Why dread a bump on the head?

The neuroscience of traumatic brain injury

Lesson 3: How does a CT scan help diagnose TBI?

I. Overview
In this lesson, students examine computed tomography (CT) scans of people with TBI and learn how to interpret these CT scans. Through readings and a segment of The Golden Hour game, students learn to identify the structures of the brain on a normal CT scan and compare them with the CT scans of TBI victims. They identify types of injury such as open head injury, diffuse axonal injury, and hematomas, as well as the loci of injury in the brain. Having identified the loci of injury, they revisit what they learned about functional roles of the different areas of the brain in order to predict the type of impairment or disorder that might be caused by the injury.

Connections to the driving question
To understand the functional consequences of a traumatic brain injury, students need to be able to explain the close relationship between brain anatomy and physiology. In this lesson, students examine various CT scans and identify the structural changes to the brain after TBI. Students discuss the physiological and functional consequences of these structural changes making connections to The Golden Hour, a Project NEURON interactive game. Students discuss the use of CT scan technologies for intervention to a traumatic brain injury and how quick identification of the location and the extent of the injury are critical during the golden hour.

Connections to previous lessons
In the previous lesson, students learned the basics of brain anatomy and physiology. In this lesson, they add another layer by discussing the importance of imaging technologies for diagnosis and intervention and by learning to read CT scans in order to distinguish between a normal brain and one that has been injured. Once they are able to identify the injury type and location, they can then apply what they learned in the previous lessons about TBI classification and brain structures to discuss potential effects of the injury on behavior and function.

II. Standards

National Science Education Standards
Content Standard F: Personal and Community Health
- Hazards and the potential for accidents exist. Regardless of the environment, the possibility of injury, illness, disability or death may be present. Humans have a variety of mechanisms—
sensory, motor, emotional, social, and technological—that can reduce and modify hazards. (9–12 F: 1/1)

- The severity of disease symptoms is dependent on many factors, such as human resistance and the virulence of the disease-producing organism. Many diseases can be prevented, controlled or cured. Some diseases, such as cancer result from specific body dysfunctions and cannot be transmitted. (9–12 F: 1/2)

- Personal choice concerning fitness and health involves multiple factors. Personal goals, peer and social pressures, ethnic and religious beliefs, and understanding of biological consequences can all influence decisions about health practices. (9–12 F: 1/3)

Families serve basic health needs, especially for young children. Regardless of the family structure, individuals have families that involve a variety of physical, mental, and social relationships that influence the maintenance and improvement of health. (9-12 F: 1/6)

**Benchmarks for Science Literacy**
The Human Organism: Mental Health
- Biological abnormalities, such as brain injuries or chemical imbalances, can cause or increase susceptibility to psychological disturbances. (6F/H2)

The Human Organism: Physical Health
- New medical techniques, efficient health care delivery systems, improved diet and sanitation, and a fuller understanding of the nature of health and disease give today's human beings a better chance of staying healthy than their ancestors had. (6E/H3a*)

### III. Learning Objectives

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<th>Learning Goals</th>
<th>Assessment Criteria</th>
<th>Location in Lesson</th>
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<tr>
<td>Explain the diagnostic role of CT scans</td>
<td>Students are able to explain the use of computed tomography (CT) as a diagnostic tool and how it is used to identify traumatic brain injuries.</td>
<td>Introduced in Activity 1 and explained throughout lesson</td>
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<tr>
<td>Identify certain structures and lobes of the brain on a normal CT scan</td>
<td>Students locate and identify the structures and lobes of the brain on a normal CT scan.</td>
<td>Activity 1</td>
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<tr>
<td>Compare a normal CT scan with a CT scan of a brain-damaged patient and explain the structural changes</td>
<td>Students are able to make comparisons between normal and injured CT scans to identify irregularities in an injured brain.</td>
<td>Activity 1 &amp; Activity 2</td>
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Identify the different types and the loci of brain injury on CT scans | Using a variety of CT scans, students examine various types of injuries that result from TBI and practice identifying the types and loci of damage. | Activity 2 & Homework

