THINK F.A.S.T.: AN EDUCATIONAL REVIEW OF STROKES

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Abstract

Strokes are the fifth leading cause of death in the United States, killing on average 800,000 Americans annually. An overview of the three main components of the cardiovascular system (the heart, the blood, and the blood components) will be established with an in-depth look at the cerebral vasculature to explain the physiological mechanism of a stroke. There are two main categories of stroke, both with distinct causes and treatments, although they both occur without prior warning. A summary of the causes, treatment, and prevention methods are listed for both types of strokes, with some overlap between the two. Finally, a community outreach portion is included, comprised of a lesson plan to teach elementary students about strokes and explaining why it is important to teach young children about science in general.
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Introduction

A stroke is characterized as the cessation of blood flow that can occur in any cerebral artery. A stroke can be caused by the blockage or rupture of an artery; these are defined as an ischemic stroke and a hemorrhagic stroke, respectively.

Strokes are incredibly prevalent, affecting 795,000 people in the United States alone each year.\textsuperscript{29} The CDC reports that every forty seconds, a citizen of the U.S. suffers a stroke, leading to a death every four minutes.\textsuperscript{29} Because of this, strokes are constantly being studied to find better methods to prevent, diagnose, and treat strokes and their subsequent effects.

When blood flow is cut off from a tissue, that tissue no longer receives oxygen and nutrients. Within minutes, that tissue will begin to undergo necrosis, premature cell death that cannot be reversed. Depending upon which blood vessels are affected, that area of the brain will no longer be able to function normally. This leads to the possibility of long-term, permanent damage to the sufferer, often requiring therapies for years after the initial event.

As new treatments emerge for those who have suffered a stroke, doctors unanimously agree that the quicker a patient receives treatment, the better their prognosis will be in the long term.\textsuperscript{29} Because of this, it is crucial that the public become educated and familiar with the classic symptoms of a stroke so that they can get themselves and those they love the treatment they need in a timely manner. Furthermore, this paper aims to educate on the overall prevention of strokes by decreasing modifiable risk factors, in the hopes that readers will internalize this
knowledge and make a change in their own life. This purpose is especially apparent in the community outreach portion, where elementary students can be taught about risk factors and their ability to mitigate them from a young age. Strokes are currently the fifth leading cause of death in America; it is now more important than ever to discuss this issue that affects so many.29

The Cardiovascular System

The Cardiovascular (CV) System is essential to sustaining life. Made up of blood, blood vessels, and the heart, the CV system is the body’s highway structure to transport oxygen and nutrients. Secondary functions include regulation of body temperature, hormone distribution, and waste collection. The CV system can be thought of as a pump system, where the heart is the pump that keeps things moving, the blood is the fluid that is circulated, and the blood vessels are the tubing that keeps the blood organized. The CV system is a closed system, meaning that each of the blood vessels are interconnected, originating from the heart and ultimately returning to the heart.1

The Heart

Anatomically, the heart is located in the mediastinum, which is behind the sternum, in front of the

Figure 1
vertebral column, and between the lungs. The heart is situated above the diaphragm and is approximately the size of a fist. It is a hollow organ, with vessels attached which act to transfer the blood to and from specific places in the body. Larger in circumference at the base (the top of the heart) than it is at the apex (the bottom of the heart), the heart is made up of three layers of tissue, with a protective sac on the periphery.

The sac that the heart lies in is termed the pericardium, and it is made up of two portions: the serous pericardium and the fibrous pericardium. The fibrous pericardium acts as a tough, protective layer around the entire heart. The serous pericardium is further divided into two more layers: the parietal pericardium and the visceral pericardium. Between the two layers is the pericardial space, which is where the pericardial fluid is housed. This fluid helps to decrease the friction between the tough layers and the cardiac muscle, allowing it to move around just enough for unimpeded beats.

Of the three layers that actually make up the heart, the epicardium is the outermost. The epicardium is also known as the visceral layer of the serous pericardium. The layer beneath that is known as the myocardium.

![Heart Diagram](https://commons.wikimedia.org/wiki/File:Heart_Diagram.png)
myocardium is made up of the cardiac muscle cells that contract to pump the blood through and out of the heart. Cardiac muscle is striated, yet involuntary, and it is constantly contracting (at various rates, depending on the metabolic demand of the individual) throughout a person’s life. The muscle fibers lie in a spiral fashion, so that the heart can contract as though it is wringing out a wet towel to better project the blood up and out of the heart.

The final layer is the endocardium, which lines the inside of the heart much like the endothelial inner layer of the vessels.

The heart is a four-chambered muscle that accepts and subsequently ejects blood from two separate systems: the pulmonary and the systemic. The four chambers consist of two atria and two ventricles: the right and left atria accept blood from the systemic and pulmonary circulation, respectively, and the right and left ventricle ejects blood to the pulmonary and system circulation, respectively. The pulmonary circulation acts to reoxygenate the blood and return that blood back to the heart. The systemic circulation delivers blood to the rest of the body, and returns with blood that needs more oxygen.

To prevent backflow through the heart, there are valves made up of fibrous connective tissue. These valves separate two distinct structures: the atria from the ventricles, and the ventricles from each large artery. The atrium to ventricle valves are known as the atroventricular (AV) valves. They are unique because they consist of leaflets, also known as cusps, which open when the pressure in the atria exceeds the pressure in the ventricle. The number of cusps depends on the side of the heart. Between the right atrium and the right ventricle, the AV valve is termed the tricuspid valve because there are 3 cusps that make up the valve. Between the left
atrium and the coordinating left ventricle, the AV valve is designated the bicuspid (or mitral) valve because there are only 2 cusps. Each AV valve is anatomically and physiologically similar, in that they both open into the ventricle via pressure differences and papillary muscles inside the ventricle. Each of the cusps are attached to structures termed chordae tendineae. These tendons are then attached inside the ventricles to the papillary muscles. These muscles help prevent the valve from opening up backwards into the atrium during ventricular contraction.\(^5\)

The second set of valves are the semilunar valves. Each of the semilunar valves separate the ventricles from the arteries leaving the heart. The pulmonary semilunar valve separates the right ventricle from the pulmonary artery, which carries deoxygenated blood to the lungs. The aortic semilunar valve separates the left ventricle from the systemic aorta, which carries oxygenated blood to the systemic circulation. The semilunar valves are each made up of three leaflets that tend to “crown” when they are closed.\(^5\) The semilunar valves work differently than the AV valves in that they do not require the use of muscles to keep their structural integrity intact. Instead, the semilunar valves are able to use solely the pressure differences between the ventricles and the large arteries. When the pressure is higher in the ventricle than in the artery the valve is opened. When the pressure switches, so that it is higher in the artery than in the ventricle, the valve closes, inhibiting backflow of blood into the heart.\(^5\)

**Blood**

Blood is the viscous liquid that moves throughout the body, dropping off and picking up many different substances as needed. It is made up of two components,
plasma and blood cells. The plasma is the fluid that carries these cells around the cardiovascular system. The majority of plasma is water (91.5%) but it also carries some elements that are solubilized (8.5%). The blood cell portion is a combination of red blood cells, white blood cells, and platelets. Each has a significant role in the functionality of blood.

