LUPINE PUBLISHERS

Current Trends on Biostatistics & Biometrics

DOI: 10.32474/CTBB.2020.02.000141

ISSN: 2644-1381

Perspective

On a Simple Mathematical Model for Epilepsy Motivated by Networks

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Received: March 04, 2020 **Published:** March 12, 2020

Abstract

Simple mathematical models motivated by networks are given for epilepsy. The coexistence solutions and their stability are derived.

Introduction

Epilepsy is one of the most common brain diseases [1]. Several approaches are used to model it e.g. dynamical systems [1] and networks [2]. In [2] a network is given or a 3-node graph one represents low (unexcited) cells(L). The second represents medium (M) and the third represent high (excited) cells (H). Here this system is approximated by the dynamical system:

$$\begin{aligned} dL/dt &= aL(1-L)-H \\ dM/dt &= bL-H \\ dH/dt &= -dH+M+cL \end{aligned} \quad (1)$$

where a, b, c, d are positive constants. The coexistence solution is

$$\begin{aligned} L &= 1-b/a \\ H &= b(1-b/a) \\ m &= (bd-c)(1-b/a) \end{aligned} \quad (2)$$

It exists if $b/a<1$ and $bd>c$ (3) and is locally asymptotically stable if

$$[d+a(2L-1)][c+1+ad(2L-1)]>b+a(2L-1) \quad (4)$$

The model (1) can be reduced to a 2-species model as follows:

$$\begin{aligned} dL/dt &= aL(1-L)-H \\ dH/dt &= -dH+cL \end{aligned} \quad (5)$$

and coexistence solution is:

$$\begin{aligned} L &= a-c/d \\ H &= (c/d)L \end{aligned} \quad (6)$$

And is stable if $2L>1$ (7) Healthy state exists if $H<<L$. Now we introduce the drug resistant type in epilepsy [3]. The populations are low L, susceptible high Hs and resistant high Hr. The model is

$$\begin{aligned} dL/dt &= aL(1-L)-bHs-Hr \\ dHs/dt &= cL-HsHr \\ dHr/dt &= HsHr-dHr \end{aligned} \quad (8)$$

The coexistence solution is

$$\begin{aligned} Hs &= d \\ Hr &= (c/d)L \\ L &= \left\{(a-c/d)\pm\sqrt{\left(a-\frac{c}{d}\right)-4bd}\right\}/2 \end{aligned}$$

In the physically acceptable case $Hr<<L$ hence $(c/d)<<1$, the coexistence solution is locally asymptotically stable.

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DOI: 10.32474/CTBB.2020.02.000141