Interpret the CT scans and explain the potential functional outcomes of the TBI for the patient | Students see various types of traumatic brain injuries and they practice interpreting the functional outcomes of various types of injury by looking at the location of damage as shown in the CT scans. | Activity 2 & Homework

IV. Adaptations/Accommodations
Parts of the lesson require that the students have access to computers that are connected to the web. If access to computers is limited, 2–3 students can be assigned to each computer. If computers and/or the internet cannot be accessed the day of the lesson, the activities requiring The Golden Hour game can be revisited at a later time and used to review and further support learning of the concepts covered in this lesson.

Safety
There are no additional safety concerns associated with this lesson.

V. Timeframe for lesson

Opening of Lesson
• Discussion to review previous lesson and introduce current lesson – 5 minutes

Main Part of Lesson
• Activity 1: How to read a CT scan – 25 minutes
• Activity 2: How to read an abnormal CT scan – 45 minutes

Conclusion of Lesson
• Class discussion about CT scans – 5 minutes

VI. Advance prep and materials

Activity 1: How to read a CT scan

Materials:
• Handouts of “How to Read a CT Scan”: U4_L3_StudentSheet_HowToReadCTscan
• Computers connected to the internet (1 computer for 1–3 people)

Preparation:
• Familiarize yourself with the content presented in the PowerPoint. For further information regarding the use of the CT scans, benefits and drawbacks, how to interpret them etc. refer to the resources listed in the following section.
• Make enough copies of “How to Read a CT Scan” to hand out to each student.
• Open the link to The Golden Hour game through the Project NEURON website (neuron.illinois.edu). Be sure to select the “Classroom Mode” version of the game. Conduct a trial run of Scene 2: CT Scan of The Golden Hour game on a computer before beginning the lesson to make sure it can be accessed and is running smoothly on the computers. Prepare all the computers so students can quickly and easily begin the game.

Activity 2: How to read an abnormal CT scan

Materials:
• Handouts of “How to Read an Abnormal CT Scan”: U4_L3_StudentSheet_HowToReadAnAbnormalCTscan
• Handouts of “TBI Case Puzzle”: U4_L3_StudentSheet_TBICasePuzzle
• Computers connected to the internet (1 computer for 1–3 people)

Preparation:
• Familiarize yourself with the content presented in the PowerPoint. If you need to, refer to Emergency Neuroradiology book Head Injury CT scans chapter (listed under Resources section) for further information.
• Make enough copies of “How to Read an Abnormal CT Scan” and “TBI Case Puzzle” to hand out to each student.
• Conduct a trial run of Scene 2’s CT Scan Assessment of The Golden Hour game on a computer before beginning the lesson to make sure it can be accessed and is running smoothly on the computers.

Homework

Materials:
• “Lesson Journal”: U4_L1_Homework_LessonJournal
• Link to Project Neuron website (to access The Golden Hour): neuron.illinois.edu

Preparation:
• Make sure students still have their Lesson Journals that were given to them in Lesson 1. Additional copies of Lesson 3 page of the Journal may need to be distributed.
• All students will need to be able to access this link and play a segment of the game for homework. For those students who will not be able to complete this task at home, a
computer lab may need to be reserved to give them an opportunity to complete this homework.

VII. Resources and references

Teacher resources
Resources for additional information about brain anatomy and function:
- Harvard University Medical School, *The Whole Brain Atlas*:
  http://www.med.harvard.edu/AANLIB/home.html

Resources for additional information about CT Scan technology:
- Radiology Info: http://www.radiologyinfo.org/en/info.cfm?pg=headct#part_eight

Resources for additional information on brain trauma:

References
- Harvard University Medical School, *The Whole Brain Atlas*:
  http://www.med.harvard.edu/AANLIB/home.html
VIII. Lesson Implementation

Opening of Lesson:
Briefly review with students what they have learned in the unit so far. The following are some questions that can be used to guide the discussion. During the discussion, project an image or have some form of visual aid available of the brain to support students in thinking through and answering these questions. If the students are having trouble remembering, direct them to refer to their *Dissection of the Sheep Brain: Exploration Guide*.

