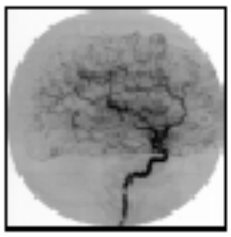
Brain's Blood Supply

Visualizing and measuring blood flow to the brain



To carry out its vital functions, the human brain consumes a great deal of energy in the form of glucose. To supply glucose for energy, the brain receives up to one-quarter of the total cardiac output of blood through two pairs of arteries—the internal carotids and the vertebrals. X-rays can be used to study these arteries in a living person, often to diagnose abnormalities in blood flow to the brain.

Open **Neck and Chest Arteriogram**. This is a digital copy of an X-ray image of the neck and chest region.

File/Open Sample

Blood vessels can be made visible in an X-ray image by using a dye that absorbs X-rays that would otherwise pass right through soft tissues. The dye is injected into blood vessels and a **radiograph** is made. The resulting radiograph is called an **arteriogram**.

1. Why are the arteries white in this image?

Locate the subject's head, neck, shoulders and chest in this image.

2. Why do you think the subject of the image is in this position?

3. Where is the heart located in this image?

You may want to use the magnifier to enlarge the image

Ordinary X-ray images appear less exposed (brighter) where denser tissues are located, because dense tissues absorb more X-rays than less dense tissues.

Radiograph is a general term for an x-ray image.

Investigating the brain's blood supply

When X-ray film is developed, it is placed on a light source for examination. The physician or technician can then study the visible structures and perhaps measure them with a ruler. However, if an X-ray image is digitized, the information contained in the image can be manipulated and analyzed in many different ways. In this activity, you will see how digital image processing can help a physician see the structure of arteries that carry blood to the brain.

Look-Up Table (LUT) manipulation

A digital image is composed of individual picture elements called **pixels**. Each pixel in a grayscale image has a value from 0 to 255 that corresponds to a shade of gray (0 = white and 255 = black) assigned in the Look-Up Table (LUT). Colors can also be assigned to values in the LUT.

Choose Image/Lookup Table/Fire.

4. How does applying a false color table to the image help you see detail?

Experiment with other color tables **Image/Lookup Table** .

Return the image to grayscale.

Duplicate the image.

Invert the pixel values of the copy to make a "negative" of the image.

5. Compare the inverted image to the original. Can you see detail in one image better than the other? Why or why not?

Close the inverted image.

Use the tool to magnify the image until you can see the pixels. Reverse magnification by double-clicking the tool.

Image/Lookup Table /**Grays**

Image/ **Duplicate**

Edit/Invert

Click on each image to activae it.

Digital filters

Digital filters can be used to sharpen, blur, shadow or find edges in a grayscale image.

Try the filters in the **Process** menu including **Sharpen**, **Shadow** and **Find Edges**. Choose **File/Revert** after you try each filter.

File/Close... or click on the in the upper left corner of the image.

Digital filters change the pixel values in an image using mathematical algorithms.

6. Which filter enhances the image for best visualization of details, i.e. which one would you use to make a diagnosis about the condition of the patient? Why?

Close **Neck and Chest Arteriogram**.

Measuring

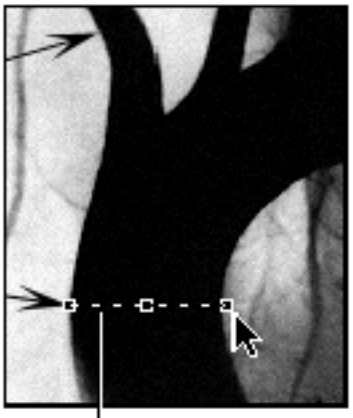
Another advantage to working with a digital image is measurement. With image processing, you can define a scale for an image and make very accurate measurements.

Open **Labeled arteriogram**. Use the **>** and **<** keys to move back and forth between the labeled and unlabeled slices of this stack.

Use this stack to review or learn the anatomy of the arterial blood supply to the brain before you measure any structures.

7. Which of the arteries in the neck deliver blood to the brain itself?

Use the tool to select the diameter of the aorta at the indicated place.. The diameter of the aorta at this point is 38 millimeters.



selection of diameter of aorta

Are you selecting the diameter of the whole vessel or of the lumen?

