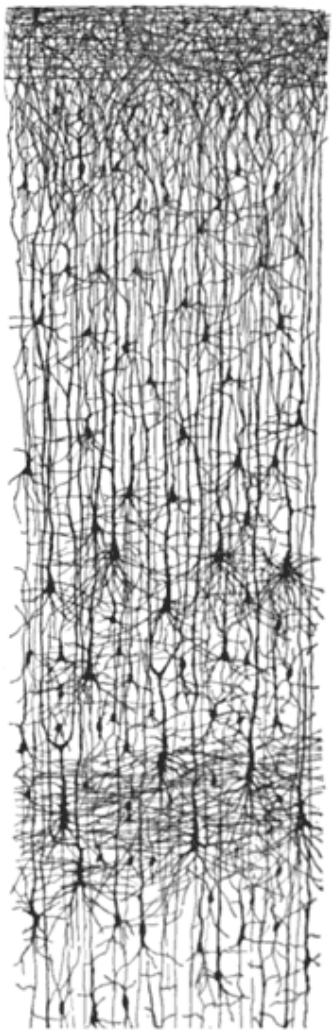
The cerebral cortex is a thin layer of nerve cell bodies covering the surface of each hemisphere. **It is the part of the brain most often affected by stroke.** Axons arising from the estimated 100 billion cell bodies of the cortex run both horizontally and vertically, and each connects with thousands of other neurons, creating a highly complex network.

The cerebral cortex is highly convoluted and folded, which increases its surface—a phenomenon unique to humans. The cell bodies of the cortex have a high metabolic requirement, using six times more blood than other parts of the brain. The interconnectedness of the nerve cells creates a flexible system, with redundancy that allows recovery of function following injury to the brain.

The cerebral cortex has historically been divided by function and structure areas into the somatosensory, somatomotor, primary motor, visual, and auditory areas. These descriptions derive from early brain research and are no longer considered to be accurate except as a broad overview. New imaging techniques show that the cortex is more extensively interconnected than previously thought.

The cerebral cortex is the thinking and processing part of the brain. The cortex originates thoughts and commands and receives information from the periphery and other parts of the brain for processing and interpretation. **Motor commands flow from efferent nerve fibers** originating in the cortex out to the muscles.

Nerve Cell Bodies in the Cerebral Cortex



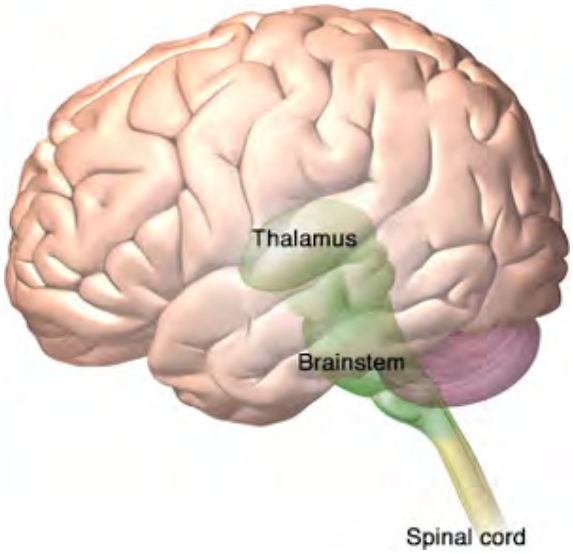
The human cortex showing a highly interconnected network of nerve cells. Source: Ramon y Cajal, 1899.

Sensory information flows via bundles of afferent nerves residing in the cortex from the peripheral nervous system for processing. The cerebral cortex—especially the frontal areas—is the area of the brain most commonly damaged by stroke.

The Thalamus

The thalamus or "inner chamber" is a small ovoid mass about 3 cm long located at the base of the cerebral hemispheres. Sensation travels to the thalamus from peripheral sensory neurons. The thalamus is closely integrated with the cerebral cortex and is responsible for the initial processing of all sensory information (except olfaction).

The Thalamus



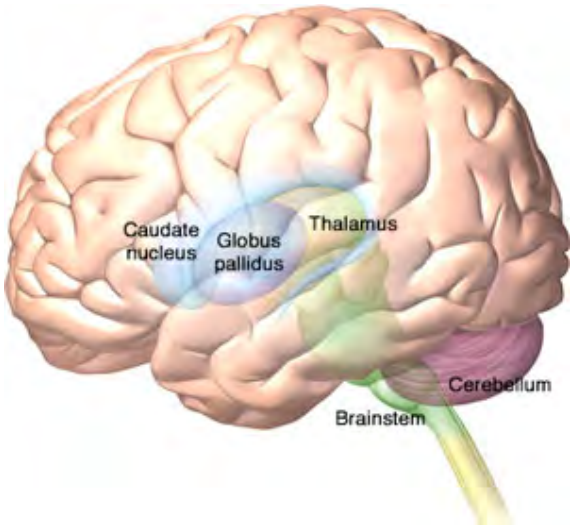
The thalamus is the destination of spinothalamic tract—the sensory pathway responsible for processing pain, temperature, and crude touch. Source: 3Dscience.com. Used with permission.

The thalamus accepts and sifts sensory information and is the part of the brain where sensation is first consciously experienced or felt.

Subcortical Structures

The subcortical structures—the **basal ganglia**, also known as the *extrapyramidal system*—are three large masses of cells (ganglia) that lie at the base of the cerebral cortex and surround the thalamus. The three masses that compose the basal ganglia are called the caudate nucleus, the putamen, and the globus pallidus. The names of these three structures are combined in various ways: the caudate nucleus and the putamen together are referred to as the **striatum** and the globus pallidus and the putamen together are known as the **lentiform nucleus**.

Lateral Brain with Basal Ganglia



This image illustrates the left lateral view of the brain and spinal cord, as well as the caudate nucleus and basal ganglia deep in the brain, and a contour of the rest of the thalamus. The cerebral hemisphere (in pink) surrounds the caudate nucleus thalamus (in the center). Source: 3Dscience.com. Used with permission.

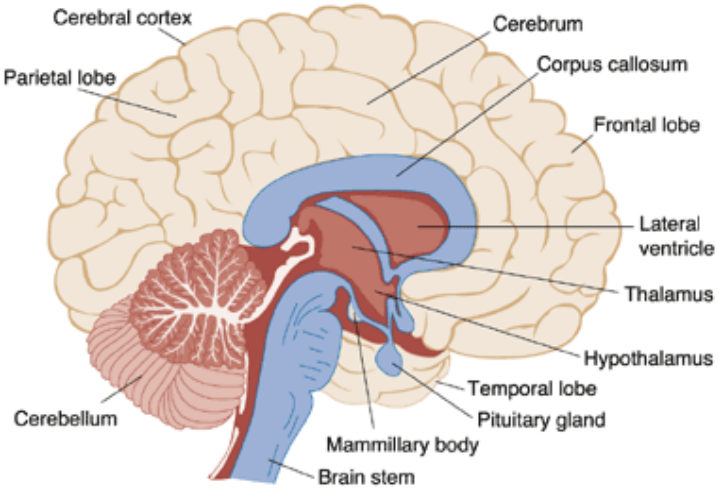
The basal ganglia, together with the cerebellum and the motor cortex, are involved with motor control. A motor command initiated by the cortex is modified and processed within the basal ganglia. This part of the brain helps the cerebral cortex execute subconscious, learned movements. It scales movement and determines how large, small, fast, or slow a movement needs to be for optimum performance. The basal ganglia also work in conjunction with the substantia nigra as part of the dopamine circuit, which is damaged in Parkinson's disease.

The basal ganglia are sometimes referred to as the "extrapyramidal system" to differentiate them from the "pyramidal system" (more accurately referred to as the corticospinal tract). Disorders affecting the basal ganglia are still sometimes referred to as extrapyramidal disorders.

The Brainstem and Cerebellum

The brainstem is located above the spinal cord and beneath the thalamus and consists of the **medulla oblongata**, the **pons**, and the **midbrain**. The brainstem contains well-defined clusters of nerve cell bodies or nuclei that receive sensory input from the cranial nerves and send this information upstream to the thalamus for further processing. The brainstem has an ill-defined central core called the brainstem **reticular formation** that houses the respiratory and cardiovascular centers that influence breathing, respiration, blood pressure, circulation, and vasomotor tone.

Medial View of the Brain



This illustration identifies the various areas of the human brain.
Source: Oscar-Berman et al., 1997.

The **cerebellum**, or "little brain," is located behind and above the brainstem and makes up about 10% of the total volume of the brain. Despite its small size, the cerebellum contains more than half of all the neurons in the brain, arranged in a highly regular and repeating pattern. The cerebellum is connected to the brainstem via three pairs of peduncles ("little feet") that are bundles of nerve fiber tracts entering and exiting the cerebellum. These nerve fiber tracts carry information to and from the spinal cord, cerebrum, and brainstem.

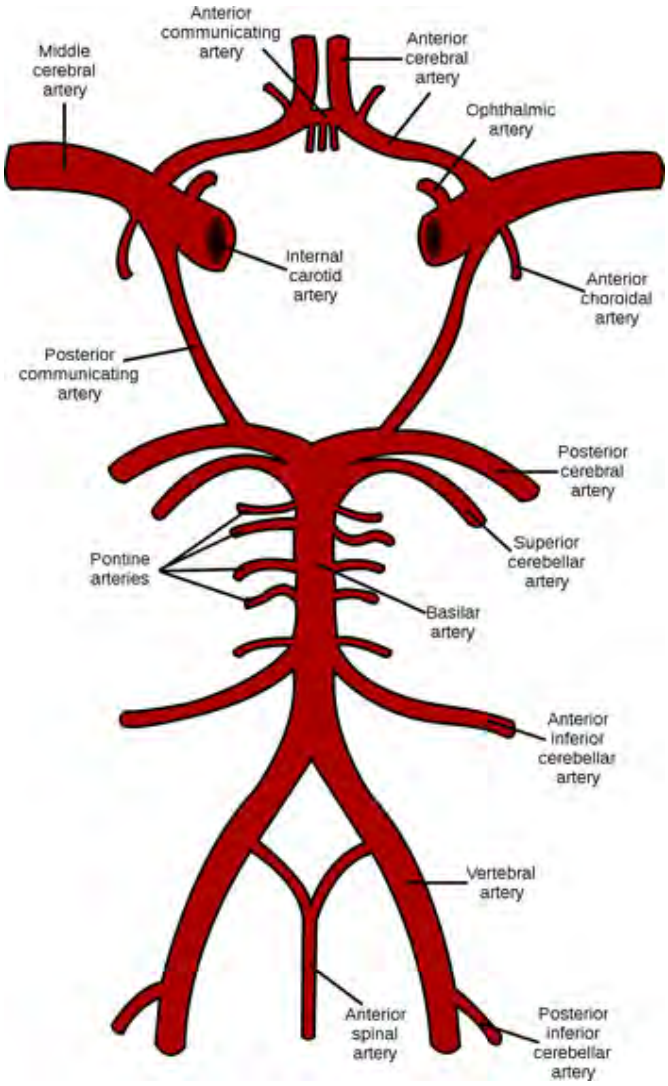
The cerebellum works with other motor control areas of the brain to control and coordinate movement. Specifically, the cerebellum corrects deviations in movement by comparing one movement with another and fine-tuning subsequent movements. The cerebellum is primarily responsible for the rapid adjustments needed for normal motor activity. It also sends information to and receives information from the vestibular system and helps to control balance by controlling the axial muscles of the body.

Carotid and Vertebrobasilar Disorders

Blood flows from the heart to the brain via two large arterial systems: the **carotid** and the **vertebrobasilar** arterial systems. The vast majority of strokes—both ischemic and hemorrhagic—occur in the part of the brain supplied by the carotid circulation, which channels blood to most of the cerebral hemispheres.

The middle cerebral artery, the anterior cerebral artery, and the ophthalmic artery are the three clinically important branches of the **carotid circulation**. The middle cerebral artery supplies blood to the lateral part of the cerebral cortex, to most of the basal ganglia, and parts of the internal capsule. At the base of the brain, the carotid and vertebrobasilar arteries form a circle of communicating arteries known as the **circle of Willis**.

The Circle of Willis

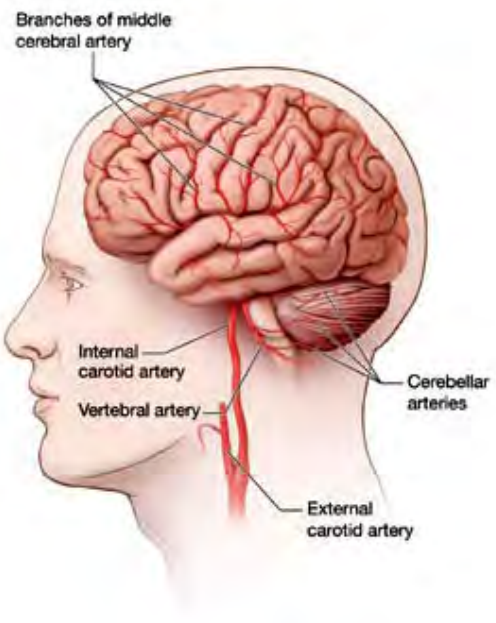


Schematic representation of the circle of Willis showing the arteries of the brain and brain stem. Source: Wikimedia Commons. Used with permission.

The **middle cerebral artery**, which supplies blood to the lateral surface of each hemisphere, is the largest of the cerebral arteries and the most common artery involved with stroke; embolism is the most common cause of blockage (Slater, 2014). Men are affected by middle cerebral artery stroke more often than women at a male-to-female ratio of 3 to 1 (Slater, 2014).

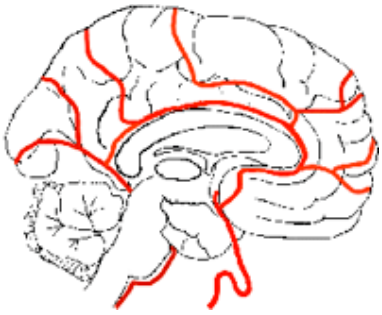
Because the middle cerebral artery is the area most commonly affected by ischemic stroke, its symptoms are the most familiar to healthcare providers: contralateral weakness and sensory loss in the face, neck, and arm (and to a lesser degree in the leg) and homonymous hemianopsia (loss of half of the visual fields of both eyes), as well as cognitive deficits that affect speech, language, and comprehension.

Carotid and Vertebral Arteries



The **anterior cerebral artery** supplies the medial surfaceof the brain, and the ophthalmic artery supplies blood to the eye and adjacent structures of the face. Deep branches from the carotid system also supply blood to the regions of the brain below the cerebral cortex—the basal ganglia and the thalamus, together sometimes referred to as the extrapyramidal system, as noted earlier.

Anterior Cerebral Artery



Medial surface of the brain showing the areas perfused by the anterior cerebral artery. Source: Lauren Robertson. Used by permission.

The carotid and vertebral arteries ascend through the neck and divide into branches that supply blood to different parts of the brain. Source: NINDS, Stroke Challenge Brochure, p. 18.

Blood traveling through the two vertebral arteries joins at the level of the brainstem to form the **basilar artery**. The vertebrobasilar artery supplies blood to the posterior part of the cerebral hemispheres, including the occipital lobes and the posterior portions of the temporal lobes, the cerebellum, and the brainstem. This is referred to as the **vertebrobasilar or posterior circulation.**

Carotid (Anterior) Circulation Disorders

[For more on this topic, see Module 15, Cognitive changes after a Stroke.]

> Neurology's favorite word is "deficit," denoting an impairment or incapacity of neurological function: loss of speech, loss of language, loss of memory, loss of vision, loss of dexterity, loss of identity, and myriad other lacks and losses of specific function (or faculties). For all of these dysfunctions (another favorite term), we have privative words of every sort—aphonia, aphemia, aphasia, alexia, apraxia, agnosia, ataxia—a word for every specific neural or mental function of which patients, through disease or injury, or failure to develop, may find themselves partly or wholly deprived.
>
> Oliver Sachs
> *The Man Who Mistook His Wife for a Hat*

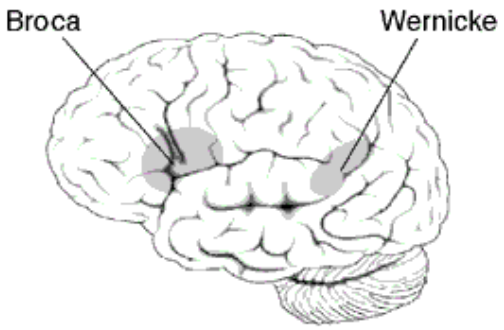
A stroke in any of the major arteries within the *carotid* circulation (middle cerebral, anterior cerebral, and ophthalmic artery) disrupts higher cognitive, motor, and sensory processing. The most common problems—aphasia, apraxia, agnosia, and hemi-neglect, and other cognitive losses—occur in the areas of the brain supplied by the *middle* cerebral artery. Similar problems can occur with occlusions of the *anterior* cerebral artery, in which case the lower extremities and proximal upper extremities are more affected.

A stroke occurring as a result of a blockage in the middle cerebral artery on the left side of the brain can lead to a type of language impairment called **aphasia**. There are different types of aphasia, which are typically defined by the region of the brain that has been damaged.

Wernicke's aphasia is caused by damage to the lateral surface of the left temporal lobe. It is sometimes referred to as receptive or fluent aphasia because a patient's is fluent but the words carry no meaning. Sentences can be long and meandering—usually longer than seven words.

Broca's aphasia is caused by damage to the lateral surface of the left frontal lobe. It is sometimes referred to as expressive or non-fluent aphasia because a patient is unable to communicate and sentences are short and choppy—usually less than seven words. **Global aphasia** is a combination of Wernicke's and Broca's aphasia in which a person is unable to understand the spoken word or communicate with speech. A severe stroke may begin with global deficits then slowly resolve to a lesser deficit.

Areas Related to Broca's and Wernicke's Aphasia



Source: Wikimedia Commons.

If damage occurs on the right side of the brain, speech and comprehension are usually unaffected but other high-level cognitive deficits occur, including behavioral changes, general confusion and disinhibition, unintentional fabrication of information, memory deficits, attentional deficits, apraxia, and neglect.

Apraxia is another common cognitive problem caused by damage from a stroke in the carotid circulation. **Apraxia** is the loss of the ability to organize a movement or perform a purposeful act. It is a disorder of the execution of movement that cannot be attributed to weakness, incoordination, sensory loss, poor language comprehension, or attention deficit. Apraxia is a weakening of the top-down formulation of an action—the inability to sustain the intent to complete a movement. As a result, the nervous system is easily influenced by irrelevant input—a sort of pathologic absent-mindedness.

Apraxia affects all modalities including speech, writing, gesturing, dressing, and all activities of daily living (ADLs). It is difficult to for caregivers to understand and identify. Examples of apraxia are: picking up a telephone and beginning to talk without dialing, lighting a candle and trying to smoke it as if it were a cigarette, using a knife to brush one's hair, using a pencil to butter bread. In all these examples the brain commands the body to perform a movement but the command fades before the movement is completed. The patient tries to complete the movement but has already forgotten what the task was. Nevertheless, an attempt is made to complete the task—perhaps by guessing.

A Stroke Patient's Experience

Barbara is a 73-year-old woman who recently had a stroke and is in the rehabilitation unit of a large nursing home. She has been diagnosed with severe apraxia but has no weakness or trouble with her mobility. She is sitting at the side of the bed and, with the help of a nursing assistant, is trying to get dressed. She picks up a sock and moves to put the sock on her right foot. Instead, she places the sock next to the phone. The nursing assistant, in a hurry, hands the sock back to Barbara and tells her to finish getting dressed. Barbara again moves to put the sock on her right foot but slips it over her right hand. The nursing assistant grabs the sock and puts it on Barbara's foot, thinking Barbara is being intentionally uncooperative. After she gets Barbara dressed, the nursing assistant reports to the charge nurse that Barbara is uncooperative and refused to get dressed.

In fact, Barbara is not being uncooperative or refusing to follow instructions. She wants to do what she is asked but can't seem to remember how to do anything. Unfortunately, her apraxia will show up in every activity she attempts—from eating to bathing to dressing. If the nursing assistant understood the nature of Barbara's difficulties she could ask for help in dealing with apraxia. The most obvious tactic is to break tasks down for Barbara and understand that she very quickly forgets what she is trying to do. Lots of verbal reinforcement and patience is needed to help Barbara complete her daily activities.

Agnosia is a sensory disorder in which a person is unable to recognize an object by sight, touch, or hearing in the absence of defects in the sensory apparatus of these systems. The person can touch, hear, and see but cannot recognize or identify the object. Agnosia is usually tested by asking a person to identify a series of objects that are placed out of sight in a bag or behind a partition. The person with agnosia will be unable to name an object by touch alone but will be able to identify the object using vision.

Anosognosia (hemi-neglect) is a sensory disorder caused by damage to the parietal lobe in which a person is unaware of the contralateral (opposite) side of the body including half of the visual field. It causes a disruption of a person's body schema and spatial orientation and affects balance and safety awareness. The person is often unaware that the second half of the body exists and will deny that anything is wrong. Those with hemi-neglect may ignore food on the left side of a plate, walk into objects in the left half of the visual field, and completely ignore the left extremities. They may even claim that the affected arm or leg belongs to another person.

A stroke in the ACA circulation affects the medial surface of the brain. It can cause contralateral weakness and sensory loss, primarily in the leg. There may be some weakness in the contralateral arm, especially proximally. It affects the lower extremities more than the upper extremities, leading to difficulties with balance, gait, and mobility. Behavioral disturbances and confusion may be present, and urinary incontinence is not uncommon.

A small clot (**microembolus**) in the ophthalmic artery, the first branch of the internal carotid artery, can cause partial or complete loss of vision in one eye lasting seconds to minutes; this is called temporary monocular blindness or *amaurosis fugax* (fleeting blindness). It is caused by temporary loss of blood flow to the retina and can be a sign of an impending stroke. It is often described as a gray or black shade that comes down over the eye or as blurring, fogging, or dimming of vision. A clot lodged in the ophthalmicartery can also lead to a sudden and brief bilateral symmetric loss of vision in half of the visual fields that is called **homonymous hemianopsia**.

Loss of Visual Fields in Homonymous Hemianopsia

Paris as seen with right homonymous hemianopsia. The right visual field is missing in both eyes. Source: Wikimedia Commons.

Thalamic Disorders

After a stroke affecting the thalamus, a person may become hypersensitive to pain. This syndrome, called thalamic pain or "central pain syndrome," is due to damage to the spinal tracts that carry pain and temperature sensation from the periphery to the thalamus. Damage to these tracts, called the **spinothalamic** or **trigeminothalamic** tracts result in severe, spontaneous pain in the parts of the body connected to the damaged tracts. Thalamic pain starts several weeks after the stroke and presents as an intense burning pain on the side of the body affected by the stroke; it is often worsened by cutaneous stimulation.

Pain is typically constant, may be moderate to severe in intensity, and is often made worse by touch, movement, emotions, and temperature changes, usually cold temperatures. One or more types of pain sensations may be present—the most prominent being burning. Mingled with the burning may be sensations of pins and needles; pressing, lacerating, or aching pain; and brief, intolerable bursts of sharp pain similar to the pain caused by a dental probe on an exposed nerve. Individuals may have numbness in the areas affected by the pain. The burning and loss of touch sensations are usually most severe on the distant parts of the body, such as the feet or hands.

Basal Ganglia Disorders

In addition to the lateral surface of the cerebral cortex, the middle cerebral artery also supplies blood to the basal ganglia. A stroke affecting the basal ganglia usually causes motor control problems rather than hemiparesis. Damage typically causes too much movement (hyperkinesia) or too little movement (hypokinesia).

Hyperkinesia

> What then is the opposite of deficit—an excess or superabundance of function? Neurology has no word for this—because it has no concept. A function, or functional system, works—or it does not; these are the only possibilities it allows. Thus a disease which is "ebullient" or "productive" in character challenges the basic mechanistic concepts of neurology, and this is doubtless one reason why such disorders—common, important, and intriguing as they are—never have received the attention they deserve. And this alone suggests that our basic concept or vision of the nervous system—as a sort of machine or computer—is radically inadequate, and needs to be supplemented by concepts more dynamic, more alive.
>
> Oliver Sachs
> *The Man Who Mistook His Wife for a Hat*

Hyperkinesia is too much movement, and although our understanding of its cause may be unclear, we have many words to describe such disorders. **Chorea** is a hyperkinetic movement disorder characterized by arrhythmic, rapid, involuntary movement that flows from one part of the body to another. The most common type of non-drug-related chorea is Huntington's chorea. **Dystonia** is a hyperkinetic movement disorder characterized by involuntary movement that is twisting, sustained, and repetitive. Over time, the affected body part may assume a fixed posture involving one joint (focal dystonia), two joints (segmental dystonia), or several joints (generalized dystonia).

Athetosis is a hyperkinetic movement disorder characterized by spontaneous writhing movements of the hand, arm, neck, or face. **Tardive dyskinesia** is a slow-onset, drug-induced hyperkinetic movement disorder characterized by rhythmic, unwanted movements of the face and extremities such as facial grimacing, tongue movements, and pill-rolling motions with the fingers. **Tourette syndrome** is characterized by excessive energy, tics, jerks, verbal noises, compulsive behavior, and grimaces. It is also associated with other behavioral disorders such as attention deficit disorder.

Hypokinesia

Hypokinesis is too little movement. Parkinson's disease (*paralysis agitans*) is one of the most common hypokinetic movement disorders and is characterized by resting tremor, rigidity, masked faces, bradykinesia, and festinating gait. Parkinson's disease is caused by widespread destruction of a portion of the brainstem (the substantia nigra), which is responsible for sending dopamine to the basal ganglia. Although Parkinson's disease is not caused by stroke it is mentioned here as an example of a hypokinetic movement disorder.

Vertebrobasilar (Posterior) Circulation Disorders

Recall that the vertebrobasilar artery supplies blood to the posterior part of the cerebral hemispheres, including the occipital lobes and the posterior portions of the temporal lobes, the cerebellum, and the brainstem. Posterior circulation ischemia causes a variety of symptoms that are distinctly different from those found with carotid artery strokes. If the damage is in the area of the brainstem there may be loss of brainstem function, cranial nerve abnormalities (with or without hemiparesis), or hemi-sensory deficits.

If damage is in the area of the cerebellum, you can expect to see ataxia, intention tremor, and hypotonia. **Ataxia** is motor incoordination due to irregularities in the timing, rate, and force of a muscular contraction. Ataxia causes unsteady, grossly uncoordinated, or "drunken" gait, loss of balance, and a tendency to fall. It also affects the ability to judge the distance or scale of a movement, typified by overshooting or undershooting an object (dysmetria). As a result, vertigo, nausea, vomiting, and nystagmus are common occurrences following a cerebellar stroke.

Intention or **action tremor** is another common type of abnormal movement associated with cerebellar damage**.** The tremor is not present at rest (as with Parkinson's) but occurs as soon as a movement is initiated. For example, a person may reach for a glass of water but be unable to control the force and range of the movement, especially at the end of the movement. While reaching for the glass the tremor increases and the individual may overshoot the glass entirely, touch the glass with too much force, or lift it too rapidly.

Hypotonia is a decreased resistance to the passive stretch of a joint. Muscles feel soft to the touch and lack normal tone. Hypotonia can be tested by tapping the patellar tendon reflex with a reflex hammer. A tap on the patellar tendon will normally produce a quick extension of the lower leg, which will come to rest after one or two swings. If cerebellar damage is present, a tap on the patellar tendon will cause the lower leg to oscillate 6 or 7 times before coming to rest. This is called a **pendular swing** and is typical of cerebellar damage.

Gender, Age, and Racial Disparities

[This section taken from NINDS, 2015a, unless otherwise noted.]

Although men have a higher risk for stroke (1.25 times that for women), more women die from stroke. Because men do not live as long as women and are usually younger when they have a first stroke, men have a higher rate of survival than women. Even though women have fewer strokes than men, women are generally older when they have strokes and are more likely to die from them.

During the acute onset of a stroke, women report nontraditional symptoms more frequently than men, including pain and reduced level of consciousness. Women may also have other symptoms, such as nausea, face, arm or leg pain, hiccups, feeling very tired, chest pain, shortness of breath, or a racing heartbeat (womenshealth.gov, 2012). Recognizing nontraditional symptoms is critical in order to prevent a delay in diagnosis and treatment of stroke.

Some risk factors for stroke apply only to women (eg, pregnancy, childbirth, menopause) and are tied to hormonal fluctuations and changes that affect a woman in various stages of life. Research in the past few decades has shown that high-dose oral contraceptives can increase the risk of stroke in women by as much as 20%; fortunately, they have been replaced with safer and more effective ones containing lower doses of estrogen. Some studies have shown the newer low-dose oral contraceptives may not increase the risk of stroke in women significantly.

Pregnancy and childbirth can also put a woman at an increased risk for stroke. Pregnancy increases the risk of stroke as much as 3 to 13 times, although it still remains a relatively small risk—approximately 8 in 100,000 women. Up to 25% of strokes during pregnancy end in death, and hemorrhagic strokes are the leading cause of maternal death in the United States. Subarachnoid hemorrhage, in particular, causes 1 to 5 maternal deaths per 10,000 pregnancies.

The risk of stroke during pregnancy is greatest in the six weeks following childbirth. The risk of ischemic stroke after pregnancy is about 9 times higher and the risk of hemorrhagic stroke is more than 28 times higher for postpartum women than for women who are not pregnant or postpartum. Both preeclampsia and eclampsia cause a rise in blood pressure and an increased tendency to form blood clots that can contribute to this increased stroke incidence.

Hormonal changes at the end of the childbearing years can increase the risk of stroke. Several studies have shown that menopause can increase a woman’s risk of stroke and that hormone replacement may reduce that risk. The mechanism by which estrogen can prove beneficial to postmenopausal women could include its role in cholesterol control. Studies have shown that estrogen acts to increase levels of HDL while decreasing LDL levels.

Stroke in Young People

[This section taken from NINDS, 2015a, unless otherwise noted.]

People 18 to 45 years of age are considered young adults and have risk factors for stroke such as drug use, alcohol abuse, pregnancy, head and neck injuries, heart disease or heart malformations, and infections. Some other causes of stroke in the young are linked to genetic diseases.

Hemorrhagic stroke is the most common type of stroke in young adults. Hemorrhagic strokes represent 20% of all strokes in the United States and young people account for many of these. Intracranial hemorrhage accounts for 41% and subarachnoid hemorrhage accounts for 17% of these strokes. The remaining 42% of strokes due to ischemia in the young adult usually require a more exhaustive workup to determine the cause. Despite advances in diagnostic procedures, 20% of strokes in young people continue to be of unknown etiology (Slater, 2014).

Stroke in Children

[This section taken from NINDS, 2015a, unless otherwise noted.]

Medical conditions that can lead to stroke in children include intracranial infection, brain injury, vascular malformations, occlusive vascular disease, and genetic disorders such as sickle cell anemia, tuberous sclerosis, and Marfan's syndrome.

The symptoms of stroke in children are different from those in adults. A child experiencing a stroke may have seizures, a sudden loss of speech, a loss of expressive language (including body language and gestures), hemiparesis, hemiplegia, dysarthria (impairment of speech), convulsions, headache, or fever. It is a medical emergency when a child shows any of these symptoms.

In children with stroke, the underlying conditions that led to the stroke should be determined and managed to prevent future strokes. For example, giving blood transfusions to young children with sickle cell anemia greatly reduces the risk of stroke.

Most children who experience a stroke will do better than most adults after treatment and rehabilitation. This is due in part to the young brain's greater plasticity and the ability to adapt to deficits and injury. Children who experience seizures along with stroke do not recover as well as children who do not have seizures. Some children may experience residual hemiplegia, though most will eventually learn how to walk.

Stroke in Ethnic and Racial Minorities

African Americans are affected by stroke more than any other racial or ethnic group in the U.S. These differences are related to higher rates of hypertension and diabetes, sickle cell anemia, and high rates of smoking and obesity (NSA, 2014b). When compared to White Americans, African Americans experience strokes at a younger age and are twice as likely to die from stroke (NSA, 2014b).

The incidence of stroke in African American males is 93 per 100,000 and in African American females it is 79 per 100,000 compared to 63 per 100,000 in Caucasian males and 59 per 100,000 in Caucasian females (MD Guidelines, 2014).

Hispanic Americans are also disproportionately affected by stroke. Compared to White Americans, they have strokes at a younger age. After a first stroke, those with atrial fibrillation have a higher risk of another, more severe stroke. In addition, language barriers and lack of transportation contribute to Hispanic Americans delaying care, avoiding visits to the doctor, and stopping treatment once they feel better (NSA, 2014b).

American Indians and Alaska Natives are more than twice as likely as White Americans to have a stroke. Hypertension, smoking, diabetes, and obesity are major risk factors for stroke in this population (NSA, 2014b).

Racial and Ethnic Disparities in Post Stroke Rehabilitation

There are significant racial and ethnic disparities related to post-stroke rehabilitation. This is despite the fact that African Americans, Hispanics, and other minorities are at a greater risk of stroke, have strokes at younger ages, and experience greater stroke severity, mortality, or residual impairments (Ellis et al., 2014).

When looking at potential disparities in post-stroke rehabilitation outcomes between various ethnic and racial groups in the U.S., the majority of the studies between at least two groups demonstrated that racial/ethnic minorities were less likely to achieve equivalent outcomes compared to their nonminority counterparts, despite both groups receiving rehabilitation. African American stroke survivors frequently achieved lower post-rehabilitation discharge scores, fewer gains and changes, and lower efficiency scores. African Americans are also more likely to have residual post-stroke activity limitations (e.g., walking, bending, carrying, etc.) when compared to Whites Americans (Ellis et al., 2014).

Prevention of Stroke

Primary prevention refers to the treatment of individuals with no history of stroke. Measures often include use of platelet anti-aggregants, statins, and exercise. The 2011 AHA/ASA guidelines for the primary prevention of stroke emphasize the importance of lifestyle in reducing modifiable risk factors (Goldstein et al., 2011).