- What are the 4 main lobes of the cerebrum? (Or different parts of the brain – forebrain, midbrain, hindbrain...)
- What do you remember about the case of Phineas Gage?
- What comes to your mind when you hear the word ‘brain damage’?
- Which hemisphere of the brain is thought to host the two main speech and language areas?
- Visual information goes to which lobe of the cortex first?
- Which structure in the brain is mainly responsible for balance and precise movement?
- What are some major roles of a nervous system?

Teacher Pedagogical Content Knowledge
Additional details of the anatomy and the function of the brain at various anatomical planes (coronal, sagittal, axial section) and levels can be accessed by downloading the *Brain Voyager Brain Tutor* free software (http://www.brainvoyager.com/downloads/downloads.html). This application allows the viewer to navigate through a 3D human brain model. It is very user-friendly and easy to navigate once familiar with the program.

*Brain Voyager* can be used at the beginning of the lesson as a review of the material presented in Lesson 2. Because the program integrates the 3D and the 2D images of the human brain, it is a good transition between sheep brain dissections and reading the CT scans. This software can be used as an extended practice of the material presented in Lesson 2 by showing students how brain structures look on a CT scan or an MRI by choosing the name of the structure from the drop-down menu and selecting the X, Y, Z plane.

This software can also be downloaded to smart phones and tablet computers for free.
Main Part of Lesson:

Activity 1: How to read a CT scan
In this activity, students learn about a widely used imaging technique as a very valuable diagnostic tool in medical settings. They learn how to read a normal CT scan and identify the basic structures on a CT scan.

To capture students' interest in the activity, ask the following questions:

- Have you ever had an X-ray before? If so, which part of your body was X-rayed?
- Have you heard of MRI or CT scan? What do these words mean?
- Have you ever seen a CT scan or an MRI image? What do these look like?
- Have you seen an X-ray device, a CT scanner or an MRI device?
- What are these CT scans used for? Which structures of the body can be viewed using these tools?
- Have you seen these devices being used in popular medical TV shows (such as House M.D. or Grey's Anatomy or other TV shows)? For what types of diseases or injuries do the TV doctors use these technologies?

Teacher Content Knowledge: Medical Technology
Medical imaging has a very crucial role in diagnosis of various diseases or disorders. Students may have familiarity with various medical imaging technologies such as X-rays, ultrasound, MRI or CT scans either by direct experience or by knowing someone who had a procedure using these technologies. Therefore, the use of medical imaging technology is very relevant to their lives. This lesson may provide a good opportunity to discuss the role of technology in medicine and how imaging techniques differ from each other and the relative strengths of each. After capturing the students' attention and interest in this activity, explain the use of this technology in the medical settings. MRI and CT imaging are highly advanced diagnostic tools that can be used to see the 3D view of the internal structures of the body including the brain and other internal organs. One of the differences between a MRI and a CT scan is that the MRI has higher resolution; with the CT scan, it is hard to see the precise details of soft tissue. On the other hand, MRI is more expensive and requires much longer time to produce the image. Thus, the CT scan is often very useful in medical emergencies when time is a critical factor. Even though the CT scan emits more radiation than a regular chest X-ray, the benefits may outweigh the risks. Describe the strengths and weaknesses of each technology and ask students when would they recommend using one technology over another? For example, would they use a CT scan for dental work or braces? A head injury in a car accident?
For more information, please refer to the following resources:

- http://www.radiologyinfo.org/en/info.cfm?pg=headct#part_eight

After the students answer the questions at the beginning of this activity, tell them that they will learn some of the basics on how to read a CT scan in today’s lesson.