Set a scale for this image by choosing **Analyze/Set Scale**. Change Units to Millimeters and enter the Known Distance (38).

Now measure six other arteries in this image including one each of the subclavian, common carotid, internal and external carotid and vertebral arteries. Use the following techniques.

Carefully consider where to measure the diameter of each artery by choosing a representative area.

Use the tool to magnify the area you want to measure. -click to reverse magnification.

Use the tool to select the diameter across the artery.
Choose **Analyze/Measure** to measure the distance.
Record your measurement.

8. Record the diameters in the table on your **Data Sheet**.

9. How much larger is the diameter of the aorta than the common carotid artery? Than the vertebral artery?

$$\text{How much larger?} = \frac{\text{diameter of aorta}}{\text{diameter of artery}}$$

10. To better estimate the amount of blood carried by each artery, calculate the cross-sectional area of each artery you measured using the equations in the margin. Record your answers in the table.

$$\text{cross-sectional area} = \pi r^2$$

$$\text{radius } (r) = \frac{\text{diameter}}{2}$$

$$\pi \cong 3.14$$

11. Assuming the same velocity of blood in each vessel, use cross-sectional area to estimate the percentage of cardiac output directed to the brain by both internal carotids and by both vertebrals.

$$\text{Estimated \% cardiac output} = \frac{\text{total cross-sectional area of arteries}}{\text{cross-sectional area of aorta}}$$

12. What other factors can you think of (besides cross-sectional area) that might affect blood flow through an artery?

$$R \propto \frac{1}{r^4}$$

Note: Use a scientific calculator to calculate r^4 or multiply r times itself four times.

13. Resistance to blood flow through a vessel is inversely proportional to the fourth power of the vessel radius. Calculate the resistance (R) to blood flow for each of the arteries you measured. Record your results in the table on your **Data Sheet**.

14. Based on your data, what relationship do you observe between vessel radius and resistance? Construct a graph to display the relationship.

15. How does this relationship affect the percent cardiac output that you estimated for the carotid and vertebral arteries in #11?

Close **Labeled arteriogram.**

Moving up

As the dye makes its way through the brain, the structure of the blood supply to the brain is revealed. **(The next image will take a while to load!)**

Angio- is a prefix denoting relationship to a vessel or vessels.

Open **Angiogram**. Use the **>** and **<** keys to move back and forth through this stack of arteriogram images.

File/Open...

What do you think the round objects that appear raised are?

Apply a false color table if you want **(Options/Color Tables)**

Observe the flow of blood as it moves through the brain.

16. Which slices of the stack show blood flowing through the ***arteries*** of the brain? The ***capillaries*****?** The ***veins*****?**

The slice numbers are shown in the title bar of the image file, as shown below.

slice #1 of 14

Capillary circulation

Arteries are too large to exchange materials directly with the cells in brain tissue. Capillaries must accomplish this task.

Open **Cerebral cortex capillary**. This image shows a capillary directly in contact with brain tissue.

17. By what mechanism does gas exchange take place across the capillary wall?

18. How does the diameter of the capillary compare to the diameter of an artery?

19. How does the diameter of the capillary compare to the size of a red blood cell?

20. What is the functional significance of this?

21. Medium-sized arteries have muscular walls and can control their diameter. How do you think this affects distribution of blood?

22. Given what you know from the data you have collected, write a paragraph summarizing the relationships between vessel diameter (or radius), cross-sectional area and the resistance to blood flow in the aorta, arteries and capillaries.

More exploration

The carotid sinus

Open **Labeled arteriogram**.

Carefully observe the carotid arteries at the point where the internal and external carotid arteries branch.

A. This enlargement at the base of the internal carotid is called the carotid sinus. What role does the carotid sinus play in circulation to the brain?

Close **Labeled arteriogram**.

Blood-brain barrier

Open **Cerebral cortex capillary**. Examine this image. Can you see the cells of the capillary walls?

File/Open...

You will need to use your textbook or other reference to complete these activities.

