2-Step 머신러닝 알고리즘을 활용한 심혈관 의사결정 보조 시스템

김영우* · 이준상**

Coronary artery decision making system by 2-Step machine learning algorithm

Young Woo Kim*, Joon Sang Lee*

Abstract : A two-step machine learning (ML) algorithm for estimating both fractional flow reserve (FFR) and decision (DEC) for coronary artery is introduced in this study. The primary purpose of this model is to suggest the possibility of ML-based FFR to be more accurate than the FFR calculation technique based on a computational fluid dynamics (CFD) method. For this purpose, a two-step ML algorithm that considers the flow characteristics and biometric features as input features of the ML model is designed. The first step of the algorithm is based on the Gaussian progress regression model and is trained by a synthetic model using CFD analysis. The second step of the algorithm is based on a support vector machine with patient data, including flow characteristics and biometric features. Consequently, the accuracy of the FFR estimated from the first step of the algorithm was similar to that of the CFD-based method, while the accuracy of DEC in the second step was improved. This improvement in accuracy was analyzed using flow characteristics and biometric features.

1. Introduction

CFD(Computational Fluid Dynamics) have long been used for diagnosis and treatment of blood vessel related diseases. Most common usage of CFD is to calculate FFR(Fractional Flow Reserve) for making clinical decision [1], or to analyze wall shear for prediction of rupture risk and outcome of stent insertion[2]. Compared to conventional invasive FFR method, this CFD FFR method requires less cost and time.

Yet the cost and time of CFD FFR is insufficient to be fully used in clinical field. The performance of CFD relies on the power of computational resource, and the cost of time for CFD FFR is usually expected to be about 3 hours[3]. Also, the accuracy and calculation time is always in trade-off situation, and therefore decreasing the calculation time blindly might cause the decrease of the accuracy.

To overcome this weakness of CFD FFR, a new method of using ML(Machine Learning) technique is being suggested[4]. Assuming that ML algorithm is operational, the time for calculation is less than a minute and requires less computational power. However, the problem of ML FFR is that it is hard to collect sufficient volume of data required to develop ML algorithm. Because of the complicity of blood vessel and individual difference, the number of data required is estimated to be over 10,000 cases. Obtaining these data from real patients is practically impossible.

The alternative method is to use CFD study of synthetic vessel as the input data for ML algorithm. There are some advantages of using CFD data compared to using clinical data. First, it is able to increase the number of cases almost infinitely. Secondly, the control of variables is easier than clinical vessel. To develop accurate ML algorithm, not only the number of cases but also the diversity of each variables are important, and in synthetic model this can be easily controlled In this paper, 2-step algorithm is introduced by fusing CFD and ML algorithm to develop decision making system for coronary artery.

* 연세대학교 기계공학부

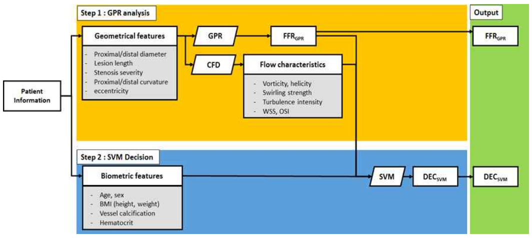

Fig. 1 Overall process of 2-step algorithm.

2. Methods & Results

2.1. Numerical Methods

For the CFD solver, LBM(Lattice Boltzmann Method) is used. LBM has few advantages when simulating blood vessel, including the parallel process to increase calculation speed and lattice grid form for complicated vessel geometry[5].

For the base of 2-step algorithm, Gaussian Regression model and support vector machine is used. Fig. 1 shows the overall flowchart of algorithm. The purpose of first step is to estimate FFR, and is trained by synthetic models with CFD results. Second step is to make decision making with higher accuracy than the first step, whici is trained by clinical patient data.

2.2. Results

The overall accuracy of 2-step algorithm have shown 75%, with sensitivity and specificity of 50% and 80% each. Detailed simulation chart is shown in Fig. 2.

3. Conclusion

2-Step algorithm has been developed for the purpose of coronary artery decision making. By using CFD results with synthetic models, it was able to increase both quantity and quality of the data used for training the algorithm.

Yet the number of cases used for testing the model is not enough to prove the accuracy of the model and provide feedback to incrase the accuracy. Also, for the future work, the scale of synthetic geometries should be expanded to the whole coronary artery, along with the situation of multiple stenosis. Moreover, other variables than vessel geometry should be also considered such as age or overall body parameters.

No.	Patient ID	FFR_{EXP}	DEC_{EXP}	FFR_{CFD}	FFR_{GPR}	DEC_{SVM}	Category
1	F155	0.38	1	0.722	0.723	1	1 (Matched)
2	F187	0.53	1	0.624	0.622	1	
3	F172	0.71	1	0.767	0.773	1	
4	F200	0.78	1	0.696	0.701	1	
5	F134	0.79	1	0.704	0.698	1	
6	F194	0.85	0	0.842	0.838	0	
7	F87	0.86	0	0.904	0.906	0	
8	F133	0.87	0	0.823	0.819	0	
9	F18	0.9	0	0.901	0.901	0	
10	F176	0.91	0	0.847	0.844	0	
11	F201	0.94	0	0.926	0.928	0	
12	F152	0.88	0	0.752	0.745	0	2 (Only SVM matched)
13	F188	0.88	0	0.782	0.784	0	
14	F178	0.90	0	0.759	0.763	0	
15	F198	0.77	1	0.789	0.8140	1	
16	F159	0.79	1	0.799	0.7942	0	3 (Only GPR matched)
17	F163	0.78	1	0.799	0.7920	0	
18	F136	0.6	1	0.86	0.8537	0	4 (Mismatched)
19	F116	0.77	1	0.829	0.8291	0	
20	F168	0.94	0	0.760	0.7512	1	

Fig. 2 Reslut chart of the 2-step algorithm.

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