Give students the “How to Read a CT Scan” (U4_L3_StudentSheet_HowToReadCTscan) handout.

Allow students about 5 minutes to read through the handout with a partner and discuss some of the information that may be new to them. Then, go through the handout briefly with them to cover the following main concepts:

- A Computer Tomography (or “CT”) Scan is a type of x-ray that is used to see the brain.

- Due to the way in which X-ray beams work, high density materials, such as the skull, appear very light on the CT scan and low density things, such as air or some tissues, appear dark on the CT scan.

- One of the main things to remember when looking at a CT scan is that, you are looking from the bottom of the brain towards the top. Therefore, the structures that you see on the right side of the CT image are actually in the LEFT hemisphere of the patient and vice versa. For example, in most people, Broca’s Area (the part of the brain responsible for certain elements of language production) is located in their left hemisphere—on which side would Broca’s Area appear on a CT scan?

- As the CT scan moves from the bottom of the brain to the top, you are seeing slices of the brain (almost like slices of a loaf of bread).

Tell them that they can refer back to this sheet while they do the computer activity that comes next.

Before beginning the game, remind the students what they have already done in the game. As the medical student, they are working on a medical emergency case in which a patient was brought into the hospital after a bike accident where he fell and suffered a head injury.

Allow students to play Scene 2 (CT Scan) of the game. Explain that, in this second scene of the game, students learn about CT scans and use their knowledge to identify the type of injury the patient has suffered.

To begin the game, ask the students to click the link to “The Golden Hour”.

SEPA SCIENCE EDUCATION PARTNERSHIP AWARD
After the opening scene of the game, when the menu screen appears, ask the students to click on the “Scenes” button and then on “CT Scan Scene”, the link to Scene 2.

An image of a woman will appear at the opening of Scene 2—this is the CT technician who will help the players through this scene of the game.

- The character will introduce herself in a dialogue box saying “Hi, my name’s Allana. I’m excited that you have the change to help us with this patient! I hope you’ll do well and can be a part of our team.”

From this point on, the students progress through the game by clicking the right pointing (next) arrow in each dialogue box or by clicking as directed by the dialogue.

- If a player does not respond within a certain amount of time, an object in the game will flash yellow, to further direct the player about what to do next.

Note: The Golden Hour game will continue to be updated. Therefore, some of the details provided here (i.e. quoted dialogue) may change. However, overall, the content covered in each section of the game will remain the same.

In this scene of the game, students first briefly review how a CT scan works. Students then explore the anatomical landmarks of a healthy brain while comparing an illustrated brain with a CT scan image of the brain. Encourage students to take their time examining each landmark in both the CT scan and the illustrated image. They should also carefully read the descriptions of each landmark’s function. They will review the following anatomical landmarks of the brain and their functions:

- Frontal Lobe
- Temporal Lobe
- Occipital Lobe
- Skull
- Cerebellum
- Lateral Ventricle
- Thalamus

As the students review the landmarks, ask them to compare how the structures look on a CT scan vs. the real brain (from the illustration shown in the game as well as the material they covered doing the dissection in lesson 2).

After students review the anatomical landmarks of the brain, the game takes them through a short quiz where they identify the parts they just learned on a CT scan image.

By the end of the CT scan Quiz, students should be fairly familiar with how the structures look on a CT scan. Have the students pause playing after this quiz to have a discussion about the following questions before moving on to the next section on brain injury types:
In what way are CT scans important for patients with TBI?
- Have you ever seen the X-ray image of a broken limb? Is it clear to identify the damage on the X-ray image?
- What do you think the CT scan of a patient with a brain injury looks like?

**Activity 2: How to read an abnormal CT scan**
This activity will simulate the medical setting, giving students a chance to see the effect of a trauma in the brain at macroscopic level. Students look at a number of TBI CT scans and identify the affected structures and interpret the functional impact of the injury.