Secondary preventive measures are important for people already identified as having had a stroke. For these individuals, lifestyle changes are appropriate; however, there is an increased emphasis on use of medications to manage medical co-morbidities as well as those directed specifically toward stroke.

The 2011 AHA/ASA guidelines recommended emergency department-based smoking cessation interventions and considered it reasonable for the ED to screen all patients for hypertension and substance abuse, especially stimulant abuse (Goldstein et al., 2011).

Guidelines issued in 2014 by the AHA/ASA on the secondary prevention of stroke continue to emphasize nutrition and lifestyle, but include a new section on aortic atherosclerosis (Hughes, 2014). These recommendations include the following:

- Patients who have had a stroke or TIA should be screened for diabetes and obesity.
- Patients should be screened for sleep apnea.
- Patients should undergo a nutritional assessment and be advised to follow a Mediterranean-type diet.
- Patients who have had a stroke of unknown cause should undergo long-term monitoring for atrial fibrillation.
- The new oral anticoagulants dabigatran, apixaban, and rivaroxaban are among the drugs recommended for patients with non-valvular atrial fibrillation.
- The guidelines no longer recommend the use of niacin or fibrates to raise high-density lipoprotein (HDL) cholesterol or reduce secondary stroke risk. (Hughes, 2014)

Despite the advent of new treatments for acute ischemic stroke and the promise of other acute therapies, prevention remains the best approach for reducing the incidence of stroke. Age, gender, race, family history, and medical history (such as a previous stroke) are non-modifiable risk factors for stroke. But those who practice a healthy lifestyle have an 80% lower risk of a first stroke compared with those who do not (JAHA, 2011b).

Once a stroke occurs, rapid diagnosis is essential so that clot-busting drugs or other treatment can be given immediately, because "time is brain." However, many gaps have been identified in the public knowledge of stroke symptoms. It has long been the goal of the Centers for Disease Control (CDC), in conjunction with the American Heart Association (AHA) and the American Stroke Association (ASA), to increase public awareness of stroke signs and symptoms.

The public needs education about lifestyle changes that can reduce their risk of stroke. Messages about prevention have focused on modifiable risk factors such as reducing high blood pressure, reducing cholesterol, improving emergency response, decreasing tobacco use, improving nutrition, increasing physical activity, decreasing obesity, and decreasing and controlling diabetes.

Blood Pressure

> Hypertension remains the most important, well-documented, modifiable risk factor for stroke, and treatment of hypertension is among the most effective strategies for preventing both ischemic and hemorrhagic stroke.
>
> *Journal of the American Heart Association*, 2011

About 1 out of 3 American adults has high blood pressure and another 25% have pre-hypertension—blood pressure numbers that are higher than normal, but not yet in the high blood pressure range. In 2010 high blood pressure cost the United States $76.6 billion in healthcare services, medications, and missed days of work. About 70% of those with high blood pressure who took medication had their high blood pressure controlled (CDC, 2014c).

Cholesterol

Approximately 1 in every 6 adults—more than 16% of the U.S. adult population—has high total cholesterol (240 mg/dL and above). People with no additional risk factors, but with high total cholesterol, have approximately twice the risk of heart disease as people with optimal levels (below 200 mg/dL). Lowering saturated fat and increasing fiber in the diet, maintaining a healthy weight, and getting regular physical activity can reduce a person's risk for cardiovascular disease and stroke by lowering cholesterol levels. In addition to lifestyle changes, statins (eg, lovastatin, simvastatin) may be needed to reduce cholesterol levels (CDC, 2013b).

Emergency Response

Heart attacks and strokes are life-and-death emergencies in which every second counts. Nearly half of all stroke and heart attack deaths occur before patients are transported to hospitals. For this reason, prehospital emergency medical service (EMS) organizations and providers are vital partners with public health to reduce death and disability from heart attacks and strokes. Additionally, it is important for the public to recognize the major warning signs and symptoms and the need to immediately call 911(CDC, 2014d).

Tobacco

Cigarette smokers have twice the risk of stroke compared to nonsmokers. Smoking decreases the amount of oxygen in the blood, causing the heart to work harder. Smoking promotes atherosclerosis and increases levels of blood clotting factors (NINDS, 2015).

Nutrition

A healthy diet can reduce the risk for acquiring medical conditions such as hypertension, diabetes, high lipid levels, coronary artery disease, and obesity. All of these conditions increase the chance of having a stroke. Recent studies indicate that a diet rich in fruits and vegetables can lower the risk of heart disease and stroke. Those people who ate more than five servings of fruits and vegetables per day had roughly a 20% lower risk of coronary heart disease and stroke compared with individuals who ate less than three servings per day (Harvard School of Public Health, 2011a).

Another study found that a diet rich in fruits, vegetables, and low-fat dairy products lowered systolic blood pressure by 11mm Hg and diastolic blood pressure by almost 6mm Hg—as much as achieved by medications (Harvard School of Public Health, 2011a).

The average American consumes 3400 mg of sodium each day, most of which comes from processed, store-bought, and restaurant foods. Only about 5% comes from salt added during cooking and about 6% comes from adding salt at the table. Current dietary guidelines recommend that adults should consume no more than 2,300 mg of sodium per day. However, the following population groups should consume no more than 1,500 mg per day:

- People 40 years of age or older
- African Americans
- Those with hypertension (CDC, 2014e)

Two out of three (69%) adults in the United States fall into one or more of these three groups that are at especially high risk for health problems from too much sodium (CDC, 2014e).

Blood pressure rises with increasing amounts of sodium in the diet, and sodium reduction lowers cardiovascular disease and death rates over the long term. Higher salt intake is associated with a 23% increase in stroke and a 14% increase in heart disease (Harvard School of Public Health, 2011b).

Physical Activity

Physical activity can help maintain a healthy weight and lower cholesterol and blood pressure. The Surgeon General recommends that adults should engage in moderate-intensity exercise for at least 30 minutes on most days of the week (CDC, 2014f).

Obesity

Because people who are overweight or obese have an increased risk for cardiovascular disease, diabetes, hypertension, and stroke, weight management can reduce a person’s risk from these factors (CDC, 2014f).

Diabetes

People who have diabetes are at least twice as likely as someone who does not have diabetes to have heart disease or a stroke. People with diabetes also tend to develop heart disease or have strokes at an earlier age than other people. Women who have not gone through menopause usually have less risk of heart disease than men of the same age. But women of all ages with diabetes have an increased risk of heart disease because diabetes cancels out the protective effects of being a woman in her childbearing years (NDIC, 2014).

People with diabetes who have already had one heart attack run an even greater risk of having a second one. In addition, heart attacks in people with diabetes are more serious and more likely to result in death. High blood-glucose levels over time can lead to atherosclerosis (NDIC, 2014). If blood-glucose levels are high at the time of a stroke, then brain damage is usually more severe and extensive than when blood glucose is well-controlled. Treating diabetes can delay the onset of complications that increase the risk of stroke (NINDS, 2014b).

Carotid Endarterectomy

Carotid endarterectomy is a surgical procedure in which fatty deposits are removed from one of the two carotid arteries located in the neck. Carotid endarterectomy is done to prevent stroke for those who have a certain level of blockage and to prevent recurrent stroke; this is not an acute stroke treatment.

The carotid arteries are the main suppliers of blood to the brain. Two recent NINDS trials showed that carotid endarterectomy is a safe and effective stroke prevention therapy for most people with greater than 50% stenosis of the carotid arteries when performed by a qualified and experienced neurosurgeon or vascular surgeon (NINDS, 2015a).

Patients may need a carotid endarterectomy if they have:

- Had a TIA or stroke with at least 70% narrowing of the carotid artery.
- Had a TIA or mild stroke in the past 6 months that did not leave them completely disabled, and the carotid arteries are at least 50% narrowed.
- Not had a TIA or stroke, but the carotid arteries are narrowed 60% or more and they have a low risk of complications from the surgery. (WebMD, 2014)

Those most likely to benefit from surgery are people who have had symptoms and have 70% or greater narrowing (stenosis) of their carotid artery. People with less than 50% narrowing do not seem to benefit from surgery (WebMD, 2014).

Carotid Endarterectomy

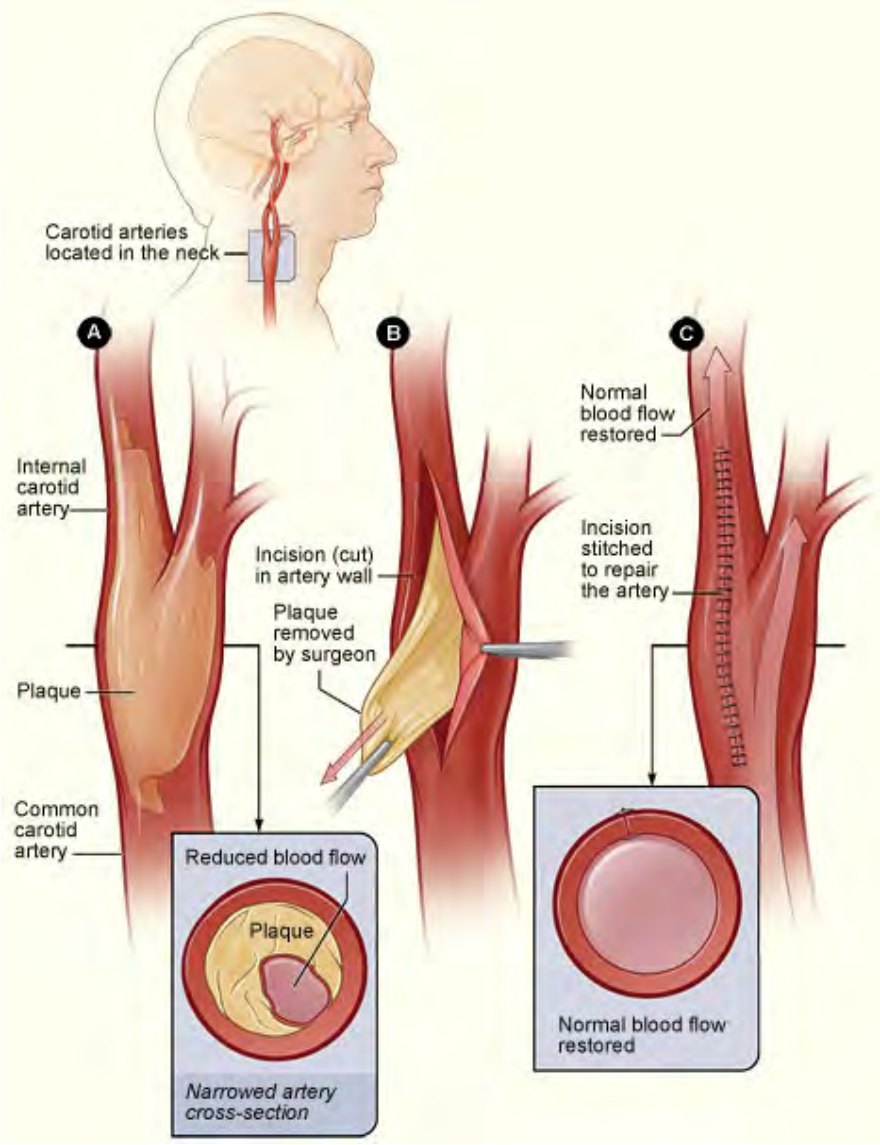


Figure A shows a carotid artery with plaque buildup. The inset image shows a cross section of the narrowed carotid artery. Figure B shows how the carotid artery is cut and how the plaque is removed. Figure C shows the artery stitched up and normal blood flow restored. The inset image shows a cross section of the artery with plaque removed and normal blood flow restored. Source: NIH, n.d.

A large clinical trial was done to test the effectiveness of carotid endarterectomy versus carotid stenting. Stenting involves inserting a long, thin catheter into an artery in the leg and threading the catheter through the vascular system into the stenosis of the carotid artery. Once the catheter is in place, the radiologist expands the stent with a balloon on the tip of the catheter to open the stenosis (NINDS, 2015a).

Following up after an average of 2.5 years, there was no difference in the estimated 4-year rates of early stroke and later stroke, heart attack, or death—between carotid artery stenting and carotid endarterectomy. The study also found that the age of the patient made a difference. At age 69 and younger, stenting results were slightly better. Conversely, for patients older than 70, surgical results were slightly superior to stenting (NINDS, 2012).

Carotid endarterectomy has been shown to reduce the risk of TIA and stroke in people with moderate to severe narrowing (70%–99%) of the carotid arteries. Carotid endarterectomy is three times more effective than treatment with medication alone in these patients (WebMD, 2014).

Carotid endarterectomy is *recommended* for patients with a non-disabling stroke or transient ischemic attack (TIA) within 6 months and 70% to 99% ipsilateral stenosis when the perioperative rate of major adverse events is <6% (UMHS, 2014).

A carotid endarterectomy can be *considered* for patients with a non-disabling stroke or TIA within 6 months and 50% to 69% ipsilateral stenosis, based on individual patient factors when the perioperative rate of major adverse events is less than 6% (UMHS, 2014).

Perform carotid endarterectomy as early as judged possible after the stroke or TIA, when risk of another stroke is highest. This benefit of surgery decreases with time (UMHS, 2014).

Carotid stenting is an alternative to carotid endarterectomy when patients are at high risk for surgery or in specific circumstances (e.g., high carotid bifurcation, extensive radiation induced stenosis, prior carotid intervention). The perioperative morbidity and mortality of carotid stenting should be less than 6% (UMHS, 2014).

Other therapies: All patients with carotid disease after stroke should be on optimal medical therapy and have appropriate lifestyle modifications, whether or not an intervention is performed (UMHS, 2014).

Atrial Fibrillation

Atrial fibrillation (AF) is a major risk factor for stroke. As already noted, the 2011 AHA/ASA primary stroke prevention guidelines recommend that ED's screen for atrial fibrillation and assess patients for anticoagulation therapy if AF is found (Goldstein et al., 2011).

In several trials, oral anticoagulation with warfarin was shown to be superior to aspirin plus clopidogrel for prevention of vascular events in patients with AF who were at high risk for stroke. The Atrial fibrillation Clopidogrel Trial with Irbesartan for prevention of Vascular Events (ACTIVE W) was stopped early because of clear evidence of the superiority of anticoagulation as opposed to antiplatelet therapy (Connolly et al., 2006).

For patients with AF after stroke or TIA, the 2010 AHA/ASA secondary stroke prevention guidelines are in accord with the standard recommendation of warfarin or other anticoagulant, with aspirin as an alternative for patients who cannot take oral anticoagulants. Clopidogrel should not be used in combination for these patients because the bleeding risk equals that of Coumadin or other anticoagulants, but without the benefits (Wann et al., 2011).

Recognizing Stroke Symptoms

The most common identifying feature of stroke is its acute onset. Every second a clot blocks blood flow to the brain, 32,000 brain cells die. Administration of clot-busting thrombolytic drugs must happen as soon as possible after onset of symptoms to prevent further brain damage. A New York study determined that only 20% of patients arrived at a designated stroke center within 3 hours of stroke symptom onset (the recommended time frame for use of thrombolytics). This study showed that more than 70% of respondents would call 911 if they noticed someone having difficulty speaking, but only 33% would call 911 for double vision or trouble seeing (Jurkowski et al., 2008).

Stroke Symptoms

Source: National Institutes of Health.

The delay between symptom onset and arrival at a hospital is influenced by:

- Identification of stroke symptoms
- Determination that the symptoms require immediate emergency care
- Calling 911
- The time it takes until hospital arrival

Evidence suggests that most of the delay between symptom onset and hospital arrival occurs before the call to 911 is made (Jurkowski et al., 2008).

The CDC, AHA, and ASA, among others, have developed public health programs that emphasize quick recognition of stroke signs and symptoms.In June 1998 the Brain Attack Coalition, a group of professional, volunteer, and government entities dedicated to reducing stroke-related death and disability, reached consensus on the symptoms of stroke. Previously, standardized definitions for stroke signs and symptoms did not exist (Wall et al., 2008, updated 2013).

The consensus symptoms are:

- Sudden numbness or weakness of face, arm, or leg, especially on one side of the body
- Sudden confusion or trouble speaking or understanding speech
- Sudden trouble seeing in one or both eyes
- Sudden trouble walking, dizziness, or loss of balance or coordination
- Sudden severe headache with no known cause

The “suddens” were adopted by several national and state-based educational campaigns and are used to convey stroke symptoms in clinical and public health settings and among advocacy organizations concerned with stroke.

Although consensus on stroke symptoms has been achieved, public awareness has still lagged behind. For example, advocacy organizations in Massachusetts have annually conducted at least one campaign on the signs and symptoms of stroke. Yet in 2003 only 18% of Massachusetts adults were aware of all signs and symptoms of stroke, but 80% said they would call 911 if they thought someone was having a stroke or heart attack. Because early recognition leads to early treatment and improved clinical outcomes, increasing symptom recognition could vastly improve stroke survival and quality of life (Wall, 2008, updated 2013).

To address the lack of recognition of stroke symptoms in their state, the Massachusetts Department of Public Health Heart Disease and Stroke Prevention and Control Program (HSPC) hired a social marketing and communications company to develop an evidence-based approach to educate the public to recognize the signs of stroke and respond by calling 911. The campaign showed that a public awareness campaign that includes mass media can increase stroke recognition but should target family, coworkers, and caregivers of those at highest risk for stroke. Moreover, educational efforts should focus on behaviors that promote early seeking of hospital care (Wall, 2008, updated 2013).

In another instance, the Cincinnati Prehospital Stroke Scale (CPSS), a three-item scale based on a simplification of the National Institutes of Health Stroke Scale was accurately used by untrained laypeople to identify stroke signs in mock patients and in stroke survivors when prompted by a 911 telecommunicator. The CPSS can identify stroke patients who are candidates for thrombolytic treatment when performed by a physician and has similar results when used by prehospital care providers (Wall, 2008, updated 2013).

The CPSS was modified with the addition of a fourth item, so that it could be used by lay people before they called 911. These and other studies lead to the development of the **Stroke Heroes Act FAST** campaign which, in a retrospective chart review of 3500 stroke patients, successfully identified almost 90% of patients with stroke or transient ischemic attack (Wall, 2008, updated 2013).

Checking for Signs of Stroke

F: Does the face look uneven?

A: Does the arm drift down?

S: Does the speech sound strange.

T: Every second brain cells die. Call 911 at any sign of stroke.

Source: CDC, 2014b.

Acute Stroke: Readiness for Stroke Patients

Pre-Hospital Care

Most strokes occur at home and the EMS is the first medical contact for more than half of all patients who have a stroke. Because EMS transport significantly shortens arrival time to the emergency department and because of the narrow window for delivery of time-dependent medications, EMS plays a pivotal role in the rapid treatment of stroke. A recent 3-year data analysis found that stroke patients brought in by EMS were twice as likely to receive a timely CT scan compared to those who did not use EMS (NSA, 2014a).

Nine-one-one dispatchers, first responders, EMTs, and paramedics are often the first source of medical information and play a vital role in the initial triage of potential stroke victims. It is imperative that the stroke system of care provide training and education for these people in order to minimize delays in pre-hospital dispatch, assessment, and transport (JAHA, 2010).

Studies have found that the greatest portion of the delay between onset of symptoms and emergency treatment is the time it takes for a patient to recognize the signs of stroke and decide to seek medical care. Between one-half and three-quarters of ischemic stroke patients do not arrive at the hospital within the 3-hour window of treatment that is needed to make an assessment and begin therapy. Some of the factors in the delays include lack of knowledge regarding stroke symptoms, treatment options, and the need for quick therapy (Williams et al., 2009).

Delays in treating stroke also occur because of poor recognition of stroke by 911 dispatchers and misdiagnosis of stroke by EMS personnel. Dispatch is a crucial link in the chain of care, yet dispatchers miss as many as 70% of stroke cases because they do not have the understanding or tools to properly assess the symptoms reported by callers. A similarly high misdiagnosis rate (61%) was documented for the responding EMS personnel when diagnosing stroke in the field (Williams et al., 2009).

These findings underscore the challenges facing the emergency systems of care. The lack of close coordination of stroke care among healthcare providers has resulted in a fragmented system for stroke prevention, emergency care, treatment, and rehabilitation (Williams et al., 2009).

To improve stroke outcome, a better integration of the facilities, agencies, and professionals that provide stroke care is needed. There needs to be rapid access to EMS, use of diagnostic algorithms, and EMS protocols that reflect the most current stroke treatment, as well as recommendations to dispatch EMS as rapidly as possible to improve outcomes. Emergency physicians and stroke experts should be involved in the design of protocols and training programs, stroke assessment and thrombolytic screening tools, and should encourage rapid transport to a stroke center (Williams et al., 2009).

The CDC, in collaboration with the North Carolina office of EMS, created the NEMSIS-based North Carolina Prehospital Medical Information System (PreMIS), to develop and implement EMS stroke performance improvement toolkits. The EMS toolkits focus on:

- Prompt recognition of stroke through the use of stroke screening
- Documentation of stroke symptom onset—the last time the person was seen well
- Screening the blood glucose of the patient for hypo- and hyperglycemia
- Maintaining EMS scene times of 10 minutes or less
- Rapid transport (with early notification) to a stroke center (Williams et al., 2009)

EMS providers should provide pre-arrival notification to a medical facility capable of providing acute stroke care. Pre-arrival notification has been found to increase the number of stroke patients who receive fibrinolytic therapy. Recent studies indicate a favorable benefit from triage of stroke patients directly to designated stroke centers (JAHA, 2010).

In 2006 the Minnesota Department of Health (MDH) and the Minnesota Stroke Partnership (MSA) conducted two surveys. The survey for emergency medical services organizations, mailed to every licensed ambulance service in Minnesota, asked about transportation policies and training needs. The survey for hospitals, mailed to every hospital in the state, asked about capacity to treat acute stroke (Tsai, 2008).

The Minnesota Stroke Partnership made several recommendations as a result of the survey:

- Prehospital EMS personnel should continue to treat stroke as an emergent event.
- First responders should be taught to recognize the signs of stroke and to communicate such information to ambulance personnel.
- Ambulance service organizations should be encouraged to use the Cincinnati Stroke Scale as the standard for assessing patients suspected of having stroke.
- Hospital emergency staff should be informed that the Cincinnati Stroke Scale standard is being encouraged, and prehospital providers should include instructions in their standard operating procedures to always verbally provide stroke scale information to hospital emergency staff.
- Prehospital EMS providers should be informed about the locations of primary stroke centers and educated about recent recommendations for stroke systems of care.
- Training should be provided for prehospital EMS providers on stroke issues annually or semi-annually. This training should be offered, but not mandated, for ambulance personnel.
- Classroom education or regional conferences and seminars should be provided.
- Internet-based training also should be provided as an option for continuing education. (Tsai, 2008)

Emergency Department Care

As in the prehospital phase, initial patient assessments made in the emergency department (ED) are based on evaluation of airway, breathing, and circulation, vital signs, and neurologic status. Most acute ischemic stroke patients arrive to the ED hemodynamically stable; however, patients with decreased level of consciousness may require airway management.

Acute stroke produces an increase in blood pressure in approximately 80% of patients and pressure must be monitored frequently. Control of blood pressure is important because significant elevation in blood pressure is an exclusion criterion for administration of thrombolytic therapy (recombinant tissue plasminogen activator, or rt-PA). Elevated blood pressure after administration of rt-PA is associated with increased risk of intracerebral hemorrhage.

When a suspected stroke patient arrives to the ED, triage is usually the function of the nursing staff. Acute stroke patients should be identified as quickly as possible to determine those eligible for thrombolytic therapy, which must be administered within 3 hours of known onset of stroke symptoms. The triage nurse, using the 5-level Emergency Severity Index, will assign most stroke patients an acuity level 2, meaning the patient needs immediate assessment. The nurse must be able to recognize symptoms suggestive of stroke and determine the last time the patient was seen normal (Jeffrey, 2009).

Because the benefit of thrombolytics in acute ischemic stroke is strongly time-dependent, ED personnel are trained to "think FAST"—meaning they look for (F) facial droop, (A) arm drift, (S) slurred speech, and (T) time to act quickly. Each minute that goes by, more nerve cells die. Treatment is most beneficial in the first minutes after stroke and declines steadily during the first 3 hours (Jeffrey, 2009).

Because there is no way to tell whether symptoms are from a TIA or an acute stroke, assume that all stroke-like symptoms signal an emergency—do not wait to see if they go away. A prompt evaluation (within 60 minutes) is necessary to identify the cause of the event and determine appropriate therapy. Depending on the patient's medical history and the results of a medical examination, the physician may recommend drug therapy or surgery to treat or reduce the risk of stroke. Patients seen as ineligible for thrombolytic therapy immediately undergo a rapid secondary categorization to establish their treatment plan.

Response systems—including optimal time frames—must be established, maintained, and monitored in all emergency departments. Evaluation and treatment of acute stroke within one hour of arrival to the emergency department must include:

- An initial patient evaluation within 10 minutes of arrival in the ED. This should include patient history, insertion of 2 to 3 peripheral IVs, bedside blood glucose, initiation of lab work, and NIHSS (National Institutes of Health Stroke Scale) assessment by the physician. An electrocardiogram does not take priority over the CT scan, but should be done as soon as possible (JAHA, 2010).
- Notify the stroke team within 15 minutes of arrival.
- Initiate a CT scan within 25 minutes of arrival.
- Interpret the CT scan and labs within 45 minutes of arrival.
- Ensure a door-to-drug (needle) time of 60 minutes from arrival for eligible patients.

The patient should be transferred to an inpatient setting, preferably a stroke unit, within 3 hours of arrival to the emergency department (JAHA, 2010).

Because of the narrow therapeutic window for the use of thrombolytic medications, acute stroke teams are recommended to ensure the fastest onset-to-treatment time possible. The teams should comprise:

- **Code team**—responds to a code pager and delivers urgent treatment. May consist of a neurologist, ED physician, and nurse.
- **Task force**—works daily to facilitate patient access to treatment. May include members from neurology, emergency medicine, neurosurgery, nursing, pharmacy, laboratory, physical medicine, and rehabilitation (Ellmers, 2013)

The NIH Stroke Scale

The American Heart Association recommends that all emergency departments assess the severity of stroke using the National Institutes of Health Stroke Scale (NIHSS). The NIHSS is a graded neurologic examination assessing consciousness, eye movements, visual fields, motor and sensory impairments, ataxia, speech, cognition, and inattention. The scale was developed as a communication tool; it is simple and quick, and has shown significant reliability across diverse groups, settings, and languages. However the NIHSS also contains items with poor reliability and redundancy. The modified NIHSS (mNIHSS) minimizes redundancy and eliminates items with poor reliability (Meyer & Lyden, 2010).

Note: Since the mNIHSS is more reliable, it allows for improved communication, better medical care, and refinement of trial enrollments. The mNIHSS should serve as the primary stroke clinical deficit scale for clinical and research aims (Meyer & Lyden, 2010).

The NIHSS is used to evaluate the level of impairment sustained by a stroke patient, immediately and at intervals post onset. Scores increase as neurologic deficits increase. Although a level of neurologic deficit on the NIHSS has not been established for treatment with thrombolytics, the Food and Drug Administration (FDA) has included a package insert in rt-PA instructions listing a score greater than 22 as a warning. Additionally, patients with a score higher than 22 are at greater risk for hemorrhage transformation if they are given rt-PA. The mNIHSS is summarized in the table below.

Modified NIH Stroke Scale Summary (mNIHSS)		
Item	Name	Response
1A	Level of consciousness	0=Alert 1=Not alert 2=Unresponsive
1B	Level of consciousness questions. Patient is asked the month and his/her age.	0=Answers both questions correctly 1=Answers one question correctly 2=Answers neither correctly
1C	Level of consciousness commands. Patient is asked to open and close the eyes and then to grip and release the non-paretic hand.	0=Performs both tasks correctly 1=Performs one task correctly 2=Performs neither task
2	Best gaze. Only horizontal eye movement will be tested.	0=Normal 1=Partial gaze palsy 2=Total gaze palsy
3	Visual fields: Visual fields (upper and lower quadrants) are tested by confrontation, using finger counting or visual threat, as appropriate.	0=No visual loss 1=Partial hemianopsia 2=Complete hemianopsia 3=Bilateral hemianopsia
4	Facial palsy. Ask the patient to show teeth or raise eyebrows and close eyes. Score symmetry of grimace.	0=Normal 1=Minor paralysis 2=Partial paralysis 3=Complete paralysis
5	Motor arm: The limb is placed in the appropriate position: extend the arms (palms down) 90 degrees (if sitting) or 45 degrees (if supine). Drift is scored if the arm falls before 10 seconds.	a. Left or b. Right 0=No drift 1=Drift before 10 sec 2=Fall before 10 sec 3=No effort against gravity 4=No movement

Modified NIH Stroke Scale Summary (mNIHSS)		
Item	Name	Response
6	Motor leg: The limb is placed in the appropriate position: hold the leg at 30 degrees (always tested supine). Drift is scored if the leg falls before 5 seconds.	a. Left or b. Right 0=No drift 1=Drifts before 5 sec 2=Fall before 5 sec 3=No effort against gravity 4=No movement
7	Ataxia: Test with eyes open. In case of visual defect, ensure testing is done in intact visual field. The finger-nose-finger and heel-shin tests are performed on both sides, and ataxia is scored only if present out of proportion to weakness.	0=Absent 1=One limb 2=Two limbs
8	Sensory: Sensation or grimace to pinprick when tested, or withdrawal from noxious stimulus in the obtunded or aphasic patient.	0=Normal 1=Mild loss 2=Severe loss
9	Language: The patient is asked to describe pictures and read a list of sentences.	0=Normal 1=Mild aphasia 2=Severe aphasia 3=Mute or global aphasia
10	Dysarthria: If patient is thought to be normal, an adequate sample of speech must be obtained by asking patient to read or repeat words from an attached list.	0=Normal 1=Mild 2=Severe
11	Extinction/inattention: Sufficient information to identify neglect may be obtained during the prior testing.	0=Normal 1=Mild 2=Severe

Source: NIH, n.d.

For hemorrhagic strokes, the Glasgow Coma Scale is used in addition to the NIH Stroke Scale to determine level of consciousness and severity of the underlying change of consciousness. The Glasgow Coma Scale ranges from 3 to 15, in which progressively higher scores indicate higher levels of consciousness.

Imaging Studies

[This section taken largely from NINDS, 2015a, except where noted.]

The most important function of an imaging study for acute stroke is to differentiate between ischemic and hemorrhagic stroke. It can also be used to rule out other conditions such as tumors. Further, imaging studies can be used to determine the extent of the ischemic damage and to guide the use of therapies.

There are a variety of imaging devices used to evaluate stroke patients. The most widely used imaging procedure is the computed tomography (CT) scan. Also known as a CAT (computed axial tomography) scan, CT creates a series of cross sectional images of the head and brain. Because it is readily available at most major hospitals and produces images quickly, CT is the most commonly used diagnostic technique for acute stroke.

CT also has unique diagnostic benefits. It will quickly rule out a hemorrhage, can occasionally show a tumor that might mimic a stroke, and may even show evidence of early infarction. Infarctions generally show up on a CT scan about 6 to 8 hours after the start of stroke symptoms.

If a stroke is caused by hemorrhage, a CT can show evidence of bleeding into the brain almost immediately after stroke symptoms appear. Hemorrhage is the primary reason for avoiding thrombolytic therapy. Thrombolytic therapy cannot be used until the doctor can confidently diagnose the patient as suffering from an ischemic stroke because this treatment could make a hemorrhagic stroke worse.

Magnetic resonance imaging (MRI) is also used with stroke patients. MRI uses magnetic fields to detect subtle changes in brain-tissue water content. One effect of stroke is the slowing of water movement, called diffusion, through the damaged brain tissue. MRI can show this type of damage within the first hour after stroke symptoms start. The benefit of MRI over a CT scan is more accuracy and earlier diagnosis of infarction, especially for smaller strokes, while showing equivalent accuracy in determining when hemorrhage is present. MRI is more sensitive than CT for other types of brain disease, such as brain tumor, that might mimic a stroke. MRI cannot be performed in patients with certain types of metallic or electronic implants, such as pacemakers.

In 2010 the American Academy of Neurology concluded that diffusion-weighted imaging MRI is superior to non-contrast CT scans for diagnosing ischemic stroke within 12 hours of onset of symptoms. However, due to time constraints for administration of thrombolytics, the longer time required to complete an MRI, and because MRI is often not immediately available, a non-contrast CT is still recommended to rule out hemorrhagic stroke in patients being considered for thrombolysis (Anderson, 2010).

Other types of MRI scans—often used for the diagnosis of cerebrovascular disease and to predict the risk of stroke—are magnetic resonance angiography and functional magnetic resonance imaging (fMRI). Neurosurgeons use magnetic resonance angiography to detect stenosis (blockage) of the brain arteries inside the skull by mapping flowing blood. Functional MRI uses a magnet to pick up signals from oxygenated blood and can show brain activity through increases in local blood flow.

Duplex Doppler ultrasound and arteriography are two diagnostic imaging techniques used to decide if an individual would benefit from carotid endarterectomy—used to remove fatty deposits from the carotid arteries to help prevent stroke. Doppler ultrasound is a painless, noninvasive test in which sound waves above the range of human hearing are sent into the neck. Echoes bounce off the moving blood and the tissue in the artery and can be formed into an image. Ultrasound is fast, painless, risk-free, and relatively inexpensive compared to magnetic resonance angiography and arteriography, but it is not considered to be as accurate as arteriography.

Arteriography involves use of an x-ray of the carotid artery that is taken as dye is injected into the artery. The procedure carries its own small risk of causing a stroke and is costly to perform. The benefits of arteriography over magnetic resonancing techniques and ultrasound are that it is extremely reliable and still the best way to measure stenosis of the carotid arteries.

In-Patient Hospital Care

In some cases stroke patients are transferred to intensive care until they are stabilized. Those who have received rt-PA are always sent to intensive care, as are many of those with hemorrhagic stroke.

