METHOD AND SYSTEM FOR MACHINE LEARNING BASED ASSESSMENT OF FRACTIONAL FLOW RESERVE

[0001] This application is a continuation of U.S. patent application Ser. No. 15/958,483, filed Apr. 20, 2018, which is a continuation of U.S. patent application Ser. No. 15/616,380, filed Jun. 7, 2017 and issued as U.S. Pat. No. 9,974,454, which is a continuation of U.S. patent application Ser. No. 14/516,163, filed Oct. 16, 2014 and issued as U.S. Pat. No. 9,700,219, which claims the benefit of U.S. Provisional Application No. 61/891,920, filed Oct. 17, 2013, the disclosures of which are herein incorporated by reference in their entirety.

BACKGROUND OF THE INVENTION

[0002] The present invention relates to non-invasive functional assessment of coronary artery stenosis, and more particularly, to machine learning based non-invasive functional assessment of coronary artery stenosis from medical image data.

[0003] Cardiovascular disease (CVD) is the leading cause of deaths worldwide. Among various CVDs, coronary artery disease (CAD) accounts for nearly fifty percent of those deaths. Despite significant improvements in medical imaging and other diagnostic modalities, the increase in premature morbidity and mortality for CAD patients is still very high. The current clinical practice for diagnosis and management of coronary stenosis involves the assessment of the diseased vessel either visually or by Quantitative Coronary Angiography (QCA). Such assessment provides the clinician with an anatomical overview of the stenosis segment and parent vessel, including the area reduction, lesion length, and minimal lumen diameter, but does not provide a functional assessment of the effect of the lesion on blood flow through the vessel. Measuring the fractional flow reserve (FFR) by inserting a pressure wire into the stenosed vessel has been shown to be a better option for guiding revascularization decisions, since the FFR is more effective in identifying ischemia causing lesions, as compared to invasive angiography. QCA only evaluates the morphological significance if the stenosis and has a number of other limitations. Pressure wire based FFR measurements involve risks associated with the intervention necessary to insert the pressure wire into the vessel, and for a very narrow stenosis, the pressure wire may induce an additional pressure drop.

[0004] Recently, mechanistic models have been proposed that use mathematical equations to model the physics of the blood flow in a three-dimensional anatomical model of the coronary vessels of a patient extracted from medical images. Such approaches rely on physics-based mathematical equations to model the physiology at rest and at hyperemia, thereby allowing one to numerically solve the equations on a computer and determine the flow and pressure drop for an individual patient. The most widely used physics-based model is the Navier-Stokes equation, which is a non-linear partial differential equation that is based on principles of mass, momentum, and energy conservation and is used to characterize the flow of blood in the coronary arteries. This is often coupled with mathematical equations that model the physiology of the upstream (heart, aorta) and downstream (myocardium) regions of the anatomy. Depending on the complexity and clinical use case, these methods can be used to incorporate physiological models at various scales. Although various types of physics-based models, boundary conditions, and physiological assumptions have been proposed for blood flow, a common theme of mechanistic models is their use of mathematical equations to model the various physiological interactions explicitly. However, a drawback of such mechanistic models is the high computational cost and complexity of associated with the model preparation and numerical solution of the physics-based equations. Additionally, such mechanistic models typically incorporate only anatomical and some partial physiological measurements, and leave out other meaningful measurements.

BRIEF SUMMARY OF THE INVENTION

[0005] The present disclosure provides methods and systems for machine learning based assessment of hemodynamic indices from medical image data. Embodiments of the present invention provide a data-driven, statistical methods to calculate one or more hemodynamic indices, such as fractional flow reserve (FFR), coronary flow reserve (CFR), instantaneous wave-free ratio (IFR), hyperemic stress reserve (HSR), basal stenosis resistance (BSR), and index of microcirculatory resistance (IMR), from input parameters including one or more of anatomical, functional, diagnostics, molecular, and demographic information from an individual patient, or directly from medical image data. Embodiments of the present invention employ machine-learning algorithms to learn the complex mapping between the input parameters or the input medical image data and the output hemodynamic index.

[0006] In one embodiment of the present invention, medical image data of the patient including the stenosis of interest is received. A set of features for the stenosis of interest is extracted from the medical image data of the patient. A FFR value for the stenosis of interest is determined based on the extracted set of features using a trained machine-learning based mapping.

[0007] In another embodiment of the present invention, a medical image of the patient including the stenosis of interest is received. Image patches corresponding to the stenosis of interest and a coronary tree of the patient are detected. An FFR value for the stenosis of interest is determined using a trained deep neural network regressor applied directly to the detected image patches.

[0008] These and other advantages of the invention will be apparent to those of ordinary skill in the art by reference to the following detailed description and the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] FIG. **1** illustrates a method of training a machine-learning based mapping for determining FFR according to an embodiment of the present invention;

[0010] FIG. **2** illustrates a framework for implementing the method of FIG. **1** according to an embodiment of the present invention;

[0011] FIG. **3** illustrates geometric features characterizing the shape of a stenosis;

[0012] FIG. **4** illustrates an algorithm for training a machine-learning based mapping using enhanced image-based boosting ridge regression according to an embodiment of the present invention;