Now that students are familiar with identifying structures on a CT scan, hand out the “How to Read an Abnormal CT Scan” (U4_L3_StudentSheet_HowToReadAnAbnormalCTScan) to them. This is a brief guide to learn about different types of TBIs and how to identify them on CT scans.

Ask students to work in their partners or groups to look through this handout for about seven minutes to familiarize themselves with the four TBI types and how they appear on a CT scan. They will need to use this guide to complete the “TBI Case Puzzle”.

Hand out one “TBI Case Puzzle” (U4_L3_StudentSheet_TBICasePuzzle) to each student. In this puzzle, students are given 4 different patients and their CT scan images of different types of brain injury. For each patient case, the students need to: 1) decide which brain injury type they have, 2) Select whether the injury is in the patient’s left or right hemisphere, 3) identify the areas of the brain affected by the injury, and 4) based on the location, describe what functions of the patient may be affected/impaired.

Encourage the students to refer back to the materials presented in Lessons 1 and 2 as well as resources from Lesson 3 and use their knowledge of neuroanatomy and physiology as they complete the patients’ reports.

When the students complete this activity, bring the class together to share and discuss responses.

Begin the discussion by first asking which brain injury type each patient was diagnosed with. This will help to make sure all students are on the same page for the remainder of the discussion.

While answers to the first 3 sections of each report should be the same for everyone, responses to the last two questions will likely vary slightly from group to group. In some cases there are multiple possible correct answers to brain areas and cognitive functions affected by injury. This is a good opportunity to remind the students that although certain areas of the brain are specialized for certain functions, all brain areas are very closely interconnected and lines between areas are not as rigid as they might appear in the illustrations.

The following are some questions that should be considered for each case.

- What is the location of injury in each case?
- What signs did you use to figure out which injury each CT scan was showing?
- Predict which patient might have a speech disorder following TBI.
- Predict which patient might experience partial/temporary or permanent visual loss following TBI.
- Predict which patient might have severe memory problems.
- Predict which patient might have moderate to severe paralysis on the right side of his body.
- Predict which patient’s prognosis for recovery is lowest.

**Teacher Pedagogical Content Knowledge**

All of these questions about the location of injury, affected brain areas, and possible functional outcomes require the students to draw on knowledge they have been developing throughout the unit. The questions on location of injury are fairly straightforward but the later questions, which ask for affected areas and possible outcomes, require students to synthesize some of the material they have learned. Therefore, if preferred, student responses to the last two questions can be collected and used as a formative assessment of their understanding of the material thus far. Another option is to assign the entire TBI Case Puzzle worksheet as an in-class assessment.

Tell the students that now they have learned about different types of brain injuries and how to read CT scans, they are now ready to assess what type of TBI their patient in The Golden Hour game has suffered.

Ask the students to now continue playing the game. Through the game, the students review the four kinds of brain injuries: 1) open or penetrating head injury; 2) epidural hematoma, 3) subdural hematoma, and 4) diffuse axonal brain injury.

After viewing these brain injuries, the students will come to a dialogue box that states, “*Now that you are familiar with the CT imaging system, let’s take a look at the patient’s scans.*” Students then identify the patient’s injury as it appears on the CT scan and then will decide which type of TBI it is.

Finally, at the end of the scene, students are prompted to complete a CT Scan Report (or CT Assessment) of their findings. They are led through a dialogue with the lead physician in charge of this case (Dr. Picotte) where they will need to decide the most appropriate next step and support their decision.

- This dialogue is designed within the claim, evidence, reasoning (CER) framework and encourages students to think critically about the information they have gathered. Through the dialogue and multiple-choice questions, the students are guided to select their claim, evidence, and reasoning for recommending next steps.
At the end of the dialogue, students are prompted to write their recommendation in paragraph form. In this paragraph, encourage students to write the recommendation for what the next step should be (their claim), the evidence they collected that supports that claim, and the reasoning that explains how the evidence supports the claim.