Delivery systems for acute stroke hospital care are relatively primitive compared to systems for state-of-the-art emergency cardiac care. This is partly a reflection of being able to provide only supportive care to ischemic stroke patients until the approval of rt-PA. The approval of intravenous rt-PA for selected patients with ischemic stroke exposed these deficiencies and mandated changes in the hospital care system. These long-needed changes will also benefit patients with hemorrhagic strokes (NINDS, 2014a).

Once a patient has been evaluated and treated in the ED, the patient should be transferred to a specialized stroke unit (usually intensive care). Primary and comprehensive stroke centers have stroke units with specially trained staff and a multi-disciplinary approach to treatment and care of stroke patients. These units have been shown to be superior to general medical units and have been shown to result in positive effects that last for years. Stroke unit care reduces the likelihood of death and disability by as much as 30% in men and women of any age with mild, moderate, or severe stroke (AHRQ, 2010a).

Nursing care focuses on continued stabilization of the stroke patient. Vital signs and neuro checks must be done every 15 minutes for 2 hours after administration of rt-PA, then every 30 minutes for 6 hours, and every hour for the next 16 hours. The NIH stroke scale is done every hour for the first 24 hours after rt-PA administration. The NINDS rt-PA Stroke Study and the AHA recommendations for rt-PA include strict monitoring and regulation of blood pressure below defined upper limits with antihypertensive agents. There are protocols for emergency management of hemorrhage in rt-PA-treated patients, specific guidelines for the control of hypertension, and recommendations for management of bleeding complications. Any neurologic changes must be reported to the physician immediately (NINDS, 2015a).

In addition to careful monitoring and treatment of blood pressure and neurologic status, it is important to prevent hypoxia, maintain euthermia (normal body temperature), and control blood glucose. Other complications from stroke (eg, deep vein thrombosis, prevention of urinary tract infection) must be addressed. All patients who have had a stroke must have a swallow evaluation prior to being given anything by mouth to prevent aspiration pneumonia. During this time the focus will be to discover the cause of the initial stroke, prevent complications from treatment, and initiate therapies to prevent another stroke (JAHA, 2010).

Specialized Stroke Centers

[This section is from The Brain Attack Coalition (Adams et al., 2007).]

The concept of specialized stroke centers evolved in response to the complexity of caring for patients with acute stroke. The Brain Attack Coalition recommended establishing two tiers for stroke centers: primary stroke centers (PSCs) and comprehensive stroke centers (CSCs). The Joint Commission now provides accreditation for both. These centers have the following characteristics:

- **Primary Stroke Center (PSC):** Designed to maximize the timely provision of stroke-specific therapy, including the administration of rt-PA; the PSC is also capable of providing care to patients with uncomplicated stroke.
- **Comprehensive Stroke Centers (CSC):** Shares the commitment that the PSC has to acute delivery of rt-PA and also provides care to patient with hemorrhagic stroke and intracranial hemorrhage, as well as to all patients with stroke who require emergent advanced imaging, intra-arterial therapies, neurosurgical interventions, and management in a neurosurgical intensive care unit.

PSCs and CSCs are most effective when integrated into a regional stroke system of care so that patients are treated at the most appropriate level based on factors including severity, co-morbidities, and timing. Integrating pre-hospital services (911 and EMS) into this system of care, ensures that the patients receive the most appropriate care from field to bed. Additionally, stroke centers have personnel trained in the monitoring of stroke vital signs, including the following:

- Blood pressure
- Glucose levels
- Temperature
- Oxygenation
- Change in neurologic status

A further tier, **acute stroke-ready hospitals**, is being defined as hospitals having most of the resources needed to emergently evaluate and potentially treat with fibrinolytics, possibly with the assistance of remote stroke care experts done through telemedicine. These systems of care must manage patient transactions following regional guidelines in order to optimize outcomes in patients requiring care at remote sites.

Overall Coordination of Care

Once the patient is identified as a potential stroke patient, ED evaluations are fast-tracked to allow completion of laboratory tests and non-contrast head CT scans, as well as to notify stroke staff. Some EDs have developed **code stroke protocols** for their department. These protocols extend to EMS personnel, who are trained to recognize possible stroke symptoms and arrange for preferential transport to a PSC or CSC if one is available.

Code stroke teams are a system-based approach requiring cooperation of the ED, radiology, pharmacy, neurology, and ICU staff. A successful stroke system of care ensures effective communication and collaboration among the agencies, services, and individuals providing prevention, timely identification, triage, transport, treatment, and rehabilitation of stroke patients.

Once the patient is stabilized, the stroke team includes consultations with additional team members who can provide more comprehensive services once the critical phase is over. These consultations may include:

- Occupational therapists
- Physical therapists
- Speech therapists
- Rehabilitation therapists
- Dietitians
- Home health care coordinators
- Social Workers
- Psychiatrists

Treatment of Stroke

Ischemic Stroke Therapies

Ischemic stroke, resulting from thrombotic or embolic occlusion of an intracranial artery, accounts for 87% of all strokes (Go et al., 2014). The administration of intravenous fibrinolysis with recommended tissue plasminogen activator (rt-PA) within 3 to 4.5 hours of onset is the only current treatment shown to reduce disability from ischemic stroke.

Recombinant tissue plasminogen activator (**rt-PA**) is the only drug approved by the FDA for acute ischemic stroke and is ideally given intravenously within 3 hours of **time of onset** (the last time the patient was seen to be normal) of stroke symptoms; however, the best outcomes are associated with a door-to-treatment time of 60 minutes or less.

This window is often referred to as the **golden hour** of ischemic stroke treatment because during this time a focused diagnostic workup must be completed to rule out conditions that may mimic stroke as well as contraindications to rt-PA administration (Jauch, 2014). Additional procedures, such as interventional radiology and mechanical removal of the clot, have increased the time frame for ischemic stroke treatment (Gesensway, 2010).

Thrombolytics

The FDA approved the use of rt-PA in 1996, partly on the basis of a study done by the National Institutes of Neurological Disorders and Stroke (NINDS, 1995). The study, published in *New England Journal of Medicine* in 1995, showed neurologic improvement was achieved in 31% to 50% of patients treated with rt-PA compared with 20% to 38% of patients given a placebo. The major risk of treatment was symptomatic intracranial hemorrhage (NINDS, 2009).

The 1995 NINDS study was a major breakthrough in the treatment of ischemic stroke. The FDA, the AHA, the National Stroke Association (NSA), and the media touted the effectiveness of rt-PA (also known as *alteplase*). The AHA launched a nationwide campaign that encouraged use of the term **brain attack** instead of stroke, largely based on the purported effectiveness of alteplase.

A 1998 follow-up analysis of the NINDS trial found that after their initial hospitalization, people who received rt-PA were less likely to require inpatient rehabilitation or nursing home care. The authors estimated that this lower dependency on long-term care would translate into a savings to the healthcare system of more than $4 million for every one-thousand individuals treated with rt-PA (NINDS, 2009).

Because rt-PA interferes with blood clotting and has also been shown to increase leaking along the blood-brain barrier, it carries a risk of intracerebral hemorrhage. According to the original NINDS study, hemorrhage is most likely to occur in the first 3 hours after infusion but may occur up to 36 hours later. In the original study, intracranial hemorrhage occurred within 36 hours of treatment in 6.4% of the NINDS patients who received tPA as compared to 0.6% who received the placebo (NINDS, 1995). Nearly half of those hemorrhages were fatal.

Subsequent studies have demonstrated that using rt-PA more liberally than is recommended in the NINDS protocol resulted in a higher rate of intracranial hemorrhage. Complications are more likely when rt-PA is used in patients over 70 years old, those with more severe stroke (NIHSS over 15), or those with glucose over 300 mg/dl. Therefore, rt-PA is not recommended for patients who do not meet the inclusion and exclusion criteria. Because brain cells rapidly die as they are deprived of oxygen and because the risk of rt-PA-induced hemorrhage increases over time from stroke onset, its use is limited to the first 3 hours (in most cases) after the start of stroke symptoms (NINDS, 2009).

Thrombolytic agents are used to treat an ongoing acute ischemic stroke by restoring blood flow in the affected area, which may lead to improvements or resolution of neurologic deficits. rt-PA is a genetically engineered form of tPA, a thrombolytic or clot-busting substance made naturally by the body. It should be used only after it has been confirmed that the patient has suffered an ischemic stroke (NINDS, 2015b).

In an ischemic stroke, there is an area of irreversibly damaged brain tissue surrounded by an area of at-risk but viable tissue called the *penumbra*. During the first 3 to 4.5 hours after the onset of symptoms, reperfusion therapy can save this viable tissue by using clot-busting drugs (thrombolytics) to dissolve the clot. The longer therapy is delayed, the more brain cells will die (NINDS, 2009).

rt-PA is currently the only drug approved by the FDA for use in acute ischemic stroke (Rivera-Bou, 2014). It has a 30% recanalization rate when given within 3 hours of symptom onset in the acute setting, and has been shown to improve overall recovery rates at 1 year post stroke (Cronin, 2011).

For patients with ischemic stroke who meet the inclusion and exclusion criteria, the American College of Chest Physicians' evidence-based clinical practice guidelines recommend administration of IV rt-PA in a dose of 0.9 mg/kg (maximum of 90 mg), with 10% of the total dose given as an initial bolus and the remainder infused over 60 minutes (AHRQ, 2012).

Contraindications for treatment with rt-PA include recent hemorrhage, increased risk of hemorrhage, arterial puncture at a non-compressible site, and systolic pressure >185 mm Hg or diastolic pressure >110 mm Hg (Papadakis et al., 2015).

As mentioned earlier, treatment must be initiated within 3 to 4.5 hours of clearly defined symptom onset and all unnecessary delays must be avoided because the benefits of rt-PA therapy diminish rapidly over time.

Did you know. . .

For patients with extensive and clearly identifiable hypo-density on CT, the guideline developers suggest not using rt-PA (AHRQ, 2012).

Unfortunately, fibrinolytics may also cause symptomatic intracranial hemorrhage. Other complications include significant hemorrhage, angioedema, or other allergic reactions (Adams et al., 2007). Therefore, when considering thrombolytics for a stroke patient with symptom onset greater than 3 hours and less than 4.5 hours, a thorough review of the inclusion and exclusion criteria must be performed.

Exclusion criteria largely focus on identifying risk of hemorrhagic complications associated with fibrinolytic use. A sample of the AHA/ASA inclusion guidelines for administering rt-PA are as follows:

- Diagnosis of ischemic stroke causing measurable neurologic deficit
- Neurologic signs not clearing spontaneously to baseline
- Neurologic signs not minor or isolated
- Symptoms do not suggest subarachnoid hemorrhage
- No head trauma or prior stroke in the past 3 months
- No myocardial infarction in the past 3 months
- No GI/GU hemorrhage in previous 21 days
- No major surgery in past 14 days
- Systolic blood pressure <185 mmHg, diastolic blood pressure <110 mmHg
- Not taking oral anticoagulant, or if taking oral anticoagulant INR <1.7
- Platelet count >100,000/μL
- Blood Glucose >50 mg/dL
- CT scan does not show evidence of multi-lobe infarction or intracerebral hemorrhage
- Family understands the potential risks and benefits of therapy (Adams et al., 2007)

Involvement of team members having stroke expertise is critical for assessing risk/benefit considerations and educating decision makers regarding realistic expectations.

Note: In 2009 the American Heart Association (AHA) and the American Stroke Association (ASA) published a science advisory recommending that the time window for rt-PA administration be increased to 4.5 hours after onset of stroke symptoms, although this change has not been approved by the FDA (Slater, 2014). Despite the potential benefit of rt-PA extending out to 4.5 hours, it should be administered as early as possible for the best outcome (Saver, 2014).

Interventional Radiology

Interventional radiology offers a longer treatment window for some patients with acute ischemic stroke. Intra-arterial rt-PA can be given up to 6 hours after onset of stroke symptoms and has the same efficacy as intravenous rt-PA. Using x-ray guidance, a catheter is threaded through the femoral artery into the tiny arteries of the brain where rt-PA is delivered directly into the clot (Cronin, 2011). Because less rt-PA is used, there is less chance of intracranial bleeding.

Mechanical clot removal can be a treatment option for stroke patients who may arrive at the hospital too late, or who have contraindications to the use of rt-PA. The mechanical embolus removal in cerebral ischemia (MERCI) retriever can be used up to 8 hours after symptom onset. The device is threaded through the femoral artery to the site of the stroke to retrieve the clot. The retriever has received approval from the FDA for use in patients with persistent vessel occlusion after IV rt-PA (Lutsep, 2013).

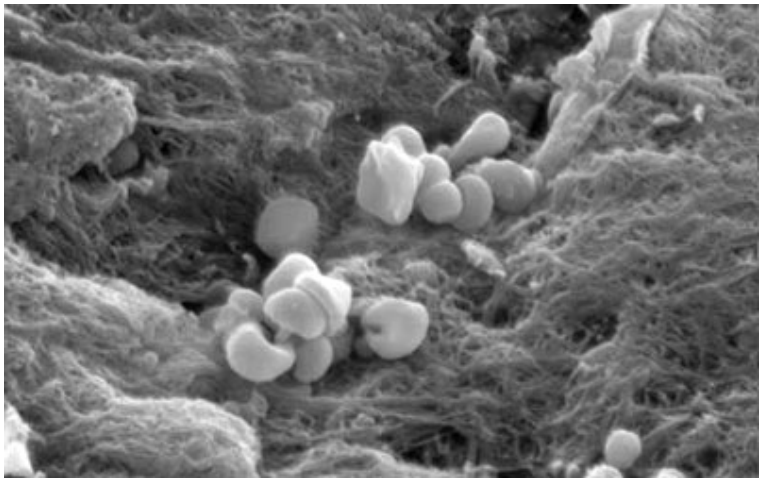
One study showed recanalization occurred in 55% of patients who were treated with a MERCI device alone and in 68% of patients who were treated with a MERCI device plus adjuvant treatment (Lutsep, 2013).

Approved in 2007 by the FDA, the penumbra system uses aspiration to remove a clot. The system is threaded through the femoral artery via catheter to the thrombus site, where the radiologist breaks up the clot with a separator and then aspirates it. This system can be used up to 8 hours from symptom onset and has shown up to an 82% recanalization success rate (Cronin, 2011).

Antiplatelets

Antiplatelet therapy is used for both the prevention and management of acute ischemic stroke. Antiplatelet drugs inhibit the activity of cells called *platelets*, which stick to damaged areas inside blood vessels and lay the foundation for blood clots. Antiplatelets do not break up clots. Patients with ischemic stroke or TIA who are not on anticoagulation should be taking an antiplatelet agent such as aspirin. When patients are aspirin-intolerant, clopidogrel (Plavix), or a combination of low-dose aspirin and dipyridamole (Aggrenox), modified release, should be used. Dipyridamole may also be taken alone (AHRQ, 2010b).

Platelets Attached to Blood Vessels



Platelets (magnified here thousands of times) cling to damaged areas of blood vessels and contribute to the formation of clots. Antiplatelet drugs can help reduce the risk of ischemic stroke. Source: NIH, n.d.

Aspirin is the oldest and most common antiplatelet medicine. In a meta-analysis of trials of aspirin in the secondary prevention of cardiovascular and cerebrovascular events, aspirin reduced the number of strokes by more than 20%. For patients with acute ischemic stroke who are not receiving thrombolysis, early aspirin therapy is recommended to stop the growth of the clot (initial dose of 150–325 mg) (AHRQ, 2010b). Aspirin has also been proven to be the most effective immediate treatment after an ischemic stroke to reduce the likelihood of another stroke. Aspirin should not be given within 24 hours of administration of rt-PA.

The maximal antiplatelet effect of aspirin may take several days when given in doses as low as 75 mg/day, so low doses are used for the long-term prevention of heart attacks and strokes. When immediate anti-clotting effects are needed, moderate doses of aspirin (160–325 mg) are used (medicinenet.com, 2009).

Anticoagulants

Anticoagulants reduce stroke risk by preventing the formation of clots and the extension of existing clots, but do not break them up. The most commonly used anticoagulants include warfarin (Coumadin), heparin, and enoxaparin (Lovenox) (NINDS, 2015a).

There have been several trials to test the efficacy of anticoagulants versus antiplatelet drugs. It has been found that, although aspirin is an effective therapy for the prevention of a second stroke in most patients with atrial fibrillation, some patients with additional risk factors do better on warfarin therapy. A recent study tested the effectiveness of low-molecular-weight heparin (enoxaparin) in stroke prevention. This study showed that **heparin anticoagulants are not generally effective in preventing recurrent stroke or improving outcomes** (NINDS, 2015a).

Warfarin (Coumadin)

Warfarin is often prescribed to prevent the possibility of clotting and stroke in patients with atrial fibrillation. Atrial fibrillation raises the risk of stroke 4 to 6 times. Some of these patients have a lower risk of stroke and are treated with aspirin, which reduces clotting but is not as strong as warfarin. Other treatments include medications such as beta blockers or calcium channel blockers to slow the heartbeat, and anti-arrhythmic drugs or electrical cardioversion to normalize the heartbeat (NINDS, 2009).

Although effective in prevention of clots, warfarin has many disadvantages. It carries many drug–drug and food–drug warnings that may result in either under- or over-coagulation of the blood as measured by the INR. Once patients on warfarin enter a period of instability with regard to their INR, they are subjected to frequent, occasionally daily, blood draws in order to prevent a dangerous bleed or clot from developing.

Heparin and Enoxaparin (Lovenox)

Heparin is an effective anti-coagulant, but only when given via intravenous therapy. Enoxaparin is also an effective anticoagulant, however it must be given subcutaneously up to several times a week, and compared to either warfarin or heparin, the cost is prohibitive for ongoing use and may not be covered for use in the outpatient setting.

Searching for drugs that combined ease of use, decreased monitoring requirements, and effectiveness, in 2010 the Food and Drug Administration (FDA) allowed three new drugs to be used in the United States.

Dabigatran (Pradaxa)

Dabigatran is the first of the three newer agents and was approved by the FDA for use in the United States in 2010. Dabigatran is a direct inhibitor of thrombin and can prevent thrombus development. It may be used as an alternative to warfarin for the prevention of stroke and systemic thromboembolism in patients with either paroxysmal or permanent atrial fibrillation.

Rivaroxaban (Xarelto)

The second of the newer anticoagulants to be released is rivaroxaban. This was approved for use in the United States in 2011. Rivaroxaban is a Factor Xa inhibitor indicated to reduce the risk of stroke and systemic embolism in patients with non-valvular atrial fibrillation. The dose must be adjusted according to estimated creatinine clearance.

Apixaban (Eliquis)

Apixaban is also a Factor Xa inhibitor; it inhibits platelet activation, causing indirect inhibition of platelet aggregation induced by thrombin. Indications are substantially the same as those for the previous two agents. This drug received approval for use in the United States by the FDA in 2014.

Advantages of the New Agents

Advantages of these newer agents compared to warfarin is that they do not require routine coagulation monitoring tests and their onset of action is comparatively rapid. However, their anticoagulation effect declines quickly in the face of non-compliance (Gomez-Outes et al., 2012). Additional advantages are minimal drug and dietary interactions. These properties allow the newer agents to be administered in fixed doses without regular monitoring, making them more convenient to use in the outpatient setting (Eriksson et al., 2011).

Patients with acute ischemic stroke treated with rt-PA should not be treated with anticoagulation for at least 24 hours post thrombolysis (Cruz-Flores, 2015).

At the present time, patients with acute ischemic stroke treated with intravenous recombinant tissue plasminogen activator (rtPA) clearly should not be treated with anticoagulation for at least 24 hours post thrombolysis (Cruz-Flores, 2015).

Hemorrhagic Stroke Therapies

[This section taken largely from National Heart Lung and Blood Institute, 2014.]

Hemorrhagic stroke occurs if an artery in the brain leaks blood or ruptures. Patients with hemorrhagic stroke usually present with neurologic symptoms similar to ischemic stroke patients, but they tend to be sicker. The first step in treating a hemorrhagic stroke is to find the cause of bleeding in the brain and then control it.

Surgery may be needed to treat a hemorrhagic stroke. If an aneurysm is the cause of a stroke, aneurysm clipping or coil embolization may be done. An **aneurysm clipping** is done to block off the aneurysm from the blood vessels in the brain. During the procedure, a surgeon places a tiny clamp at the base of the aneurysm.

Coil embolization is a less complex procedure for treating an aneurysm. The surgeon inserts a catheter into an artery in the groin that is threaded to the site of the aneurysm. A tiny coil is then pushed through the tube and into the aneurysm, causing a blood clot to form, blocking blood flow through the aneurysm, and preventing it from bursting again.

If an arteriovenous malformation (a tangle of faulty arteries and veins that can rupture within the brain) is the cause of hemorrhagic stroke, a repair may be done to prevent further bleeding. Types of repair are:

- Surgery to remove the arteriovenous malformation
- Injection of a substance into the blood vessels of the arteriovenous malformation to block blood flow
- Radiation to shrink the blood vessels of the arteriovenous malformation

Did you know. . .

All strokes are treated as ischemic until a CT scan confirms otherwise. The reason is that, with an ischemic stroke, the staff must follow the strict timeline and protocol for possible rt-PA administration. If a hemorrhage is present, different treatment is required.

Post Stroke Rehabilitation

There is no doubt that, at least in developed countries, more people are surviving stroke than did in the past. New medications and advances in prehospital and emergency medicine mean people are surviving strokes that would have killed them in the past. Post stroke rehabilitation is advancing also. Technologic advances, information gleaned from brain imaging, and new theories about motor control have led researchers and clinicians to consider new and more effective approaches to rehabilitation.

Although the incidence* of stroke is decreasing (at least among white Americans), because people are living longer, the *number* of strokes each year is increasing (Siegler et al., 2013). Unfortunately, many of those who survive a stroke experience chronic deficits that affect their quality of life, mobility, and independence. Because of this, there is an urgent need to improve our understanding of the recovery process and develop therapeutic strategies to improve post stroke outcomes.

Incidence: Incidence is the number of new cases of a condition, symptom, death, or injury that develop during a specific time period, such as a year. Incidence shows the likelihood that a person in that population will be affected by the condition (National Library of Medicine).

For those who survive a stroke, most (about two-thirds) receive rehabilitation services of some type lasting for an average of about 15 days (Cullen et al., 2013). Rehabilitation usually starts in the acute care hospital. Once the patient is stable, post stroke rehabilitation generally continues in one of four places: an inpatient rehabilitation facility (IRF), a skilled nursing facility (SNF), an outpatient facility, or a home-based rehab program.

Whatever the location, the goal of post stroke rehabilitation is to improve motor, sensory, and cognitive function and, when possible, encourage a return to independent living. Focus is on mastery of basic and complex activities of daily living as well as household and community mobility. Cognitive retraining, speech and language skills, swallowing, and safety awareness are key components.

Rehabilitation has become an integral part of post stroke care. It has been shown to improve outcomes, decrease morbidity, and increase independence. Not surprisingly, we are learning from research that organized stroke unit care provided by nurses, doctors, and rehabilitation therapists is consistently associated with better outcomes (Langhorne, 2013).

Unfortunately, many new techniques and breakthroughs have not been implemented on a day-to-day basis in post stroke rehabilitation. In the United States, in the absence of a centralized healthcare system, care is fragmented and inconsistent and post stroke services are spread across an array of facilities and practitioners. Let's begin by looking at where post stroke takes place.

In the United States, there are more than 6,000 acute care hospitals managing nearly 1 million beds (AHA, 2014a). As soon as possible following an acute stroke, patients are evaluated for therapy and may begin a basic rehab program within a day or two. Once stabilized, patients are typically transferred to what Medicare refers to as *post-acute care*. All told, there are nearly 29,000 post-acute care providers in the United States (NHPF, 2012).

In urban areas with greater resources and large numbers of Medicare patients, post-acute care may be provided in an **inpatient rehabilitation facility (IRF).** In those areas without an IRF, post stroke rehab will likely take place within the acute care hospital or in a **skilled nursing facility (SNF).** Those with less severe symptoms may be discharged to home with home health services or receive services in an **outpatient rehab clinic**. The quality and quantity of post stroke rehabilitation services vary widely depending on local healthcare policy, local culture, and resource availability (Cullen et al., 2013).

Post Hospital Stroke Discharge Locations (MedPAC, 2013a)	
Locations	Percentage
Inpatient rehab facilities (IRF) (n=1,165)	19%
Skilled nursing facilities (n=15,000)	25%
Home health agencies (*n=>11,000)	12%
**All other settings	44%

*CMS, 2011.
**All other settings include outpatient care, home, and other inpatient facilities.

Unfortunately, in the United States there are no consistently applied clinical guidelines for what type of care a patient should receive following a stroke. Typically, the decision of where to receive rehab is made in the acute hospital, often by the patient's physician, ideally in consultation with nursing and therapy. The American Heart Association/American Stroke Association (AHA/ASA) has called for this discharge decision to be interdisciplinary, taking into account the patient's medical condition and family situation. AHA/ASA has also recommended the establishment of "stroke systems of care." This means a healthcare organization makes a commitment to stroke prevention, community education, emergency medical services, acute and sub-acute stroke care, rehabilitation, and performance review of stroke care delivery (Jauch et al., 2013).

Not surprisingly, healthcare organizations that have implemented stroke systems of care report improved outcomes; patients treated in such a setting are more likely to be alive, independent, and living at home than those treated in any other setting, a benefit that lasts at least for a decade (Meretoja et al., 2010).

Rehab in the Acute Hospital

In the acute care setting, rehabilitation ideally begins immediately after a diagnosis of stroke has been confirmed and the patient has been stabilized. In this setting, patient mobilization, emotional support, and education are priorities. Assessment of general health and prevention of secondary stroke and stroke-related complications are critical components of care in the acute phase (Sunnerhagen et al., 2013).

As soon as the patient's medical and neurologic condition permits, a clinician experienced in rehabilitation should perform a screening exam to determine if the patient is appropriate and ready for more intense rehabilitation. The screening should incorporate medical information, a neurologic exam, a standardized disability instrument (eg, activities of daily living) and a mental status screening test (Teasell et al., 2013a).

During the days and weeks following a stroke, patients with severe disability and those who have poor physical endurance or limited attention spans are usually managed in a low intensity rehab program, often in a skilled nursing facility. These programs may offer single or multiple therapies in an interdisciplinary setting 1 to 3 hours a day, 3 to 5 days a week (Teasell et al., 2013)

The general belief has been that patients with severe disability will not benefit from intensive rehab as much as those with milder strokes. However, the results from a recent study involving 196 non-ambulatory stroke patients (Teasell et al., 2013) demonstrated that patients with severe stroke can achieve impressive rehabilitation goals. In the study, patients were admitted to a specialized, enriched, multidisciplinary rehabilitation program for a period of close to 3 months. Upon completion, 43% of patients were able to return home and 28% were no longer wheelchair dependent (Teasell et al., 2013).

It has become increasingly common to provide very early rehabilitation, often less than 24 hours after the stroke has occurred. A multi-center study called AVERT (A Very Early Rehabilitation Trial) tested the safety and feasibility of very early mobilization. Stroke patients randomly received either standard care or very early mobilization. The study showed that there was no harm to patients in the very early mobilization group compared to those who had standard care (Jauch et al., 2013).

The study also showed that early mobilization lessens the likelihood of complications such as pneumonia, deep vein thrombosis, pulmonary embolism, and pressure sores (Jauch et al., 2013). A grant to conduct the larger study, to test the effectiveness of very early mobilization has been obtained (clinicaltrials.gov, 2014). The larger trial is underway in the United Kingdom, Australia, Canada, New Zealand and Southeast Asia (Teasell et al., 2013).

Inpatient Rehabilitation Facilities

Inpatient rehabilitation facilities (IRFs) are a type of acute-care hospital. They provide intensive, team-based rehabilitation to patients after an injury, illness, or surgery. There is strong evidence that inpatient rehab, initiated rapidly after stroke through multi-disciplinary teams within dedicated stroke units, represents the option with the strongest evidence base and thus is considered gold standard care for recovery in the post-acute phase (Jan et al., 2013).

In the United States, there are about 1,165 certified inpatient rehab facilities, 80% of which are hospital-based. Overall, the number of IRFs has been slightly but steadily declining since 2005 (MedPAC.gov, 2013). In 2013, stroke patients represented about 19% of patients treated in IRFs with an average stay of 15 days (Dobson & DaVanzo, 2014).

Rehabilitation at an inpatient rehabilitation facility must be directly supervised by a rehabilitation physician (physiatrist). Services are comprehensive and include physical and occupational therapy, speech–language pathology, around-the-clock rehab nursing, and prosthetic and orthotic services. If the facility is free-standing—rather than a department in an acute-care hospital—it must have on staff a full-time medical director (with training or experience in inpatient rehabilitation). If hospital-based, a qualified physician must provide services for 20 hours per week (MedPAC, 2013a).

Inpatient rehabilitation facilities tend to be concentrated in highly populated states in areas with large Medicare populations. Overall, for Medicare beneficiaries:

- 69% live in a county that has at least one IRF
- 44% live in a county with two or more IRFs
- 31% live in a county that does not have an IRF (MedPAC, 2013a)

Despite demonstrably better outcomes, inpatient rehab facilities may be adversely affected by proposed changes in Medicare's payment system. One proposed change, "bundling," would pay for an "episode of care," which would include a hospital stay and 30 days of care following discharge from the hospital (MedPAC, 2014).

Another proposal, called "site-neutral" payments, stems from the Medicare Payment Advisory Commission Commission's (MedPAC) position that Medicare should not pay more for care in one setting than in another if the care can be safely and efficiently (that is, at low cost and with high quality) provided in a lower cost setting" (MedPAC, 2014).

Yet another change is the MedPAC recommendation that physicians no longer be required to see patients at least 3 times per week and IRFs no longer be required to provide intensive therapy to patients each day.

The proposed changes are not without controversy and are expected to adversely affect IRFs in particular. According to Toby Edelman of the Center for Medicare Advocacy, site-neutral payments would likely reduce payments to IRFs, reduce the availability of IRFs for Medicare patients, and increase cost-sharing. Post-acute bundling would also likely shift Medicare patients from IRFs to SNFs (Edelman, 2014). Click here for more information.

On January 15, 2015, MedPAC finalized its recommendation to Congress that Medicare should begin to move toward site-neutral payments where there is clear overlap in the services provided, such as for certain patients served by SNFs and IRFs. The American Hospital Association, an industry trade group, has expressed concerns about the payment changes. "We have a number of concerns about MedPAC's IRF-SNF site neutral recommendation, including that it may lead to the provision of SNF-level care for beneficiaries who actually would have achieved a better outcome if they had received IRF-level care," said Joanna Hiatt Kim, American Hospital Association vice president of payment policy.

Rehab at a Skilled Nursing Facility

In the United States, there are more than 15,000 skilled nursing facilities (SNFs) managing more than 1.6 million beds. Nationwide, Medicare Part A is the primary payer for about 14% of those receiving services at a skilled nursing facility—usually as part of a department offering generalized rehabilitation services. In 2009 about 14% of Medicare admissions to SNFs involved stroke patients (AHCA, 2012).

In the world of skilled nursing facilities, an ever-higher percentage of patients is being admitted for short-term rehab; in fact, the majority of patients admitted to a SNF are people who need skilled services or rehabilitation following an acute injury or illness. Of the 3.7 million individuals who received care in a nursing facility in 2009, only about 23% resided in the facility for at least a year. Of the remaining 2.9 million, 80% were admitted for short-term rehabilitation covered by Medicare (AHCA, 2012).

Post stroke rehabilitation services carried out in a SNF can vary wildly depending on the size of the SNF, location (rural vs. urban), the availability and expertise of the therapists, and nurse and nursing assistant staffing. Physician oversight is minimal, nursing staff are not required to have expertise in rehabilitation, and therapists are (by necessity) generalists, rather than stroke specialists. The majority of direct patient care is provided by nursing assistants who receive little of no training in stroke care. Often there is little space for rehab—sometimes only a couple of converted patient rooms—and very little specialized equipment. There are fewer requirements for patients entering rehab at a SNF compared to an IRF; only 1.5 hours of therapy are required each day (Mon-Fri).

To qualify for post stroke rehab at an SNF:

- There must be a need for skilled nursing care 7 days a week or skilled therapy services at least 5 days a week;
- A patient must have been formally admitted as an inpatient to a hospital for at least 3 consecutive days. Patients must enter a Medicare-certified skilled nursing facility within 30 days of leaving the hospital;
- A patient must have Medicare Part A before discharge from the hospital; and
- There must be a need for care that can only be provided in a SNF (Medicare Interactive, nd).

If these requirements are met, Medicare generally covers the skilled nursing facility care, including care needed to improve a patient's condition or maintain their ability to function. Medicare should cover skilled care if it helps a patient to maintain functional abilities or prevents or slows a decline in function. Between 2005 and 2009, the average length of stay for a stroke patient in a SNF was approximately 32 days (Dobson & DaVanzo, 2014).

Requirement	IRFs	SNFs
Physician oversight	Rehabilitation physicians must see patients at least three times per week	Physicians must see residents within 14 days of admission and then every 30 days
Registered nurse staffing	24 hours per day	8 hours per day
Therapy services	Intensive; often described as at least three hours per day	No requirements; Medicare reimbursement rate depends on amount of therapy SNF says it provided
Average length of stay	15 days	32 days

Source: Center for Medicare Advocacy, 2014. Reprinted with permission.

Long-Term Care Hospitals

Although most people who need inpatient hospital services are admitted to an acute-care hospital for a relatively short stay, some may need a longer hospital stay. Long-term care hospitals (LTCHs) are certified as acute-care hospitals, but focus on patients who are severely ill and who, on average, are hospitalized for more than 25 days. Prior to the 1980s most LTCHs had evolved from tuberculosis and chronic disease hospitals. The late eighties and early nineties saw the growth of LTCHs, although they were generally privately owned and served mostly ventilator-dependent patients; in the 1990s LTCHs began to develop within acute hospitals. As of 2011, there are 436 Medicare-certified LTCHs nationwide (MedPAC, 2013b).

