BiteScis | Student

Mechanical Waves: Applications in Medicine

Introduction

In your everyday life you have likely interacted with many different types of mechanical waves, from sound waves, to ocean waves and earthquake waves. You may have even felt the vibration of a blaring speaker before. That sensation was due to a mechanical wave traveling through your body. Although it may be strange to think about mechanical waves traveling through you, scientists are now using mechanical waves in the tissues of your body to make medical procedures less painful and more efficient.

You can think of soft tissue such as your skin or liver as a wiggly block of jello. Decades ago, scientists noticed that when body tissues are subjected to vibrations, they move in waves. Scientists can measure properties of the waves moving through the tissue to gather information, including information about the tissue's elasticity. **Elasticity** is a measure of how much a substance deforms when a force is applied and how well the substance returns to its original shape when the force is released. A rubber band is an example of a highly elastic material. You can deform it by applying a force, but when you let go, it returns to its original shape. Healthy tissues tend to be more elastic than diseased tissues. A tissue becoming stiffer, can be a warning sign of diseases such as inflammation (swelling), cancer, or **fibrosis** (the hardening of a tissue).

Because the stiffness of a tissue is so well correlated to the tissue's health, physicians have used their sense of touch as a diagnostic tool for centuries. This is known as **palpation**. A commonly known use of palpation is in the detection of breast cancer by feeling for the presence of stiff lumps. Even during open surgery, surgeons use their sense of touch to assess organs, identify the edges of tumors, and to locate hidden blood vessels.

While palpation is a useful first step toward assessing health, it is not very precise or quantifiable. Further, we typically can't (or don't want to) directly palpate internal organs. To measure the elasticity of internal organs scientists have developed a new biomedical imaging technique called **elastography**. Elastography makes use of mechanical waves in order to give doctors insights into the stiffness of body tissues.

What To Do

Answer the analysis questions below, reading the Bite when instructed.

Analysis Questions

1. Define *elasticity* in your own words. Give an example of a solid with high elasticity that is not mentioned in the introductory text.

2. What is palpation and why do doctors use it? What are the limits of palpation as a diagnostic technique?

STOP & read Science Bite: Making Waves to Detect Illness

3. Describe elastography in your own words. What are some advantages of elastography over other types of medical diagnosis procedures?

4. A shear wave does not just travel on the surface of an object, but travels through the entire body of the object. Why do you think shear waves are used to study body tissues instead of waves that just exist on the surface of an object? Explain your answer.

There are four types of seismic waves, the waves responsible for earthquakes. Diagrams of each type of wave are shown in **Figure 1**.

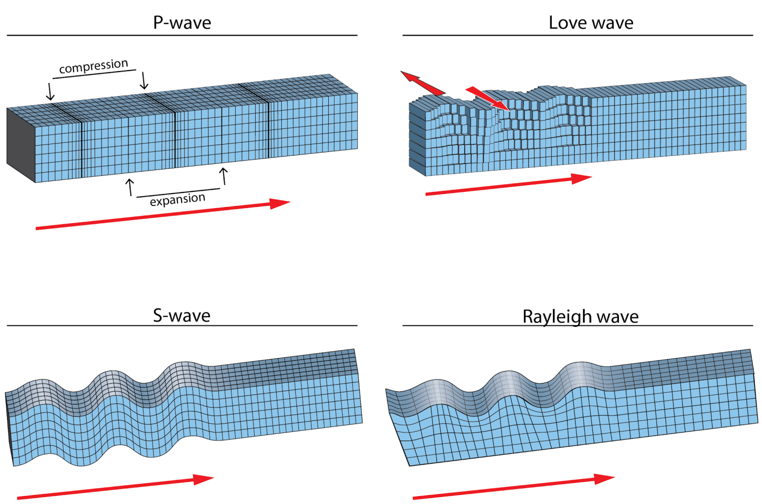

Figure 1. The Four Main Types of Seismic Waves. Two types of seismic waves, s-waves and p-waves, travel through Earth while Love waves and Rayleigh waves travel along Earth's surface. S-waves and p-waves travel faster than Love and Rayleigh waves, but Love and Rayleigh waves tend to do the most damage to structures.