The blood has 3 main functions in the body: transportation, regulation, and protection. Transportation partially involves the red blood cells, which carry necessary oxygen to somatic cells and carbon dioxide waste away from somatic cells. But the blood also carries substances such as hormones and nutrients, which are dissolved in the plasma. The blood acts as a rapid way for the body to get oxygen and nutrients to target areas quickly, and because of this, it is necessarily present in every tissue. The blood also acts to regulate certain body parameters, such as heat and pH. The blood is equipped with a tremendous buffering system so that the pH does not deviate much either way. In addition, when the body’s core temperature gets too high, blood will be shunted to the surface of the skin to release the heat to the external environment. Lastly, the blood helps to protect the body against foreign invaders and blood vessel rupture. White blood cells are the main line of defense against any external attackers that make it inside the body. The platelets can clot together to form a protective barrier on a broken blood vessel, in order to decrease the amount of blood that escapes from the closed system.
Red blood cells (RBCs) are also known as erythrocytes, and assist in carrying oxygen and carbon dioxide to and from the cells. RBCs have a lifespan of about 120 days, but they are unable to divide by themselves; they are created in the bone marrow of long bones. Red Blood Cells have flexible plasma membranes that allow them to be folded over in tight capillary spaces. RBCs are round disks with concave sides on the top and bottom, as can be seen in Figure 3. They do not have any organelles, and they do not have a nucleus. Instead, RBCs can be thought of as bags of hemoglobin, the subunit that carries the oxygen in the blood.

Hemoglobin is made up of four heme units, which contain iron. Iron loosely binds with the oxygen molecules; thus, one hemoglobin molecule can carry four oxygen molecules. This is amplified by the fact that there are about 280 million hemoglobin molecules in just one red blood cell. The oxygen carrying capacity is tremendous for such a small cell.

In addition to carrying oxygen, the red blood cell can also carry carbon dioxide. RBCs are responsible for transporting twenty-three percent of the carbon dioxide that is created in the cells and must be carried to the lungs for expulsion.
order for cells to make energy efficiently for daily functions, they must use oxygen. This oxygen is inhaled down into the lung’s alveoli (small sacs that are embedded in capillary beds). Oxygen diffuses through the alveolar wall and into the blood where it is picked up by passing RBC’s hemoglobin. The oxygen travels through the blood system bound to the heme group of hemoglobin until it reaches its destination. The oxygen then dissociates and diffuses through the vessel and the cell wall. When the oxygen is gone, the RBC is now free to pick up the carbon dioxide byproduct that the cell has made in addition to its energy molecule, ATP. The RBC carries the carbon dioxide back to the lungs, where it can diffuse into the alveoli and be exhaled out of the body. These pathways are why RBCs are crucial to the body’s routine function.

White Blood Cells (WBCs), also known as leukocytes, are the body’s line of defense against microbial attackers. There are two subtypes of WBCs: agranular and granular leukocytes (an example can be seen in the Figure 3). Agranular leukocytes received their name because they do not show tiny granules under a microscope when stained. They consist of lymphocytes and monocytes, which normally begin and oversee the immune reaction to a foreign invader. Granular leukocytes do show tiny granules after being stained, and they are broken up into three types: neutrophil, eosinophil, and basophil. Of the three, neutrophils are by far the most abundant, averaging seventy percent of the total white blood cell count. The granulocytes are used mostly in situations of inflammation, although they all have their own specialties. The amounts of each of the types of WBCs vary depending on the health of the individual at that point in time. If one type of WBC is needed in
abundance, the count will raise disproportionately when compared to the other types of WBCs.

The last element in the blood is platelets, also known as thrombocytes. Platelets are fragments of megakaryocytes that have broken off into 2000 to 3000 tiny pieces (an illustration of a platelet can be found in Figure 3). Because they are pieces of a whole cell, they do not have their own organelles or nuclei. But they do have vesicles filled with blood clotting factors, which when released can help promote clot formation. Platelets are made in the bone marrow along with the other two types of blood cells.

One of platelets main functions involves the coagulation cascade. Two different pathways can originate this cascade: the extrinsic pathway and the intrinsic pathway. Both pathways can be seen in the Figure 4. The extrinsic pathway occurs when there is trauma to the outside of the blood vessel. The intrinsic pathway occurs when there is damage from the inside of the blood vessel that affects the endothelial lining. Both pathways start off with different factors, but converge to a final, common pathway, as seen in Figure 4. The pathways end with the activation of prothrombinase, which helps cleave
prothrombin into thrombin. Thrombin then cleaves fibrinogen into fibrin. Fibrin, along with thrombin, creates the clot that will plug up any leaks in the vessel wall.$^2,^4$

However, this cascade can often be triggered under false pretenses. Any type of rough edges inside of the vessel will set off this cascade, causing unnecessary clots to develop. This can be dangerous because the clot can grow to be large enough that it will occlude blood flow. The body has systems to stop this potentially big problem from getting out of control. A major source of this clot breakdown (or fibrinolysis) is the fibrinolytic system, which works with the active form of plasminogen, plasmin, to breakdown the fibrin threads of the clot.$^2$

When a clot is formed due to the irregular edges of plaque, that clot is usually broken down. Sometimes, the clot escapes these backup systems, and travels around in the blood stream. A blood clot that is traveling around the body is called an embolus, and it can wreak havoc on the smaller capillary vessels as it progresses through them.$^2,^4$

