THERMAL THERAPY FOR EYE DISEASES

by

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Hot compress is a commonly used method to deal with various eye diseases, but its bio-mechanism is not clear yet. Here we give a complete theoretical analysis of thermal therapy. The increase of temperature will greatly improve the metabolic activity of the infected eyes and decrease remarkably the longevity of virus. The optimal temperature and period of hot compress are discussed, and some case studies are provided.

Key words: *metabolic rate, host, virus, allometry, Yin-Yang system, Taiji, geometric potential*

Introduction

Eye diseases are common in China, the most common one is the dry eye disease [1], and this paper we will study the thermal therapy for virus-induced eye diseases. It a general fact that a more complex virus (*e. g.*, HIV, AIDS-virus, and SARS coronavirus) always tends to be more fatal [2], this can be explained by virus metabolic activity. A virus has always a higher metabolic rate due to its complex boundary, which can produce a higher geometric potential [3-7] than a spherical cell with the same radius. The boundary-induced force [3-7] can guarantee the virus to absorb much energy from its environment. Some metabolically active organs, *e. g.*, brain, have less opportunity to get ill than metabolically inactive ones, because a metabolically active organ can restrain viruses from obtaining enough energy for their survival.

When a virus invades eyes, due to its higher fractal dimensions, it can obtain enough energy for reproduction. The procedure is slow but fatal [8]. Though there are many drug therapies, this paper focuses on the thermal therapy to improve the metabolic activity of infected eyes.

Effect of temperature on metabolic rate

Generally the metabolic rate of an organ can be expressed [9-11]:

$$B \propto M^{a} \tag{1}$$

where B is the metabolic rate, M – the organ mass, and a – the scaling exponent, which is a temperature-related function.

In much literature, a was chosen as 3/4. However hibernators in a low temperature environment has a much smaller value of a, and for all trophic groups $a \approx 1$ [10]. So we assume that:

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$$a_{\max} = 1 \tag{2}$$

It is a well-known fact that temperature affects greatly the metabolic rate [12-15], Gilloly *et al.* [14] suggested the following model:

$$B \propto M^{3/4} \mathrm{e}^{-E_i/kT} \tag{3}$$

where E_i represents an average activation energy for the rate-limiting enzyme-catalyzed biochemical reactions of metabolism, T [K] – the absolute temperature, k – the Boltzmann's constant.

White and Seymour [13] gave a correction for temperature difference in the form:

$$M_{\mathrm{C}} = M 10^{(T_{\mathrm{c}} - T_{\mathrm{b}}) \log Q_{10}/10} \tag{4}$$

where M_{C} is the temperature-corrected basal metabolic rate, T_{c} – the temperature to which all observations need correction, and Q_{10} – the increase in basal metabolic rate associated with a temperature increase of 10 °C.

In eqs. (3) and (4), the scaling exponent does not depend upon temperature, so we suggest the following modification:

$$B \propto M^{a}, \quad a = \frac{3 + \beta(T - T_{\mathrm{b}})}{4} \tag{5}$$

where T_{b} [°C] is the body temperature and β is a constant.

Considering $T_{\max}$ = 40 °C and $T_{\mathrm{b,min}}$ = 0 °C, we have β = 1/40. We, therefore, have:

$$a = \frac{3}{4} + \frac{T - T_{\mathrm{b}}}{40} \tag{6}$$

and the following scaling law:

$$B \propto M^{3/4 + (T - T_{\mathrm{b}})/40} \tag{7}$$

The prediction given by eq. (7) is valid within the limited range of *biologically relevant* temperatures between approximately 0 °C and 40 °C. This is the range that organisms commonly operate within under natural conditions. Near 0 °C, metabolic reactions cease due to the phase transition associated with freezing water, and above approximately 40 °C, metabolic reaction rates reduced by the increasing influence of catabolism.

Longevity of an organ or a virus scales with:

$$L \propto M^{1/4 - (T - T_{\mathrm{b}})/40} \tag{8}$$

where L is the life span. eq. (8) means a higher temperature leads to a lower life span.

Thermal therapy

Thermal therapy is to improve the metabolic activity of an infected organ. The basal metabolic rate of a host organ, B_{host}, scales allometrically with respect to its mass, M_{host}, in the form:

$$B_{\mathrm{host}} \propto M_{\mathrm{host}}^{3/4} \tag{9}$$

Allometric scaling is considered as a unifying framework for ecological modeling, for viruses, we have:

$$B_{\text{virus}} \propto M_{\text{virus}}^{a} \tag{10}$$

where a is an allometric exponent.

We consider the case when the metabolic rate of the infected organ is equal to that of the virus:

$$B_{\text{virus}} = B_{\text{host}} \tag{11}$$

Under such case, the infected organ will not be ill, and it can be considered a parasite-host system.

When $B_{\text{virus}} > B_{\text{host}}$, the infected organ becomes ill, and when $B_{\text{virus}} < B_{\text{host}}$, the infected organ will recover its health gradually. This can be explained by the oldest Taiji theory as illustrated in fig. 1. An infected organ can be considered as a Yin-Yang system, when the metabolic rates of the infected organ and virus are harmoniously matched, there will be no harm to the organ, but when the balance is broken due to the virus' higher metabolic activity, the infected organ will become ill.