LTCH patients are, in general, more severely ill than those in acute care hospitals; many are transferred from an intensive or critical care unit. LTCHs specialize in treating patients who may have more than one serious condition, but who may improve with time and care, and return home. LTCHs typically provide comprehensive rehabilitation, respiratory therapy, head trauma treatment, and pain management.

The average length of stay for patients in LTCH is 27 days, compared to 5 days for general acute hospitals, and almost 7 days for ICUs in general acute hospitals (AHA, 2014b).

Comprehensive Outpatient Rehab Facilities (CORFs)

CORFs provide coordinated outpatient diagnostic, therapeutic, and restorative services at a single fixed location for the injured, disabled, or sick individuals. Physical therapy, occupational therapy, and speech-language pathology services may be provided in an off-site location. A CORF must minimally offer physician services, physical therapy, and social or psychological services. CORFs differ from general outpatient rehab facilities in that, in addition to physician and therapy services, a fully staffed CORF must provide these additional services:

- Respiratory therapy
- Prosthetic and orthotic services
- Nursing services
- Durable medical equipment

Besides CORFs, about 30% of stroke survivors receive therapy services in a general services outpatient clinic (Higashida et al., 2013), which is typically provided 3 times per week. Outpatient therapy can also be provided in other locations:

- Offices of privately practicing therapists
- Medical offices
- Outpatient hospital departments
- Outpatient rehabilitation facilities (other than a CORF)
- Skilled nursing facilities (SNFs)
- At home, from privately practicing therapists (CMS, 2014)

Home Health Rehabilitation

Home health agencies, with 12,000 throughout the United States, are the most commonly used post-acute care provider, with 3.4 million Medicare users (NHPF, 2012). Home health agencies provide services through Medicare for homebound patients, usually upon discharge from an inpatient rehab facility or skilled nursing facility. The patient's physician must certify that the patient is homebound and state the reasons why skilled services are needed. Outpatient and home-based therapy are less expensive alternatives to inpatient therapy following a stroke and, in some cases, may be just as effective.

Early-Supported Discharge

Early supported discharge (ESD) is an approach that provides interdisciplinary rehabilitation in the home instead of in a hospital. The early supported discharge model links inpatient care with community services and allows patients to be discharged home with support of the rehabilitation team.

ESD is common in Great Britain, where the National Health Service has established the goal of facilitating early supported discharge to home for 40% of stroke patients. Difficulties with access to care, variations in the definition of ESD, and staffing shortages have limited the number of people who receive these services.

A 2012 Cochrane review has provided evidence that ESD is cost effective, can reduce long-term dependency, and results in positive outcomes for stroke patients. A review of 14 trials involving nearly 2,000 participants who received ESD services from doctors, nurses, and therapists showed that ESD patients returned home earlier and were more likely to remain at home in the long term and to regain independence in daily activities when compared to those who received conventional rehab services. The best results were seen with well-organized discharge teams and patients with less severe strokes (Fearon & Langhorne, 2012).

Comparing Outcomes

When comparing outcomes for stroke patients receiving rehab services, most research has looked at IRFs and SNFs, where care differs significantly. A study involving 20% of Medicare beneficiaries, matched on demographic and clinical characteristics, looked at the difference in 2-year outcomes between patients discharged from IRF and SNF rehab. Rehabilitation in IRFs leads to lower mortality, fewer readmissions and ER visits, and more days at home than rehabilitation in SNFs for the same condition. This suggests that the care is not the same at IRFs and SNFs and that the care setting has an effect on patient outcomes (Dobson & DaVanzo, 2014).

In terms of mortality, even though stroke patients treated in IRFs were discharged significantly sooner than patients treated in SNFs (16.5 days earlier), among matched stroke patients, IRF patients lived longer than SNF patients. Nearly half of those discharged from a SNF died within 2 years while only a little more than a third died within 2 years of discharge from an IRF. Stroke patients discharged from an IRF rehab program lived nearly 97 days longer than those discharged from a SNF rehab program (Dobson & DaVanzo, 2014).

These differences were apparent for home health and outpatient services as well. When comparing IRFs and home health/outpatient services, those who went to an IRF had statistically significant improvements in applied cognitive function compared to those who received only home health or outpatient services. These differences were statistically significant, were evident six months after the stroke, and persisted even after controlling for patient characteristics such as age, stroke severity, pre-stroke function, the burden of co-morbid illnesses, as well as treatment hours (Chan et al., 2013).

Despite high-level evidence that stroke patients experience better outcomes when treated by interdisciplinary stroke specialists, this care is not available to many stroke patients. There are a number of reasons for this:

- Lack of access to specialist hospital staff
- Fluctuating or small-stroke patient numbers when a critical mass is required
- Cultural resistance to change (Brusco et al., 2014)

Motor Impairment and Neural Plasticity

In the past it was thought that the brain was completely formed by adulthood and was therefore incapable of forming new connections. It is now known that the brain adapts, compensates, and learns throughout life, a process called **neural plasticity** or neural *modifiability*. Neural plasticity is described as "a continuum from short-term changes in the efficiency or strength of synaptic connections, to long-term structural changes in the organization and numbers of connections between neurons" (Shumway-Cook & Woollacott, 2012).

New technologies, such as noninvasive exploration of the brain, are increasing our understanding of neural plasticity and its relationship to stroke recovery (Takeuchi & Izumi, 2013). Studies in animals using these technologies have yielded new information about plasticity:

- Motor learning results in changes in the motor cortex
- Sensory stimulation may facilitate motor recovery
- Intensive training increases brain plasticity
- Enriched environments result in a greater number of synapses

- The greater the damage to a specific brain area, the greater the plasticity in adjacent areas (Teasell & Hussein, 2013)

Neuroplasticity Video (4:59)

https://www.youtube.com/watch?v=iAzmyB9PFt4

Various stroke rehabilitation techniques have been developed based on the concept of neural plasticity. However, the effectiveness of interventions among patients with stroke varies widely because the mechanisms underlying motor recovery are diverse and, as yet, not well understood.

Abnormal Tone

Following a stroke, abnormal muscle tone is a common complication. Many of those who survive a stroke experience an abnormal increase in muscle tone referred to as **spasticity** or *hypertonia*. Additionally, many stroke patients experience an abnormal decrease in muscle tone, which is referred to as **paresis** or *hypotonia*. Both spasticity and paresis typically occur on one side of the body, usually the opposite side from the brain lesion.

There are a number of other abnormal signs associated with muscle over-activity:

- Increased deep tendon reflexes (also called tendon jerks)
- Clonus—rapid, involuntary muscular contractions and relaxations
- Extensor and flexor spasms
- Babinski sign—an upward extension of the big toe when the sole of the foot is stroked or stimulated with a blunt instrument
- Positive support reaction—a reflex pattern of plantar flexion and inversion of the ankle during weight bearing
- Co-contraction—the simultaneous contraction of the agonist and antagonist muscles surrounding a particular joint

- Spastic dystonia—involuntary muscle contractions that cause slow repetitive movements or abnormal postures

This type of muscle over-activity comprises the *positive* signs of upper motor neuron damage.* Decrease in muscle tone, visual loss, loss of dexterity, sensory loss, reduction of deep tendon reflexes, and numbness are referred to as *negative* signs of upper motor neuron damage (Trompetto et al., 2014).

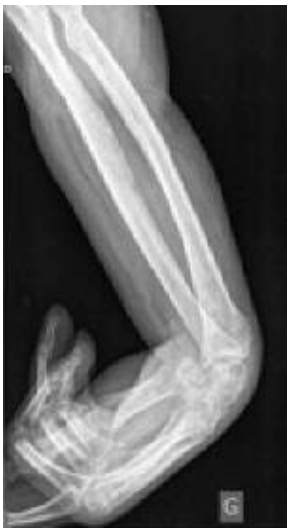
*__Upper motor neuron__: motor neurons that originate above the level of the spinal cord in the brainstem or the motor cortex.

Spasticity (Hypertonicity)

Spasticity is defined as a velocity-dependent increase in tonic stretch reflexes with exaggerated tendon jerks, resulting from hyper-excitability of the stretch reflex. Also called *hypertonia*, it is a type of abnormal tone that occurs in a significant percentage of people following a stroke; up to 42% of stroke survivors exhibit abnormal hypertonia (Pundik et al., 2014). Spasticity is part of an overall disruption in movement that includes weakness, stiffness, contracture, decreased smoothness of movement, and dysfunction in the patterns of muscle recruitment (Marciniak, 2011).

In addition to velocity-dependent increases in tonic stretch reflexes, spasticity is a length-dependent phenomenon. For example, in the quadriceps, spasticity is greater when the muscle is short than when it is long. This is probably one of the mechanisms underlying the so-called clasp knife phenomenon. Bending the knee, at first (when the muscle is short), a great resistance is met. Then, when the quadriceps lengthens, the resistance suddenly disappears. Spasticity is most often seen in the flexor muscles of the upper limb and in the extensor muscles of the lower limb (Trompetto et al., 2014).

Contracture of the Wrist



An x-ray showing spasticity and contracture of the wrist of a 42-year-old man following a stroke. Source: Wikiversity.

Rehabilitation is a challenging task for those who exhibit spasticity. It can limit practice of coordinated movement, restrict movement, and hinder functional recovery. This abnormally elevated muscle tone impacts quality of life because it affects many aspects of everyday function, produces pain and discomfort, and prevents normal movements (Pundik et al., 2014).

In terms of post stroke recovery, some studies show that a more complete restoration of motor function is achieved when spasticity is absent (Pundik et al., 2014). Other reports suggest adverse effects on recovery. A longitudinal study of 95 subjects found that, at 3 months post stroke, patients without spasticity had significantly better motor and activity scores than patients with spasticity (Belagaje et al., 2014).

Medications for Spasticity

Multiple medications and treatments have been developed and are used routinely in the clinical setting for post stroke spasticity, including baclofen, tizanidine, dantrolene, and benzodiazepines (Francisco & McGuire, 2012). Improvements in passive function only and reduction in disability after botulinum toxin administration to spastic muscles have been reported (Belagaje et al., 2014).

In their approval of botulinum toxin for post stroke spasticity, the Food and Drug Administration (FDA) cited three studies that showed improvement in upper limb muscle tone as measured by Modified Ashworth Scale* and physician global assessment of treatment response. It is still unclear whether the treatments improve functional outcomes after a stroke (Belagaje et al., 2014).

***Modified Ashworth Scale**: a clinical tool used to assess spasticity by rating the perceived level of resistance to passive range-of-motion about a single joint.

Hemiparesis and Hemiplegia

Paresis or paralysis following a stroke is defined as "decreased voluntary motor unit recruitment, which reflects the inability or difficulty in recruiting skeletal motor units to generate torque or movement" (Shumway-Cook & Woollocott, 2012). It is the result of damage to the part of the nervous system and brain associated with motor control. Depending on the size and location of the lesion, weakness can range from complete loss of motor activity (paralysis) to partial loss (paresis).

Weakness and loss of dexterity are usually immediately apparent following a stroke and often contribute to decreased active and passive range of motion of the involved joints. Profound hemiparesis can lead to joint contractures, which severely impair mobility and may lead to pressure ulcers. Passive and active range of motion exercises are used to reduce the risk of secondary musculoskeletal impairment from decreased joint range of motion (Trompetto et al., 2014).

Paresis affects all activities of daily living. For example, a patient with hemiparesis bears more weight on the opposite lower extremity, which can lead to asymmetry and impaired posture. The weight-bearing asymmetry is associated with the increased postural sway and poor balance. The inability of the non-affected lower extremity to compensate for the paretic limb also contributes to the postural imbalance (Arya et al., 2014).

Maladaptive Plasticity

Following a stroke, the brain immediately goes to work trying to compensate for neurologic changes. But the brain doesn't always choose the best compensation; it chooses those that are fast and efficient. In some cases the compensation can be *maladaptive*, creating an unwanted result or consequence such as loss of function or injury (Takeuchi & Izumi, 2012). Maladaptive plasticity can trigger behavioral changes or even development of disease symptoms as a result of neurophysiologic changes in the human brain (Cerasa et al., 2014).

Several studies have reported that maladaptive plasticity weakens motor function and limits motor recovery after stroke. Several mechanisms for maladaptive plasticity have been proposed, including (1) compensatory movements, (2) changes to ipsilateral motor projections, and (3) competitive interaction between the damaged and undamaged hemispheres of the brain (Takeuchi & Izumi, 2012).

Compensatory Movements

Compensation is the appearance of new motor patterns resulting from the adaptation of remaining motor elements or substitution, meaning that functions are taken over, replaced, or substituted by different end effectors or body segments. It is common in stroke patients with severe impairment that compensatory movements by the less-affected side of the body be encouraged to maximize functional ability (Takeuchi & Izumi, 2012).

In the upper extremity, compensatory movement can include the use of motor patterns that incorporate trunk displacement and rotation, scapular elevation, shoulder abduction, and internal rotation. The use of compensatory movement can assist arm and hand transport and aid in hand positioning/orientation for grasping (Takeuchi & Izumi, 2012).

In the lower limb, stroke patients often use larger arm and leg swing amplitudes on the non-paretic side to increase walking speed. Although compensatory movements may help stroke patients perform tasks in the short term, the presence of compensation may be associated with long-term problems such as reduced range of joint motion and pain (Takeuchi & Izumi, 2012).

Intense use of the non-paretic limb might have harmful effects on motor recovery of the paretic limb and may drive neural plasticity in a direction that is maladaptive for functional outcome. Compensatory movement patterns may improve performance of daily activities after stroke but may also induce maladaptive plasticity and limit motor recovery (Takeuchi & Izumi, 2012).

Ipsilateral Motor Projections

Motor projections on the same (ipsilateral) side of the body as the brain lesion may be enhanced after a stroke. In an undamaged nervous system, ipsilateral motor projections are relatively weak—especially those innervating the *distal* upper extremity—while contralateral projections are strong. Following a stroke, it is believed that latent ipsilateral motor projections are activated to compensate for the loss of contralateral motor projections. Because they are so weak, the ipsilateral motor projections are unable to replace the normal, contralateral motor projections to the distal extremity (Takeuchi & Izumi, 2012).

The attempt by the nervous system to compensate for the loss of contralateral motor control by activating ipsilateral motor projections might be not only unhelpful but also maladaptive. Although ipsilateral motor projections to the *proximal* (upper arm and shoulder) muscles may contribute to some preservation of proximal limb control, increased expression of ipsilateral motor projections to the paretic proximal side may contribute to the generation of abnormal *inter-joint coupling** movement after stroke. With less contralateral neural input to the proximal limb, an increase in the activity of ipsilateral motor projections may explain the loss of independent joint control and abnormal inter-joint movement observed in the proximal limb after stroke. This might contribute to the generation of abnormal motor patterns, leading to poor motor ability after stroke (Takeuchi & Izumi, 2012).

***Interjoint coupling or coordination**: the ability to move joints smoothly and in coordination with one another.

Competitive Interaction

Following a stroke, the unaffected cerebral hemisphere inhibits the affected hemisphere through abnormal *inter-hemispheric inhibition*, which restricts motor function. This hypothesis is supported by reports that inhibitory stimulation using repetitive transcranial magnetic stimulation over the unaffected hemisphere improves motor function rather than weakening it (Takeuchi & Izumi, 2012).

Inter-hemispheric competition is thought to be the result of changes in both hemispheres after stroke. This is based on the observation that stroke patients with poor motor function show increased activation of the *unaffected* hemisphere. This hyper-excitability has a negative correlation with motor function after stroke. Compensatory usage of the non-paretic side may promote the unbalance between the hemispheres (Takeuchi & Izumi, 2012).

Task-Specific Training

In the past, the practice of movement patterns was a central theme in stroke rehabilitation. These techniques, developed over decades, are based on the reflex-hierarchical theory of motor development, which posits that the nervous system is organized in a top-down manner and when damage occurs in the brain, “normal reflexes become exaggerated and so-called pathological reflexes appear” (Shumway-Cooke & Woollacott, 2012). Although therapeutic techniques based on this approach results in clear improvements, it is now thought that task-specific training yields better results.

Task-specific or task-oriented training is an approach that emphasizes the practice of functional tasks related to mobility rather than movement patterns. It is also referred to as the *systems approach*. This approach assumes that movement is an interaction of many different systems and that movement is organized around a behavioral goal and is constrained by the environment. In the task-oriented approach, the patient learns by actively trying to solve the problems associated with the functional task (Shumway-Cooke & Woollacott, 2012).

Task-specific training has become a well-accepted principle of stroke rehabilitation. It can help a person effectively recover a wide array of motor behaviors involving the upper limbs, lower limbs, sit-to-stand movements, and gait. Repetitive, task-specific training has been found to achieve better functional gains compared to non-repetitive training (Takeuchi & Izumi, 2013).

Neurophysiologic and neuroimaging studies have confirmed the efficacy of task-specific training. For example, in a study looking at the neural effects of task-specific training on paretic upper extremity movements, neural changes in the sensorimotor cortex of the affected hemisphere were noted. Compared to traditional stroke rehabilitation approaches, task-specific training induces long-lasting motor learning and associated cortical reorganization (Takeuchi & Izumi, 2013). There is strong evidence for physical therapy interventions favoring intensive high-repetition, task-oriented, and task-specific training in all phases post stroke (Veerbeek et al., 2014).

Environmental Enrichment

Environments that provide greater opportunity for a variety of activities are referred to as **enriched environments**. These types of environment provide stimulating motor, cognitive, sensory, and social activities and increasingly are thought to play an important role in stroke rehabilitation.

Stroke studies involving rat models have demonstrated that enriched environments facilitate motor recovery and increase neural plasticity. The enriched environment provided greater opportunities for physical activity, play, and social interactions compared to standard laboratory cages (Takeuchi & Izumi, 2013). Animals raised in complex or enriched environments have greater brain weight, thicker cortical tissue, greater neuron size, a greater degree of dendritic branching, higher dendritic spine frequency, larger synaptic contacts, and more synapses per neuron (Teasell & Hussein, 2013b).

Short-term changes include the immediate expression of early genes, alterations in synaptic efficacy, and long-term potentiation, whereas long-term changes include an increase in dendritic arborization, spine density, axonal sprouting, and the number of synapses per neuron. These modifications are likely due to the availability of greater sensory stimuli and more learning experiences, which in turn are expressed as structural changes within the brain (Teasell & Hussein, 2013b).

In a 2013 study involving 29 patients, the difference in change of physical, cognitive, and social or any other activity were directly observed in stroke patients located in a mixed rehabilitation unit and exposed to an enriched environment versus a non-enriched environment. The stroke patients in the enriched environment were more likely to engage in social activities, less likely to be inactive and alone and less likely to be asleep than patients without enrichment. The preliminary trial suggest that the comprehensive model of enrichment developed for use in a rehabilitation unit was effective in increasing activity in stroke patients and reducing time spent inactive and alone (Teasell & Hussein, 2013b).

Clinically, care administered by a well-coordinated, multidisciplinary team can provide an enriched environment for patients with stroke. Care in an organized stroke unit provides individuals with a clear understanding of what is expected of them during task-specific training, resulting in neural plasticity that improves their performance (Takeuchi & Izumi, 2013).

Involving patients in the setting of interdisciplinary goals has been shown to encourage motivation and engagement in therapy, resulting in better rehabilitation outcomes. The reported benefits of stroke unit care extend to patients of all ages and to patients with varying stroke severity. It is increasingly clear that stroke rehabilitation programs should include meaningful, repetitive, intensive, and task-specific training in an enriched environment in order to promote neural plasticity and motor and functional recovery (Takeuchi & Izumi, 2013).

Regaining Balance After a Stroke

Balance is the ability to maintain your center of gravity over your base of support; it is often severely affected following a stroke. The ability to regain functional motor skills and increase the intensity of exercise and practice in rehabilitation centers around the acquisition of balance. Although there are many different types of exercise available, some are more likely to improve balance and prevent falls than others. Overall, it appears that balancing mechanisms are very specific to the action being performed, the purpose of the action (the task), and the environment in which it takes place (Carr & Shepherd, 2011).

Practicing balance exercises while standing, along with exercises for lower extremity muscles performed while standing against body weight resistance, is the optimal way to improve balance as well as flexibility, strength and endurance, and fitness. Exercises can include standing up and sitting down, step-ups, heels raises, marching, stair walking, semi-squats, and reaching to the floor sideways and forward to pick up an object. These exercises should be performed with increasing numbers of repetitions and without reliance on the upper limbs for support and balance. Exercises can be made more challenging by increasing the height of steps and chairs and by increasing and varying speed (Carr & Shepherd, 2011).

Balance and functional mobility can be effectively assessed using an assessment tool such as the Berg Balance Scale. This tool consists of 14 tasks, scored from 0 to 56, that assess a variety of functional, balance, and gait activities. Each task is scored on a 1–4 scale; a score of 0 indicates an inability to perform the task while a score of 4 means the patient is independent with that task. The Berg Balance Scale has excellent internal consistency and good test/retest reliability and requires little specialized training. It can be performed with minimal equipment in a small space and can be used in any clinical setting.

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Sensory Organization for Balance

Of the many systems and organs that provide sensory input to the central nervous system, the somatosensory, visual, and vestibular systems are the ones most directly involved with balance. Understanding how these sensory systems malfunction helps explain the profound difficulties patients have with balance and mobility following a stroke.

The sensory system receives input from the environment through specialized receptors located in the sensory end-organs in the eyes, vestibular apparatus of the inner ear, muscle spindles, Golgi tendon organs, and touch receptors in the skin. Sensory input provides a continuous flow of information to the central nervous system, which in turn utilizes this incoming information to make decisions about movement. The central nervous system sifts, compares, weighs, stores, and processes sensory input and uses this information to alter the force, speed, and range of motion.

The **somatosensory system** (touch and proprioception) has perhaps the strongest influence on balance. Somatosensory input from touch, heat, cold, pressure, joint position, muscle stretch, and pain, among others, is continuously fed to the brain. There the sensory information is automatically processed and used to make the many quick adjustments that keep us balanced. Somatosensory input provides us with critical feedback about our position in space, body sway, and changes in terrain. This allows our muscles to make constant, automatic adjustments to maintain balance and avoid falls.

The **visual system** is another key contributor to balance. It allows us to determine the movement of objects in our environment; it tells us where we are in relation to parts of our own body and to other objects. Our visual system does this using both central and peripheral vision. Central vision is processed mostly through the macula—the part of the retina that allows us to see clearly. Peripheral vision provides information to the brain about general spatial orientation and is more important for postural control and balance than central vision. Vision works in conjunction with the vestibular system, comparing information about velocity and rotation with actual visual information (Shumway-Cook & Woollacott, 2012).

The **vestibular system** is responsible for processing information about movement in relation to gravity—specifically, rotation, acceleration/deceleration, and head stabilization during gait. The vestibular system works with the visual and somatosensory systems to help us maintain our orientation in space; it works with the visual system to stabilize the eyes and maintain posture during walking (vestibulo-ocular reflex). Vestibular disorders cause a feeling of dizziness and unsteadiness and affect the ability of the nervous system to mediate inter-sensory conflicts.

The vestibular system declines with age, and there may be as much as a 40% loss of vestibular nerve and hair cells by age 70. Vestibular decline has a profound effect on balance and postural control. This is because it is used as a reference system by the visual and somatosensory systems when those systems are in conflict. Vestibular impairment can lead to problems with gaze stabilization, blurred vision, and vertigo (Shumway-Cook & Woollacott, 2012).

Sensory Disorganization

The loss or disruption of sensory input in the visual, vestibular, or somatosensory systems can affect balance in a number of ways. How balance is affected depends on several factors, including the extent of the nervous system damage, the number and extent of sensory losses, and the availability of the other senses for compensation. In many instances, more than one sensory system is impaired, as in the case of a person with a peripheral neuropathy and visual impairment (common with diabetes and stroke). But, just as an individual with impaired vision develops a keener sense of hearing, a person with a sensory loss will attempt to compensate by using the unaffected or less-affected senses to improve balance.

Sensory Conflict

Even in an undamaged nervous system, our sensory organs don't always provide accurate information to our brains. We've all had the experience of being stopped at a stoplight and having the car next to us start to move—we think we are moving and slam on the brake. As soon as your foot touches the brake you instantly know that you aren't moving and even feel a little foolish. This is an example of a *sensory conflict*—the brain gives preference to visual input for a split second—momentarily overriding somatosensory input. In this case, the sensory conflict is quickly resolved, thanks to the somatosensory and vestibular systems. The touch of your foot on the brake along with position receptors in your back and legs quickly tell you that you are, in fact, sitting still. At the same time the hair cells in the vestibular system let you know that there is no forward motion.

Improper Sensory Weighting

Sensory loss may lead to inflexible or *improper sensory weighting*. A person may depend on one particular sense for postural control even if that sense leads to further instability (Shumway-Cook & Woollacott, 2012). You may notice a person walking with head down, carefully watching every step. In this case, vision has become the dominant sense being used for balance. Retraining would involve improving the use of somatosensory and vestibular input to reduce dependence on visual input. The visual and vestibular systems may be affected, causing visual disorientation and vertigo.

Sensory Disruption and Loss

Sensory disruption—blurred vision, intermittent numbness, pain, and pressure from swelling—can have a profoundly negative effect on balance and postural control. How (and how much) balance is affected depends on several factors, including the extent of the nervous system damage, the number and extent of sensory losses, and the ability of the other senses to compensate for the damage. If more than one sensory system is impaired—as occurs with a stroke—it may be difficult to compensate for sensory losses.

Sensorimotor Adaptation

The nervous system has a powerful ability to compensate for actual or perceived disabilities. Once an injury has occurred, the nervous system immediately goes to work attempting to compensate for neurologic changes, weakness, and loss of function. As mentioned earlier, the goal of therapy is to help the nervous system develop strategies and compensations that minimize musculoskeletal damage and maximize function.

Stroke and Fall Rate

Balance difficulties and falls are two of the serious medical complications associated with a stroke. Most people who have had a stroke (75%) fall during the first 6 months post stroke compared with a 30% annual fall rate in the general older adult population (Schmid et al., 2010).

Falls are an important issue during the acute stay, and fall prevention should be addressed immediately following a stroke. For stroke patients, there is an increased fall risk during acute hospitalization. Falls and other medical complications are associated with triple the length of the acute hospital stay (Schmid et al., 2010).

Stroke severity, specifically a National Institutes of Health Stroke Scale (NIHSS) score ≥8, can be used to identify stroke patients who are at greatest risk of falling. Those determined to be at risk for falls should have a fall prevention program initiated while they are still in the acute inpatient hospitalization period (Schmid et al., 2010).

In a recent Canadian study, a lower score on the Berg Balance Scale was associated with greater falls for both stroke and control groups. Researchers found that people recently discharged from rehabilitation to home were at high risk for falls in their home. This may be because, following a stroke, people spend more time at home or are more cautious when outside their home. This finding reinforces the importance of a home assessment, home safety education, and environmental modifications as part of discharge planning (Simpson, 2011).

Regaining the Ability to Walk

Because an acquired neurologic injury (such as a stroke) affects both sensory and motor function, walking can be severely affected. Sensory changes, weakness, and spasticity affect *movement strategies*, which alter a person's ability to successfully respond to losses of balance. A stroke affects how much and how often a person walks and also affects *walking adaptability*—the ability to adapt to different conditions during ambulation—as well as endurance. Gait training generally starts as soon as possible following a stroke, using manual techniques, task-specific training, strengthening, and, when available, body weight-assisted treadmill training and robotic devices.

Gait Training

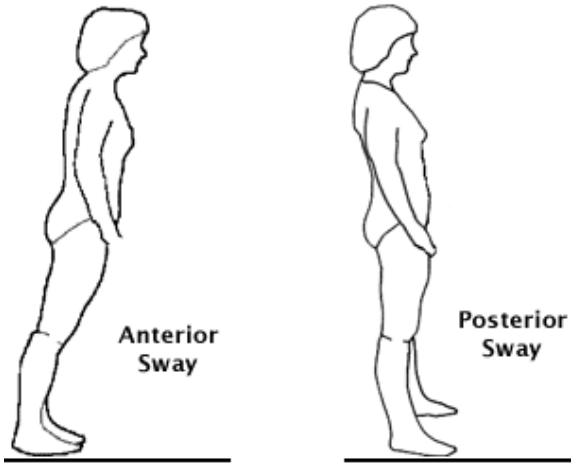
An example of over-ground gait training.

Movement Strategies Altered by Stroke

A movement strategy or synergy is a flexible, repeatable pattern of movement that can be quickly and automatically accessed by the central nervous system. Movement strategies allow us to store and reuse patterns of movement that have been successful in the past. Strategies are efficient, automatic movement patterns that evolve over time. Each time a loss of balance threatens, the nervous system draws on these pre-programmed movement strategies to ensure the maintenance of balance.Movement strategies used by the nervous system to respond to perturbations are diminished following a stroke.

The **ankle strategy**—also called *ankle sway*—is used in response to small perturbations or losses of balance. When a small loss of balance occurs—as when standing on a moving bus—the foot acts as a lever to maintain balance by making continuous automatic adjustments to the movement of the bus. When a small balance adjustment is needed, muscles close to the floor (anterior tibialis and gastrocnemius) activate first and flow upward in a *distal to proximal* pattern.

Ankle Sway



The ankle strategy is used in response to small perturbations is also called ankle sway. Source: Lauren Robertson.

When a perturbation is too large to be successfully handled by the ankle strategy, the hip strategy is needed. When the **hip strategy** is used, movement is centered about the hip and ankle muscles (anterior tibialis and gastrocnemius) are almost silent. The muscles in the trunk activate first as activation flows downward to the legs in a *proximal to distal* pattern. So, if the bus stops suddenly and the body bends forward, the low back and hamstrings

will contract in that order to return the body to upright.

If the perturbation is strong and your center of gravity moves well past your base of support, it is necessary to take a forward or backward step to regain balance. This is referred to as a **stepping strategy**. Studies have shown age-related changes in stepping in older adults. Compared to younger people, older adults initiate the stepping strategy in response to smaller losses of balance and tend to take several small steps rather than one larger step (Maki & McIlroy, 2006).

Arm movements have a considerable role in balance control and are part of the strategies discussed above. The upper limbs start to react at the very beginning of a disruption of balance and continue to be active as the body attempts to regain control. By automatically reaching and grasping for support, the arms perform a protective function. In the case of a small perturbation, upper limb movements can prevent a fall by shifting the center of gravity away from the imbalance.

When upper extremity paresis or spasticity is present, post stroke subjects exhibit poor protective reactions during a perturbation of balance. They demonstrate a deficit in anticipatory and reactive postural adjustments. These impairments of the affected upper limbs limit a person’s ability to recover from perturbations during functional tasks such as walking (Arya et al., 2014).

Even in the absence of a neurologic disorder, age-related changes affect upper extremity reaction time when balance is disrupted. Older adults reach for support surfaces more readily than younger adults but the reach-reaction time is slower. Increased tendency to reach for support and a slowing of these reactions have been found to be predictive of falling in daily activities (Maki & McIlroy, 2006).

Comparing Reflexes, Automatic Reactions, and Volitional Movement

Reflexes

Think for a moment that you are cooking dinner and accidentally touch a scalding hot fry pan. You feel the heat and withdraw instantaneously. You aren't thinking "I better take my hand off the hot pan before it burns me"—your reflexes take care of that for you. The withdrawal is almost instantaneous because your nervous system senses danger and reflexively withdraws.

Automatic Reactions

This type of reaction is used in movement strategies; they are slower than reflexes but faster than volitional movement. They are fast enough to help us respond to losses of balance without having to think.

Volitional Movement

This type of movement requires thought and is relatively slow compared to reflexive and automatic movement. Using our brains to think about movement isn't very practical when we need something done really fast—by the time your brain warns you to bend your waist, step forward, or grab onto something when the bus stops abruptly, it's already too late to regain balance.

Activity

Stand up next to your chair. Make sure you are standing on a flat, firm surface. Now close your eyes. Notice that your body sways a little—you are using the ankle strategy to stay balanced. Notice also that after a short amount of time you sway less—that means your nervous system is adjusting. Often, following a stroke, a person looses the ability to use the ankle strategy. This can have a profound impact on balance.

Stand up again. Ask someone to give you a **little** nudge from behind. Try not to take a step. If it was a truly small nudge you will likely bend at the waist to try to regain your balance. This is an example of the hip strategy.

Now ask your partner to give you a slightly bigger nudge from behind. If the nudge is big enough you'll have to take a step. This is the stepping strategy.

We use these strategies automatically, all day long, without effort. Someone who has had a stroke can't access these strategies as quickly as you can. If faced with a nudge from a passerby, or a bus starting/stopping, or a walk on uneven ground, the inability to adjust quickly may result in a fall.

Importance of Walking Early and Often

Regaining the ability to walk following a stroke is of paramount importance to patients and caregivers alike; improving balance and walking leads to greater independence and improves general well-being.

In the first week following a stroke, only one-third of patients are able to walk without assistance. In the following weeks, walking ability generally improves. At 3 weeks, or at hospital discharge, more than half of stroke survivors can walk unaided. By 6 months, more than 80% are able to walk independently without physical assistance from another person (Balasubramanian et al., 2014).

Following a stroke, walking can take a lot of energy; impaired muscle function, weakness, and poor cardiovascular conditioning can double the amount of energy expended. The high energy cost of walking can affect a person's ability to participate in daily activities and lead to a vicious cycle where physical activity is avoided. For example, in one study, stroke patients walked 50% of the daily amount of matched sedentary adults and used 75% of their VO2 peak for walking at a submaximal rate (Danielsson et al., 2011).

Walking may improve more rapidly when patients are involved in setting specific goals. The results of several motor learning studies in which the person's attention was focused on the outcome of an action rather than the action itself produced more effective performance than focusing on the quality of the movement (Carr & Shepherd, 2011).