**Blood Vessels**

Blood vessels run throughout the body in a closed system. A vessel's main function is to carry blood to and from the heart. There are many types of blood vessels, and they are categorized based on where the blood is coming from and going to. Arteries carry blood away from the heart. They are characterized by being large in diameter and elastic. Arteries turn into arterioles, which are generally smaller in size than arteries but have a large range of diameter dimensions. Arterioles are very good at constriciting the blood flow to certain tissues and increasing flow to others, depending upon metabolic needs (this is why they are
called resistance vessels). Arterioles get even smaller until they become capillaries. Capillaries have thin walls to allow for easy diffusion of gases and nutrients. Capillary beds are large networks of capillaries with immense surface area so that it can reach virtually every cell. After capillaries, the vessels get a little larger and become venules. Venules are also thin walled and they are not as elastic as arterioles. Venules eventually turn into veins, which are characterized as volume reservoir vessels because they have the ability to hold greater than half the total blood supply. Veins have valves, which help to prevent backflow and keep blood moving towards the heart, often against the force of gravity.\(^4\)

The rate of flow through the blood vessels is dependent on the pressure exerted by the heart and the resistance in the arterioles. Organ systems that need more blood will decrease resistance compared to tissues that need less blood. A key example of this can be seen during aerobic exercise: skeletal muscle needs more nutrients and oxygen at such a metabolically demanding time, so blood is shunted (using resistance) away from gut organs and channeled to the muscle.\(^17\) The resistance of a vessel is determined mostly by the radius of the vessel: the larger the radius of the vessel, the less resistance to flow there is. This concept can be seen using the flow equation: \(F = \frac{\Delta P}{R}\) where \(F\) is the flow of the blood through the vessel, \(P\) is the pressure exerted by the vessel, and \(R\) is the resistance to flow of the blood.\(^4\)

Once the blood gets to the capillaries, the major function of the vascular system is the diffusion of oxygen and nutrients between the tissues and the vessels. There are three different types of capillaries, which allow different levels of diffusion: continuous, fenestrated, and sinusoidal capillaries.\(^4\) Continuous capillaries
are made up of compact cells and account for the majority of the capillaries in the body. There are little to no spaces between the cells, so only small particles can diffuse through, such as gases and glucose. Fenestrated capillaries have slightly larger spaces between the cells, allowing for movement of salts in addition to gases and glucose. Sinusoidal, or discontinuous, capillaries have the largest spaces of all capillaries. They are able to transport cells and larger proteins to and from the tissues. These capillaries are found in the bone marrow, liver, and lymph nodes. Tissues with large metabolic demands require more vasculature than others: the brain, liver, kidneys, and the nervous system are good examples of this.

Capillaries deliver oxygen and nutrients via concentration gradients. On the arteriolar side of the capillary, the blood has high oxygen and low carbon dioxide concentrations. In contrast, the tissues have low oxygen and high carbon dioxide. As the blood moves through the capillary, the gases exchange down their gradients, so that oxygen diffuses into the tissue and carbon dioxide diffuses out. By the time the blood reaches the venule side of the capillary, it is saturated with carbon dioxide, and depleted of oxygen.
As blood travels back up through the veins, the flow of blood tends to decrease. Veins are distensible, and as thus are called capacitance vessels. There are tactics that the body uses to promote blood flow back to the heart: cardiac contraction, vasoconstriction of the veins, skeletal muscle contraction, the use of venous valves, and respiratory suction. These all help to keep blood moving back to the heart, especially during times of high metabolic demand (i.e. exercise). The entire vascular system acts to keep blood flowing around the body in a way that prioritizes oxygen hungry tissues. The delivery of oxygen and nutrients helps to keep cells metabolically active so that the body can continue to function in an effective way; the vascular system has a large role in this critical function.

The Brain

The brain is the command center, which coordinates and executes everything from involuntary, life-sustaining functions to higher-order thought processes about the world around us. The brain is divided into three parts: the hindbrain, the midbrain and the forebrain. The hindbrain makes up the top of the spinal cord, the majority of the lower brain stem, and the cerebellum. The midbrain is composed of the rest of the brain stem, connecting the hindbrain to the forebrain. The forebrain is primarily composed of the cerebrum, where thought, emotions, and decision making come into play.

Regions of the Brain

The hindbrain is important for fundamental processes such as breathing and swallowing. It houses each of the twelve cranial nerves except for cranial nerves one and two (olfaction and vision, respectively). The hindbrain portion of the brain
stem is critically important for life, and is composed of the pons and medulla oblongata structures. They account largely for the transmission of signals (both afferent and efferent) between the spinal cord and the cerebrum. Due to the vital functions that the hindbrain performs, damage to this area can be wholly debilitating. Lack of activity within the hindbrain (or the brain stem as a whole), is termed “brain dead” because the body is still able to function with assistance, but there is no thought process or cognition. The hindbrain is also composed of the cerebellum, which helps the body keep its balance and move with fluidity.

The midbrain is relatively small but has a large hand in reflexes. The primary function is motor based, with a special emphasis on voluntary movement of the eye. Two notable structures that make up the midbrain are the superior and inferior colliculi. The superior colliculus is used in visual reflexes, where it integrates information from the retina and the visual cortex. The inferior colliculus helps to integrate auditory stimulation, relaying that information to the superior thalamus.

![Figure 6](ASU School of Life Sciences. Brain Regions. 2010. Web.)
The final section, the forebrain, is the most advanced. Its functions are less necessary for sustaining life, but it has helped create the world in which we live. Personality, opinions, and decisions: these are all processes that take place in the forebrain, but more specifically the cerebrum. The cerebrum is composed of two hemispheres, which are broken up into the frontal lobe, parietal lobe, temporal lobe, and occipital lobe. Both frontal lobes have a premotor and motor cortex anterior to the central sulcus, where movements are decided upon and executed, respectively. The premotor cortex on the frontal lobe of the left hemisphere partially consists of Broca’s Area involved in the production of speech. The rest of the frontal lobe is devoted to “executive function” in the prefrontal cortex. It takes information from the internal and external world to control when vocalization or movements are appropriate.

Within the parietal lobes, the somatosensory cortex is positioned posterior to the central sulcus. Although in separate anatomical lobes, the motor cortex and sensory cortex work hand in hand to sense the external world and then act upon that information in a physical way. The parietal lobes have two major roles: acquiring sensory information and then integrating that information in a cohesive way that can be used by other parts of the brain. Basically, the parietal lobes receive every piece of sensory information and then merge it all into one organized thought or feeling. The parietal lobe works specially with the visual stimuli because vision is relied upon so heavily.