5. Examine the wave diagrams in **Figure 1**.

    a. Which type or types of seismic waves are transverse? Justify your response with evidence from **Figure 1.**

    b. Which type or types of seismic waves are longitudinal? Justify your response with evidence from **Figure 1.**

    c. Which type of seismic wave is most similar to the shear waves used in elastography? Justify your answer with evidence from **Figure 1** and the Science Bite**.**

6. As noted in the introduction, the waves used in elastography are mechanical waves. What property or properties of the waves used in elastography makes them mechanical waves?

7. In your own words, describe how shear wave elastography (SWE) data is collected.

8. What do researchers look for when they are diagnosing liver fibrosis using SWE? Why do they look for this?

9. How did the researchers assess the validity of SWE as compared to liver biopsy? Cite specific evidence from the text to support your answer.

Suppose you are a physician at a local hospital working with a patient who may have liver fibrosis. You have just received an email from a lab technician with the patient's elastography results. Unfortunately, the file has been corrupted and the full results of the scan are gone. You only have the wavelength that the lab technician determined from each of the five scans of the patient's liver (shown in **Table 1** below). You also know that your hospital is equipped with a Magnetic Resonance Elastography (MRE) system. This system is based on MRI technology and operates at a frequency of 60 Hz. The lab technician left for vacation right after they sent you the email, so it is up to you to analyze the results and determine if the patient has liver fibrosis.

Trial	Wavelength
1	0.0478 m
2	0.0476 m
3	0.0442 m
4	0.0421 m
5	0.0466 m

Table 1. Patient Data. The only data remaining from the corrupted elastography results file.

10. Analyze the data in **Table 1** to answer the following questions.

a. Determine the wave speed for each of the wavelengths provided. Show all work and include units in your answer.

b. Based on your minimum wave speed value, does the patient have severe liver fibrosis? Explain your answer.

c. Take the average of your wave speed values. Based on that information does the patient have severe liver fibrosis? Explain.

d. Determine the median of your wave speed values. Based on that information does the patient have severe liver fibrosis? Explain.

e. Do you think the patient has severe liver fibrosis? Provide evidence and reasoning for your claim.

f. Typically, when conducting an elastography analysis of someone's liver, the technician will take at least ten different readings in up to three different locations on the body. Why do the results shown above demonstrate the importance of taking multiple trials when conducting an experiment, especially one used in diagnosis?

The study described in the Bite investigated the average speed of the shear wave in patients with varying levels of liver fibrosis, shown in the table below.

Least Fibrotic	→			Most Fibrotic
1.52 m/s	1.60 m/s	1.79 m/s	2.16 m/s	2.81 m/s

Table 2. Average Shear Wave Speed in Livers with Different Levels of Fibrosis.
Source: Manish *et. al.* 2017.

11. Examine **Table 2** above.

a. Describe the trend in wave speed as the severity of liver fibrosis increases. Why does that make sense? Cite specific evidence from the introduction and Bite.

Suppose researchers used a Fibroscan, one of the more popular elastography systems available commercially, to collect the data shown in **Table 2**. The Fibroscan operates at 50 Hz.

b. What would be the average wavelength of the shear wave in the least fibrotic livers?

c. What would be the average wavelength of the shear wave in the most fibrotic livers?

d. What is the relationship between wavelength and wave speed? Why does that make sense based on the equation for wave speed?

12. Connect to the Big Question In this lesson, we learned how scientists use their observations to determine if someone is ill. Compare and contrast the different types of observations you learned about in this lesson. How does this change your personal definition of "observe"? What types of observations should doctors rely more on? Why do you think so?