In the hospital, an early goal for walking might be to walk to the next appointment, or to walk at least part of the way, rather than being transported in a wheelchair. Each day the patient should be encouraged to select a distance to walk independently and safely. Initially, this may be only a few steps. The goal is to walk the chosen distance a certain number of times a day, increasing distance as soon as possible, and keeping a record of progress, which gives the patient a specific focus (Carr & Shepherd, 2011).

Walking Adaptability, Stepping, and Postural Control

Walking is greatly dependent upon our ability to adapt to varying environmental conditions and tasks. Walking from the bedroom to the bathroom with a walker requires a different level of attention and adaptability than walking across a busy street carrying a bag of groceries. Even walking and talking can be a challenge for post stroke patients.

Over time, up to 85% of individuals with a stroke regain independent walking ability, but at discharge from inpatient rehab only about 7% can manage steps and inclines or walk the speeds and distances required to walk competently in the community. Limited ability to adjust to changes in the task and environment means a person either avoids walking in complex situations (a safety strategy) or has a heightened risk of falls when required to walk under these challenging conditions (Balasubramanian et al., 2014).

Despite its importance, assessment of walking adaptability has received relatively little attention. Frequently used assessments of walking ability after stroke involve walking short distances (such as the Timed Up and Go test) and examination of isolated limb movements (such as the Fugl-Meyer Assessment). Although valuable, these assessments do not take into account the skills needed to re-engage in safe and independent ambulation in the home and community. Comprehensive assessments and specific interventions are needed to improve walking adaptability (Balasubramanian et al., 2014).

In addition to the ability to adapt to different conditions and tasks, walking adaptability has two other requirements: (1) stepping, and (2) postural control (Shumway-Cook & Woollocott, 2012). Stepping involves the ability to generate and maintain a rhythmic, alternating gait pattern as well as the ability to start and stop. Postural control involves both the musculoskeletal and nervous systems.

To walk effectively, the central nervous system must:

1. Generate the basic stepping pattern of rhythmic reciprocal limb movements while supporting the body against gravity and propelling it forward.
2. Maintain control of posture (equilibrium) to keep the center of mass over a constantly moving base of support and maintain the body upright in space.
3. Adapt to environmental circumstance or changes in the behavioral goal (Balasubramanian et al., 2014).

These components are especially necessary for complex tasks. For example, walking adaptability is crucial on uneven ground or cluttered terrains and when the task requires walking and turning or negotiating a curved path. There are endless combinations of task goals and environmental circumstances that must be considered to comprehensively capture walking adaptability (Balasubramanian et al., 2014).

Walking Adaptability

Source: Balasubramanian et al., 2014.

Walking adaptability is very important for community ambulation. Patla and Shumway-Cook have described "dimensions" that affect a person's ability to adapt while walking. These are external demands that must be met for successful community mobility:

- Distance (distance walked)
- Temporal factors (time needed to cross a busy street or crosswalk, ability to maintain the same speed as those around them)
- Ambient conditions (rain, heat, snow, etc.)

- Physical load (packages carried, number of doors that need to be opened)
- Terrain (stairs, curbs, slopes, uneven ground, grass, elevators, obstacles)
- Attentional demands (distractions in the environment, noise, cars, crowds, talking)
- Postural transitions (stopping, reaching, backing up, turning head, change direction)
- Traffic density (number of people within arm's reach, unexpected collisions and near collisions with other people) (Shumway-Cook et al., 2002)

Improving Endurance for Walking

> It is evident that many patients are discharged from inpatient rehabilitation severely deconditioned, meaning that their energy levels are too low for active participation in daily life. Physicians, therapists, and nursing staff responsible for rehabilitation practice should address this issue not only during inpatient rehabilitation but also after discharge by promoting and supporting community-based exercise opportunities. During inpatient rehabilitation, group sessions should be frequent and need to include specific aerobic training. Physical therapy must take advantage of the training aids available, including exercise equipment such as treadmills, and of new developments in computerized feedback systems, robotics, and electromechanical trainers.
>
> Janet Carr and Roberta Sheperd
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Although many people affected by stroke have regained some ability to walk by the time they are discharged from rehab, many have low endurance, which limits their ability to perform household tasks or even to walk short distances. After a stroke, walking requires a much higher level of energy expenditure, and upon discharge many stroke patients are not necessarily *functional* walkers (Carr & Sheperd, 2011).

Functional walking is assessed using tests of speed, distance, and time. Minimal criteria for successful community walking include an independent walking velocity of 0.8 m/s or greater (about 2.6 feet/second), the ability to negotiate uneven terrain and curbs, and the physical endurance to walk 500 meters or more. In a review of 109 people discharged from physical therapy, only 7% achieved the minimum level. Cardiorespiratory fitness training can address both the efficiency with which people affected by stroke can walk and the distance they are able to achieve (Carr & Sheperd, 2011).

The loss of independent ambulation outdoors has been identified as one of the most debilitating consequences of stroke. Among stroke survivors 1 year after stroke, the most striking area of difficulty was low endurance measured by the distance walked in a 6-minute walk test. Those subjects able to complete this test were able to walk on average only 250 meters (820 feet) compared to the age-predicted distance of >600 meters (almost 2,000 feet), equivalent to 40% of their predicted ability and not far enough for a reasonable and active lifestyle. The detrimental effect of low exercise capacity and muscle endurance on functional mobility and on resistance to fatigue is likely to increase after discharge if follow-up physical activity and exercise programs are not available (Carr & Sheperd, 2011).

In 2002 the American Thoracic Society (ATS) published guidelines for the 6-minute walk test with the objective of standardizing the protocol to encourage its further application and to allow direct comparisons among different studies and populations. The American Thoracic Society guidelines include test indications and contraindications, safety measures, and a step-by-step protocol as well as assistance with clinical interpretation (Dunn et al., 2015).

Key components of the protocol include the test location, walkway length, measurements, and instructions. According to the American Thoracic Society protocol, the test should be performed on a flat, enclosed (indoor) walkway 30 m (just under 100 feet) in length. This protocol requires 180° turns at either end of the walkway and additional space for turning. The guidelines advise that shorter walkway lengths require more directional changes and can reduce the distances achieved. The influence of directional changes may be amplified in the stroke population, who characteristically have impaired balance, asymmetric gait patterns, and altered responses for turn preparation. Conversely, reducing the number of directional changes may increase the distance achieved (Dunn et al., 2015).

Body Weight-Supported Treadmill Training

Body weight-supported treadmill training (BWSTT) is an increasingly being used to encourage early walking following a stroke. It is a rehabilitation technique in which patients walk on a treadmill with their body weight partly supported. Body weight-supported treadmill training augments walking by enabling repetitive practice of gait (Takeuchi & Izumi, 2013).

In patients who have experienced a stroke, partial unloading of the lower extremities by the body weight-support system results in straighter trunk and knee alignment during the loading phase of walking. It can also improve swing1 asymmetry, stride length, and walking speed, and allows a patient to practice nearly normal gait patterns and avoid developing compensatory walking habits, such as hip hiking and circumduction2 (Takeuchi & Izumi, 2013).

[1]**Swing phase of gait**: during walking, the swing phase begins as the toe lifts of the ground, continues as the knee bends and the leg moves forward, and ends when the heel come in contact with the ground.

[2]**Circumduction**: a gait abnormality in which the leg is swung around and forward in a semi-circle. The hip is often hiked up to create enough room for the leg to swing forward.

Locomotor Training

Locomotor Training Program (LTP). Source: Duncan et al., 2007.

Another example of a body-weight supported treadmill. Source: NIH, 2011.

Treadmill walking allows for independent and semi-supervised practice, for those with more ability, as well as improving aerobic capacity and increasing walking speed and endurance. The very early practice of assisted over-ground and harness-supported treadmill walking is probably critical to good post-discharge functional capacity in terms of both performance and energy levels (Carr & Shepherd, 2011).

The Locomotor Experience Applied Post Stroke (LEAPS) trial—the largest stroke rehabilitation study ever conducted in the United States—set out to compare the effectiveness of the body weight-supported treadmill training with walking practice. Participants started at two different stages—two months post stroke (early locomotor training) and six months post stroke (late locomotor training). The locomotor training was also compared to a home exercise program managed by a physical therapist, which was aimed at enhancing flexibility, range of motion, strength, and balance as a way to improve walking. The primary measure was improvement in walking at 1 year after the stroke (NINDS, 2011).

In the LEAPS trial, stroke patients who had physical therapy at home improved their ability to walk just as well as those who were treated in a training program that requires the use of a body weight-supported treadmill device followed by walking practice. The study, funded by the NIH, also found that patients continued to improve up to 1 year after stroke—defying conventional wisdom that recovery occurs early and tops out at 6 months. In fact, even patients who started rehabilitation as late as 6 months after stroke were able to improve their walking (NINDS, 2011).

"We were pleased to see that stroke patients who had a home physical therapy exercise program improved just as well as those who did the locomotor training," said Pamela W. Duncan, principal investigator of LEAPS and professor at Duke University School of Medicine. "The home physical therapy program is more convenient and pragmatic. Usual care should incorporate more intensive exercise programs that are easily accessible to patients to improve walking, function, and quality of life."

Robotic Gait Training Devices

Several lower-limb rehabilitation robots have been developed to restore mobility of the affected limbs. These systems can be grouped according to the rehabilitation principle they follow:

- Treadmill gait trainers
- Foot-plate-based gait trainers
- Over-ground gait trainers
- Stationary gait trainers
- Ankle rehabilitation systems
  - Stationary systems
  - Active foot orthoses (Díaz et al., 2011)

Many robotic systems have been developed aiming to automate and improve body weight-assisted treadmill trainers as a means for reducing therapist labor. Usually these systems are based on exoskeleton type robots in combination with a treadmill. One such system—the Lokomat—consists of a robotic gait orthosis and an advanced body weight-support system, combined with a treadmill. It uses computer-controlled motors (drives) that are integrated in the gait orthosis at each hip and knee joint. The drives are precisely synchronized with the speed of the treadmill to ensure a precise match between the speed of the gait orthosis and the treadmill (Díaz et al., 2011).

The Lokomat System

Source: Diaz et al., 2011.

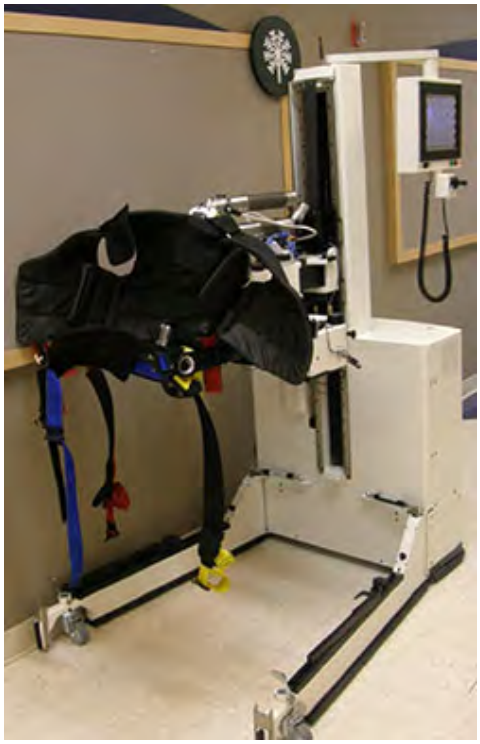
The LocoHelp System

The LokoHelp is another device developed for improving gait after brain injury. The LokoHelp is placed in the middle of the treadmill surface, parallel to the walking direction and fixed to the front of the treadmill with a simple clamp. It also provides a body weight-support system. Clinical trials have shown that the system improves the gait ability of the patient in the same way as the manual locomotor training; however, the LokoHelp required less therapeutic assistance and thus therapist discomfort is reduced. This fact is a general conclusion for almost all robotic systems to date (Díaz et al., 2011).

The LokoHelp gait trainer "Pedago." Source: Diaz et al., 2011.

The KineAssist

Over-ground gait trainers consist of robots that assist the patient in walking over ground. These trainers allow patients to move under their own control rather than moving them through predetermined movement patterns. The KineAssist is one robotic device used for gait and balance training. It consists of a custom-designed torso and pelvis harness attached to a mobile robotic base. The robot is controlled according to the forces detected from the subject by the load cells located in the pelvic harness (Díaz et al., 2011).



Source: Diaz et al., 2011.

The ReWalk Robotic Suit

ReWalk is a wearable, motorized quasi-robotic suit that can be used for therapeutic activities. ReWalk uses a light, wearable brace support suit that integrates motors at the joints, rechargeable batteries, an array of sensors, and a computer-based control system. Upper-body movements of the user are detected and used to initiate and maintain walking processes (Díaz et al., 2011).

The capacity of robots to deliver high-intensity and repeatable training make them potentially valuable tools to provide high-quality treatment at a lower cost and effort. These systems can also be used at home to allow patients to perform therapies independently, not replacing the therapist but supporting the therapy program. However, despite the attractiveness of robotic devices, clinical studies still show little evidence for the superior effectiveness of robotic therapy compared to current therapy practices, although robotics have been shown to reduce therapist effort, time, and costs (Díaz et al., 2011).


Source: Diaz et al., 2011.

Regaining Use of the Upper Extremity

After a stroke, many people experience motor and sensory impairment in the upper extremity. In contrast to lower extremity recovery, in which outcomes are more favorable, recovery of upper limb function after stroke is poor. In the Copenhagen Stroke Study for example, about a third (32%) of stroke patients had *severe* arm paresis at admission while more than a third (37%) had *mild* paresis. In 13%, the arm remained entirely non-functional despite comprehensive rehabilitation efforts (Foley et al., 2013b). These discouraging outcomes reflect the complex structure, range-of-motion, neurologic control, and function of the shoulder, arm, and hand.

The upper extremity is responsible for both reaching and grasping, and pathology affecting one often affects the other (Shumway-Cook & Woollocott, 2012). Motor control problems include:

- Delayed movement times
- Loss of ability to adapt to changing task demands
- Slowed reaction times (Shumway-Cook & Woollocott, 2012)

Upper extremity rehabilitation programs are typically designed and delivered by physical or occupational therapists, based on their assessment of movement impairment. The success of this approach depends on the skill and experience of the therapist and on the duration of treatment. However, there is no standard procedure for the assessment and treatment of the impairment in arm movement. This leads to the variability in the effectiveness of therapy and to the inability to compare interventions across practitioners and clinics (Olesh et al., 2014).

Additionally, current consensus is that physical therapy continues to be effective months and years after a neurologic damage such as stroke. However, with the current one-on-one hospital session approach, prolonged treatment is extremely expensive and usually does not last beyond the first month following a stroke (Olesh et al., 2014).

A variety of techniques and devices are used by rehabilitation therapists to treat patients with upper extremity dysfunction. Neurodevelopmental treatment (NDT) techniques, bilateral arm training, robot-assisted training, constraint-induced movement therapy, and neuromuscular electrical stimulation, to name a few, have all, to one degree or another, been shown to improve upper extremity function following a stroke. In general, research indicates that training should start as early as possible and be intensive, repetitive, and task-oriented (Brauer et al., 2013).

A review of the evidence for upper extremity interventions following stroke by Canadian researchers noted that the initial degree of motor impairment is the best predictor of motor recovery. Functional recovery goals are appropriate for those patients who are expected to achieve a greater amount of motor recovery in the arm and hand. Compensatory treatment goals should be pursued if there is an expected outcome of poor motor recovery. Attempts to regain function in the affected upper extremity should be limited to those individuals already showing signs of some recovery (Foley et al., 2013b).

For those with severe motor, sensory, and functional deficits in the involved limb after stroke, additional treatment for the upper limb will not result in any significant neurologic change. The evidence to date suggests that interventions may not lead to meaningful functional use of the affected limb, at least for those with severe deficits (Foley et al., 2013b).

Neurodevelopment Treatment (NDT)

There are a number of approaches that fall under the heading of neurodevelopmental techniques. These include the Bobath, Brunnstrom, and proprioceptive neuromuscular facilitation (PNF) approaches. Arguably, the Bobath approach is the most commonly used in the treatment of upper extremity impairment following a stroke (Foley et al., 2013b).

The motor control theory underlying neurodevelopmental treatment (NDT) emphasizes the concept that abnormal muscle patterns or muscle tone arise as a result of damage to the brain following a stroke. In order to inhibit abnormal tone, normal patterns must be practiced to facilitate functional and voluntary movements.

In several reviews of NDT vs. other treatment approaches, reviewers concluded that NDT was *not* superior to other types of interventions. A systematic review of specific neurologic treatment approaches also concluded that, compared to a Bobath (NDT) approach, no one particular program was favored over another with respect to improvement in functional outcomes (ADLs), muscle strength or tone, and dexterity, although motor relearning programs were associated with shorter lengths of hospital stays (Foley et al., 2013b). Despite this, theories based on neurodevelopmental theories continue to be used in the clinical setting.

Bilateral Upper Limb Training

Bilateral upper limb training involves the simultaneous use of both upper limbs with one limb moving actively and the other limb moving actively, passively, or with assistance (van Delden et al., 2012). This type of training is by no means a new form of stroke rehabilitation. Since days long past, therapists have used equipment (such as pulleys) to move the impaired upper limb simultaneously with the less impaired upper limb. Recently, there has been increased interest in bilateral upper limb training as new theories of neural plasticity have gained support (Foley et al., 2013b).

Theoretically, the use of the intact limb promotes functional recovery of the impaired limb through *coupling* between the upper limbs. Practicing bilateral movements may activate the intact hemisphere and facilitate the activation of the damaged hemisphere through neural networks linked via the corpus callosum (Foley et al., 2013b).

Coupling of upper extremity function is based on the following concepts:

1. Neurally mediated dependencies between the right and left upper extremities
2. Interhemispheric interactions along with bimanually triggered activation of similar neural networks in both hemispheres
3. Training-related plasticity of the brain (Sleimen-Malkoun et al., 2011)

Coupling between the two upper limbs has been investigated extensively in healthy subjects using rhythmic, inter-limb movements. Healthy subjects have a tendency to organize their arm movements in a symmetrical manner (same movement with both arms) or in a coordinated, alternating manner (same movement with opposite arms). These tendencies reflect the coupling between the upper limbs (van Delden et al., 2012).

Bilateral upper limb training is often done with either manual or computerized devices, which can be simple in design or part of a sophisticated robotic device. There is some evidence that bilateral arm training may be most effective in the early stages following a stroke when brain reorganization is at its peak (Shumway-Cook & Woollacott, 2012). These devices provide good support, allowing for unlimited repetitions and a wide variety of movements. Some examples are described in the next section.

Recent systematic reviews have produced mixed results on the superiority or inferiority of bilateral upper limb training over other interventions used in post stroke rehabilitation. Two reviews found strong evidence in support of bilateral upper limb training after stroke while three other systematic reviews concluded that bilateral training is as effective as other treatments but not better (van Delden et al., 2012).

Manual Bilateral Training Devices

BATRAC

Bilateral arm training with rhythmic auditory cueing (BATRAC) was introduced in 2000, together with a custom-made bilateral arm trainer. The device consists of two independent T-bar handles mounted on nearly frictionless tracks that can move in the transverse plane perpendicular to the user. The handles have to be pushed forward and pulled back, either with both upper limbs simultaneously (in-phase) or alternately (anti-phase), at a frequency paced by a metronome providing auditory cues. If a patient is unable to hold the handle with the hand of the most impaired upper limb, the hand is strapped onto it. The original BATRAC protocol focuses expressly on shoulder and elbow function (van Delden et al., 2012).

The BATRAC Training Devices

Left: Modified BATRAC apparatus. Right: A commercial version of BATRAC, called Tailwind, which, in addition to a forward and back motion, allows upward and outward movements. Reprinted with permission.

Reha-Slide Duo

The Reha-Slide Duo consists of a board with two sledges running on parallel tracks. Two handles on the sledges can be moved forward and backward separately, similar to the Tailwind used for BATRAC. The board on which the tracks are placed can be inclined up to 20° for upward movements, and friction for forward and backward movements can be adjusted for both handles separately via adjustable rubber brakes (with the board horizontal) (van Delden et al., 2012).

The Reha-Slide Bilateral Training Device

Reha-Slide Duo. Reprinted with permission (http://www.reha-stim.de/).

The Rocker for APBT

The Rocker for APBT

The Rocker for active-passive bimanual movement therapy. Reprinted with permission.

The device used for active-passive bimanual movement therapy (APBT) is a custom-built system of connected crankshafts located in the body of a unit that couples two manipulanda. It supports mirror symmetrical or near-symmetrical (a phase lag of 60°) coordination of wrist flexion and extension movements in the horizontal plane. With this system an actively moving less-impaired upper limb can passively move the most impaired upper limb in either a synchronous or (60° phase lag) asynchronous fashion (van Delden et al., 2012).

Robot-Mediated Bilateral Training Devices

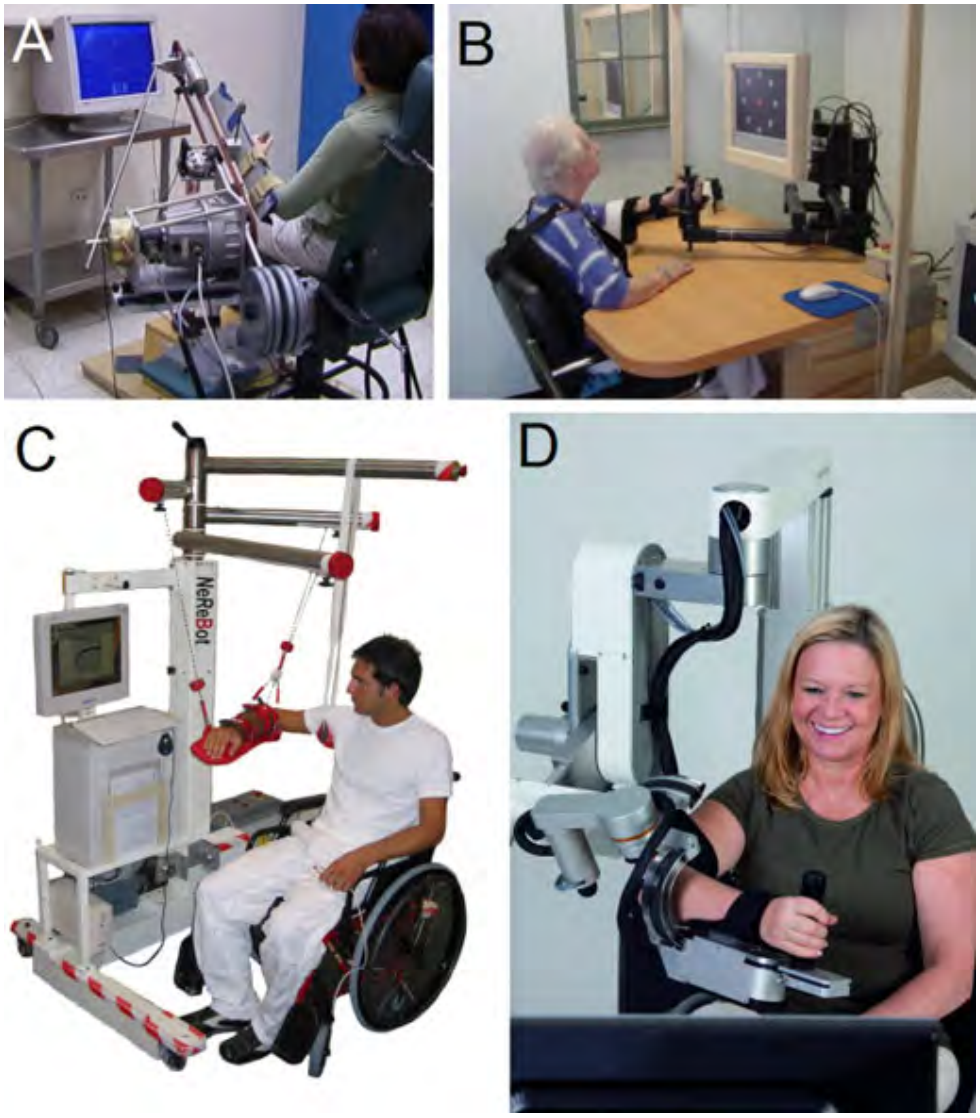
Robot-mediated therapy for the treatment of upper limb impairment dates back to the 1990s. Since then a number of robotic devices have become commercially available to clinics and hospitals. Robotic devices can provide high-intensity, repetitive, task-specific, interactive training. Typically, such robots deliver forces to the paretic limb while practicing multi-joint gross movements of the arm. Most of the robotic devices applied in clinical trials or clinical practice offer the possibility of choosing among four modalities for training: active, active-assisted, passive, and resistive (Basteris et al., 2014).

There is evidence that robotic interventions improve upper limb motor scores and strength, but these improvements are often not transferred to performance of ADLs. These findings are shared among the most recent studies, including the largest randomized controlled trial related to robot therapy to date. A possible reason for a limited transfer of motor gains to ADLs is that the earlier studies on robot-mediated therapy have only focused on the proximal joints of the arm. Integration of distal with proximal arm training is now recognized as essential to enhance functional gains (Basteris et al., 2014).

A growing body of evidence has shown that large numbers of repetitions—carried out within intense and specific task-oriented training programs—are required to drive neuroplastic changes and to improve function. Robot-mediated training is highly repetitive in nature, which allows stroke patients—including those with severe impairment—to repeat movements hundreds of times. This is physically impossible using ordinary treatment methods. This feature is mostly due, in the most advanced systems, to the use of active robotic controllers. Performance-based algorithms enable the robot to adjust the mechanical assistance during the training session according to the patient's motor performance. Most robotic devices use "assisted-as-needed" programs, the aim of which is to provide only as much assistance as the patient requires to complete the task (Duret et al., 2014).

Since the first clinical studies of the MIT-MANUS robot at the Massachusetts Institute of Technology, this innovative tool has continued to be studied clinically for the rehabilitation of the paretic upper limb, mainly after stroke. There are a multitude of studies of patients both in the acute and sub-acute phases of stroke recovery and in the chronic phase. The results are promising, showing that robotic therapy is safe and well tolerated and that it has a positive impact on improving motor impairments. These results led to the endorsement of the use of upper extremity robotics in the 2010 guidelines of the American Heart Association for Stroke Care (Duret et al., 2014).

Upper Limb Rehabilitation



Examples of mechanical structures or robotic devices for upper limb rehabilitation. A: ARM Guide—a simple system using linear bearing to modify orientation; B: InMotion ARM—an end-effector-based commercial system; C: NeReBot—a cable-driven robot; D: ArmeoPower—an exoskeleton-based commercial system (courtesy of Hocoma AG).

There is strong evidence that sensorimotor training with robotic devices improves upper extremity functional outcomes and motor outcomes of the shoulder and elbow. There is also strong evidence that robotic devices do *not* improve motor outcomes of the wrist and hand (Foley et al., 2013b).

Strength Training

A small group of studies have evaluated treatments directed at increasing strength as opposed to function in the upper extremity. A much larger pool of studies has been published on strength training in the lower extremity. In a review of five studies that evaluated strength training and that assessed measures of strength, reviewers found strong evidence that strength training increases grip strength following stroke (Foley et al., 2013b).

Constraint-induced Movement Therapy

Constraint-induced movement therapy (CIMT) is a therapeutic strategy that forces the use of the affected arm by requiring a patient to perform functionally oriented activities while the non-paretic arm is physically restrained with a sling or glove. It is thought that the repetitive training of the paretic arm and constraint of the non-paretic upper arm might be important for promoting neural plasticity (Takeuchi & Izumi, 2013).

Constraint-induced
Movement Therapy (CIMT)

This figure illustrates one of the key therapeutic principles of CIMT: restriction of the less affected hand induces the patient to use the affected arm to drink a glass of water. Source: NIH, n.d.

Different categories of CIMT have been identified, depending on the duration of the immobilization and the intensity of task-specific practice: (a) original CIMT, (b) high-intensity modified CIMT, (c) low-intensity modified CIMT, and (d) immobilization of the non-paretic arm (‘‘forced-use’’) (Veerbeek et al., 2014).

Several studies reported neural plasticity after CIMT as evidenced by neuroimaging and neurophysiologic techniques. Previous studies using transcranial magnetic stimulation (TMS) found that the cortical representation size of the paretic hand was increased after therapy. Neuroimaging studies also demonstrated altered neural network activity after CIMT. Moreover, a structural magnetic resonance imaging (MRI) study reported that CIMT increased gray matter in the bilateral sensorimotor cortices compared with control therapy. Thus, there is evidence that CIMT induces both structural brain and physiologic changes in patients with stroke (Takeuchi & Izumi, 2013).

Although there is conflicting evidence of the benefit of CIMT in the acute stage of stroke, there is strong evidence of the benefit of modified CIMT in the acute/subacute stage of stroke. There is strong evidence of benefit of CIMT and modified CIMT in comparison to traditional therapies in the chronic stage of stroke. Benefits appear to be confined to stroke patients with some active wrist and hand movements, particularly those with sensory loss and neglect (Foley et al., 2013b).

Mirror Therapy

Mirror therapy is a technique that uses visual feedback about motor performance to improve rehabilitation outcomes. It has been adapted from its original use for the treatment of phantom limb pain as a method to "re-train the brain" as a means to enhance upper-limb function following stroke, and to reduce pain. In mirror therapy, patients place a mirror beside the unaffected limb, blocking their view of the affected limb, creating the illusion that both limbs are working normally (Foley et al., 2013b).

Mirror therapy is based on the theory that the recovery of skilled movement following a stroke requires accurate somatosensory function, in particular, light touch and proprioception. It appears that a relationship exists between the amount of sensory impairment and the degree of motor recovery. With somatosensory loss present in more than 60% of people with stroke, it is important that rehabilitation interventions target sensory as well as motor impairments because somatosensory function contributes to performance of ADLs following stroke (Kuys et al., 2012).

The effectiveness of mirror therapy was evaluated recently in a Cochrane review. The results from 14 RCT (567 subjects) were included. A modest benefit of treatment was reported in terms of motor function, but the treatment effect was difficult to isolate due to the variability of control conditions (Foley et al., 2013b).

Mirror therapy is a treatment for which there is a limited body of evidence in its application to stroke rehabilitation. There is conflicting evidence that mirror therapy improves motor function following stroke and moderate evidence that it does *not* reduce spasticity (Foley et al., 2013b).

Preventing Contracture

Spastic contracture following stroke is the expression of hypertonicity or increased active tension of the muscle. Contracture may also occur as a result of atrophic changes in the mechanical properties of muscles. Since surgery is the only treatment option once a contracture has developed, prevention is essential (Foley et al., 2013b).

Splinting

Splints have been widely used in clinical practice, with the aim of preventing contractures and reducing spasticity; however, splints have not been well studied. There is strong (Level 1a) evidence that hand splinting neither reduces the development of contracture nor reduces spasticity (Foley et al., 2013b).

Stretching

Stretching may help to prevent contracture formation and, although well accepted as a treatment strategy, it has not been well studied. There is moderate evidence that a nurse-led stretching program can help to increase range of motion in the upper extremity and reduce pain in the chronic stage of stroke (Foley et al., 2013b).

Electrical Stimulation

The application of electrical stimulation at a *sensory* level may help to enhance plasticity of the brain, which in turn may help with motor recovery. This is typically accomplished using a **transcutaneous electrical nerve stimulator (TENS)**, which provides a current intensity beneath motor threshold, generating a "pins-and-needles sensation." Similar to acupuncture, TENS is one method of achieving increased afferent (sensory) stimulation (Foley et al., 2013b).

By contrast, at a *motor* level, neuromuscular electrical stimulation can improve neuromuscular function in patients with stroke by providing an electrical current that is strong enough to cause a muscle contraction. This can be used to strengthen muscles, increase motor control, reduce spasticity, decrease pain, and increase range of motion. Neuromuscular electrical stimulation is generally categorized as either therapeutic electrical stimulation or functional electrical stimulation (FES) (Takeuchi & Izumi, 2013).

The defining feature of *functional* electrical stimulation is that it provokes a muscle contraction and produces a functionally useful movement during stimulation. Several upper extremity FES devices are available, and the use of these devices seems to have a positive effect on upper-limb motor function in both acute and chronic stages of stroke (Takeuchi & Izumi, 2013).

FES has also been combined with different walking training strategies and has been shown to result in improvements in hemiplegic gait in both acute and chronic stages of stroke (Takeuchi & Izumi, 2013). In the shoulder joint, FES is mainly used to stimulate those muscles that are responsible for maintaining the head of the humerus in the glenoid fossa—especially the supraspinatus and the posterior deltoid, which counteract the inferior displacement of the humerus and can therefore prevent or restore subluxation, reduce pain, and improve function (Vafadar et al., 2014). Another well-known application of FES is the peroneal nerve stimulator in patients with a drop foot Quandt & Hummel, 2014).

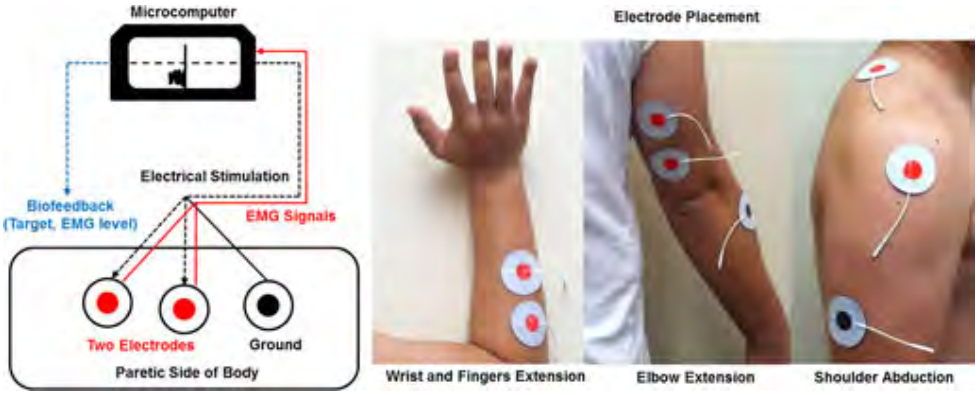
FES systems can be used to either substitute for or support movements and they are often applied in patients whose functional recovery has already plateaued. However, it has been shown that repeated muscle activation through FES might also lead to improvement of voluntary motor control beyond the time of stimulation, thus compounding the terms *therapeutic* and *functional* electrical stimulation and raising questions about exactly how FES influences motor recovery (Quandt & Hummel, 2014).