The temporal lobe is posterior to the frontal lobe and inferior to the parietal lobe. Its parameters are dictated by the Sylvian sulcus. The temporal lobe has many
different areas dealing with sight, taste, and most prominently sound. Sight is integrated in the secondary visual cortex, where identification is the main function. Taste is registered in the gustatory cortex, which is located on the insula area formed by the Sylvian sulcus.\textsuperscript{12} What the temporal lobe is really known for is the primary and secondary auditory cortices. They receive the auditory information and process it so that it can be understood.\textsuperscript{13} The temporal lobe also lends a hand in memory (via the hippocampus) and emotions (via the amygdala). The sensory information and memories are paired with an emotion, demonstrating intricate connections between the different parts of the temporal lobe.\textsuperscript{12}

The occipital lobe is located in the posterior region of the brain. It’s main function is visual: the optic nerves run from the retina to the occipital lobe, and send electrical signals when light is detected by the photoreceptor cells. The region that is directly responsible for receiving the stimuli is the primary visual cortex.\textsuperscript{14} Although researchers are still hypothesizing, it seems as though the perception of color is due to different cones (which are wavelength sensitive) projecting signals to different places within the occipital lobe. The occipital lobe also works closely with the parietal lobes and the

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{Major_Arteries_of_the_Head_Neck_and_Brain.png}
\caption{Major Arteries Of The Head, Neck, And Brain}
\end{figure}

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{Circle_of_Willis.png}
\caption{Circle of Willis}
\end{figure}
temporal lobes to gather all of the information necessary for a full sensory picture involving sight, sound, and hearing.\textsuperscript{12,14}

\textit{Vasculature of the Brain}

The brain's vasculature is unique because the blood supply needs to be maintained at a constant rate, without large deviations. There are four major arteries that run from the heart to the brain: the left and right common carotid and the left and right vertebral arteries. These arteries supply blood to different areas of the brain. The carotid arteries originate from the aortic arch and they feed the cerebrum, ascending laterally on each side of the skull. The common carotid arteries eventually split to become the internal and external carotid arteries. The internal carotid artery continues to climb vertically up and to the base of the brain. The external carotid artery veers out laterally to feed the outermost portions of the brain. The vertebral arteries originate from the subclavian arteries; they eventually merge together to form the basilar artery, which ascends posteriorly up the brainstem. This artery ultimately feeds the brainstem and cerebellum.\textsuperscript{15}

The most unique part of the vasculature is called the Circle of Willis. The Circle of Willis is mainly comprised of the left and right vertebral arteries (now the basilar artery) and the left and right internal carotid arteries. The Circle of Willis is positioned inferior to the brainstem and continues anteriorly toward the middle of the brain's base.

\textbf{Figure 8}

Children's Hospital of Wisconsin. \textit{Detail of the Circle of Willis}. Web.
where the Circle of Willis lies. The internal common carotid arteries travel up the sides of the neck and head region, before meeting with the basilar artery. The three main arteries are joined together by communicating arteries (anterior and posterior) that create the uninterrupted circle. These connections between arteries (or anastomoses) are critically important if one artery becomes blocked. However, only about fourteen percent of the general human population has a complete circle of Willis. From this circle, the anterior, middle, and posterior cerebral arteries break off to feed their respective portions of the brain. These arteries then begin to split into smaller and smaller vessels (arterioles) as they get deeper into the brain.

The cerebral arteries and veins comprise the macrocirculation within the brain. The capillary beds (which are abundant throughout the brain) are considered the microcirculation. This is where the nutrients and oxygen can be exchanged. Because the brain relies completely upon constant blood flow, it is hypothesized that every neuron has its own capillary for blood supply. The major driving force for exchange of oxygen is the resistance of flow determined by cerebral arterioles, directly affecting the amount of blood cerebral capillaries receive. Therefore, if cerebral arterioles dilate (due to metabolites), greater diffusion from the capillaries to the neurons is possible. It's important to note that cerebral arteries never constrict, due to the lack of sympathetic innervation. Thus, blood flow can only increase to the brain, it cannot decrease.

The cerebral veins drain the blood from the capillaries back down to the heart. The venules are numerous, but they begin to fuse together as they get closer to the heart, eventually creating four large veins: the right and left internal and
external jugular veins. The internal jugular veins connect to left and right subclavian veins, creating the left and right brachiocephalic veins. The left and right brachiocephalic veins come together to form the superior vena cava, leading directly to the left atrium of the heart. The external jugular veins follow the same path, but they join the left and right subclavian veins at a more distal point compared to the internal jugular veins. Also, just like in the systemic circulation, the cerebral arteries and veins are anatomically different. The cerebral arteries have many layers of smooth muscle to help dilate the arterioles when needed. The cerebral veins are very thin walled and have high compliance, enhancing their ability to form sinuses. However, cerebral veins differ from systemic veins in that they do not have valves. Cerebral veins have the force of gravity on their side to prevent backflow, thus rendering valves redundant.\textsuperscript{15}

\textit{The Stroke}

A stroke, or cerebrovascular accident, occurs within the confines of the cranium.\textsuperscript{2} Characterized by a lack of oxygen, a stroke can affect different parts of the brain depending on where it takes place. There are two major types of strokes: hemorrhagic and ischemic.\textsuperscript{4} Although each type of stroke has unique mechanisms that cause them, both often end up triggering irreversible brain damage. Strokes are associated with transient ischemic attacks (TIAs), which have the same physiological progression as strokes, but cause symptoms lasting less than 24 hours.\textsuperscript{21} However, TIAs tend to precede strokes and can act as vital indicators for the occurrence of future strokes; therefore, their presence should not be ignored.
Types of Strokes

A hemorrhagic stroke is often caused by a rupture in the vasculature of the brain. Weak points in the vessels are called aneurisms; aneurisms can be diagnosed via brain CT, but often go unnoticed. When the vessel ruptures, blood that is normally kept within the closed vascular system is allowed out into the cerebral tissue. Aneurysms can occur in any artery found in the vascular system and tend to appear inflated because of the weakened artery walls. When the blood gushes from the vessel, it invades the highly compact cranial space, increasing the intracranial pressure within the brain.

