THE AFFECT OF CHEMOTHERAPY AND IMMUNE SYSTEM RESPONSE ON BREAST CANCER GROWTH

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ABSTRACT. Place abstract here. The abstract summarizes in one paragraph the main question and conclusions draw from your investigation.

1. BACKGROUND/MOTIVATION

Mathematical oncology is field of oncology, the study of cancer, that employs math to study cancer and its behavior. In the words of Dr. Rockne and MD Scott, "it [serves] as a bridge between...the biologist, and the practicing clinician (2019)." Some of the most recent and important reasons for math modeling in oncology is to understand and model the characteristics and growth of cancer. Moreover, it seeks also to understand and model the relationship between cancer and the immune system and/or its response to treatment or resistance to it. Lastly, one of the biggest goal is to use this modeling to then develop more personable treatment to individuals facing the plight of cancer [**?**].

Tumor growth modeling is a well researched area of mathematical oncology. Its main purpose is to model tumor growth without any intervention as well as growth in response to external factors such as immunological response or treatment. In the absence of any intervention, several models have been made to try to show the growth of a tumor, measured by *tumor burden*, denoted T, (see A for definitions), as a function of time t. The models range from simple ODEs such as linear growth, logistic growth, to more complicated models employing stochastic differential equations and algebraic differential equations (which would be outside the scope of material learned in Vol 4 for analysis).

The more commonly used models due to their simplicity are linear, exponential, and logistic models (see B for equations). However, these do not accurately reflect the full growth of the model as time increases. In particular, the exponential model (3) is characterized by an infinite growth as t increases which does not reflect the fact that a tumor can have a maximum size, even when considering a death rate. Moreover, the logistic model (4) converges too fast to the max size, $T_{\max}$, a tumor can be [**?**].

The *Gompertz* model is a logistic model that was created to describe the growth of human mortality in 1825 by Benjamin Gompertz. In particular, the ODE is given

Date: October 29 2024.

by

$$\frac{\mathrm{d}T(t)}{\mathrm{d}t} = k_g T \ln\left(\frac{T_{\max}}{T}\right), \tag{1}$$

where k_g is a growth constant of the tumor, T is the total number of cancer cells, and t is days. The solutions to the ODE are of sigmoidal nature. Like the logistic growth model (4), the Gompertz model starts off with a quasi-exponential growth at the beginning that is short lived. However, unlike the logistic model, the Gompertz model slowly converges to the carrying capacity of that a tumor can have with available nutrients. That is, the Gompertz model slows down first and more significantly than a logistic [**?**].

TODO Add graph showing the different models

2. MODELING

The primary aspect of the project is the modeling of the chosen phenomenon. If your group's repeated attempts resulted in abject failure, or your group succeeded, detail them in this section. Be sure to account for the various attempted models and why they were not appropriate. Include numerical simulations for each attempted model. Reference figures and plots, like Figure **??**.

3. RESULTS

Clearly and succinctly state and describe the conclusions that you can draw from the model you have achieved (or the many failed attempts). Does your model(s) perform well quantitatively or qualitatively?

4. ANALYSIS/CONCLUSIONS

Discuss the appropriateness of the techniques/methods you employed in modeling. Did your group appropriately model the chosen phenomenon? If not, what different steps could you have taken if you had more time? What did you learn about the techniques/method that were used in the group project? If your model was successful, what additional insight/conclusions could you obtain from it? For instance, if you had a successfully modified SIR model, how might it affect different government policy? If you had a successful model for the spread of inaccurate information on social media, how might it be implemented to help reduce the spread of inaccurate information?

This part should all be done before you get to *page 11*. The bibliography can spill on to page 11, but we won't read text that goes past page 10.

APPENDIX A. DEFINITIONS

The following definitions are derived from the National Cancer Institute

- Chemotherapy: a cancer treatment where drugs are used to kill cancer cells or stop them from dividing

  - Neoadjuvent Chemotherapy: chemotherapy administered before the primary treatment of the tumor is performed. Typically, surgery is the primary treatment. Its main goal is to shrink the tumor so that it is easier to remove.
  - Adjuvent Chemotherapy: Chemotherapy administered after primary tumor treatment is administered. Its intent is to lower the risk of the cancer returning.
- Cancer: a term for diseases in which abnormal cells divide without control and can invade nearby tissues
- Tumor: an abnormal mass of tissue that forms when cells grow and divide more than they should or do not die when they should. Tumors may be *benign* (not cancer) or *malignant* (cancer). For this project, defined the tumor burden as the number of cancer cells in the body.
- Tumor burden: the size of a tumor or number cancer cells. This is the total amount of cancer found in the body.

APPENDIX B. MODELS

- Linear growth:

$$\frac{\mathrm{d}T}{\mathrm{d}t} = k, \tag{2}$$

  where k is the growth rate
- Exponential Growth:

$$\frac{\mathrm{d}T}{\mathrm{d}t} = kT \tag{3}$$

  or with a death rate constant of d, $\frac{\mathrm{d}T}{\mathrm{d}t} = (k-d)T$
- Logistic Growth:

$$\frac{\mathrm{d}T}{\mathrm{d}t} = kT\big(1 - \frac{T}{T_{\max}}\big), \tag{4}$$

  where $T_{\max}$ is the max size a tumor can be, which is equivalent to the carrying capacity.

REFERENCES

[RRpr] Scott JG. Rockne RC. Introduction to mathematical oncology. 2019 Apr.