Mathematical modelling and simulation of transdermal iontophoresis

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Abstract

Intelligent drug delivery devices have been developed during the last decades to deliver drugs in a controlled manner at specific locations. Some of these systems use stimuli-responsive polymers (where the drug is entrapped) that are able to respond to the modification of the external environment (like electric fields, pH and temperature). Electric fields are an interesting type of stimulus because they can be precisely controlled, and the drug delivery responses can be predicted.

The use of electric fields as enhancers is popular in transdermal drug delivery where iontophoresis and electroporation, or a combination of both, are usual procedures. Each of the above applications involves complex phenomena. For instance, in transdermal drug delivery, enhanced by an electric field, the drug leaves the polymeric matrix, enters the stratum corneum and is transported through the skin to reach the circulatory system. In both media, the transport occurs by passive diffusion, electromigration (migration of ions due to the electric field) and electroosmosis (transport due the solvent movement).

We are interested in studying transdermal iontophoretic applications consisting of a coupled system having a reservoir containing a charged drug and a target tissue. In this case, the polymeric reservoir is in contact with the skin which is a multilayered tissue: epidermis ($100\mu m$), dermis ($2-3mm$) and subcutaneous tissue. These three layers have different histological characteristics, therefore, to simplify the mathematical model, we represent the skin as one layer. The applied electric field is generated by an applied potential of low intensity maintained during long periods of time.

The main objective of this talk is to present a mathematical model that describes the drug transport through the media - the reservoir and the target tissue - and the electric field. The electric potential induces a convective field that enhances the drug transport. In this scenario, the time-space evolution of the drug in both media is described by convection-diffusion equations coupled with an elliptic equation for the electric potential. The coupled initial boundary value problem is studied from analytical and numerical perspectives. We establish energy estimates for the coupled system and we propose a semi-analytical discrete coupled model that mimics the continuous model. The qualitative behaviour of the system is illustrated.

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