Because the cranial volume is fixed, this increase in pressure can collapse the unharmed vessels so that blood flow is reduced significantly. Reduced blood flow translates into depleted oxygen and nutrient supply for the brain as a whole, which is what causes ischemia and necrosis of the tissue.4

Figure 9

Figure 10
An ischemic stroke is caused by a blocked artery within the cerebral vasculature. Arteries can become blocked for two primary reasons: an embolus or atherosclerosis. An embolus is a traveling clot of fibrin and cells that can either break off from a previous artery wall or it can be produced by turbulent blood flow. Emboli become stuck in the microvasculature of the brain: the arterioles and the capillaries. When they block the vessel, no blood can get through, causing a lack of oxygen and nutrient delivery. The part of the brain that normally relies on that vessel will “starve” if the clot is not broken down in a timely fashion. Atherosclerosis is similar to a blood clot in that it occludes blood flow, but it is characterized as the buildup of cholesterol plaque on the walls of the arteries. When too much plaque is deposited in one area of the vessel, the flow of blood is decreased, resulting in a lack of oxygen for the proceeding cerebral tissue. An occlusion can also be caused if plaque is pulled from the wall of the artery, initiating the coagulation cascade. This will have the same effects as described in the embolus-containing stroke. Ischemic strokes account for 80-90 percent of all diagnosed strokes.

Causes

Because strokes are a cardiovascular phenomenon (localized to the cerebrum), many of the risk factors for a stroke mirror those of myocardial infarction or any other cardiovascular diseases. The risk factors for a stroke can be divided up into two categories: non-modifiable and modifiable. For both types of strokes, examples of non-modifiable risks are age, gender and race, as well as a genetic predisposition to cerebrovascular disease. In fact, age is the number one indicator of possible stroke for both hemorrhage and ischemic types. The greater
the age, the more prone to strokes the individual is. In regards to gender, men are more likely to have a stroke than women are on average. However, because women generally live longer than men, more women overall have strokes each year.\textsuperscript{21}

Certain races, specifically African-Americans and African-Caribbeans, have an increased risk of stroke solely due to their ethnicity.\textsuperscript{2,21}

Strokes have many causes, and because of this, “genetic predisposition” simply refers to an individual's natural inclination towards certain risk factors. For example, hypertension is chronic elevated blood pressure and can have many causes, one of which is purely having a family history of hypertension. Despite some patients’ best efforts, blood pressure cannot be controlled by anything but medication. This natural hypertension in turn makes them more susceptible to a stroke, the cause of which is then deemed a genetic predisposition.\textsuperscript{4}

Modifiable risk factors are those variables that can be controlled by the patient. Hypertension is an example of a non-modifiable and a modifiable risk factor, depending on why the blood pressure is elevated. If it is modifiable, a healthy diet, regular, aerobic exercise, and medication will keep the blood pressure at a manageable level, reducing the risk of a stroke.\textsuperscript{2,21} Hypertension is a risk factor for both types of strokes; it is estimated that two-thirds of the patients who have suffered from a hemorrhagic stroke had been previously diagnosed with hypertension.\textsuperscript{19} This chronic high blood pressure presses continuously on the weak walls of an aneurysm, which leads to the rupture of the vessel.\textsuperscript{2} Smoking, another modifiable factor, increases the risk for a stroke by two-fold.\textsuperscript{21} Additionally, obesity and diabetes mellitus are known to put individuals at a higher risk for a stroke.
Obesity is an umbrella term that encompasses many of the secondary effects already discussed, namely hypertension, high cholesterol, and diabetes mellitus. A diagnosis of diabetes mellitus will double the likelihood of a stroke, as will lack of aerobic exercise. High cholesterol and poor diet lead to the buildup of plaque in arteries, which is the beginning of an occluded artery (eventually causing an ischemic stroke).20

_Treatments_

When a patient is having or has suffered a stroke, warning signs can be remembered via an anagram: FAST. “F” stands for “face” which tells the physician or bystander to look for symmetry of the face. If one side is sagging or drooping, this is a good indication of a stroke. “A” stands for “arm,” instructing the patient to hold out their arms in front of them. If one of the arms is lagging behind or unable to be lifted, this is another warning sign of a stroke in progress. “S” stands for “speech” because if a stroke occurred, the patient may have slurred speech when trying to talk.

Figure 11
_American Stroke Association, Spot A Stroke_. Web.
Finally, “T” stands for time, because it is imperative that an individual who has recently undergone a stroke be transported immediately to emergency care. There are treatments for strokes, which can prevent irreversible damage, but only if they are enacted before the damage has been done.4

Treatment options differ depending upon which type of stroke has occurred. To interpret the type of stroke, an MRI or a CT are needed; there is no way to tell which type of stroke has happened by simply looking at the patient.21 If there is clearly free blood in the cerebral cavity, this indicates a hemorrhagic stroke. The cause of the hemorrhagic stroke is important to know because the cause dictates the treatment. If the patient’s stroke is caused by high blood pressure, a surgical procedure must be completed so that the intracranial pressure does not become too high. Because the cranium is a rigid structure, an increase in pressure will cause the brain to swell up against the
cranium, potentially causing damage to the cerebral vasculature and to certain areas of the brain. To relieve the pressure, a surgeon will remove a section of the cranium (this is called a craniotomy), allowing the brain to swell without consequence.

Because the brain may continue to swell for long periods of time, the section of skull removed can be surgically implanted underneath the skin to keep it viable. If the hemorrhagic stroke is caused by a ruptured aneurysm, the vessel must be closed off so that the bleeding stops as well as to prevent future additional bursts by that aneurysm. To close off a vessel with an aneurysm, there are two surgical options: aneurysm “clipping” and coil embolization. The former procedure physically occludes the vessel with a clamp. The latter procedure places a small coil into the aneurysm, causing a blood clot to form and subsequently blocking blood flow through the vessel.

Ischemic strokes are treated differently. Unlike hemorrhagic strokes, an ischemic stroke is characterized by a lack of blood flow. If the stroke is caused by a blood clot, anticoagulant medicines can be given in order to keep the blood clot from increasing in size. A therapy that is widely used is called tissue plasminogen activator (tPa) and it breaks up existing clots to allow reperfusion of the tissue. tPa works by breaking down the fibrin that holds a clot together; however, tPa does not act without consequence. When tPa is given, it can trigger a second stroke (this time a hemorrhagic stroke) because tPa is not selective when breaking down fibrin. If there are blood vessels that have previously been healed using clots, those clots will be broken down, allowing the blood vessel to leak or burst. tPa can only be given within 3-4 hours of stroke onset to be effective. For both types of strokes, there is
new literature that says that “cold therapy” has been shown to be effective against permanent brain injury. Being placed in a hypothermic state allows for the brain to switch into a survival mode where it needs less oxygen. The field of treatments for strokes is expanding at a remarkable pace.