Numerous studies have found a positive impact of neuromuscular electrical stimulation for hand motor recovery after stroke, although strong evidence for its efficacy is still missing. A recent Cochrane review reported the superiority of electrical stimulation to no treatment; however, it could not identify an advantage over other treatment options such as conventional physical therapy (Quandt & Hummel, 2014).

Coupled Bilateral Training and Neuromuscular Stimulation

One effective rehabilitation protocol for those with post stroke upper extremity paresis involves coupled bilateral movements and neuromuscular stimulation on the more impaired arm. A study involving twelve volunteers with post stroke upper extremity weakness looked at the effects of neuromuscular stimulation on the impaired wrist and finger extensors, elbow extensors, and shoulder abductors. Subjects attempted to contract their impaired and weakened muscles while moving their other arm in the same motion (Kang et al., 2014).

Neuromuscular Stimulation



Experimental setup for providing electrical stimulation and recording EMG activation. Source: Kang et al., 2014.

The coupled bilateral movement training revealed more blocks moved, faster reaction time, greater force production, and higher peak limb velocity. Subjects attempted to contract their impaired and weakened muscles while moving their other arm in the same motion. Surface electrodes attached to the weakened muscles and microcomputer monitored activation levels. Once the muscle activity reached a target intensity level, the microcomputer automatically provided neuromuscular stimulation and movement was executed. The coupled bilateral movement training helped the impaired muscles perform basic movements (Kang et al., 2014).

When Upper Extremity Impairment Is Severe

Many of the techniques discussed in the previous section are effective for patients with mild to moderate weakness in an upper extremity. In more impaired patients, two issues limit the active involvement of the arm and hand in training:

- Reduced proximal arm function to transport the hand to a target, and
- Inability to actively open and close the hand once at the target (McCombe et al., 2014).

Device for Rhythmic Bilateral
Arm Training

The Tailwind. Source: van Delden et al., 2012.

Studies focusing on more severe populations show promising results but are limited to proximal training approaches, which do not result in improvements in paretic hand function. To address these specific challenges, researchers at the University of Maryland developed a two-phase rehabilitation approach. Participants received either 6-weeks of bilateral proximal training followed sequentially by 6-weeks unilateral task-oriented training (COMBO) or 12-weeks of unilateral task-oriented training alone (SAEBO) (McCombe et al., 2014).

In Phase 1, participants received progressive bilateral arm training with rhythmic auditory cueing (BATRAC) for 6 weeks with a focus on improving **proximal** motor function and to potentially "prime" the central nervous system before transitioning in Phase 2 (McCombe et al., 2014).

Saeboflex Device for Hand Orthosis

The Saeboflex dynamic hand orthosis. Source Saebo.com. Used with permission.

In Phase 2, participants received unilateral task-oriented training using the Saeboflex dynamic hand orthosis to aid in active participation of the hand. Researchers compared this training approach to two 6-week sessions of time-matched unilateral task-oriented Saeboflex training with no proximal movement priming (McCombe Waller et al., 2014).

The results indicated that combining bilateral and unilateral task-oriented training improved arm and hand function more than unilateral task-oriented training alone in participants with moderate to severe chronic hemiparesis (McCombe et al., 2014).

Treatment of Edema

Hand edema with hemiparesis is associated with pain and stiffness, which can lead to a decrease in active motion and disuse. The etiology of the development of hand edema is unclear—it may be an isolated problem or occur as a symptom of shoulder-hand syndrome. The most widely accepted explanation is increased venous congestion related to prolonged dependency and loss of muscle pumping function in the paretic limb (Foley et al., 2013b).

Three different treatment approaches to aid in the reduction of hand edema following stroke have been studied, including passive motion exercises, neuromuscular stimulation, and intermittent pneumatic compression. There is moderate evidence that intermittent pneumatic compression does *not* reduce hand edema following stroke. There is limited evidence that both neuromuscular nerve stimulation and continuous passive motion help to reduce hand edema compared to limb elevation (Foley et al., 2013b).

Swallowing (Dysphagia)

Therapist Assisting Dysphagia Patient

Source: NIH, 2013.

Dysphagia, or difficulty eating and swallowing, is a major complication following both hemispheric and brainstem stroke. Dysphagia has been associated with higher rates of respiratory complications and increased risk of aspiration pneumonia, dehydration, and nutritional compromise. Dysphagia has also been associated with poorer outcomes in stroke and increased likelihood of residential placement (Langdon & Blacker, 2010).

Speech and language pathologists have a key role in the assessment, diagnosis, and treatment of stroke-associated dysphagia. Because a large percentage of patients will have ongoing problems with swallowing, the speech-language pathologist plays a key role in monitoring and reviewing a patient's progress over time.

Screening for Dysphagia

Screening for dysphagia is an important aspect of care in the acute phase of a stroke, regardless of stroke severity. There is good evidence that the presence of dysphagia following a stroke is associated with poor clinical outcomes including higher mortality, disability, chest infection, and longer hospital stay (RCP, 2012). Screening should be completed by nursing soon after admission, before the patient is given any food or fluids. Anyone showing signs of dysphagia should receive a formal swallowing evaluation by a speech-language pathologist as soon as is feasible.

In a review of swallowing assessment methods, the bedside swallow assessment was the most frequently used method (RCSLT, 2014). If a more thorough assessment is needed, videofluoroscopy (a type of x-ray) is commonly used. Another assessment tool, **fiber-optic endoscopic evaluation of swallowing (FEES)** has improved accuracy for the detection of dysphagia, aspiration, and its underlying causes. It is also used to evaluate methods of management by examining the impact of different head positions and dietary substances and the impact of these on improving swallowing (RCSLT, 2014).

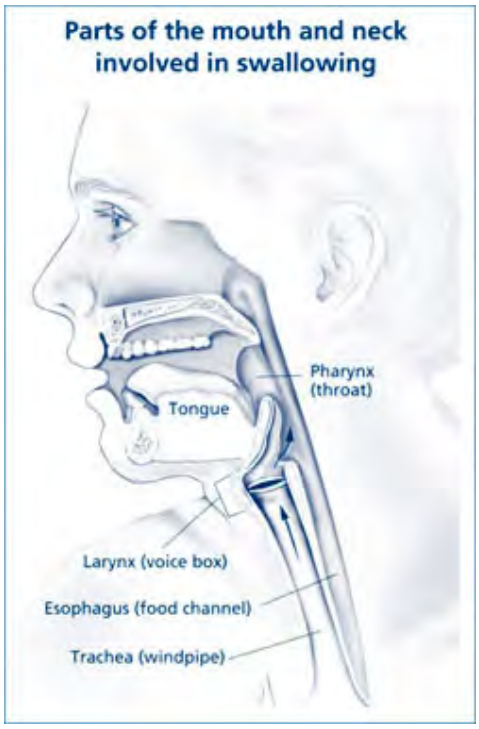
In recent years, cervical auscultation has been adopted for the bedside/clinical assessment of dysphagia. Cervical auscultation is the use of a listening device, typically a stethoscope, to assess the sounds associated with swallowing. Listeners interpret the sounds and make inferences about the efficiency of the swallow or cause of the impairment. There is no agreement on the origin and implication of the sounds heard when using this technique to assess swallowing and the reliability of raters using this technique has been found to be poor (RCSLT, 2014).

Pulse oximetry has also been suggested as an alternative to monitoring swallowing and detecting aspiration. Pulse oximetry is well tolerated, requires little patient co-operation, and is an inexpensive option to other instrumental assessments such as videofluoroscopy. Using pulse oximetry to detect aspiration is based on the principle that reduced and oxygenated hemoglobin exhibits different absorption characteristics to red and infrared light emitted from a finger or ear probe. Pulse oximetry measures the frequency and severity of oxygen desaturation of arterial blood, which is recognized as a possible marker of aspiration. Although pulse oximetry is a quick and non-invasive method to detect aspiration following stroke, its association with oxygen desaturation has been inconclusive (RCSLT, 2014).

Stages of Swallowing

Swallowing is a complex process. Some fifty pairs of muscles and many nerves work to receive food into the mouth, prepare it, and move it from the mouth to the stomach. This happens in three stages. During the first stage, called the **oral phase**, the tongue collects the food or liquid, making it ready for swallowing. The tongue and jaw move solid food around in the mouth so it can be chewed. Chewing makes solid food the right size and texture to swallow by mixing the food with saliva. Saliva softens and moistens the food to make swallowing easier. Normally, the only solid we swallow without chewing is in the form of a pill or caplet. Everything else that we swallow is in the form of a liquid, a puree, or a chewed solid (NIDCD, 2014).

Anatomy of Swallowing



Source: NIH, 2010.

The second stage begins when the tongue pushes the food or liquid to the back of the mouth. This triggers a swallowing response that passes the food through the pharynx, or throat (see figure at right). During this phase, called the **pharyngeal phase**, the larynx (voice box) closes tightly and breathing stops to prevent food or liquid from entering the airway and lungs (NIDCD, 2014).

The third stage begins when food or liquid enters the esophagus, the tube that carries food and liquid to the stomach. The passage through the esophagus, called the **esophageal phase**, usually occurs in about three seconds, depending on the texture or consistency of the food, but can take slightly longer in some cases, such as when swallowing a pill (NIDCD, 2014).

Treatment of Dysphagia

The first critical point in nutritional control for patients with dysphagia is to prevent aspiration. Although thickener is generally applied to liquid boluses to prevent early inflow into the pharynx and larynx, increased bolus viscosity may decrease the bolus transit speed, potentially increasing the risk of pharyngeal residue. As for solid boluses, swallowing without sufficient mastication can again lead to residue and an increased risk of aspiration (Yokoyama et al., 2014).

A number of techniques and interventions have been reviewed for their efficacy in treating swallowing disorders. One such treatment—tongue pressure resistance training—has emerged as an innovative treatment for dysphagia. Studies by JoAnne Robbins, a professor at the University of Wisconsin School of Medicine and Public Health, have shown that 8 weeks of intensive tongue pressure resistance training improved tongue strength in healthy seniors and those with both chronic and acute dysphagia following stroke (Steele et al., 2013).

In these studies, Robbins had the participants complete an 8-week tongue-strengthening training protocol with an Iowa oral performance instrument (IOPI). Her findings included significantly improved isometric tongue pressures and swallowing pressures in all of the three populations that she studied (healthy participants, acute dysphagia, and chronic dysphagia). Although significant gains were made in airway protection, as judged by reduced scores on the penetration-aspiration scale, it is of ongoing concern that people with dysphagia after a stroke often have difficulty controlling the flow of thin liquids. Early arrival of a liquid bolus in the pharynx, secondary to poor oral control, represents a risk of penetration-aspiration (entry of material into the airway) (Steele et al., 2013).

Another promising approach to the treatment of dysphagia is neuromuscular electrical stimulation of the swallowing muscles. Electrical stimulation has two general purposes: to cause muscle contractions and to stimulate the sensory pathways. In the first approach, the intensity of electrical current is increased until the muscle contraction occurs. Strengthening of the swallowing muscles may improve airway protection and increase the width of the upper esophageal sphincter opening (Poorjavad et al., 2014).

In the sensory approach, the sensory threshold is usually identified as the lowest current level at which the patient feels a tingling sensation on his or her neck skin. Considering the sensory stimulation effects on the long-term reorganization of the human cortex, some researchers use sensory electrical stimulation to improve swallowing function (Poorjavad et al., 2014).

Cognitive Changes After a Stroke

The human brain is responsible for all of the functions that define who we are and how we relate to one another—our talents, our intellect, our creativity, our ability to participate in sports, to communicate, and to understand and share in the emotions of others. Stroke can interfere with any or all of these functions. In fact, most of the brain supports cognitive and integrative processes underlying complex systems, such as attention, working memory, cognitive control, and language that are critical for these activities. Yet, stroke outcomes research traditionally has focused on recovery of the basic activities of daily living, such as feeding oneself and walking (Hillis & Tippett, 2014).

Studies that have investigated quality of life or health-related quality of life after stroke have focused on motor function, communication, and ADLs. These studies have found that age, nonwhite race, impaired upper-extremity function, and greater number of comorbidities are all associated with reduced health-related quality of life within the *physical* domain. A larger number of comorbidities are also associated with poorer health-related quality of life in the domain of *memory* and *thinking*, and stroke survivors whose hemiparesis affected the dominant side or had ischemic (rather than hemorrhagic) stroke reported poorer health-related quality of life in the domain of *communication* (Hillis & Tippett, 2014).

At the Stroke Cognitive Outcomes and Recovery (SCORE) Lab at Johns Hopkins University School of Medicine, researchers have noted that stroke survivors or their caregivers frequently reported problems that are not typically measured by stroke scales—difficulty in sleep or sex, overwhelming fatigue, change in personality, and so on (Hillis & Tippett, 2014). In an attempt to clarify problems and issues not captured by traditional outcome measures such as Modified Rankin Scale, the Barthel Index, and the National Institutes of Health Stroke Scale, researchers developed a survey tool focused on cognitive issues.

The single most frequently reported important/moderate consequence by both survivors of *left* hemisphere stroke and their caregivers was difficulty in spelling or writing. Word retrieval and mood problems were also frequently reported, as was right-sided weakness (Hillis & Tippett, 2014).

Right hemisphere stroke survivors reported fatigue, left-sided weakness, problems with mood, reading, writing, memory, and sexual function. The most frequently reported important/moderate consequence by caregivers of right hemisphere stroke survivors was impaired recognition of the emotions of others (loss of emotional empathy), identified by 50% of caregivers, followed by “other cognitive problems,” “change in personality and behavior,” and “walking” (Hillis & Tippett, 2014).

These results reveal that deficits in spelling and writing after left hemisphere stroke and loss of empathy after right hemisphere stroke are probably underestimated as residual consequences of stroke. Spelling has taken on new importance in a community that relies on email, texting, and online shopping and banking. The importance of empathy in communication and social relationship has been understood by social scientists for decades, but little attention has been given to impairments of empathy after stroke. Efforts to understand the variables that mediate these deficits and interventions to alleviate these problems are essential to improve quality of life after stroke (Hillis & Tippett, 2014).

Cognitive Impairment and Dementia

As many as two-thirds of stroke patients experience cognitive impairment or cognitive decline following a stroke; approximately one-third go on to develop dementia. The risk for cognitive impairment or decline is increased by a history of stroke. The risk for developing dementia may be 10 times greater among individuals with stroke than those without. Mortality rates among stroke patients with dementia are 2 to 6 times greater than among stroke patients without dementia (Teasell, McClure, Salter, Murie-Fernandez, 2014).

While cognitive decline may continue post stroke, about one-fifth of patients with cognitive impairment improve. Most improvement occurs in the first 3 months after a stroke although recovery may continue for up to a year (Teasell, McClure, Salter, Murie-Fernandez, 2014).

Cognitive impairment is associated with decreased ADL and independent ADL function and patients with impaired cognition may require longer-term, ongoing rehabilitation. Reduced cognition has been associated with a decreased ability to perform ADLs, with poorer physical functioning at discharge and with a greater likelihood of mortality within 1 year of discharge (Teasell, McClure, Salter, Murie-Fernandez, 2014).

The presence of cognitive impairment is strongly linked to post stroke outcomes. Estimates of cognitive function assessed 2 to 3 weeks post stroke strongly predict patients' practical functioning after 13 months of post stroke recovery. In addition, cognitive impairment measured 3 months after first-ever stroke has been associated with increased risks of death and disability 4 years later (Han et al., 2014).

Cognitive rehabilitation focuses on several areas of cognition such as attention, concentration, perception, memory, comprehension, communication, reasoning, problem-solving, judgment, initiation, planning, self-monitoring and awareness (Teasell, McClure, Salter, Murie-Fernandez, 2014).

Cognitive rehabilitation aims to:

- Reinforce, strengthen, or reestablish previously learned patterns of behavior
- Establish new patterns of cognitive activity through compensatory cognitive mechanisms for impaired neurological systems

- Establish new patterns of activity through external compensatory mechanisms such as personal orthoses or environmental structuring and support
- Enable persons to adapt to their cognitive disability (Teasell, McClure, Salter, Murie-Fernandez, 2014)

Apraxia

As mentioned earlier, apraxia is the loss of the ability to organize a movement or perform a purposeful act. It is a disorder of the execution of movement that cannot be attributed to weakness, incoordination, sensory loss, poor language comprehension, or attention deficit. **Apraxia** is a weakening of the top-down formulation of an action—the inability to sustain the intent to complete a movement. As a result, the nervous system is easily influenced by irrelevant input—a sort of pathologic absent-mindedness.

Apraxia is common in patients with left hemispheric strokes, especially in lesions involving the left frontal and parietal lobes. It can be spontaneous during everyday activities (difficulty with dressing, using utensils, starting the car, turning keys to open doors). In can cause difficulty when performing motor tasks and becomes evident when the patient is asked to do something and appears unable to initiate or complete the task (Teasell, McClure, Salter, Murie-Fernandez, 2014).

Visual-Perceptual Disorders

[This section taken largely from Teasell, MClure, Salter, Murie-Fernandex, 2014.]

Unilateral spatial neglect is a visual-perceptual disorder that can be one of the most disabling features of a stroke. **Neglect** is a sensory dysfunction caused by damage to the parietal lobe in which a person is unaware of the contralateral (opposite) side of the body, including half of the visual field. It causes a disruption of a person’s body schema and spatial orientation and adversely affects a person’s balance and safety awareness. Those suffering from neglect are often unaware that the second half of the body exists and will deny that anything is wrong.

Clinically, the presence of severe unilateral spatial neglect is apparent when a patient collides with his or her surroundings, ignores food on one side of the plate, and attends to only one side of the body. However, symptoms of unilateral spatial neglect have to be quite severe for this impairment to be observed easily during the performance of functional activities. More subtle forms of unilateral spatial neglect may go undetected in a hospital setting but are a major concern for client function and safety upon discharge. Mild symptoms of unilateral spatial neglect become apparent during high-level activities such as driving, riding a bicycle, working with tools, or while interacting with others.

Unilateral spatial neglect has been reported to have a negative impact on functional recovery, length of rehabilitation stay, and the need for assistance post discharge. While the majority of patients diagnosed with visuospatial inattention post stroke recover by 3 months, those with severe visuospatial inattention on initial presentation have the worst prognosis. The presence of unilateral spatial neglect has been associated with poorer functional outcome, poorer mobility, longer length of stay in rehabilitation, and a greater chance of institutionalization upon discharge from rehabilitation.

There are currently more than sixty standardized and non-standardized assessment tools available to assess unilateral neglect. Line bisection test, Albert's test, single letter cancellation test, star cancellation test, and Bell's test are all examples of simple, pencil-and-paper tests used to detect the presence of unilateral spatial neglect. All can be administered at the bedside in just a few minutes. However, the patient must be able to follow instructions as well as hold and use a pencil with reasonable accuracy in order to complete these types of tests reliably. In 2006 the Canadian Stroke Rehabilitation Outcomes Consensus Panel selected the line bisection tool as its preferred standard for the identification of unilateral spatial neglect.

In general, rehabilitation interventions to improve neglect may be classified into those that (1) attempt to increase the patient's awareness of or attention to the neglected space and; (2) those that focus on the remediation of deficits of position sense or body orientation.

Examples of interventions that attempt to improve awareness of or attention to the neglected space include the use visual scanning retraining, arousal or activation strategies, and feedback to increase awareness of neglect behaviors.

Interventions that attempt to improve neglect by targeting deficits associated with position sense and spatial representation include the use of prisms, eye-patching and hemi-spatial glasses, caloric stimulation[1], optokinetic stimulation[2], TENS, and neck vibration.

[1]**Caloric stimulation**: a procedure in which cool or warm water is introduced into the ear canal.

[2]**Optokinetic stimulation**: the use of visuospatial patterns such as moving white vertical stripes, random black dots, or other moving patterns to produce nystagmus.

Aphasia

Aphasia is an acquired language disorder that affects a person's ability to comprehend and produce language. The most common form of aphasia occurs because of damage to the left cerebral hemisphere; the left hemisphere is dominant for language in 99% of right-handed people (93% of the population). Aphasia can occur in left-handed people as a result of damage in the right hemisphere—about 30% of left-handed people with post stroke aphasia have right hemispheric strokes (Teasell et al., 2014).

Aphasia affects about one-third of the stroke population, and roughly 40% continue to have significant language impairment a year and a half after the stroke (Bronken et al., 2013). Impairment ranges from mild, involving difficulties in finding words, to severe, involving severe impairment of all language modalities (expression and comprehension of speech, reading, and writing and the use of language as a flexible tool in everyday life) (Bronken et al., 2013).

There is a large body of evidence suggesting the brain undergoes tremendous recovery and reorganization of structure and function following a stroke. Specific linguistic impairments, such as phonological disorders[1], lexical semantic impairments[2], and syntactic impairments[3], can show substantial recovery in the first few months following a stroke (Kiran, 2012).

[1]**Phonological disorders**: A type of speech disorder also known as an *articulation disorder*. Can be caused by changes in the structure or shape of the muscles and bones that are used to make speech sounds. Also can be related to damage to parts of the brain or the nerves that control how the muscles and other structures work to create speech.

[2]**Lexical semantic impairments**: A disruption in a person's ability to recognize word forms (sound, spelling, and word properties), and perceive and understand their meaning. Traditionally associated with Wernicke's aphasia.

[3]**Syntactic impairments**: Speech that lacks structure—traditionally associated with Broca's aphasia. Typically involves word substitutions and omissions, reduced sentence length, and reduced sentence complexity.

Recovery of language function after stroke is thought to occur in three overlapping phases, each with a unique set of underlying neural phenomenon:

- Acute phase—lasts for about 2 weeks after the onset of the lesion.
- Second phase—the subacute phase—usually lasts up to 6 months after onset.
- Chronic phase begins months to years after stroke, and it may continue for the remainder of the person's life (Kiran, 2012).

Although each of these phases is accompanied by a tremendous amount of physiologic change, much is unknown about the precise mechanisms underlying language recovery in post stroke aphasia. There have been several recent reviews examining advances in neuroimaging of recovery from aphasia, and all of them underscore the need for further careful and systematic research in this topic. Even in situations when language is recovered, it is not known whether the regions of activation observed are truly due to reorganization of language abilities to other functionally capable regions or due to utilization of abnormal cognitive strategies (Kiran, 2012).

The conventional treatment for aphasia usually begins during hospitalization in the intensive rehabilitation unit. The therapeutic management of aphasia is a long-term process that frequently does not end with a complete recovery of language and communication functions. For many patients the progress toward functional communication is steady but slow, while other patients need to be assisted to learn compensatory strategies for an effective communication. After discharge, the complex issues associated with stroke often reduce a patient's autonomy and can affect their ability to continue with outpatient rehabilitation (Agostini et al., 2014).

In a large study of chronic aphasia recovery, researchers found that the single most important determinant of recovery of speech production was time since onset of stroke, indicating that improvement continues over time, even in the chronic stage. The brain recovers from a focal lesion like stroke through a variety of mechanisms that take place at different times after onset (Hillis & Tippett, 2014).

Bilingual Aphasia

[This section taken largely from Ansaldo & Saldi, 2014.]

The bilingual population is large and growing worldwide, and bilingual aphasia is becoming more and more frequent. The behavioral patterns observed in bilingual aphasia are complex, involving two (or more) languages, whose recovery does not always follow monolingual patterns. Given the almost endless possible combinations of language pairs, the issue of bilingual aphasia therapy is a big challenge. Even the most *avant garde* educational policies aimed at training bilingual speech-language pathologists are likely to provide only partial solutions to the clinical management of this population.

Bilingualism imposes challenges regarding the assessment and intervention provided to bilingual clinical populations, particularly those who suffer from cognitive impairment. The complexity of this issue extends well beyond the linguistic knowledge required to interact with the patient. Beyond language, there is communication, which is essential for the understanding—what is normal and what is not—in the context of a given culture.

The issue of language impairment in bilingual people has interested cognitive neuroscientists for more than a century. This has led to the development of bilingual aphasia tests for a variety of language pairs, among which the Bilingual Aphasia Test (BAT)—developed for more than 59 languages—and the Multilingual Aphasia Examination developed in six languages. Additionally, there are tests normalized in several languages, such as the Aachen Aphasia, and the Boston Diagnostic Aphasia Examination. These tests provide a linguistically valid assessment of bilingual aphasia.

Recently, researchers have focused on the complex issue of bilingual aphasia language therapy, with the purpose of developing the most efficient procedures for triggering language recovery in this population. This is a relatively new field, and a complex one, given that it requires juggling the complexities of bilingual language processing, which amounts to more than simply the additive processing of two languages.

Psychosocial Issues and Depression

A significant number of people struggle with psychological and psychosocial issues and depression following a stroke. Many will require mental health treatment to address depression, anxiety, frustration, or anger.

These psychiatric comorbidities have a powerful influence over both quality of life and functional outcomes. In a sample of more than 50,000 ischemic stroke patients, those patients diagnosed with depression or other mental health concerns had an increased risk of death 3 years post stroke, even after the influences of other chronic conditions were statistically controlled (Han et al., 2014).

Post Stroke Depression

Post stroke depression has both physical and psychological components and it is thought that about one-third of all people who have had a stroke will develop depression (Hackett et al., 2008). The presence of depression is significantly and independently associated with the presence of cognitive impairment in stroke survivors 1 year following the stroke event (Teasell, McClure, Salter, Murie-Fernandez, 2014). Women are at a higher risk than men for experiencing depression, and people who have had difficulties with depression prior to stroke are more likely to have a resurgence of their depressive symptoms post stroke.

Depression, grief, and sadness have an enormous impact on stroke survivors and their caregivers. People who were accustomed to living independently suddenly become reliant on others—either voluntary or hired. This results in physical, psychological, and financial adjustments that must be made to their day-to-day life. Therapy and other forms of counseling can help people regain some level of independence and gradually adjust to changes induced by the stroke (Hackett et al., 2008).

Several factors may affect the risk and severity of depression after a stroke, including:

- Area of the brain where stroke damage occurred
- Personal or family history of depression or other mood or anxiety disorders
- Level of social isolation before the stroke (NIMH, 2011)

Diagnosis of depression after stroke is the same as depression at other times. Consider a diagnosis of depression if symptoms last for more than two weeks. Warning signs include:

- Deep, ongoing sadness or anxiety
- Loss of interest in activities that were once enjoyable
- Lack of motivation, difficulty making decisions
- Poor concentration, difficulty remembering details
- Low self-esteem, feelings of worthlessness, helplessness
- Sleep difficulties, sleeping all the time, difficulty falling asleep or staying asleep
- Overeating or loss of appetite

Some people who are depressed may also be unable to modulate their emotions. They may laugh or cry inappropriately or become volatile. Pre-existing drug or alcohol problems may resurface or become exacerbated, making it more difficult to participate in rehabilitation activities.

Recovery from depression takes time, but treatments can be effective. At present, the most common treatments for depression include:

- Cognitive behavioral therapy (CBT)
- Selective serotonin reuptake inhibitors (SSRIs) such as citalopram (Celexa), sertraline (Zoloft), and fluoxetine (Prozac)
- Serotonin and norepinephrine reuptake inhibitor (SNRI) such as venlafaxine (Effexor) and duloxetine (Cymbalta) (NIMH, 2011)

People recover better from a stroke if they receive good support and comprehensive care. In the long term, they cope more successfully if their treatment is well-organized with a well-coordinated team identifying and meeting needs as they arise. Stroke recovery also requires that the individual be highly motivated in order to adhere to a plan of care. Early identification and referral when depression is suspected helps to ensure that patients receive the support and understanding needed to adjust to sudden and overwhelming changes to their life (Han et al., 2014).

To address this intersection of neurology and neuropsychology, the National Institute of Neurological Disorders and Stroke–Canadian Stroke Network (NINDS-CSN) developed a **vascular cognitive impairment (VCI)** half-hour assessment protocol. The assessment is used to monitor proactively stroke patients' cognitive, psychiatric, and functional outcomes during outpatient followup. In this model, neuropsychologic assessments are integral to supporting stroke patients' quality of life and increasing patient satisfaction with stroke-related healthcare services. Acknowledging this, recent standards called for routine, standardized cognitive and mood assessment in both clinical practice and research with stroke patients (Han et al., 2014).

Changes in Identity

The sudden and dramatic onset of cognitive changes such as aphasia following stroke is associated with major disruptions of a person's quality of life. The psychosocial adjustment process is complicated and protracted, and people with aphasia are especially prone to psychosocial problems such as anxiety and depression, disruptions related to identity, changes in their relationships with significant others, reduced social networks and social isolation and exclusion, unemployment, and loss of leisure activities. The emotional and psychosocial factors have a marked impact on recovery, the psychosocial adjustment process, and the response to rehabilitation (Bronken et al., 2013).

In particular, aphasia has a profound effect on a person's identity. It affects occupational identity, family relationships and roles, and social identity. In a number of semi-structured interviews with 12 post stroke survivors with aphasia, these themes were touched on again and again. All participants were employed fulltime prior to their strokes and none had been able to return to their previous jobs (Musser et al., 2015).

Participants spoke about the difficulty they had accepting the loss of an occupational identity and their struggle to find some kind of work they could do. Participant "J" narrated the difficulty he had accepting that he could not return to work, describing his experience of driving to his office repeatedly and trying to engage in his previous occupation. Participant "S," whose stroke was more recent, was still trying to come to terms with his options for employment and income. Both participants expressed the sense of displacement they felt when they were abruptly forced to retire from their professions (Musser et al., 2015).

Many participants, once they had received a certain amount of rehabilitation, were eager to engage in some kind of meaningful activity. Several became hospital volunteers or peer visitors to other stroke patients; they were able to draw on their own experiences in a way that they felt would be helpful to others. One participant, "B," who had previously worked as a computer programmer, responded enthusiastically to the subject of volunteering at the hospital. "B" and his partner framed his volunteer work in terms of an earlier aspiration to be a physician. This reclaiming of an occupational identity helped him to embrace a sense of meaning in his daily activities (Musser et al., 2015).

While the changes in occupational identity were often individually experienced, the shifts in relationships and family roles were often jointly negotiated by the participant and other people, their partner or children. Participants and their partners spoke of changes in the dynamic of their relationship as the result of aphasia. In some cases, the balance of responsibilities in the relationship shifted. While the participants spoke about the impact of aphasia on their occupation, "J's" wife characterized the experience in terms of this shift in balance and roles. She acknowledged feeling overwhelmed by the change (Musser et al., 2015).

Participants and their partners also talked about the changes they experienced in their sense of themselves in their broader social lives: their level of independence and their ability to meet and talk to new people. They discussed the impact of the aphasia on their friendships and social support, especially in terms of the partner. "V's" wife noted his difficulty meeting and talking to people. She describes him as friendly and talkative before the stroke, a personal style that she feels has since changed. Here, she reflects that his aphasia makes it much harder for him to relate to people in the way he did before and results in his withdrawing more at social events and enjoying them less. Previously, "V" knew himself as someone who enjoys being around others; now, he is more self-conscious and avoids situations where he might have to introduce himself or talk to acquaintances. As "V's" wife notes, while his stroke has changed his ability to interact with others, the more profound change is in "V" himself—his desire to be social and his social identity (Musser et al., 2015).

Physical Activity and Functional Exercise

Stroke survivors often have low levels of physical fitness and muscle strength, which impact their ability to perform everyday activities and adversely affect their household and community independence. There is greater awareness now of the need for patients to practice everyday actions intensively in order to regain motor control. However, it is only recently that interest has turned to the physiologic effects of inactivity—especially the effect deconditioning has on an individual's ability to engage in motor training at a level necessary to improve functional performance and promote brain reorganization (Carr & Sheperd, 2011).

Low aerobic capacity limits a person's ability to practice ADLs and increases the risk of falls and dependence on others. It is also a significant determinant of poor bone health in individuals with chronic stroke. Reduced cardiorespiratory fitness and inactivity appears to be related to a combination of pathologic (comorbid cardiovascular disease), physiologic (decreased muscle activation and motor control), and environmental factors (little opportunity or incentive for physical activity). For elders, these factors may be combined with an age-related decline in cardiorespiratory fitness reported to be approximately 10% or greater per decade (Carr & Sheperd, 2011).

The development of a task-specific training model of rehabilitation with emphasis on activating motor learning processes provides a framework for functional rehabilitation. For example, simple methods of providing increased intensity in the early period include specific and repetitive practice of standing up and sitting down, aimed both at improving the effectiveness of performance of standing up itself but also the person's ability to perform the action with sufficient repetitions to produce an efficient performance in terms of O_2 uptake (Carr & Shepherd, 2011).

Exercise Therapy

Exercise therapy refers to a regimen or plan of physical activities designed and prescribed for specific therapeutic goals and intended to restore optimal functioning (Veerbeek et al., 2014). The major forms of exercise to improve physical activity for individuals after stroke include:

- Aerobic fitness training
- Functional task and balance training
- Strength and endurance training

Weakness of the extremities is a particularly common impairment after a stroke because of damage to upper motor neurons, which leads to weakness and atrophy of muscles. Weakness in the lower extremities affects strength and balance and causes difficulty with mobility and walking. Weakness in the upper extremities affects the use of the hand and arm and affects the ability to do ADLs. Weakness is usually not confined to the extremities but also affects the muscles of the trunk, neck, face, and eyes.

Weakness and paresis following stroke commonly contributes to decreased active and passive range of motion of the involved joints. Profound hemiparesis can lead to joint contractures, which severely impair mobility and may lead to pressure ulcers. Passive and active exercises are used to reduce the risk of secondary musculoskeletal impairment from decreased joint range of motion.

Stroke can worsen pre-existing conditions such as osteoarthritis, or can lead to osteoarthritis by producing muscle imbalances that result in inappropriate forces across joints. Maladaptive activity patterns or postures can develop in upper or lower extremities after stroke as an individual attempts to regain function. For example, hyperextension of the knee is a common maladaptive pattern that allows for weight-bearing on a weakened or paretic lower extremity, but it can cause osteoarthritis and joint pain if this pattern continues over time.