Figure 1. Taiji diagram for the balance of Yin-Yang, which can represent the infected organ and virus

The thermal therapy is to improve the temperature of the infected organ, so that its metabolic activity can be enhanced:

$$B_{\text{host}} \propto M_{\text{host}}^{3/4+(T-T_{\text{b}})/40} \tag{12}$$

The temperature increase will also affect the metabolic rate of the virus:

$$B_{\text{virus}} \propto M_{\text{virus}}^{a+(T-T_{\text{b}})/40} \tag{13}$$

Equations (12) and (13) imply that:

$$\frac{\partial B_{\text{host}}}{\partial T} \propto \frac{1}{40} B_{\text{host}} \ln M_{\text{host}} \tag{14}$$

$$\frac{\partial B_{\text{virus}}}{\partial T} \propto \frac{1}{40} B_{\text{virus}} \ln M_{\text{virus}} \tag{15}$$

Taylor series solutions [16, 17] for the metabolic rates of the infected organ and virus are, respectively:

$$B_{\text{host}} = B_{\text{host}}(T_0) + \frac{1}{40} B_{\text{host}}(T - T_0) \ln M_{\text{host}} \tag{16}$$

$$B_{\text{virus}} = B_{\text{virus}}(T_0) + \frac{1}{40} B_{\text{virus}}(T - T_0) \ln M_{\text{virus}} \tag{17}$$

where T_0 is the body temperature. Considering the fact that $B_{\text{virus}}(T_0) \approx B_{\text{host}}(T_0)$ and $M_{\text{host}} \gg M_{\text{virus}}$, we have:

$$B_{\text{host}} \gg B_{\text{virus}} \quad \text{for } T > T_0 \tag{18}$$

So, the thermal therapy can increase greatly the metabolic activity of an infected eye, as a result, the eye diseases recover gradually.

The temperature of the hot compress should satisfy the following condition:

$$a = \frac{3}{4} + \frac{T - T_{\text{b}}}{40} \leq 1 \tag{19}$$

The maximal temperature should be:

$$T_{\max} = 10 + T_{\text{b}} \tag{20}$$

The body temperature of human beings ranges from 36.0 ℃ to 37.0 ℃, so the maximal temperature of hot compress should be 46 ℃, temperature higher than this threshold will lead to damage of the eyes.

The optimal temperature should be health for the infected organ, as the allometric exponent for an animal in a serious motion is 0.86 [18], we, therefore, use the following relationship to identify the optimal temperature:

$$a = \frac{3}{4} + \frac{T - T_{\text{b}}}{40} = 0.86 \tag{21}$$

which leads to the result:

$$T_{\text{optimal}} = 4.4 + T_{\text{b}} \tag{22}$$

The value of 0.86 is closed to the allometric exponent of human brain, which is 4/5 [19, 20], so eq. (22) is reasonable, the optimal temperature ranges from 40.4 ℃ to 41.4 ℃.

On the other hand, a higher temperature leads to a lower life span of virus:

$$L_{\text{virus}} \propto M_{\text{virus}}^{1/4-(T-T_{\text{b}})/40} \tag{23}$$

So the period of hot compress depends upon the temperature, a higher temperature should be a shorter period, while the optimal temperature of about 40 ℃ can last for a relatively long time.

The increase of temperature leads to the increase of metabolic rate, decrease of life span, and also stimulates the immune response. The HIV rarely affects monkey, possible explanation is that the body temperature of, *e. g.*, Japanese monkeys (Macaque Fuscata) is 38.6 °C, higher than human.

Case study

Case 1

Zhao Ailing, female, 54 years old. *Chief complaint:* Her right eye was photophobia, and accompanied by vision loss. The patent was admitted a month later. *Diagnosis*: xerophthalmia with viral keratitis. Binocular tear secretion test (od): 2 mm per 5 minute. *Physiotherapy regimen:* 1 – Hot compress 2 times a day, each time 15 minutes, temperature 42 ℃. 2 – Local eye massage twice a week. 3 – After 4 weeks of continuous treatment, the patient's

symptoms had been improved greatly and her eyes became more comfortable than before. The tear secretion was detected (Schirmer test) by 4 mm per 5 minute.

Case 2

Outpatient, male, 62 years old. *Chief complaint:* Xerotic eye, irritating tears. *Diagnosis:* xerophthalmia with viral keratitis. Binocular tear secretion test: 1 mm per 5 minute. After a week of medication treatment, the symptom was not significantly relieved, so thermal therapy was considered. *Physiotherapy regimen:* 1 – Meibomian gland massage twice a week. 2 – Hot compress 2 times a day, each time 15 minutes, temperature 39 ℃. 3 – After 4 weeks of continuous treatment, the patient's symptom was slightly better and effect was not particularly obvious. The tear secretion was detected (Schirmer test) by 2 mm per 5 minute.

Case 3

Lian Jijun, male, 52 years old. *Chief complaint:* dry eyes for a week before admission. *Diagnosis:* xerophthalmia with viral keratitis. Binocular tear secretion test (od): 2 mm per 5 minute, os 4 mm per 5 minute. *Physiotherapy regimen:* 1 – Hot compress 2 times a day, each time 15 minutes, temperature 40 ℃. 2 – Local eye massage twice a week. 3 – After 4 weeks of continuous treatment, the patient's eye comfort was better than before, and the tear secretion was detected (Schirmer test) by 10 mm per 5 minute, and his eye disease was gone which was confirmed by follow-up telephone.

All cases studies show that the thermal therapy is effective, the Case 2 show when the temperature of hot compress is lower than the optimal one, it will take a long time for amelioration.

Conclusion

We obtain a scaling law considering the effect of temperature on the scaling exponent, the case studies show the optimal temperature is of great importance in the hot compress. The theoretical analysis proposed in this paper is rigorous, it provides an alternative way to preventing virus' infection. The successful implementation of the case studies for eye diseases gives a good paradigm for preventing from virus-infection of other organs.

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