Prevention

Prevention of strokes starts with trying to mitigate the risk factors. Of the modifiable risk factors, many start with a change to diet, exercise, and overall lifestyle. Because a stroke is a vascular event, changes made to decrease the risk of a stroke will ultimately be beneficial to the entire vascular system.

When making changes to the diet, foods that are low in saturated and trans fat and sugar are the primary goal. Low-fat dairy, vegetables, fruits, nuts, and legumes are all key staples that will help achieve a balanced, healthy diet. If the chief complaint is hypertension, the DASH (Dietary Approaches to Hypertension) diet is often used to decrease blood pressure. This diet emphasizes decreased sodium intake greatly. Some foods to avoid would be red meat, sugary treats/beverages, and snacks that are high in saturated and trans fat. These foods are high in cholesterol, which can potentially increase the plaque found in artery walls (a key element for the occurrence of an ischemic stroke).

A change in diet can also help with weight loss, which may be a necessary step to take if one is at risk for a stroke or has previously suffered a stroke. Weight loss can be achieved via two important variables: exercise and diet. By implementing a reduction in daily caloric intake as well as an increase in heart and vascular healthy foods, a more sustainable diet can be attained. When diet changes
are coupled with an increase in exercise (at least 2.5 hours per week of mild to moderate aerobic exercise is recommended), significant weight loss can be accomplished. Weight loss aids in decreasing cholesterol (potential future plaque) and blood pressure, which indicates that weight loss can be used to significantly decrease the chance of both types of stroke (ischemic and hemorrhagic).

Finally, the last modifiable risk factor known is smoking. Cigarettes are composed of many toxic chemicals, the most well known being nicotine. Cigarettes are known to cause many side effects, which increase the risk of a cardiovascular event. Specific to a stroke, cigarette smoking causes blood to be in a “hypercoagulable state,” reduces the oxygen carrying capacity of hemoglobin, accelerates atherosclerosis, and increases vasoconstriction. The hypercoagulable state is derived from an unknown mechanism, where smoking increases the amount of activated fibrinogen as well as the viscosity of the blood. This leads to a greater chance of the development of a thrombus, which is the key factor causing an ischemic stroke. Also contributing to the viscosity of the blood is the increased red blood cell count due to the high levels of carbon monoxide. Carbon monoxide binds to hemoglobin with a great affinity than oxygen, which can reduce the oxygen carrying capacity of each hemoglobin overall. To circulate the amount of oxygen needed for bodily functions, more red blood cells (and therefore hemoglobin) must be made. This in turn increases the viscosity of the blood, causing it to be thicker and stickier. Atherosclerosis, the hardening of blood vessels, and vasoconstriction also work hand in hand to increase the chance of stroke. Nicotine is known to vasoconstrict blood vessels, which makes them smaller and harder to get
larger cells through. If the vessels are also atherosclerotic, the vasoconstriction can become somewhat permanent, making your body work harder to deliver oxygen and nutrients, and also increasing the odds of a stroke immensely.²³

Prevention of stroke starts with changing modifiable risk factors. By changing the diet to include more healthy foods, incorporating aerobic exercise into a daily routine, striving for weight loss to achieve a healthy weight, and quitting smoking, the stroke risk factors can decrease dramatically.

Lesson Plan

1. Introduction

“Hello Class!”

“My name is Libby and this is my assistant Dr. Cohen. Today we will be learning about the brain and what can happen to the brain if it does not get oxygen for long periods of time.”

Show them a sheep brain. Let the kids each have a turn touching the sheep brain with gloves on.

2. Demonstration of brain function

“Does anyone know what the brain does for the body?” Write down a list of the functions they can come up with. Expected answers include: breathing, movement, sensation of external environment, integrating senses, memory, speech, hearing, etc.

“Right! All of these functions are examples of what the brain does. Next, we are going to play a game to see how our brains react to different stimuli.”
Produce flashcards that are based off of the Stroop Test. Have the kids pair off and test each other by timing themselves with the different flash cards. Discuss why it is harder for our brains to discern between the color seen and the color read.

3. Demonstration of the mechanism of oxygen deprivation

“Just like we need food to survive, the brain needs oxygen to survive. Oxygen is carried by our blood in tiny tubes called vessels. When the vessels are open and clear, blood can easily move through the vessels.”

*Show them an empty PVC pipe to demonstrate that objects could move through it. Use the arm of a volunteer to reach through the pipe and show that their hand reaches the other side.*

“However, when vessels are blocked, blood cannot get through.”

*Show them a PVC pipe with a blockage in the lumen. Reach that same volunteer’s arm as far as it can go through the tube, showing them that their hand can no longer poke out of the other side.*

“If blood cannot get through, everything past that point will not get the oxygen (food) that it needs. That tissue will starve and eventually stop working properly. To demonstrate this idea, we are going to play a game.”

Around the room, set up stations that are labeled as important organs. Form a single file line with you leading the kids. Give each of the kids a handful of red M&Ms; these will represent molecules of oxygen. Instruct the children to act like oxygen carriers in the blood, delivering oxygen to each of the organs with one
red M&M. Begin at the heart station and then proceed to organs like the liver, the stomach, and the small intestine. Each time a new station is reached, each kid will drop off one red M&M. When the brain station is reached, Dr. Cohen will stand in front of that station, blocking the children from dropping off their M&M. At the end of the activity, the children should be instructed to look around at all of the stations. A discussion could be led on how this activity is relevant to the body and what they think the effects of lack of oxygen will have upon the brain.

4. What is a stroke and how is it diagnosed?

“When the brain does not get oxygen due to a blockage in the artery or the rupture of a blood vessel, brain cells die. This is called a stroke. A stroke can happen at any time without warning. Strokes have particular symptoms attributed to them, which can help everyone diagnose a stroke. The acronym FAST is an easy way to remember key symptoms that stroke sufferers often exhibit.

F: Face. Often, the face will droop on one side. This can be especially apparent when a stroke victim smiles.

A: Arms. Arms can become weak after a stroke, often leading to the inability of the victim to raise an arm.

S: Speech. Speech can be slurred or unintelligible, even when trying to pronounce elementary words.

