LAB 18

Hyperthermia Treatments for Tumors

Volume

Heating malignant tumors to a temperature of about 45°C can cause the tumors to regress. This treatment, known as hyperthermia, uses microwaves to heat the tumors. It is estimated that hyperthermia can increase the effectiveness of radiation and chemotherapy by a factor of two.

Observations

The tumor temperature during treatment is highest at the center and gradually decreases toward the edges. Regions of tissue having the same temperature, called equitherms, can be visualized as closed surfaces that are nested one inside of the other. One of the difficulties in effectively applying the hyperthermia treatment is determining the portion of the tumor heated to an effective temperature.

Purpose

In this lab, you will analyze simple tumor shapes and determine the portion of the tumor that has been heated to an effective temperature. You will use *Mathematica* to aid you in your analysis.

References

For more information about hyperthermia treatments for tumors see the article "Heat Therapy for Tumors" by Leah Edelstine-Keshet in the Summer, 1991 issue of *The UMAP Journal.*

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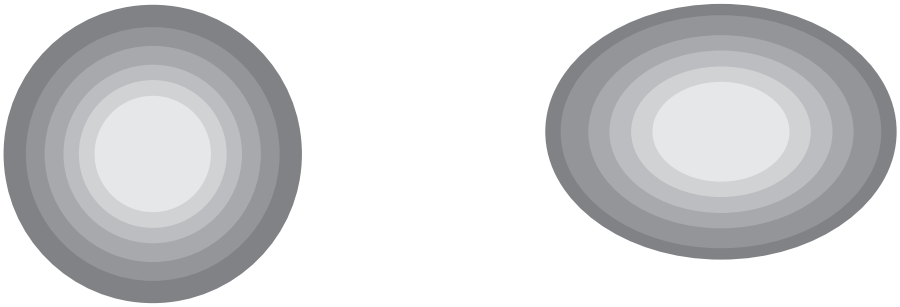
Data

When normal tissue is heated, it is cooled by the dilation of blood vessels. A tumor has very few interior blood vessels and therefore is unable to take advantage of this cooling process.

The shapes of some tumors can be approximated by spheres or ellipsoids. The equitherms for a spherical tumor and an elliptical tumor are given below. Notice in the graphs that the hottest area is at the tumor's center.

Thermal Patterns Determined by APA Technology

Courtesy of Cheung Laboratories, Inc.



The problem of determining the portion of the tumor that has been heated to an effective temperature reduces to finding the ratio V_T/V, where V is the volume of the entire tumor and V_T is the volume of the portion of the tumor that is heated above temperature T.

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Exercises

Name _____

Date _____ Class _____

Instructor _____

1. ***A Necessary Measurement?*** Is it necessary to measure the temperature of the tumor's center if you know the temperature of the equitherm at half the radius of the tumor has exceeded the effective temperature? Explain your reasoning.

2. ***Treating a Spherical Tumor.*** When treating a spherical tumor, a probe is used to determine that the temperature has reached an effective level to about one-fourth the radius of the tumor. Determine the value of the ratio V_T/V. Is the value $\frac{1}{4}$? Explain your reasoning. If the radius of the tumor is 2.5 centimeters, what percent of the tumor reached an effective temperature?

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3. Complete the Table. Complete the table below, where r is the radius of a spherical tumor, V_T is the volume of the portion of the tumor that is heated above temperature T, and V is the volume of the tumor. Describe any patterns you see in the table.

Radius of tumor that has reached an effective temperature	V_T	$\frac{V_T}{V}$
$\frac{1}{4}r$		
$\frac{1}{3}r$		
$\frac{1}{2}r$		
$\frac{2}{3}r$		
$\frac{3}{4}r$		
r		

Use the table above to answer the following questions.

a. When the temperature has reached an effective level equivalent to half the radius of the tumor, is

$$\frac{V_T}{V} = \frac{1}{2}?$$

If not, determine the portion of r that has been heated when $\frac{V_T}{V} = \frac{1}{2}$.

b. For what heated portion of r is $\frac{V_T}{V} = \frac{3}{4}$?

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4. ***A Tumor Modeled by a Wrinkled Sphere.*** A certain tumor can be modeled by the wrinkled sphere given by the equation

$$\rho = 0.5 + 0.345 \sin 8\theta \sin \phi, \; 0 \le \theta \le 2\pi, \; 0 \le \phi \le \pi.$$

Explain a strategy for estimating the volume of the wrinkled sphere without using integration. Use your strategy to calculate an estimate.

5. ***Using Integration to Calculate Volume.*** Find the volume of the tumor described in Exercise 4 using integration. How good was your estimate in Exercise 4? What was the percent error of your estimate?

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6. ***Using Mathematica to Calculate Volume.*** Find the volume of the tumor described in Exercise 4 using *Mathematica.* Compare the result to Exercise 5. If necessary, show that the results are equivalent. If the results are not equivalent, explain why not.

7. ***A Tumor Modeled by a Bumpy Sphere.*** A certain tumor can be modeled by the bumpy sphere given by the equation

$$\rho = 0.75 + 0.35 \sin 8\theta \sin 4\phi, \; 0 \le \theta \le 2\pi, \; 0 \le \phi \le \pi.$$

Find the volume of the tumor using integration.

8. ***Using Mathematica to Calculate Volume.*** Find the volume of the tumor described in Exercise 7 using *Mathematica*. Compare the result to Exercise 7. If necessary, show that the results are equivalent. If the results are not equivalent, explain why not.

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