B. It is very important that the brain's internal environment is stable. The mechanism that protects the brain's tissues from fluctuations in concentrations of hormones, ions and amino acids. Exchange of substances like oxygen, carbon dioxide and glucose happen across the capillary wall. Where is the blood-brain barrier? How does it work?

File/Close...

Close **Cerebral cortex capillary**.

Brain pathology

Open **Carotid arteriogram**.

C. Do you think this is a normal arteriogram? If not, what's wrong?

Close **Carotid arteriogram.**

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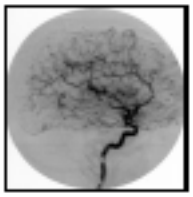

Data Sheet

Name(s)_____ Class_____

Date_____ Date_____

_____

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8. Record the diameters in the table below.

Artery	(d)	Radius (r), mm (d/2)	Cross-sectional area, mm^2 (πr^2)	Resistance ($1/r^4$)
Aorta	38 mm			

9. How much larger is the diameter of the aorta than the common carotid artery?

Than the vertebral artery?

10. To better estimate the amount of blood carried by each artery, calculate the cross-sectional area of each artery you measured using the equations in the margin. Record your answers in the table above.

11. Assuming the same velocity of blood in each vessel, use cross-sectional area to estimate the percentage of cardiac output directed to the brain by both internal carotids and by both vertebrals.

Estimated % cardiac output by internal carotid arteries:

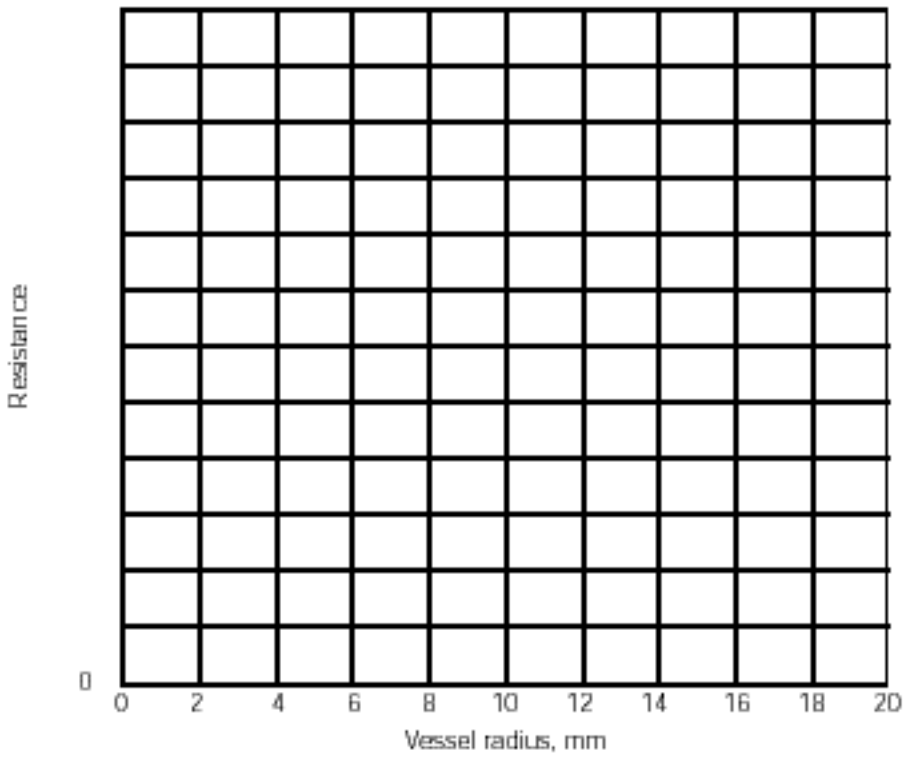
Estimated % cardiac output by vertebral arteries:

12. What other factors can you think of (besides cross-sectional area) that might affect blood flow through an artery?

13. Resistance to blood flow through a vessel is inversely proportional to the fourth power of the vessel radius.

Calculate the resistance (R) to blood flow for each of the arteries you measured. Record your results in the table above.

14. Based on your data, what relationship do you observe between vessel radius and resistance? Graph your results, with radius on the x-axis and resistance on the y-axis, to display the relationship.



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