T: Time. Time is incredibly important. It’s essential that if any of the previous symptoms are observed, you need to call 911. The faster the victim receives medical care, the better chance they have of recovering brain function.”
To drive this point home, play a game of “Simon Says.” Suggestions for commands would be “touch your nose,” “run in place,” and “complete 5 jumping jacks.” Your assistant should participate in the game as well. Once the game has been established, commands such as “hold both arms out in front of you,” “smile,” and “say ‘I love science’” should all be said. Your assistant will do these commands as well, but instead they will do them as if they themselves are stroke victims. You should point out the difference between the children’s healthy reaction to the commands and your assistant’s emulation of a stroke victim’s reaction. Stress the need to call 911 or find an adult if these symptoms are ever seen in real life.

5. Stroke Prevention

“So, now that we know what a stroke is, how a stroke is caused, and how to tell if a stroke has occurred, we can learn what to do to decrease our chances of a stroke. Luckily, stroke prevention involves developing many good habits that also benefit our overall health. In general, eating healthy, exercising daily, and saying no to smoking all help greatly reduce our risk of a stroke occurrence.”

Show the kids examples of food that you have brought. Possibilities include: cookies, a head of lettuce, rice and beans, soda, a packet of salt, a natural granola bar, skim milk, fresh fruit, ketchup, low-fat yogurt, a bag of chips, etc.

Have the class divide a large table into two sections: healthy and unhealthy. Without your input, allow the kids to work together to put the foods into
their respective categories. Then, talk about the foods that gave them the most trouble and discuss why those foods are in one category over another.

6. Conclusion

“Thank you so much for your attention today! I hope that you all remember the information we discussed and use it in case of emergency. Strokes can be scary, but it is important to stay calm and always ask for help. I can now take questions.”

Teaching Children About Science

Teaching is an undervalued profession that requires a large amount of work and attention to detail. Effective and engaging teaching, starting at a young age, is essential to developing a love for learning and a love for science. A good science teacher can lead many kids to find their calling in the diverse range of scientific fields. Conversely, an ineffective, poorly educated science teacher can ruin a child’s chances of finding that love, potentially changing the course of that child’s life forever. But, whether or not a child goes on to use advanced science concepts in his/her daily life, basic science knowledge is essential to becoming an educated member of the world.

It is important to start teaching science from a young age. With teaching requirements changing year to year, it can be tempting to cut science education until the child is “old enough” to understand concepts that can be challenging for some. As Chris Ohana points out, cutting science education in elementary school could be seriously damaging to a young child’s perception of the world. Besides teaching children basic phenomena, science also serves two purposes: ingraining the idea of
cycles and emphasizing the need for evidence. Basic science revolves around the cycles that can be seen in daily life. Examples of these cycles include life cycles, the idea of a year, the water cycle, and the carbon cycle. Cycles are a foundational idea from which all of science is built upon. If a child is not taught this, it could potentially impact comprehension of other subjects. It would put the American child at a disadvantage, especially compared to other countries where STEM fields are highly regarded and pushed in terms of teaching from a young age. In regards to evidence-based teaching, science is crucial to learning this primary skill. Science and the scientific method are centered upon a prediction, which is tested without bias to see if that prediction is true. In science classes, kids learn that they cannot make a prediction without some reason why they believe that prediction will be true. If science is cut during those formative years, kids will not be as comfortable with the notion that a prediction is not just a random guess, but instead an educated guess. This skill is not only necessary for science; it is necessary for the humanities (i.e. foreshadowing), history (i.e. seeing a pattern in history and predicting what comes next), and math (i.e. predicting the best way to start a problem based on prior experience). While it is true that teaching the actual facts of science is crucial, it is just as important to develop the good techniques rooted in scientific methods that can be used across disciplines at a very early age.

Having said that it’s important to start teaching science at a young age, the next question would be what teaching methods are the most effective and productive for these children? One researcher argues that dialogue in a classroom setting is an important component of teaching science to elementary-aged
Discussion between the teacher, an expert on the subject, and the students, first-time learners, has been shown to be particularly useful when compared with the typical lecture style seen in most classrooms today. This type of learning style emphasizes talking about and becoming familiar with the language of science, which can be a large barrier for many kids that have never been exposed to this before. Memorizing random facts and having perfect knowledge of the scientific subject being discussed becomes less important in this style of teaching; instead, discussion stresses simply being able to form ideas about science and being able to adequately convey that information. The knowledge and the memorization can come later in the child’s education, when the structure for framing a discussion is already in place. In this way, a child leaves school having the knowledge of basic scientific phenomena and being able to discuss that knowledge in an effective and intelligent way.²⁶

Another teaching method is characterized as “active learning” teaching, where students are invited to participate in activities in the classroom. This style of teaching looks to engage students in the learning process by requiring them to partake in group discussions, electronic clicker based questions, filling out worksheets in class, etc. This is different from the traditional classroom setting of a lecture because it requires participation and more focus/attention to the area of study that is being taught. Active learning studies have shown numerous times that it is a far more effective form of teaching when looking at failure rates and test performance at the undergraduate level.²⁵ This data can be extrapolated down to the elementary level because active learning is most likely engaging for all age
groups. Even under the umbrella of “active learning” there are different methods that are more effective than others. A student’s success relies less heavily on the instructor’s effectiveness and more heavily on the teaching method employed, a reassuring fact for students everywhere.25

One more consideration would be the different learning styles of which each individual student is predisposed.28 The learning styles include: visual learning, auditory learning, and tactile learning.27 Visual learning is a student’s preference for viewing information as a graph, graphic, demonstration, or on a board. Auditory learning is characterized by learning through verbal instructions or discussing ideas out loud with a group. Tactile learning is learning through touch or experimentation, often involving diving into ideas with no prior instruction.27 With a classroom full of students, the learning styles can vary significantly which means that the teaching style needs to consciously hit each of the learning styles to effectively reach the variety of students present.

The lesson plan previously given has been developed based upon the utilization of these proven teaching methods. The lesson plan begins with an introduction to the main organ of focus for the lesson, the brain. This section identifies the organ and the specific problem about that organ which is to be discussed. This section involves looking at and touching a real sheep brain, effectively enticing the students to be interested in the subject. It also hits two learning types in one activity: visual and tactile learning. By being able to see and touch the brain, these students with these learning affinities are learning the most effectively for them. The second activity involves discussing brain functions and
demonstrating some of those functions through the Stroop Test. The Stroop Test is heavy in active learning because it involves working in partners to be exposed to an interesting phenomenon of the brain. The third activity has two active learning activities, because it involves a PVC pipe demonstration (acting as a metaphorical blood vessel) and a follow the leader type activity, where the kids act as red blood cells. These two activities are particularly good for visual and tactile learners, respectively. Auditory learners will benefit from the discussion at the end of this section, when the teacher and the students will have a dialogue regarding why the students were not able to drop off oxygen at the brain.