In 2014 the American Heart Association and the American Stroke Association issued a scientific statement containing an overview of the evidence on physical activity and exercise for those who have survived a stroke. Their summary shows the clear benefit of aerobic exercise and strength training. Physical activity should emphasize low- to moderate-intensity aerobic activity, muscle-strengthening activity, reduction of sedentary behavior, and risk management for secondary prevention of stroke (Billinger et al., 2014).

Post stroke exercise programs are increasingly structured around functional activities rather than repetition of individual exercises. For example, to improve walking, the task should be broken down into specific activities that build toward walking. When possible, technology can be used to provide support, reduce the risk of falling, and reduce the burden of weight-bearing when practicing a task. This is particularly helpful with gait, in which a person’s weight is partially supported using an overhead harness and a treadmill.

Functional Exercise

[This section is taken largely from Carr & Shepherd, 2011.]

It is increasingly acknowledged that the rehabilitation team must increase the time spent in meaningful exercises and task practice to meet the needs of brain reorganization, skill relearning, and improved physical and mental fitness. The low intensity, low duration, and low frequency of physical therapy common in many rehabilitation centers, following outdated and insufficiently challenging therapy models of intervention, sometimes for as little as 30 minutes to 1 hour per day, severely restrict the optimal level of recovery required for participation in daily and social activities after stroke.

Therapists need to move away from reliance on one-to-one therapy to a model in which the patient practices not only in individualized training sessions with a therapist but also in groups, and in circuit training. In this model, patients practice at work stations set up for weight-bearing strength training exercises, and are encouraged to practice specific actions. Patients can be semi-supervised and assisted as necessary by therapists and aides who have similar attitudes and methods to those who work in sports training.

The modern rehabilitation workspace needs to provide an environment built to encourage and challenge physical activity. Such an environment may include a suspended harness system that allows practice of balancing and walking tasks, feedback and computerized devices to provide information and incentive, exercise machines such as treadmills with harness suspension, stationary bicycles, including an electronically braked isokinetic ergometer, and stepping machines. Some centers are developing and testing electromechanical training aides, including robotic devices and virtual reality systems. Even simple technologic aids can increase time spent in physical and mental activity by enabling patients to practice independently. Assistive devices and the assistance of therapy aides can drive physical participation and increase intensity of practice, motivation, competition, and personal responsibility. Patients can also work together, one assisting the practice of the other.

A modern rehabilitation program can include, in addition to task-relevant exercises, a combination of aerobic, strengthening, and flexibility exercises. Active exercise improves exercise tolerance if well prescribed, but exercises need to be sufficiently intensive and in weight-bearing positions. Exercises that share similar biomechanical characteristics—for example, weight bearing exercises that involve flexion and extension of hips, knees, and ankles —are likely to improved stair walking, squatting, and standing up and sitting down. Exercises in water may also have positive training effects, and when properly supervised can increase fitness, which is particularly useful for people with painful arthritic joints who find it difficult to exercise.

Assistive and Adaptive Equipment

Following a stroke, many patients require assistive devices, adaptive equipment, mobility aids, wheelchairs, and orthotic devices to maximize independent functioning. The type and level of functional deficit, the amount of learned adaptation, and the structural characteristics of the living environment determine the need for a particular device.

Walking and Mobility Devices

Walking and mobility devices are helpful for patients with mild to moderate gait impairments. These devices increase the base of support and reduce the effort needed to walk.

Canes and Walkers

Canes and walkers are commonly used as a safety device to aid balance and prevent falls during walking. From a motor control standpoint, these devices may have an adverse effect on the recovery of balance following a stroke. The use of a cane during walking causes a person's center of gravity to shift in the direction of the cane, reduces postural sway, and increases asymmetrical alignment. Both canes and walkers also interfere with compensatory stepping responses (Shumway-Cook & Woollacott, 2012).

When a walker is used, the body largely abandons the ankle strategy and relies heavily on the hip strategy for balance. This dependence on the hip strategy for balance paradoxically may lead to a decrease in ankle sway and contribute to further decline in balance due to loss of ankle strength and flexibility. **For this reason the pros and cons of cane and walker use must be carefully considered before a device is recommended for full-time use.**

Wheelchairs

Wheelchairs are often provided for patients with severe motor weakness or for those who easily fatigue. Chair design and options vary widely and a wheelchair prescription should be specific to the patient's needs and environment and to patient and caregiver preferences.

Companies such as Invacare and Quickie make inexpensive wheelchairs with prices ranging from as low as $150 up to just under $400–$500 for this category of chair. The common feature of these inexpensive chairs is the lack of options for sizing and seating. The chairs are available in standard widths of 16" and 18"—often too wide for the average adult user—especially older and smaller adults.

Consideration must be given to the comfort of the person using the chair. Poor fit leads to more than discomfort—it increases the risk of skin breakdown, can cause back and shoulder injuries, affects a person's ability to propel the chair independently, and contributes to loss of mobility and independence.

Deep Contour Cushion System

The J2 deep contour cushion. Note the solid base combined with layered, high-density foam and a gel overlay. The gel is contained in multiple small packets to prevent bottoming out. The foam can be cut by the clinician for custom fitting. Courtesy of Sunrise Medical Corporation.

Special attention should be paid to the seat and back of a wheelchair. Over time, the seat and back begin to sag, or "bottom out." A sagging seat greatly increases risk for skin breakdown, especially if a person sits in the chair for a long period of time. The thighs tend to roll inward, exposing the trochanters of the femur to pressure from the sides of the wheelchair. The pelvis tends to tilt backwards and flatten, causing the spine to slouch and round and increasing the tendency to slide forward in the chair. This places pressure on the ischial tuberosities (sit bones) and on the rounded mid-thoracic spine, and places a constant shear force on the skin of the buttocks, thighs, and thoracic spine.

One of the most important goals of pressure reduction—whether in a bed, chair, or wheelchair—is to distribute weight as evenly as possible with good skeletal alignment. Placing a foam or gel cushion on a sagging wheelchair seat may not solve the problem. One answer is to replace the sagging seat with a solid seat and cover it with the appropriate pressure-reducing or pressure-relief cushion.

There are a number of basic principles regarding seat depth, height, width, and length, footrest height, back support, and seat-to-back angle that should be considered to attain a correct body position. As a quick checklist when positioning a client, clinicians can look at a seated client and ask themselves the following questions: Is the client sitting in midline or are they slouched or leaning to one side? Are the client's knees higher than the hips, causing increased pressure on the sacrum? Are the chair arms or footrests causing pressure marks on the client's skin? If yes, correct the client's position.

Under certain circumstances, Medicare may cover the cost of a wheelchair rental or purchase for home use. The coverage is limited—generally only for standard wheelchairs with a width of 16 or 18 inches. Medicare does not usually cover the cost of seat cushions or custom backrests. Customized seating systems can be more than the cost of the wheelchair and are usually paid for by the client.

If the chair is going to be used often, fit is critical. Wheelchairs should not take the place of a good chair and should not be used as a primary seating option without careful consideration of fit, comfort, and pressure relief.

Eating, Bathing, and Grooming

An array of adaptive devices is available for eating, bathing, grooming, and dressing for patients with functional limitations. Many patients may need to use adaptive devices in the weeks following a stroke, but will not require them for long-term use. This should be taken into account when considering a device. Assistive and adaptive devices include:

- Eating devices
    - Eating utensils with built-up handles
    - Rocker knives
    - Plate guards
    - Non-skid place mats
- Bathing and grooming devices
    - Long-handled sponges for bathing
    - Hand-held showers
    - Tub and shower chairs
- Toileting aids
    - Elevated toilet seats
    - Grab bars
- Transfer devices
    - Transfer board
    - Safety poles
    - Hydraulic lifts

Orthotics

Lower extremity orthotics (eg, ankle-foot and knee-ankle-foot orthotics) can be effective in patients with persistent weakness and instability at the ankle or knee joint. Orthotics can facilitate gait training and should be considered early in the rehabilitation process to permit gait training as early as possible.

An orthotic should not be used as a substitute for functional exercise directed at regaining muscle strength and control, particularly if the prognosis for motor recovery is good. Prefabricated orthotics can be used in the early stages of gait training, but a custom-fit device should be provided if it is determined that the patient may require long-term use of the orthotic (VA/DOD, 2010).

Positioning devices are used to rest joints, reduce strain on a paretic or spastic joint, provide support, or help regain function.

Wrist-Hand Positioning Device

Custom-made dorsal forearm-based wrist-hand splint used to place the wrist in a resting position of approximately 30 degrees of extension. Source: NIH, n.d.

Preventing Skin Breakdown

Following a stroke, immobility, nutritional deficiencies, decreased immunity, vascular and cardiac disease, and excessive moisture can increase the risk of pressure ulceration. Pressure and tissue ischemia decrease the viability of capillaries and tissues, causing skin breakdown at significantly lower pressures applied for shorter periods of time when compared to healthy older adults.

Pressure ulcer prevention is a multidisciplinary responsibility and starts with identifying risk factors and then taking the appropriate action to avoid skin breakdown or to heal an existing ulceration. Intervention will vary depending on the client, but the main goals should be:

1. Remove the pressure.
2. Treat existing skin breakdown.
3. Initiate client and caregiver education.

There is a variation in time that various tissues can tolerate ischemia before necrosis begins. Superficial dermis can tolerate ischemia for 6 to 8 hours, but necrosis in the muscles and connective tissue begins early, after only 2 hours of ischemia. This is particularly important for clinicians to remember when they see surface skin that appears to have only minimal skin breakdown. Often, much greater tissue damage is present just below the skin's surface. This finding becomes significant when staging pressure ulcers.

It cannot be overstressed that a debilitated client with ulcers is in a potentially life-threatening situation. Healthcare providers need to respond quickly and appropriately to signs of skin breakdown. While immobile and inactive clients are at particular risk, ambulatory patients with limited mobility or cognitive issues are also at increased risk.

Positioning

Immobile or inactive clients who cannot change their position regularly must have local pressure alleviated through passive repositioning. Always consider postural alignment, distribution of weight, stability, comfort, and pressure relief when positioning a client. Correct sitting position should be encouraged in every situation, whether the client is sitting in a chair, wheelchair, bedside chair, geri-chair, gurney, living-room recliner, car seat, or scooter.

Turning schedules promotes good vascular reperfusion and are an excellent way to prevent pressure ulcers and promote healing of existing ulcers. A typical turning schedule will include a full body position change every 1 to 2 hours with smaller position shifts more often. Clients in chairs should change position every hour with smaller weight shifts every 15 minutes (Sussman & Bates-Jensen, 2012).

A full-body shift means turning the client to a new position (eg, from the left side to the right, or from sitting to either standing or side-lying in bed). Small shifts in position mean shifting the client while keeping the same basic body position. Changing the angle of the trunk or position of the extremities in the side-lying position is an example of a small shift in position. In the case of a chair-bound client, a small shift in position would mean changing the lower-extremity position or repositioning the trunk and hips so that the points of pressure are shifted. ***Take care to avoid creating shear or friction forces when moving clients from surface to surface or over bed sheets.***

Activity and Mobility

It is important to identify clients who can assist with turning and weight shifting and to provide them with the proper instruction and equipment to increase their mobility. Clients who are at least partly mobile should be taught and encouraged to use pressure-relief techniques. These include rolling from side to side, elevating the head and foot of the bed, pushing up from the seat of the chair to clear the buttocks, and shifting weight from side to side and front to back.

To help clients move themselves, overhead trapeze bars can be used to increase mobility and tissue perfusion. Initiating strengthening programs is an excellent way to increase activity in clients suffering the effects of prolonged bed rest. It is up to healthcare providers to support clients in being as active and mobile as possible. All healthcare providers need to be part coach, part educator, part cheerleader and think of creative ways to keep clients active and moving.

Positioning Devices

Pillows, towels, and positioning devices can be used to prevent continued pressure on an area of ulceration and as a part of a turning schedule to prevent skin breakdown. Pillow bridging is an excellent and easy way to minimize prolonged tissue compression. Pillows can be placed between the knees and ankles, under the legs to elevate the heels, or against the body to maintain trunk or extremity position. When elevating the heels, clinicians should not place pillows directly under the heels, but rather under the calf and knee, so that the heel is completely off the bed and the weight of the lower leg is distributed evenly across the pillows.

Types of Pillows for Positioning

Wedges and pillows can be used for positioning.

Support Surfaces

One of the best ways to prevent skin breakdown or treat existing ulcers is through the use of support surfaces. Support surfaces are categorized into two groups

1. Pressure-*reducing* surfaces
2. Pressure-*relieving* surfaces

There are specific guidelines for use of support surfaces, depending upon the state and the facility. The type of support surface used depends on the condition of the client, type of care setting, ease of use, maintenance, cost, and mobility of the client (Sussman & Bates-Jensen, 2012). The primary concern should be the therapeutic benefit to the client.

Pressure-Reducing Surfaces

Pressure-*reducing* surfaces lower tissue interface pressure, but they do not consistently provide full pressure relief (Sussman & Bates-Jensen, 2012). Common pressure-reducing surfaces include pads, cushions, overlays, and mattresses made from foam and or filled with air, water, gel, or a combination of these products. Pressure-reducing surfaces are best for clients who are at risk for but do not have ulcers, or with clients who have ulcers but can weight-shift and change position independently. Clients who have existing skin breakdown and cannot change position independently should use a pressure-*relief* surface.

Reversible Foam Overlay

Pressure-reducing surfaces do not replace other efforts to prevent skin breakdown. Without pressure relief through change of position, a client on a pressure-reducing surface can still develop skin breakdown. Clients who are partly mobile should be on a turning schedule and encouraged to participate in moving themselves. Clients with existing skin breakdown should be taught how to position themselves so that they do not weight-bear on areas of ulceration.

Foam pads and foam overlays are popular because of their low cost and ease of use. However, though they do relieve pressure over the sacrum while the client is supine, they do not reduce pressure over bony prominences, such as when clients are on their side. Foam pads and overlays tend to increase body temperature and retain moisture, both of which can increase friction and shear when a client turns or slides down in the bed. They also are easily contaminated, and their effectiveness in preventing ulcers has not been well documented.

Layered Foam Pad

The Jay Basic is a cost-effective, good-quality layered foam pad that is effective for pressure reduction. Used with permission.

Good-quality, layered foam pads have been shown to be effective for pressure reduction. Companies such as Jay Medical and Roho have created a variety of cost-effective pressure-relief cushions made of layered foam. For additional pressure relief, a small gel packet can be added. The gel is strategically placed to reduce pressure over bony prominences. The combination of high-quality, layered foam and light gel packets along with a low shear, breathable fabric cover, provides good pressure reduction.

Combination Gel and Foam Pad

The Jay Basic is a cost-effective, good-quality layered foam pad that is effective for pressure reduction. Used with permission.

Good-quality gel pressure-reducing devices can partly and temporarily redistribute weight and reduce shear. They tend not to bottom out or retain heat or moisture, and they have a good clinical reputation for preventing ulcers. Their biggest disadvantages are cost and weight. Many insurance companies do not pay for gel devices except in special circumstances. Poor-quality gel-based cushions do tend to bottom out, especially if the gel is contained in one large bag or chamber rather than several smaller chambers. Poor-quality cushions may not only be useless but may actually increase the risk of skin damage. Watch out for rubber covers or other nonbreathable material that can cause moisture buildup between the skin and the pad and actually increase the risk of skin breakdown.

Pressure-Relieving Surfaces

Pressure-relief cushions and mattresses are a step up from the pressure-reducing surfaces discussed above. When used correctly, pressure-relief mattresses and cushions consistently reduce tissue interface pressure (Sussman & Bates-Jensen, 2012).

Pressure-relief cushions are defined according to the amount of pressure relief that is provided. The least expensive pressure-relief cushions are made from layered, good-quality memory foam or contain multi-chambered air, water, or gel packets.

Layered High-Density Foam and Gel Pad

The Jay Basic is a cost-effective, good-quality layered foam pad that is effective for pressure reduction. Used with permission.

Additional pressure relief (and additional cost) is provided by combining layers of high-density foam with strategically placed gel packets, or building in multiple—sometimes dozens, as in the Rojo Dry Flotation cushion—individual packets containing gel, air, water, or other pressure-relieving material, often placed on top of a flat, firm surface to prevent the seat from bottoming out or hammocking. The best pressure relief is provided by creating a custom seating system built to address the individual needs of a specific client.

A pressure-relief mattress is recommended for immobile clients who are at a high risk for skin breakdown or for immobile clients who have existing skin breakdown. Pressure-relief cushions are recommended for clients at high risk for skin breakdown and for clients with active skin breakdown who need to get out of bed for health reasons and for position change.

Pressure-relief mattresses are commonly grouped as low-air, high-air, or dynamic-air devices. These types of pressure-relief mattresses are usually covered by insurance but the quality varies widely from glorified air mattresses to sophisticated, high-tech, low-shear mattresses that can make a huge difference in the medical outcome and success of treatment.

The covers of cushions and mattresses are important. They should be made of a breathable, low-shear material that wicks moisture away from the skin and prevents moisture buildup. Keep in mind that no matter how good the cushion or mattress, no system can prevent skin breakdown (or promote healing) if the client stays in one position for too long, has poor body alignment, is sitting or lying on a moist cushion or mattress, or experiences skin shear because of poor positioning.

Returning Home After a Stroke

About 70% of patients who receive rehabilitation following a stroke are discharged to home. The remaining 30% either return to acute care because of a complication or transfer to a skilled nursing facility, in some cases for continued rehabilitation services (Conroy et al., 2009).

The two most powerful predictors of functional recovery and eventual discharge home are initial stroke severity and the patient's age, with initial stroke severity being by far the most important (Teasell et al., 2013). In the long term, 25% to 74% of patients have to rely on human assistance for basic ADLs like feeding, self-care, and mobility (Veerbeek et al., 2014).

Caregiver Issues

I provide care for my mom—she had a stroke about a year ago and lives with me now. She also has dementia although she's generally fairly easy to care for. Sometimes though, I get really, really mad at her—I feel like slapping her though I never have and I know that would be really wrong. I didn't used to understand the pressure on caregivers—now I do. I'm a little ashamed to admit it but I understand how someone can abuse a person they're caring for.

Caregiver, California

A **caregiver** provides assistance to a person in need. Caregivers help with physical tasks such bathing, dressing, walking, and cooking, as well as overseeing medication and home management and providing emotional support. Caregivers can provide direct care or manage care from a distance. They may be a family member, a neighbor, or a medical professional.

The experience of having a sudden illness affects every aspect of a person's life; it also affects spouses, partners, and family members. A stroke takes you away from your home, friends, pets, your own clothing, and your own food. It drops you into the middle of a nearly incomprehensible medical system with arcane rules, an unfamiliar culture, and many highly educated, overworked, and harried healthcare providers. In addition to the dramatic physical and psychological challenges that arise following a stroke, treatment itself is often a significant challenge.

Caregiving is an important part of post stroke care. It is a long-term, evolving process with key transition phases. The onset of care can be abrupt or can emerge naturally from customary family transactions, involving support given and received, that existed before the onset of an illness. Needs for care tend to escalate over time, from increased support for household, financial, and social activities, to personal care, to what for some is almost constant supervision and surveillance. Important transitions include the involvement of professional caregivers, institutionalization, and bereavement (ADI, 2013).

Caregiving is extremely taxing, both physically and emotionally, with potential adverse effects on the health of the caregiver. Caregivers are at increased risk for depression, increased use of health services, and self-administration of medications prescribed originally for the patient. Depression has been associated with physical abuse of the patient and a greater likelihood of nursing home placement.

Pre-existing family habits and characteristics play an important role in a patient's successful transition to community living. Caregivers are more likely to give adequate support if they are knowledgeable about stroke and its disabilities, are not depressed, and live in an otherwise well-functioning family unit (VA/DOD, 2010).

Community support can buffer the effects of disabilities on the patient, family, and caregivers. Educational support can be provided through printed materials, videos, computer programs, and support groups. The availability of emotional and physical support services is crucial to a successful outcome.

Family Education

Caregivers will often be actively engaged in the rehabilitation program and should be encouraged to participate in decision making and the setting of relevant goals and realistic strategies for reaching them. To sustain the gains made during inpatient care and to ensure continued improvement, the rehabilitation team should view the patient and family as the unit of care. The rehabilitation team must have a comprehensive understanding of the needs and preferences of the family and be familiar with the post discharge environment. The team must understand the patient and family history, expectations, coping styles, resources, emotional support system, and family dynamics (VA/DOD, 2010).

Stroke patients and family caregivers should receive a psychosocial assessment with interventions and referrals as needed. The psychosocial assessment should address the following areas:

- Pre-stroke functioning of the patient and the primary caregiver
- Capabilities and abilities of the primary caregiver
- Caregiver's understanding of the patient's needs
- Family dynamics and relationships
- Availability and anticipated involvement of other family members
- Spiritual and cultural preferences
- Leisure time and preferred activities
- Understanding of the condition and expectations for recovery
- Stroke-related outcomes and resources for follow-up care (VA/DOD, 2010)

Additional Issues in Stroke Care

Unfortunately, many problems exist in the provision of stroke care in the United States. Specialized stroke services are lacking in many areas of the country and are unavailable to many segments of society. Stroke care—both acute care and rehabilitation—is often provided by nurses and rehab therapists who lack education and training specific to stroke. Disparities also exist, in the incidence of stroke and in the provision of care, that profoundly affect ethnic and racial minorities.

Within stroke rehab programs, sedentary time is a serious issue and may work against desired outcomes. Additionally, the effort by patients and their families to manage a serious illness creates what is referred to as a "treatment burden." Not surprisingly, additional physical therapy has been shown to improve post stroke outcomes.

Specialized, Interdisciplinary Care

Stroke rehabilitation ideally involves an interdisciplinary team working together to provide a comprehensive treatment program for each patient. In spite of this expertise varies widely, with the greatest concentration in formal hospital-based, inpatient stroke rehabilitation units. When compared to "usual" care provided on a general medical unit, specialized interdisciplinary stroke rehabilitation provided by an interdisciplinary stroke-specific team results in improved functional outcomes (Teasell et al., 2013). A 2013 Cochrane Review concluded that patients who received more-organized care are more likely to survive their stroke, return home, and become independent compared to those receiving less-organized care (SUTC, 2013).

This holds true for outpatient services as well. Enhanced outpatient rehabilitation and discharge services, when provided in conjunction with stroke-specific inpatient care, improve functional outcomes, reduce length of hospital stay, and increase the number of patients discharged home. Enhanced rehabilitation and discharge services have a particularly strong impact on those who have suffered a moderate to severe stroke (Teasell et al., 2013).

Sedentary Time, Lack of Activity, and Isolation

Following a stroke, a large percentage of inpatient time is spent inactive or involved in non-therapeutic activity. Comparatively little time is spent in moderate- to high-level physical activities such as standing and walking. Additionally, hospitalized stroke patients tend to spend most of their time alone in their room (West & Bernhardt, 2012).

Lack of activity and isolation are especially prevalent for patients within 14 days of stroke compared to those at later stages of recovery. Hospitalized stroke patients are involved in an average of approximately one hour per day each of formal physical therapy and occupational therapy. Even during this time a number of studies have reported that patients were involved in little or no physical activity for part of the session. Patients frequently spent less than half their therapy time involved in moderate to high physical activities such as standing and walking, and even less time was spent on therapy for the upper limb (West & Bernhardt, 2012).

Even in a specialized rehabilitation facility, the amount of time a post stroke patient is sedentary is high. Australian and Swedish researchers looked at sedentary behavior and physical activity among patients in rehabilitation hospitals. In both countries, stroke survivors on average are involved in non-therapeutic or low physical activity for as much as 76% of the day (Sjöholm et al., 2014).

In a Norwegian acute stroke unit, sedentary time accounted for 77% of the day. In community settings, a recent systematic review found that in the few studies where sedentary time was reported, it was estimated to be between 63% and 87% of the day (Sjöholm et al., 2014).

A study of patients in physical and occupational therapy between 2 and 14 weeks after stroke, during which heart rate was monitored, found that therapy is of insufficient intensity to produce a cardiorespiratory training effect. On average, in a physical therapy session, 42% of the time was spent inactive in lying, 11% active in lying, 16% active in sitting, and 31% active in standing. If it was present, the aerobic component of a typical physical therapy session lasted less than 3 minutes. Although one might expect progressively higher exercise intensities over time as functional status improved, any increase in heart rate mean and heart rate peak did not reach statistical significance. During occupational therapy a considerable percentage of time was spent in sitting, discussing issues related to discharge, equipment needs, and home management (Carr & Sheperd, 2011).

This has led researchers and clinicians to consider new and different approaches to post stroke rehab that are intended to decrease sedentary activity. Clearly, if meaningful, challenging physical and mental activities play a critical part in driving optimal brain reorganization, there is a need for patients to be more active during their hospital rehab stay than they currently tend to be. However, it is not only the time spent in active exercise that is significant but whether what the individual is doing in that time is sufficiently vigorous and relevant to induce a training effect not only on motor skill but also on level of fitness (Carr & Sheperd, 2011).

Extra Physical Therapy

An interesting review of 16 randomized controlled studies involving nearly 1700 patients being treated in an acute or rehabilitation setting for a number of acute conditions (including stroke), found that an increase in the amount of physical therapy:

- Reduced length of stay by a small but significant amount

- Significantly improved walking ability
- Resulted in significantly fewer non-serious adverse events
- Improved mobility, activity, and quality of life (Peiris et al., 2011)

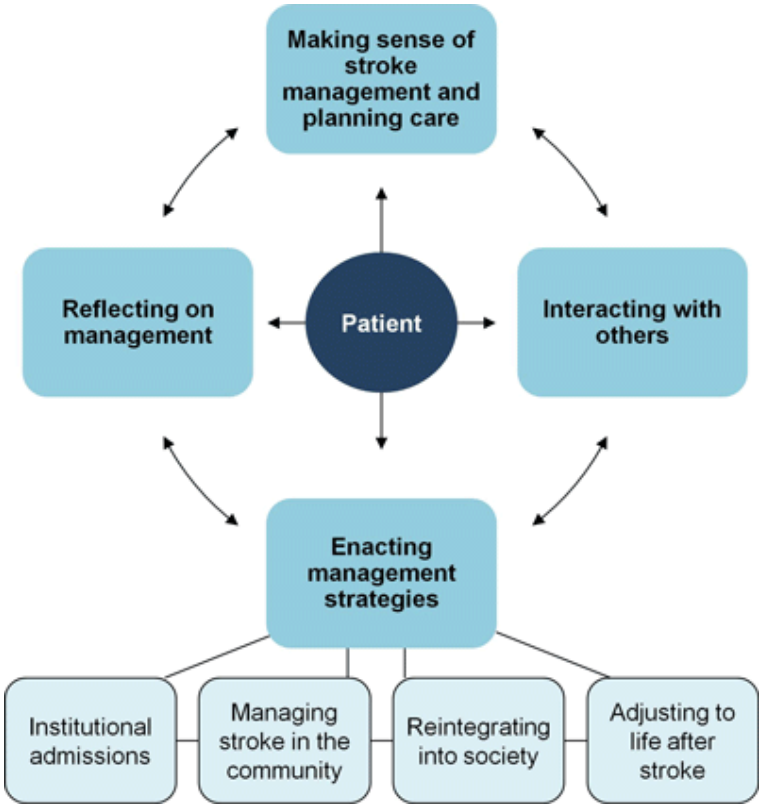
Treatment Burden

Following a stroke, a person's life is drastically disrupted, first by a medical emergency, and then by weeks, sometimes months, of intensive therapy in an unfamiliar setting. Young, energetic healthcare providers are often unaware of the stress this places on patients and their families. Treatment and rehabilitation is an extended, arduous process, demanding significant personal investment from the patient (Gallacher et al., 2013). This personal investment and the problems that arise as a result of treatment are referred to as *treatment burden*.

Treatment burden is the effort those with chronic illness must make to manage their condition. It describes the difficulties faced by patients and their caregivers as they attempt to follow the complicated management strategies developed for rehabilitation. Burden is increased significantly when a patient has multiple co-existing illnesses. Unfortunately, treatment burden can overwhelm patients (and their families), a situation that leads to poor adherence to therapies and poor outcomes (Gallacher et al., 2013).

Treatment burden, when described in terms of patients and their family members, has four components: (1) making sense of stroke management and the plan of care, (2) interacting with others, (3) enacting management strategies, and (4) reflecting on management.

Treatment Burden



Conceptual model of stroke treatment burden. The arrows represent the possible pathways between components that stroke patients may follow. The "enacting management strategies" component has four subcomponents. Gallacher et al., 2013.

Making Sense of Stroke Management

Following a stroke, patients and family members are often eager for information from their healthcare providers. They want to understand what happened, what to expect, and how to participate in the goals set by those managing their care.

In several studies, stroke patients reported that information about stroke was lacking, inadequate time was allocated, timing was inappropriate, or information was given in a form that was incomprehensible. When asked about their stroke, women (more often than men) report a lack of information from medical staff. Family education also appears to be insufficient, with patients describing the need to research information due to its lack from healthcare providers (Gallacher et al., 2013).

In other studies, patients reported that access to information following a consultation was insufficient, resulting in the need for them to spend time seeking information themselves and attempting to make personal sense of the array of changes that are occurring in their lives. Patients described difficulty making sense of and differentiating between the roles of different individuals and services, for example, who to contact for advice once discharged from hospital. A lack of continuity of care for patients and poor communication between services resulted in patients receiving conflicting information from different parties, making it harder to understand the necessary processes that promote recovery (Gallacher et al., 2013).

A Family Member's Perspective

My mother-in-law recently had a stroke. She lives in an area of the country with good healthcare services for older adults so we assumed she would get really good care. The hospital care was good, followed by inpatient rehabilitation at the same hospital. That was also pretty good—there was a knowledgeable case manager who helped us plan the next step.

Everything fell apart when my mother-in-law was transferred to a highly recommended skilled nursing facility for rehab. We toured the facility—it was clean and really nice looking. But we soon found out that it was significantly understaffed—particularly in the evening, at night, and on weekends. There was no case manager, the doctor wasn't involved at all, and the "discharge planner" didn't appear to know anything about rehab, equipment, or discharge planning. There was no therapy on Saturday and Sunday and no activities in the afternoon or evening.

One evening, my mother-in-law tried to go to the bathroom and fell—this happened on three more occasions. The nurse told us he had 22 patients and didn't have time to take my mother-in-law to the bathroom. The facility administrator told us we had to pay for a "sitter," which cost quite a bit of money.

The most frustrating thing was trying to figure out who did what. We asked for a weekly report from rehab but when they called they didn't identify themselves and we often didn't know who we were talking to. Nobody seemed to know what anybody else was doing and they didn't seem to know much about the kind of stroke my mother-in-law had, which was in the brainstem.

I've worked in healthcare all my adult life but even so it's been really hard. I can't imagine how people cope who don't know the healthcare system. I'm kind of depressed that things were so disorganized and I'm ashamed of my profession for not doing better.

Interacting with Others

Along with making sense of stroke and its management, a great deal of effort is required to engage with a range of health professionals both in the hospital and in the community. One study reported that women are more likely to form an alliance with healthcare assistants, while men form alliances with nurses and therapists or other patients. Men more frequently reported trying to exert influence over their care, while women took a more passive role. Whatever the patient preference, the literature suggests that patients are not adequately consulted about their desires to be involved in decisions about care or about their treatment priorities and goals (Gallacher et al., 2013).

Many patients reported dissatisfaction with health professionals, complaining of misdiagnosis at initial presentation of stroke and a lack of time and empathy from therapists. Poor interactions between patients and health professionals interferes with the development of trusting relationships, which in turn worsens communication and prevents patients from gaining the knowledge they need for the recovery process. It is perhaps not surprising that communication difficulties with health professionals are a particular issue for aphasic patients (Gallacher et al., 2013).

Enacting Management Strategies

Stroke patients are involved in extensive inpatient rehabilitation, attending therapy, taking medications, and working arduously to regain lost functions. During the rehabilitation process patients must adjust to their new physical abilities and learn self-care practices to prepare for discharge.

Patients must fit into the routines set by institutions and many describe negative environmental circumstances such as unfamiliarity with various gadgets, long waiting times for personal care, inadequate support during mealtimes, poor quality of hospital food, a lack of stimulating activities, and the loss of autonomy, privacy, and dignity. These complaints were similar in the hospital and nursing home setting, with a particular complaint in nursing homes being a lack of autonomy, with care that is regarded as too paternalistic (Gallacher et al., 2013).

The transition from inpatient care to the home is an important and often challenging time for patients. Generally, patients reported discharge services as poorly coordinated, badly managed, and inadequate for preparing patients for life back in the community. Studies from a variety of countries and healthcare systems described it as difficult for patients to gain access to advice and services once discharged into the community (Gallacher et al., 2013).

More Perspective from a Family Member

When my mother-in-law was ready to go home there was zero communication from the doctor, nurses, or therapists and absolutely no help from the "discharge planner." My mother-in-law was scheduled to be released on a Tuesday but the previous week, despite many calls to the discharge planner, nobody returned our calls. We ended up calling the doctor about 20 times for orders and spent hours on the phone trying to get the right equipment ordered. When my mother-in-law finally got home it took another week of phones calls to get everything she needed. We still don't have prescriptions for her medications and we're stuck between 2 doctors and an equipment company that says they can't provide the ordered equipment. At the moment we're paying privately for a hospital bed and we borrowed the other equipment we need. I don't know why we didn't get more help.

My mother-in-law's new doctor ordered home health and the local hospital-based home health agency set things up pretty quickly. But now we're inundated with PT, OT, speech, nursing, and a home health aide—without any pattern to the appointments. They call early in the morning, don't identify who they are, and want to come right away. They all come in one or two days and then don't show up for a week. Is it too much to expect healthcare professionals to identify themselves by name and profession when they call and to coordinate their visits? On top of all that, none of them knew much about stroke. It's all very stressful.