As students complete the report and answer questions in the CER-style dialogue, remind students that they can pull up the tablet (by clicking on the tablet icon in the lower right corner of the game window) for help. The tablet records the information they have collected thus far in the game and makes it available for the students’ reference. They can also use their student sheets for help.

After students have completed writing the summary of their recommendation, they can either take a screen shot or copy-paste the paragraph into a word document in order to print it. If a printer is not available, students can write their recommendation on a separate sheet of paper. This explanation completed by the students in a CER-style format can be collected and evaluated as an assessment of what they have learned thus far in the game.

The following is one example of what a recommendation summary (CER explanation) for the CT Scan scene of the game may look like.

**Example Recommendation Summary**

I recommend that the patient receive emergency surgery. Analysis of the CT scans of the patient’s head show a gray, crescent-shaped appearance just under the skull on five adjacent scans. This indicates that there is a subdural hematoma on the right side of the head near the temporal lobe. Surgery should be performed because if the blood remains or continues to collect in the head, the hematoma will increase pressure within the skull and cause additional brain damage.

**Scientific Practices: Constructing explanations and engaging in argument from evidence**

Scientists must constantly exercise the ability to defend their claims, incorporate evidence, and work with peers to develop the best explanations of scientific phenomena. Therefore, an important goal of science teaching is for students to use their understanding of science and the evidence available to them to construct logical and coherent explanations. In the final portion of The Golden Hour scene described above, students are given the opportunity and appropriate scaffolds to practice these important skills. Situated in the format of a conversation with the lead physician, students are guided to make and defend a claim based on the evidence and knowledge they have accumulated. The claim, evidence, and reasoning framework used to develop this scene supports students and further structures the process as they develop the ability to construct explanations and engage in argument from evidence.
Conclusion of Lesson:
After the students have finished the CT Assessment in The Golden Hour game, review some of the main ideas from this lesson. Facilitate a discussion to help them review and to think about these concepts by asking questions such as the following:

- How much and what kind of information can doctors gather by looking at CT scans?
- To what extent do you think the CT scans can help predict functional outcomes?
- What are the four different traumatic brain injury types you learned about?

For homework, ask students to complete Scene 3: Surgery of the game and bring in their final summary paragraphs that include their claim, evidence, and reasoning for recommended next steps for the patient.

Students should also complete their Lesson Journal for Lesson 3 (U4_L1_Homework_LessonJournal)

Teacher Pedagogical Knowledge
The Lesson Journals are completed for each lesson in the TBI unit, and they are used together as a review and assessment tool in the final lesson. Students will review material from the unit and will contribute to a class ‘zine’ that integrates ideas and content from the unit. A zine (pronounced ZEEN) is a form self-publication with original text and images. Similar to a magazine, the topics are usually of a particular interest and the method of reproduction is via photocopiers.

Assessment
There are several ways in which learning can be assessed for this lesson. The first is to collect the “TBI Case Puzzle” document where the students were asked to identify brain injury types and explain possible effects of the injury. Also, if preferred, the “TBI Case Puzzle” worksheet can be used instead as an in-class assessment. Another assessment opportunity for this lesson is the recommendation summary (CER explanation) in which students use evidence from the scene they just completed to make a claim regarding next steps in the medical procedure. Similar to scenes 1 and 2, students can bring in their recommendation summary for scene 3 (homework). This CER explanation of scene 3 can be collected and evaluated as an assessment of what students have learned about the potential functional consequences of a TBI based on its location in the brain.

The following is one example of what a recommendation summary (CER explanation) for the Surgery scene of The Golden Hour game may look like.

Example Recommendation Summary
For post-surgery, I expect that the patient may have difficulties with language processing and face recognition during recovery. These predictions can be made because the brain is made up of certain
regions and neuronal circuits, each of which is associated with certain functions. In this case, a hematoma was found pressing on the patient’s right temporal lobe; this is an area of the brain that is associated with language processing and face recognition. Therefore, damage to the right temporal lobe may cause the patient to have problems with these functions.