The fourth section is mainly discussion based, with an activity at the end. This section seeks to really educate children on how to diagnose a stroke, which is a practical application of their knowledge. The “Simon Says” game is a form of active learning, where the children have to critically think about the difference between their actions (those of a healthy individual) and the assistant’s actions (those of an individual after having suffered a stroke). The fifth section seeks to show children what eating healthy looks like visually, so that when they see those foods again in a supermarket or in their home, they will know why they are healthy as well as why they are the better choice over other foods. The conclusion asks for questions, in the hope that while the kids have been learning, they have been thinking critically enough to have developed questions on their own.

Research shows that not only is science important to teach to elementary aged kids, it is important to teach it in a way that is effective for a wide variety of people. Teachers can potentially make or break their students’ interests in the
sciences at this point in a child’s life, making it critical that teaching methods are consciously chosen so as to maintain the wonder and imagination of the young student. With the United States lagging in the education of STEM fields, this area of study is crucial to the future of society today.28

Conclusion

Forty-nine percent of Americans have at least one of the three major modifiable risk factors that can cause a stroke (hypertension, high cholesterol, and smoking).29 Such susceptibility to this debilitating event wreaks havoc on families and loved ones who are affected by this disease. By beginning stroke education at a young age, the hope is that healthy habits that promote stroke protection will develop early on and continue into adult life. Furthermore, it is also important to educate the adult public on strokes for two purposes: characteristic symptoms will be more readily recognized, allowing treatment to happen faster, and those who perceive themselves at risk will hopefully change their habits, leading to a decrease in the risk factors of which they have some control.

The first step in stroke treatment is, of course, prevention. The greatest chance to a live a normal, unaffected life begins with not having a stroke in the first place. However, not all risk factors are modifiable. As discussed, factors such as gender, age, and race all play into whether or not a stroke is triggered. Because of this, treatment as well as prevention needs to be studied further. In the future, stroke treatment hopes to move towards more effective therapies that can initiate blood flow sooner (in the case of ischemic stroke) or relieve intracranial pressure and blood loss faster (in the case of hemorrhagic stroke). Some treatments are even
hoping to use stem cell therapy to regrow damaged or dead areas of the brain after the attack is over, restoring brain function that is lost. However, PJ Lindsberg argues that these advancements will be unproductive if the chain from the onset of stroke (pre-hospital) to the stroke unit (in hospital) is not as organized and as efficient as possible. Time, one of the most important factors when it comes to strokes, appears to be the future of stroke therapy.

Stroke is the fifth leading cause of death in the United States, and the number one leading cause of serious, permanent disability, affecting the rest of one’s life. Strokes are an important health concern for people around the world. But with education beginning at an early age and a commitment to furthering existing stroke treatments, we can begin to fight strokes in a real and effective way for future generations.
References


Appendix A: Lesson Plan

1. **Introduction**
   
   *i.* “Hello Class! My name is Libby and this is my assistant Dr. Cohen. Today we will be learning about the brain and what can happen to the brain if it does not get oxygen for long periods of time.”
   
   *ii.* *Show them a sheep brain. Let the kids each have a turn touching the sheep brain with gloves on.*

2. **Demonstration of brain function**
   
   *i.* “Does anyone know what the brain does for the body?” *Write down a list of the functions they can come up with.*
   
   *ii.* Next, we are going to play a game to see how our brains react to different stimuli.”
   
   *iii.* Produce flashcards that are based off of the Stroop Test. Have the kids pair off and test each other by timing themselves with the different flash cards. Discuss why it is harder for our brains to discern between the color seen and the color read.

3. **Demonstration of the mechanism of oxygen deprivation**
   
   *i.* “Just like we need food to survive, the brain needs oxygen to survive. Oxygen is carried by our blood in tiny tubes called vessels. When the vessels are open and clear, blood can easily move through the vessels.” *Show them an empty PVC pipe for visualization.*
“However, when vessels are blocked, blood cannot get through.”

*Use a PVC pipe blocked halfway through for visualization.* “If blood cannot get through, everything past that point will not get the oxygen that it needs. That tissue will starve and eventually stop working properly.

Around the room, set up stations that are labeled as important organs. Form a single file line with you leading the kids. Give each of the kids a handful of red M&Ms; these will represent molecules of oxygen. Instruct the children to act like oxygen carriers in the blood. When the brain station is reached, your assistant will stand in front of that station, blocking the children from dropping off their M&M. A discussion could be led on how this activity is relevant to the body.

4. **What is a stroke and how is it diagnosed?**

i. “When the brain does not get oxygen due to a blockage in the artery or the rupture of a blood vessel, brain cells die. This is called a stroke. Strokes have particular symptoms attributed to them, which can help everyone diagnose a stroke. The acronym FAST is an easy way to remember key symptoms that stroke sufferers often exhibit. F: Face asymmetry. A: Arm weakness. S: Slurred speech. T: Quick time reaction to symptoms.”

ii. To drive this point home, play a game of “Simon Says.” Your assistant should participate in the game as well. Once the game
has been established, commands such as “hold both arms out in front of you,” “smile,” and “say ‘I love science’” should all be said. Your assistant will do these commands as well, but instead they will do them as if they are a stroke victim.

5. **Stroke Prevention**
   
   i. “So, now that we know what a stroke is, how a stroke is caused, and how to tell if a stroke has occurred, we can learn what to do to decrease our chances of a stroke. In general, eating healthy, exercising daily, and saying no to smoking all help greatly reduce our risk of a stroke occurrence.”

   ii. Show the kids examples of food that you have brought. Have the class divide a large table into two sections: healthy and unhealthy. Without your input, allow the kids to work together to put the foods into their respective categories. Then, talk about the foods that gave them the most trouble and discuss why those foods are in one category over another.

6. **Conclusion**
   
   i. “Thank you so much for your attention today! I hope that you all remember the information we discussed and use it in case of emergency. Strokes can be scary, but it is important to stay calm and always ask for help. I can now take questions.”
References

Cerebral Vasculature

Conclusion

Table: Risk Factors and Treatments

Appendix B: Poster

Abstract

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