Mathematical Modeling in Clinical Medicine

Chang, MW*, Sun, J., Rosendall, B.M., Lin, E., Chen, W-S, Hwang, J-N, Finlayson, B.A.
University of Washington, Seattle, WA, USA

Advancement in digital computing has made mathematical modeling an important design and analytical tool in science and engineering. However, current use of mathematical modeling in clinical medicine is still quite limited. With its rigorous scientific basis, versatility and non-invasiveness, mathematical modeling offers immense potential in prevention, diagnosis and treatment of diseases. Three clinical applications of mathematical modeling are used to illustrate its potential as well as current limitations. Recommendations for future model development in clinical application are presented.

Anticoagulation is widely used to prevent or treat diseases caused by blood clots. Successful treatment of oral anticoagulation requires customized warfrin dose. A mathematical model incorporating individualized warfrin pharmacokinetics/ pharmacodynamics was shown, in a cohort study during warfrin initialization, to reduce the number of blood testing and sub-therapeutic anticoagulation by over 50%. With the improved efficiency, risks of bleeding complications were unchanged. The model, with sound clinical judgments helps to improve anticoagulation treatment.

Swallowing difficulty (dysphagia) is a common clinical problem often associate with life-threatening pulmonary complications such as choking or aspiration pneumonia. However, most patients with dysphagia insist on oral feeding to maintain their quality of life. Understanding bolus transport in oro-pharyngeal swallowing helps to manage safe oral feeding. A computational fluid dynamic model for pharyngeal bolus transport, based on finite element analysis (FEA), helped to bring clinical insights on various characteristics of dysphagia hence prevent feeding situations with high risks of complications. Consequently, safe individualized strategies for oral feeding can be developed to help patients with oro-pharyngeal dysphagia.

Pressure ulcers are common and costly clinical problems hence prevention and early ulcer detection/management are crucial. Diagnosis and treatment of pressure ulcers rely on knowledge of high internal tissue stresses, which often cannot be measured non-invasively. A mathematical model using FEA, incorporating a digitized heel MRI, was developed to study internal tissue stresses. The model was used to illustrate that high stress zone and hence ulcers may develop under skin especially when near a bony prominence. Therefore, a common practice of visual inspection of patients' skin by clinicians may potentially miss early diagnosis and treatment of pressure ulcers. Improved early ulcer detection and management lead to better ulcer care.

In conclusion, mathematical modeling provides valuable insights into complex clinical problems. It has great potential to help customize prevention, diagnosis and treatment of patients with various diseases. Recommendations are summarized here for future development of mathematical modeling in clinical medicine: Train clinicians with skill and knowledge of mathematical modeling to integrate it into their clinical practice. Nurture close collaborative efforts between clinicians and scientists/engineers to develop models of clinical significance. Continue to understand every facet of basic science and develop its mathematical expression that is needed to build models.