A Biological Model of Acupuncture and its Derived Mathematical Modeling and Simulations

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Abstract. (**Aims**) Acupuncture was employed since 2 millenaries, but the underlying mechanisms are not globally handled. The present study is aimed at proposing an explanation by pointing out involved processes and a convincing modeling to demonstrate its efficiency when carried out by trained practitioners.

(**Method**) In the absence of global knowledge of any mechanism explaining the acupuncture process, a biological model is first developed, based on stimulation in a given domain around the needle tip of a proper mastocyte population by a mechanical stress, electrical, electromagnetic, or heat field. Whatever the type of mechanical or physical stimuli, mastocytes degranulate. Released messengers either facilitate the transfer of main mediators, or target their cognate receptors of local nerve terminals or after being conveyed by blood their receptors on cerebral cells. Signaling to the brain is fast by nervous impulses and delayed by circulating messengers that nevertheless distribute preferentially in the brain region of interest due to hyperemia. The process is self-sustained due to mastocyte chemotaxis from the nearby dense microcirculatory circuit and surrounding mastocyte pools, which are inadequate for acupuncture, but serve as a signal relay. A simple mathematical model is solved analytically. Numerical simulations are also carried out using the finite element method with mesh adaptivity.

(**Results**) The analytical solution of the simple mathematical model demonstrates the conditions filled by a mastocyte population to operate efficiently. A theorem gives the blow-up condition. This analytical solution serves for validation of numerical experiments. Numerical simulations show that when the needle is positioned in the periphery of the acupoint or outside it, the response is too weak. This explains why a

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long training is necessary as the needle implantation requires a precision with a magnitude of the order of 1 mm.

(**Conclusion**) The acupoint must contain a highly concentrated population of mastocytes (e.g., very-high–amplitude, small-width Gaussian distribution) to get an initial proper response. Permanent signaling is provided by chemotaxis and continuous recruitment of mastocytes. Therefore, the density and distribution of mastocytes are crucial factors for efficient acupuncture as well as availability of circulating and neighboring pools of mastocytes.

1   Introduction

Traditional Chinese medicine defines acupuncture points, or *acupoints*, for therapeutic objectives, more than 2500 years ago. Acupuncture was aimed at relieving a pathological state by liberating the sequestered energy and rearranging the balance of *yin* and *yang* to ensure homeostasis. A disease was indeed supposed to result from an imbalance between Yin and Yang. Yang and Yin are 2 fundamental opposing, complementary, and interdependent forces found in all things in the universe, with traces of one in the other, that support each other and can transform into one another. Nothing in the universe is completely Yin or Yang; everything is a mixture of these two. In particular, Yang may be considered as mental activity in its strength aspect, Yin mental activity in its imaginative aspect; in other words, Yang constructs, Yin instructs, or conversely. Yin is related to static and hypoactive phenomena, Yang to dynamic and hyperactive processes, or conversely.

An acupuncture needle is inserted into selected acupoints on the body's surface, on which mechanical or other types of physical stimulations are exerted (e.g., moxibustion), in particular to cause analgesia. Afferent paths are stimulated to elicit the *de–qì* sensation and signal to adequate zones in the central nervous system. Acupoints are transfer sites of *qì*. Meridians (Chinese: *jing*) and collaterals (Chinese: *luo*) are communication paths for *qì*, the vital energy master of body fluids, which can be transported to acupoints. These spatially restricted sites that do not correspond to a specialized biological tissue, but to localized structural and functional units, from which energy pours and pervades into the body's tissues.

The present study focuses on the permanent regime of acupuncture, that is, once the needle has been implanted and the stress field in the subcutaneous connective tissue is fully established. The reader is invited to read the accompanying paper [1] to get information on events occurring during the transient regime.