In this period of time after discharge from inpatient care, the patient schedule is extremely busy with healthcare appointments, with patients being required to negotiate numerous therapists. As mentioned earlier, poor knowledge about available services, poor access to care, a lack of continuity, and poor communication between therapists are described as frequent and problematic issues (Gallacher et al., 2013).

Once home, patients strive to reintegrate into society. Following a stroke, they are usually prohibited from driving for a set period and may be required to take a test determined by driving authorities. Many feel frustrated and unsupported as they struggle to understand the logic behind the ban and assessment process, which can lead to rebellion against medical and legal advice and the continuation of driving. Those who can no longer drive are required to negotiate other methods of transport, which can be difficult due to disabilities (Gallacher et al., 2013).

Following a stroke, patients create a new daily structure to accommodate their disabilities and treatments. They re-learn how to carry out once-familiar tasks, and spend extra time planning activities ahead of time as well as adopting strategies to deal with physical and cognitive disabilities, such as taking periods of rest, learning how to get up from a fall, or creating lists or filing systems. Aphasic patients describe using strategies such as carrying communication cards, repeating words, gesturing, and using drawings or technical devices. Some patients, however, found the use of such strategies either inappropriate for their needs or too laborious to use (Gallacher et al., 2013).

Reflecting on Management

Patients must make decisions about their health care, requiring an appraisal of their treatments, either with the help of healthcare providers, or based on their own judgments. Sometimes decisions are made that deliberately contradict advice given by health professionals. This appears often to be the consequence of a breakdown in communication between patient and health professional, or a lack of understanding on behalf of the patient, although informed patient preference is likely to also play a role (Gallacher et al., 2013).

Patients commonly reflect on their achievements and self-monitor progress to make judgments about their success, comparing their recovery to that of other stroke patients and monitoring for further signs of stroke. Patients describe the need to maintain confidence in their care plan, and one paper described patients keeping up to date with newly available treatments by asking health professionals for information (Gallacher et al., 2013).

What's New in Stroke Rehabilitation?

It is well-known that standard treatments available today are limited in their ability to help stroke patients attain full functional recovery. To address this, research into novel treatment strategies is ongoing. One such area of research is regenerative medicine, the aim of which is to restore or repair damaged brain tissue. Other novel treatment strategies include dopamine augmented rehabilitation, noninvasive brain stimulation, and neurorehabilitation training.

Neuroregenerative Medicine

The aim of neuroregenerative medicine is to restore or repair brain tissue damaged following a stroke. One area of study involves the use of various types of stem cells to regenerate damaged neural tissue following an ischemic stroke. A number of stem cells types, including embryonic stem cells, induced pluripotent stem cells, and neural stem cells have been utilized in cell therapy in an attempt to repair injured brain tissue. One of the major problems associated with this approach is poor cell survival. To address this problem, researchers are employing tissue engineering techniques to build "scaffolds" as carriers for cells. It is thought that the use of specialized scaffolds will improve cell survival both *in vitro* and *in vivo* (Wang et al., 2014).

Regenerative Medicine: An exciting new approach to stroke recovery (5:10)

https://www.youtube.com/watch?v=Xqh-gYWGXlI

Dopamine Augmented Rehabilitation

The emerging evidence from pilot studies indicates that the addition of certain drugs with physical and occupational therapy may improve the recovery of arm and leg movements as well as recovery of essential day-to-day activities such as walking and dressing. Studies suggest that the nerve circuits in the brain respond better to therapy when they are also exposed to drugs such as dopamine at the same time as having occupational or physical therapy. These improvements are in addition to the benefits gained from physical and occupational therapy alone (Bhakta et al., 2014).

The impact of dopamine on motor function in stroke has been investigated in small-scale clinical studies. A randomized controlled trial reported the effect of L-dopa on motor function in 53 people who were 3 weeks to 6 months post stroke. All patients received daily physical therapy sessions lasting 30 minutes for 3 weeks in a hospital setting. Motor function was assessed using the Rivermead Mobility Index (RMI). Significantly greater improvement in RMI scores and walking ability were reported in the L-dopa treated group compared with placebo. The drug was well tolerated and no serious drug-related adverse events were reported. The effect on function was still present three weeks after cessation of L-dopa (Bhakta et al., 2014).

Noninvasive Brain Stimulation

Electrical currents or magnetic fields can modify the functional activity of the brain, and in the last decade this approach, known as noninvasive brain stimulation (NIBS), has rapidly gathered a worldwide interest as a therapeutic tool. This typically involves two techniques: repetitive transcranial magnetic stimulation and transcranial direct current stimulation (Iosa et al., 2012).

Noninvasive brain stimulation aims to augment neural plasticity and improve motor function based on the *inter-hemispheric competition* model, which proposes that motor deficits in patients with stroke are due to reduced output from the affected hemisphere and excessive inhibition from the unaffected hemisphere. Noninvasive brain stimulation achieves improvement in motor deficits by either increasing the excitability of the affected hemisphere or decreasing the excitability of the unaffected hemisphere (Takeuchi & Izumi, 2013).

In a recent study at the Rehabilitation Institute of Chicago, researchers used a combination of transcranial magnetic stimulation and task-oriented occupational therapy to try to improve upper extremity function following a stroke. Treatment was 3 times per week for 6 weeks with followup at 1 week, 1 month, and 6 months. Participants showed significant improvement on the UEFM* scale, with lasting improvements in motor function (RIC, 2014).

***UEFM**: Upper extremity Fugl-Meyer Scale is used to measure upper extremity impairment after a stroke. It has four parts (shoulder-arm, wrist, hand, and coordination) containing 33 tasks scored on a scale of 0 to 2, with a maximum score of 66. Movements are first performed on the less affected side, followed by the more affected upper extremity. Higher scores indicate better movement abilities.

Navigated Brain Stimulation (5:40)

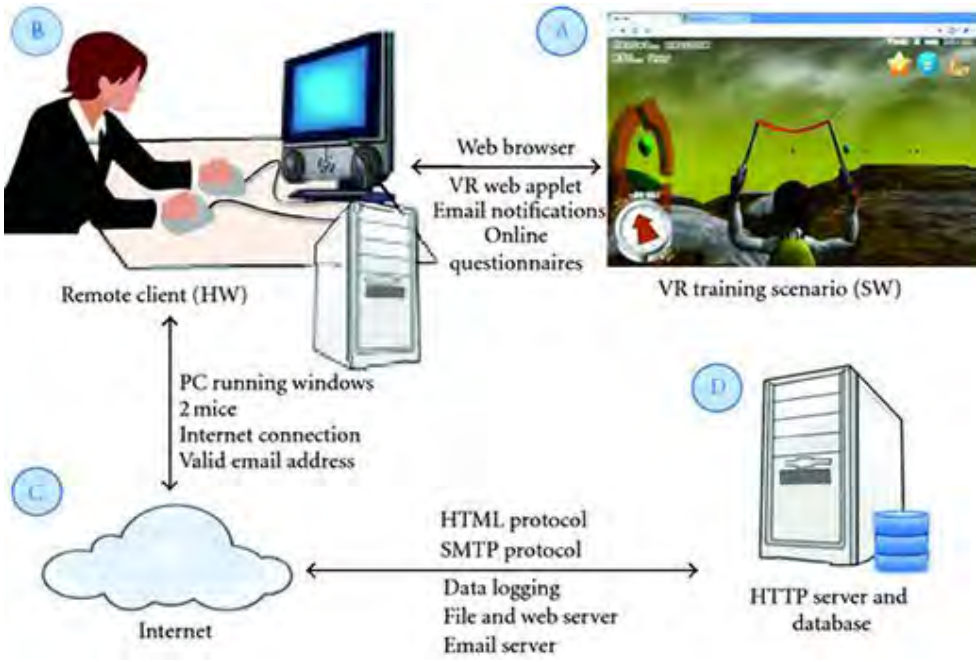
Rehabilitation Institute of Chicago. https://www.youtube.com/watch?v=Do0Be6PQwSE

Motor cortex excitability enhancement appears to be required for motor learning. In fact, pairing of rehabilitative training with noninvasive brain stimulation results in more enduring performance improvements and functional plasticity in the affected hemisphere compared with motor training or stimulation alone in patients with chronic stroke. Furthermore, cumulative noninvasive brain stimulation has been shown to be important for continuous motor improvement in patients with stroke (Takeuchi & Izumi, 2013).

Neurorehabilitation Training Toolkit (NTT)

To provide patients with effective, uncomplicated, and inexpensive rehabilitation in their homes, researchers at the Madeira Interactive Technologies Institute in Portugal have developed the Neurorehabilitation Training Toolkit (NTT), a PC-based interactive system for upper-limb rehabilitation. The NTT makes use of well-established state-of-the-art requirements for effective rehabilitation after stroke, providing training that is frequent, reiterative, and task specific, and that presents feedback on performance and outcomes. These characteristics are achieved through the use of game-like tasks displayed on a standard computer, designed to address the specific upper-limb deficits of stroke patients (Bermúdez et al., 2012).

Assisted Rehabilitation in the Home



Neurorehabilitation Training Toolkit system architecture. (A) A web browser is used to access the application and its instruction at http://neurorehabilitation.m-iti.org/NTT/ (B) NTT can be executed on any modern PC equipped with two mice and an internet connection. (C) The NTT software is accessed freely from Internet, where the NTT servers are located. (D) A number of remote servers host the NTT site, the application itself, and are used to log user data. Source: Bermúdez et al., 2012).

The NTT training task requires patients to be able to read, and not to have major cognitive deficits, seizures, sensory aphasias, or other perceptual problems that could impede the understanding of the task. The training consists of a bilateral task that requires practicing range of motion and movement coordination (Bermúdez et al., 2012).

Conclusion

The onset of stroke is a dramatic and discouraging event both for the person having the stroke and their family. A person may go from complete independence to complete dependence in a matter of minutes. Upon entering the medical system, patients are confronted with a bewildering array of tests, people, and places, as well as confusion about treatment and services.

Medical care for stroke survivors is often fragmented and inconsistent. In some cases the patient is moved quickly from the acute hospital to a skilled nursing facility or an inpatient rehab department for rehabilitation. In urban areas, care may be more comprehensive and organized, but in many other areas followup care can be hit or miss.

Advances in acute treatment are saving the lives of people who would not have survived in the past. As a result, post stroke therapy is more important than ever. Yet access to services and inconsistencies in healthcare professional knowledge about how the brain heals after a stroke mean only a small percentage of stroke survivors are able to access the latest information, equipment, and techniques.

Nursing and rehabilitation professionals play a critical role in the care of the person with a stroke. We all play a role in improving outcomes through education, training, and knowledge about the physical and psychological effects of stroke. It is our responsibility to become familiar with the roles and responsibilities of each profession involved with post stroke care, as well to keep up with the astounding advances in the emergency, acute, and long-term treatment of people who have had a stroke.

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Post Test: Stroke (137)

Use the answer sheet following the test to record your answers.

1. Stroke in the United States:

    a. Is the leading cause of death.
    b. Causes more serious long-term disabilities than any other disease.
    c. Is most deadly in white people compared to people of color.
    d. Results in death within a month for about 50% of people.

2. The risk of having a first stroke:

    a. In much higher in white Americans than in black Americans.
    b. Overall, is the highest among Hispanic Americans.
    c. Is nearly twice as high for blacks than for whites.
    d. Is lower among whites but they are more likely to die from a first stroke.

3. Following a stroke, some neural cells die immediately while others surrounding the dead cells:

    a. Are damaged and remain at risk for death if treatment is delayed.
    b. Are completely unaffected.
    c. Migrate to the dead area and replace the dead cells.
    d. Surround the dead cells and prevent further cell death.

4. Ischemic strokes:

    a. Are caused by blood that leaks into the brain, damaging sensitive nerve cells.
    b. Make up a small percentage of the total number of strokes.
    c. Are caused by thrombotic or embolic occlusions involving the major brain arteries.
    d. Occur when a major vessel of the heart is occluded by a blood clot.

5. Transient ischemic attacks (TIAs):

    a. Are small strokes in which the symptoms resolve within 2 to 3 days.
    b. Are usually caused by blood leaking into the brain.
    c. Have a gradual onset of symptoms similar to stroke with a gradual decrease in symptoms.
    d. Are usually caused by an embolism.

6. In the past, TIA was diagnosed solely by the sudden onset of symptoms that resolved spontaneously within 24 hours. Currently the diagnosis of TIA:

a. Is determined by the gradual onset of symptoms that resolve within one hour.

b. Is tissue-based rather than time-based.

c. Can wait until 24 hours have passed.

d. Is not important because symptoms will resolve.

7. Hemorrhagic stroke:

a. May include nausea, vomiting, headache, and altered level of consciousness.

b. Has the same symptoms as an ischemic stroke.

c. Is the result of blockage of one or more of the major arteries in the brain.

d. Rarely causes severe neurologic after-effects.

8. In the absence of neurovascular abnormalities such as aneurysm or angioma, nontraumatic intracerebral hemorrhage is most commonly caused by:

a. A blow to the head or a concussion.

b. A clot that lodges in the basal ganglia.

c. A thrombus that punctures an arterial wall in the brain.

d. Hypertensive damage to blood vessel walls.

9. Risk factors for both ischemic and hemorrhagic stroke:

a. Have little in common with risk factors for heart disease.

b. Include hypertension and moderate alcohol consumption.

c. Doubles for each successive decade after age 55.

d. Is unrelated to atrial fibrillation.

10. The cerebrum:

a. Is divided into four hemispheres.

b. Has two hemispheres, each divided into four lobes.

c. Is another name for the cerebellum.

d. Is not significantly interconnected with the nervous system.

11. The cerebral cortex:

a. Controls the right hemisphere of the brain exclusively.

b. Is a thin layer of nerve cells that smoothes out the convolutions of the brain.

c. Is a thin layer of nerve cells that covers the surface of both hemispheres.

d. Controls the left hemisphere of the brain exclusively.

12. The respiratory and cardiovascular centers of the brain comprise the:

a. Brainstem reticular formation.

b. Medulla oblongata.

c. Cerebellum.

d. Thalamus.

13. The cerebellum, or “little brain”:

a. Makes up nearly 40% of the total volume of the brain.

b. Houses the respiratory and cardiovascular centers.

c. Is highly convoluted and folded, which increases the surface area of the brain.

d. Helps to control and coordinate movement.

14. Blood flows from the heart to the brain via two large arterial systems:

a. The carotid and the vertebrobasilar systems.

b. The middle cerebral and the anterior cerebral arteries.

c. The ophthalmic artery and the middle cerebral artery.

d. Broca's and Wernicke's systems.

15. The middle cerebral artery (MCA), part of the carotid circulation:

a. Is not generally vulnerable to emboli.

b. Is the smallest of the arteries supplying blood to the brain.

c. Supplies blood to the right hemisphere of the brain.

d. Is the most common artery involved in stroke.

16. Broca’s aphasia is signaled by:

a. Long meandering sentences.

b. Short choppy sentences.

c. The loss of the ability to organize a movement.

d. The inability to understand the spoken word or communicate with speech.

17. Neglect is a sensory disorder caused by damage in the parietal lobe. Symptoms include:

a. The inability to recognize an object by sight, touch, or hearing.

b. Unawareness of the contralateral (opposite) side of the body including half of the visual field.

c. Loss of the ability to organize a movement or perform a purposeful act.

d. The ability to speak but the words carry no meaning.

18. A stroke affecting the basal ganglia:

a. Can cause Parkinson's disease.

b. Usually causes contralateral hemiparesis.

c. Usually causes motor control problems rather than hemiparesis.

d. Can cause apraxia and aphasia.

19. A stroke in the cerebellum may cause:

a. Ataxia, intention tremor, and hypotonia.

b. Festinating gait and resting tremors.

c. Central pain syndrome.

d. Speech and language dysfunction.

20. Strokes in women:

a. Occur more often than in men because women have smaller carotid arteries.

b. May include nontraditional symptoms such as altered level of consciousness, nausea, and hiccups.

c. May have a better outcome than male patients in motor, cognitive, and functional recovery.

d. Are easier to recognize because of a higher occurrence of traditional symptoms.

21. Guidelines on the secondary prevention of stroke include a new section on aortic atherosclerosis. These recommendations include the following:

a. For those with a stroke of unknown cause, atrial fibrillation is no longer important to monitor.

b. Increasing physical activity is no longer recommended.

c. Medications are more effective than prevention.

d. Patients should have a nutritional assessment and be advised to start a Mediterranean diet.

22. Patients need a carotid endarterectomy if:

a. If any amount of narrowing of the carotid arteries is present.

b. As a treatment for acute stroke.

c. They have had a TIA or stroke with at least 70% narrowing of the carotid artery.

d. They are completely disabled from a stroke.

23. The "suddens" refers to:

a. A sudden increase in blood pressure, weight, and diabetes leading to increases in heart attack and stroke.

b. The need for quick assessment of symptoms by EMTs to ensure prompt treatment of stroke victims.

c. Sudden weakness or numbness, confusion, trouble seeing, trouble walking, and severe headache.

d. The lack of awareness of stroke symptoms by the general public.

24. Stroke Heroes Act FAST:

a. Stands for facial weakness, arm drift, slurred speech and time to call 911.

b. Identifies almost 98% of stroke victims when used by nonmedical people.

c. Stands for facial weakness, altered level of consciousness, slurred speech, and time to call 911.

d. Is too difficult for laypeople to remember and is not effective in identifying stroke victims.

25. Recommendations made by the Minnesota Stroke Partnership advise that:

a. Prehospital personnel should transport any suspected stroke victim to the nearest ED.

b. EMS personnel should not attempt to identify stroke victims.

c. The Glasgow Coma Scale should be used as the standard for assessing suspected stroke patients.

d. EMS personnel should treat stroke as an emergent event and transport suspected patients to the nearest stroke center.

26. The goal of reaching an emergency department within three hours of the onset of stroke symptoms is:

a. To differentiate a true stroke from a TIA.

b. Critical because of the use of time-dependent medications and treatments for acute stroke.

c. Important because x-rays do not show the difference between hemorrhagic and ischemic stroke after three hours.

d. Only important if the patient has symptoms of a hemorrhagic stroke so they can receive thrombolytic drugs.

27. When a suspected stroke patient arrives in an emergency department, the goal should be:

a. An initial evaluation within 1 hour.

b. A CT scan initiated within 10 minutes.

c. Interpretation of the CT scan and labs within 15 minutes.

d. Door-to-drug (needle) time within 60 minutes of arrival.

28. The most important function of an imaging study for acute stroke is to:

a. Differentiate between ischemic and hemorrhagic stroke.

b. Determine the area of the brain damaged by stroke.

c. Determine the amount of arterial blockage.

d. Determine if an individual would benefit from carotid endarterectomy.

29. A comprehensive stroke center (CSC) differs from other types of stroke centers in that:

a. It has the staff to treat most uncomplicated acute strokes and to administer thrombolytics.

b. It focuses on stabilization of the stroke patient.

c. It has a type 2 trauma center on site.

d. It is able to perform neurosurgical and endovascular procedures on site.

30. Thrombolytic agents such as rt-PA:

a. Are effective for the treatment of hemorrhagic strokes.

b. Can halt an ischemic stroke by dissolving the blood clot that is blocking blood flow to the brain.

c. Can be used for up to 24 hours following acute onset.

d. Have been shown to be dangerous and ineffective with ischemic strokes.

31. Interventional radiology:

a. Must be used within 1 hour of acute symptom onset.

b. Increases the chance of intracranial bleeding from rt-PA.

c. Uses an x-ray guided catheter to deliver rt-PA directly into the clot.

d. Is an effective treatment for intracranial hemorrhage.

32. The use of aspirin:

a. Should be considered a substitute for rt-PA.

b. Should be given at the same time as rt-PA.

c. Is a standard treatment for patients at risk for stroke.

d. Should be combined with clopidogrel to treat acute ischemic stroke.

33. Anticoagulants reduce stroke risk by:

a. Preventing the formation of clots and the extension of existing clots.

b. By breaking up clots.

c. Reducing the amount of fat circulating in the blood.

d. Lowering cholesterol.

34. All strokes are treated as ischemic until a CT scan confirms otherwise. :

a. True

b. False

35. Stroke rehabilitation occurs in many different settings. Healthcare organizations that have implemented comprehensive, interdisciplinary stroke systems of care:

a. Tend to have patients with more serious illness so outcomes are worse than facilities without comprehensive stroke programs.

b. Have found that it makes no difference to outcomes whether care is interdisciplinary or comprehensive.

c. Get fewer referrals to their facilities because of the increased cost is passed on to patients.

d. Report improved outcomes for both morbidity and mortality.

36. Inpatient rehabilitation facilities:

a. Are basically involved with stroke research rather than rehabilitation.

b. Are generally not staffed with therapists and nurses with training and education in stroke care.

c. Are considered gold standard care for stroke treatment and recovery in the post-acute phase.

d. Provide less therapy than skilled nursing facilities.

37. When comparing outcomes, how do skilled nursing facilities (SNF) and inpatient rehab facilities (IRF) differ? :

a. IRF patients had significantly less improvements in applied cognitive function compared to those who received care in a SNF setting.

b. Rehabilitation in IRFs leads to lower mortality, fewer readmissions and ER visits, and more days at home.

c. Patients receiving care at a SNF had longer stays and as a result lived longer after discharge than those receiving care at an IRF.

d. There is no difference in outcomes when comparing stroke care at a SNFs and IRFs.

38. Neural plasticity is:

a. The brain’s ability to adapt, compensate, and learn throughout life.

b. A process that is present in childhood but stops once the brain is fully formed.

c. Unwanted or maladaptive changes in the brain following a stroke.

d. Velocity-dependent increase in tonic stretch reflexes in the brain.

39. Maladaptive plasticity is:

a. Unavoidable following a stroke.

b. Helpful in creating compensations that improve movement efficiency.

c. Decreased voluntary motor recruitment.

d. A change in neural circuitry that creates unwanted or inefficient compensations.

40. Abnormal inter-hemispheric inhibition following a stroke is:

a. A process by which the unaffected hemisphere takes over functions formerly controlled by the affected hemisphere.

b. The appearance of new motor patterns resulting from the adaptation of remaining motor elements or substitution.

c. The coupling of the neurons across the corpus callosum to make up for functionality lost due to damaged neurons.

d. Increased activation of the unaffected hemisphere, which in turn inhibits activity within the affected hemisphere.

41. Task-specific training is:

a. A central tenet of the reflex-hierarchical theory of motor development.

b. The practice of functional tasks related to mobility rather than movement patterns.

c. Does not induce long-lasting motor learning.

d. The practice of movement patterns rather than functional tasks.

42. Balance and mobility:

a. Are usually not affected following a stroke.

b. Improve quickly with the use of an assistive device.

c. Are often severely affected following a stroke.

d. Usually do not improve after someone has had a stroke.

43. The sensory systems that contribute most to balance are:

a. The somatosensory, visual, and vestibular systems.

b. The cochlea and retina.

c. Sensory organs for heat, cold, and light touch.

d. The primary visual cortex.

44. The Berg Balance Scale has been used to determine a patient's risk of falls following a stroke. A number of studies have shown:

a. There is no correlation between a patient's score on the Berg Balance Scale and risk of falls.

b. A lower score on the Berg Balance Scale was associated with a greater risk for falls for both stroke and control groups.

c. A high score on the Berg Balance Scale means a person will not fall.

d. The Berg Balance Scale can predict how a person will fall.

45. You are standing on a slow-moving bus, which starts to speed up. You lose your balance slightly but are able to regain it by swaying backwards a little and then forward. This is called:

a. The stepping strategy.

b. The vestibular strategy.

c. The ankle strategy.

d. The hip strategy.

46. Walking adaptability is particularly affected after a stroke. It is:

a. The ability to find alternate means of transportation when a person can no longer drive.

b. The ability to adapt to different conditions and tasks while walking.

c. The ability to walk long distances without falling.

d. The ability to help another person walk.

47. After a stroke, walking is:

a. Much harder, requiring a much higher level of energy expenditure than before the stroke.

b. Generally easier and safer in the community than in the home.

c. Functional for most people upon discharge from rehab.

d. Much easier, requiring less expenditure of energy than before the stroke.

48. Despite the widespread use of body weight–supported treadmill training in post stroke rehab programs, the LEAPS trial found:

a. BWSST is far superior to the usual care received by most stroke patients.

b. Treadmill training only works if it is used in conjunction with constrain-induced movement therapy.

c. Almost no improvement in gait for those using BWSTT.

d. Those with home physical therapy improved just as much as those who did locomotor training with a body-weight supported treadmill.

49. Bilateral upper arm training:

a. May be most effective in the early stages following a stroke when brain reorganization is at its peak.

b. Is effective because the unaffected arm "decouples" from the affected arm, allowing independent movements.

c. Involves the use of the unaffected arm to move the affected arm.

d. Can only be done with computerized devices.

50. Constraint induced therapy:

a. Is a technique in which the affected extremity is constrained, forcing use of the unaffected arm.

b. Has not been shown to induce structural brain changes in people following a stroke.

c. Has been shown to promote osteoporosis in the constrained extremity.

d. Appears to be most effective in the chronic phase of stroke.

51. The use of electrical stimulation following a stroke:

a. Is solely for use on the upper extremity.

b. Can completely restore upper extremity function in those with severe paresis.

c. Has strong evidence for it efficacy.

d. Can stimulate the muscles responsible for maintaining the head of the humerus in the glenoid fossa.

52. Two novel screening techniques developed for the screening post stroke patients for dysphagia are:

a. Observation of swallowing and thoracic auscultation.

b. Palpation of the larynx and observation of respirations.

c. Tongue pressure resistance and biofeedback.

d. Cervical auscultation and pulse oximetry.

53. One innovative technique that has arisen as a treatment for dysphagia is:

a. Jaw thrusts.

b. Tongue pressure resistance training.

c. Strengthening the neck muscles.

d. Distraction therapy.

54. Cognitive impairment following a stroke:

a. Occurs in as many as two-thirds of stroke patients.

b. Leads to dementia in approximately 90% of patients.

c. Has very little effect on the performance of ADLs.

d. Is not related to poorer outcomes.

55. Aphasia is:

a. Difficulty eating and swallowing.

b. Loss of the ability to organize a movement or perform a purposeful act.

c. An acquired language disorder that affects a person's ability to comprehend and produce language.

d. The disruption of a person's body schema and spatial orientation.

56. Following a stroke, the presence of depression:

a. Improves functional mobility because it slows people down and makes them more deliberate.

b. Should be addressed by a psychiatrist and not with antidepressants.

c. Is associated with the presence of cognitive impairment one year following the stroke event.

d. Is associated with low scores on the Berg Balance Scale.

57. Functional exercise after a stroke should include:

a. Low intensity, low duration, and low frequency exercises.

b. High intensity, prolonged group activities with little or no rest.

c. Only one-on-one treatments with a stroke specialist.

d. Task-relevant exercises, and a combination of aerobic, strengthening, and flexibility exercises.

58. The use of a walker for gait training following a stroke:

a. Is the best and fastest way to regain balance.

b. Can lead to a decrease in ankle sway, which contributes to further decline in balance due to loss of ankle strength and flexibility.

c. Will prevent falls during ambulation and transfers.

d. Should not be used if a person has upper extremity weakness.

59. Those at high risk of skin breakdown following a stroke include:

a. Immobile or inactive clients who cannot change their position regularly.

b. All stroke patients.

c. Patients transferred to a skilled nursing facility.

d. Patients who were very active prior to the stroke.

60. Pressure relieving mattresses and cushions:

a. Can take the place other efforts to prevent skin breakdown.

b. Consistently provide full pressure relief.

c. When used correctly, consistently reduce tissue interface pressure.

d. Are recommended for all post stroke patients.

61. Caregivers :

a. Are usually well-trained and able to help a family member who has had a stroke.

b. Are at increased risk for depression.

c. Should be kept out of the rehabilitation process.

d. Adapt easily to changes in a loved one following a stroke.

62. During post stroke rehabilitation, patients are sedentary:

a. Only in the evenings after dinner.

b. About three quarters of the time.

c. Almost never.

d. During regularly scheduled breaks only.

63. Treatment burden is:

a. The effort healthcare providers must make to manage their patient’s conditions.

b. Reduced once a patient is discharged from acute care.

c. The effort those with chronic illness must make to manage their condition.

d. The burden on society to take care of chronically ill people.

64. Noninvasive brain stimulation:

a. Improves motor deficits by either increasing the excitability of the affected hemisphere or decreasing the excitability of the unaffected hemisphere.

b. Uses dopamine to enhance brain function during occupational therapy treatments.

c. Is a PC-based interactive system for upper-limb rehabilitation.

d. Provides electrical current to the area of the brain destroyed by the stroke event.

Answer Sheet

Stroke: Emergency Care and Rehabilitation (137)

Name (Please print your name): _____

Date: _____

Passing score is 80%

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Course Evaluation: Stroke (137)

Please use this scale for your course evaluation. Items with asterisks * are required.

- 1 = Strongly agree
- 2 = Agree
- 3 = Neutral
- 4 = Disagree
- 5s = Strongly disagree

* Upon completion of the course, I was able to:

a. Discuss the incidence of stroke in the United States.

○1 ○2 ○3 ○4 ○5

b. Describe two features each of ischemic and hemorrhagic stroke.

○1 ○2 ○3 ○4 ○5

c. Describe the four main structures of the brain.

○1 ○2 ○3 ○4 ○5

d. State the two main arterial systems that supply blood to the brain.

○1 ○2 ○3 ○4 ○5

e. Identify one aspect each of gender, age, and racial differences in the presentation of acute stroke.

○1 ○2 ○3 ○4 ○5

f. Discuss five elements addressed in the prevention of stroke.

○1 ○2 ○3 ○4 ○5

g. Describe the five elements of emergency department care of the acute stroke patient.

○1 ○2 ○3 ○4 ○5

h. Summarize three therapies for the acute treatment of ischemic stroke.

○1 ○2 ○3 ○4 ○5

i. Describe the three most common destinations for post-stroke rehabilitation.

○1 ○2 ○3 ○4 ○5

j. Define plasticity and maladaptive plasticity.

○1 ○2 ○3 ○4 ○5

k. Discuss the three sensory elements that contribute to balance.

○1 ○2 ○3 ○4 ○5

l. Define walking adaptability and identify three movement strategies important for balance.

○1 ○2 ○3 ○4 ○5

m. Discuss three key points related to bilateral upper limb training.

○1 ○2 ○3 ○4 ○5

n. Identify four screening tools used to assess the presence or absence of dysphagia.

○1 ○2 ○3 ○4 ○5

o. Describe four common cognitive impairments that can occur following a stroke.

○1 ○2 ○3 ○4 ○5

p. Identify three factors that may lead to the development of depression following a stroke.

○1 ○2 ○3 ○4 ○5

q. Explain why low levels of physical fitness affect recovery following a stroke.

○1 ○2 ○3 ○4 ○5

r. Describe three common mobility devices used following a stroke.

○1 ○2 ○3 ○4 ○5

s. Describe the three interventions that must be undertaken to prevent skin breakdown following a stroke.

○1 ○2 ○3 ○4 ○5

t. Summarize three issues associated with caregiving once a stroke patient is discharged to home.

○1 ○2 ○3 ○4 ○5

u. Explain the importance of sedentary time in the inpatient rehab setting.

1 2 3 4 5

v. Summarize the four elements associated with treatment burden.

1 2 3 4 5

w. Define and describe neuroregenerative medicine.

1 2 3 4 5

* The author(s) are knowledgeable about the subject matter.

1 2 3 4 5

* The author(s) cited evidence that supported the material presented.

1 2 3 4 5

* This course contained no discriminatory or prejudicial language.

Yes No

* The course was free of commercial bias and product promotion.

Yes No

* As a result of what you have learned, do you intend to make any changes in your practice?

Yes No

If you answered Yes above, what changes do you intend to make? If you answered No, please explain why.

* Do you intend to return to ATrain for your ongoing CE needs?

- Yes, within the next 30 days.
- Yes, during my next renewal cycle.
- Maybe, not sure.
- No, I only needed this one course.

* Would you recommend ATrain Education to a friend, co-worker, or colleague?

- Yes, definitely.

- Possibly.
- No, not at this time.

* What is your overall satisfaction with this learning activity?

1 2 3 4 5

* Navigating the ATrain Education website was:

- Easy.
- Somewhat easy.
- Not at all easy.

* How long did it take you to complete this course, posttest, and course evaluation?

- 60 minutes (or more) per contact hour
- 50-59 minutes per contact hour
- 40-49 minutes per contact hour
- 30-39 minutes per contact hour
- Less than 30 minutes per contact hour

I heard about ATrain Education from:

- Government or Department of Health website.
- State board or professional association.
- Searching the Internet.
- A friend.
- An advertisement.
- I am a returning customer.
- My employer.
- Other
- Social Media (FB, Twitter, LinkedIn, etc)

Please let us know your age group to help us meet your professional needs.

- ○ 18 to 30
- ○ 31 to 45
- ○ 46+

I completed this course on:

- ○ My own or a friend's computer.
- ○ A computer at work.
- ○ A library computer.
- ○ A tablet.
- ○ A cellphone.
- ○ A paper copy of the course.

Please enter your comments or suggestions here: _____

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Registration Form: Stroke (137)

Please print and answer all of the following questions (* required).

* Name: _____

* Email: _____

* Address: _____

* City: _____ * State: _____ * Zip: _____

* Country: _____

* Phone: _____

* Professional Credentials/Designations:

_____

* License Number and State: _____

* Please email my certificate:

◯ Yes ◯ No

(If you request an email certificate we will not send a copy of the certificate by US Mail.)

Payment Options

You may pay by credit card or by check.
Fill out this section only if you are **paying by credit card.**
13 contact hours: $59

Credit card information

* Name: _____

Address (if different from above): _____

* City: _____ * State: _____ * Zip: _____

* Card type:

◯ Visa ◯ Master Card ◯ American Express ◯ Discover

* Card number: _____

* CVS#: _____

* Expiration date: _____