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# Design and Implementation of a Cardiovascular Disease Detection System Using Artificial Neural Network

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**Abstract**
Cardiovascular diseases are a major cause of death globally. The early detection of these diseases and continuous supervision by health personnel can significantly reduce the mortality rate. However, accurate detection of cardiovascular diseases in all cases and supervision of a patient round-the-clock by a doctor is not feasible since it requires more sapience, time and expertise. Therefore, the aim of this work is to design and implement a cardiovascular disease detection system using artificial neural network. For the accurate detection of cardiovascular diseases, an efficient artificial neural network technique known as Multilayer Perception (MLP) neural network was used to build the predictive model. The system requires patients' heart-related medical records to detect the presence or absence of any cardiovascular disease and it will serve as an aid for medical personnel to diagnose the disease in a more efficient way. In the project's prototype implementation, system logic implementation was achieved using Java while user interfaces were built using the JavaFX framework. The development of the system followed the waterfall model which helped in breaking down the development process into smaller sub-processes that were followed sequentially to achieve a fairly efficient cardiovascular disease detection system. The system is a stand-alone desktop application and tested using WEKA and a laptop. In order to ascertain the accuracy, validation and performance measure of the developed system, a comparative analysis of the developed system against existing cardiovascular disease detection system was done, and the developed system yielded an accurate result of about 91.10%

**Nomenclature and units**

| | |
|---|---|
| *Thalach* | Maximum Heart Rate |
| *Trestbps* | Resting Blood Sugar |
| *Restecg* | Resting Electrocardiographic Results |
| *Fbs* | Fasting Blood Sugar |
| *Chol* | Serum cholesterol |

# 1.0 INTRODUCTION

The heart is a hollow muscular organ, located behind the sternum and between the lungs, which pumps blood into the body and is the central part of the body's cardiovascular system (Brunilda Nazario, MD 2021). The cardiovascular system is also composed of a network of blood vessels, for example, veins, arteries, and capillaries which deliver blood all over the body. Irregularities in normal blood flow from the heart cause several types of heart diseases which are commonly referred to as Cardiovascular Diseases (CVD) (Sabrina Felson, MD 2021). Currently, heart diseases are one of the major causes of death in the world. The World Health Organization (WHO) has estimated that more than 17 million deaths occur worldwide, every year due to the heart attacks and strokes. According to the survey, half the deaths in the United States and other developed countries occur due to cardiovascular diseases (National Center for Chronic Disease Prevention and Health Promotion , Division for Heart Disease and Stroke Prevention). It is also the chief reason of deaths in numerous developing countries. On the whole, it is regarded as the primary reason behind deaths in adults. Hence, detection of cardiac abnormalities at an early stage and tools for the prediction of cardiovascular diseases can save a lot of lives and enable doctors to design and develop an effective treatment plan which in due course reduces the mortality rate due to cardiovascular diseases. Nowadays, with the development of smart healthcare systems, lots of patient data (Big Data in Electronic Health Record System) are available which can be used for designing predictive models for cardiovascular diseases. This discovery method of analysing big data from an assorted perspective and encapsulating them into useful information is known as Machine learning or data mining. (Patel 2016).

Existing models for cardiovascular diseases detection take up different realities with wild range of differences. These differences are most times based on functions and operational modes. Many researchers have made salient review on models or algorithms with respect to cardiovascular diseases detection.

In a study by Shadman Nashif1 (2018), a tentative design of a cloud-based heart disease prediction system was proposed to detect impending heart disease using machine learning techniques. For the accurate detection of the heart disease, an efficient machine learning technique was used which had been derived from a distinctive analysis among several machine learning algorithms in a Java based open access data mining platform, WEKA. The proposed algorithm was validated using two widely used open-access database, where 10-fold cross-validation is applied in order to analyze the performance of heart disease detection. An accuracy level of 97.53% accuracy was found from the SVM algorithm along with sensitivity and specificity of 97.50% and 94.94% respectively. Moreover, to monitor the patient round-the-clock by a caretaker/doctor, a real-time patient monitoring system was developed and presented using Arduino, capable of sensing real-time parameters such as body temperature, blood pressure, humidity, heartbeat. The developed system could transmit the recorded data to a central server which are updated every 10 seconds. As a result, the doctors can visualize the patient's real-time sensor data by using the application and start live video streaming if instant medication is required. Another important feature of the proposed system was that as soon as any real-time parameter of the patient exceeds the threshold, the prescribed doctor is notified at once through GSM technology. An Overview of the system is shown in figure 1:

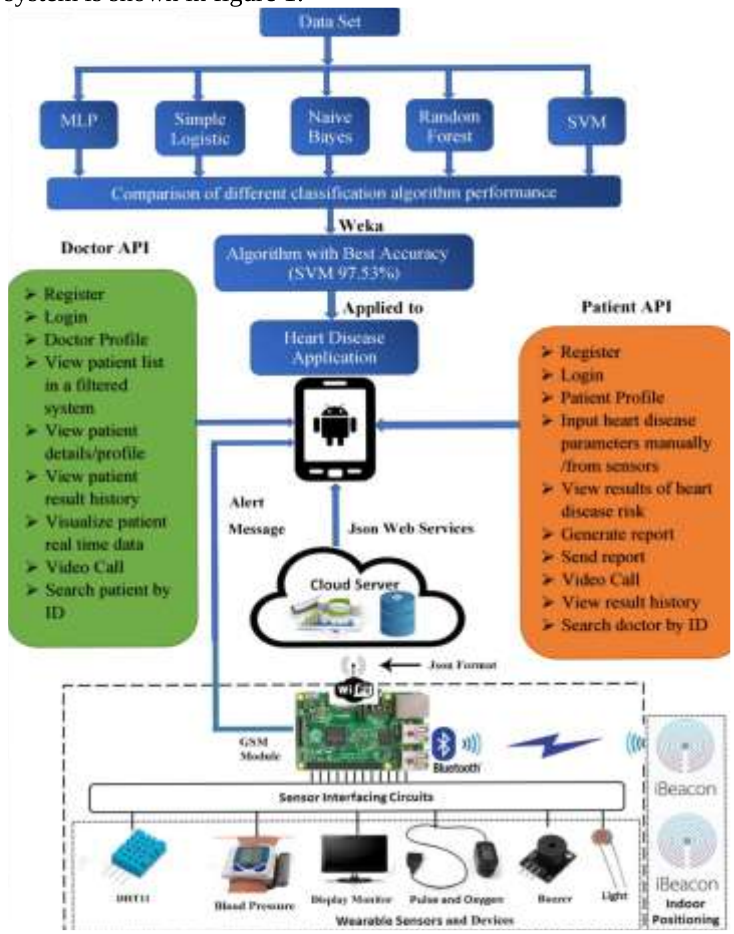


**Figure 1: System Overview (Shadman Nashif 2018)**

An intelligent heart disease prediction system using data mining techniques, namely, Decision Trees, Naïve Bayes and Neural Network was implemented by Palaniappan and Awang (2008) using .NET platform. The system was a web-based, user-friendly, scalable, reliable and expandable system. It can also answer complex "what if" queries which traditional decision support systems cannot. Using medical profiles such as age, sex, blood pressure and blood sugar, it could predict the likelihood of patients getting a heart disease. It enables significant knowledge, e.g. patterns, relationships between medical factors related to heart disease. In the research work, a data source with a total of 909 records with 15 medical attributes (factors) were obtained from the Cleveland Heart Disease database. Naïve Bayes appeared to be most effective as it has the highest percentage of correct predictions for patients with heart disease, followed by Neural Network (with a difference of less than 1%) and Decision Trees. Decision Trees, however, appeared to be most effective for predicting patients with no heart disease compared to the other two models.

Resul Das et al (2009) proposed neural network ensembles to predict heart disease. The ensemble-based methods created new models by combining the existing methods to produce the new model for disease prediction. Three independent neural networks models were used to construct the ensemble model. The number of neural networks node in the ensemble model was also increased but no performance improvement was obtained.

Latha Parthiban et al (2007) proposed a new approach based on Coactive Neuro-Fuzzy Inference System (CANFIS) for prediction of heart disease. The proposed CANFIS model combined the neural network adaptive capabilities and the fuzzy logic qualitative approach which is then integrated with genetic algorithm to diagnose the presence of the disease. The performances of the developed model were evaluated in terms of training performances and classification accuracies. Niti (2007) in their work proposed a decision support system for heart disease diagnosis using neural network. They trained their system with 78 patient records and the errors made by humans were avoided in this system.

Chitra and Seenivasagam (2013) proposed a heart disease prediction system using a machine learning classifier. In their paper, supervised learning algorithm was adopted for heart disease prediction at the early stage using the patient's medical record and the results were compared with the known supervised classifier, Support Vector Machine (SVM). The information in the patient record was classified using a Cascaded Neural Network (CNN) classifier. In the classification stage 13 attributes are given as input to the CNN classifier to determine the risk of heart disease. Their proposed system provided an aid for the physicians to diagnosis the disease in a more efficient way. The efficiency of the classifier was tested using the records collected from 270 patients. The results show the CNN classifier can predict the likelihood of patients with heart disease in a more efficient way.

From the review, most authors and researchers have used machine learning, Decision Trees, Naïve Bayes and Neural Network, Coactive Neuro-Fuzzy Inference System (CANFIS) in implementing a heart disease prediction system. Other authors used the Support Vector Machines (SVM) for predictive model for heart disease. These approaches to machine learning tend to focus on learning only one or two layers of representations of the data; hence, they are sometimes called shallow learning.

Hence, in this work, the development of an artificially intelligent system that utilizes a machine learning algorithm in making prediction of cardiovascular diseases is proposed. A machine learning algorithm, known as Multilayer Perceptron (MLP) neural network which will be validated on an open access heart disease prediction dataset.This approach gives a more accurate prediction than ordinary machine learning techniques.

## 2.0 MATERIALS AND METHOD

In this work, the following materials were used to develop the software for an effective and efficient operation of the new system: Java, FXML, JavaFX, WEKA, NetBeans IDE, JavaFX Scene Builder, JDK8 and a laptop**.**

### 2.1 Multi-Layer Perceptron (MLP) Neural Network

The method adopted for this system is the waterfall development model. This methodology supports the class of feed forward artificial neural network shown in figure2, which consists of at least three layers of nodes: an input layer, a hidden layer and an output layer. Apart from the input nodes, each node is a neuron that utilizes a nonlinear activation function. MLP uses a supervised learning technique called back propagation for training. Its multiple layers and non-linear activation distinguish MLP from a linear perceptron. In MLP, learning happens by altering connection weights after each piece of data are processed, based on the amount of error in the output compared to the expected result. This is an example of supervised learning, and is carried out through back propagation, a generalization of the least mean squares algorithm in the linear perceptron. Multilayer perceptron neural network has proved to be very useful in researches due to their ability to solve problems stochastically, which often allows approximate solutions for extremely complex problems like fitness approximation. MLP is a popular machine learning solution that finds applications in various fields such as image recognition, speech recognition and machine translation software. In this research, the heart disease dataset is used in training the multilayer perceptron neural network to generate a predictive model used in classifying a new instance.

### 2.2 Heart Disease Data Set

In the heart disease prediction system, data is captured via the graphical user interface using components such as text fields and combo boxes. Figure 3 shows the input design for the window that captures heart-related details.

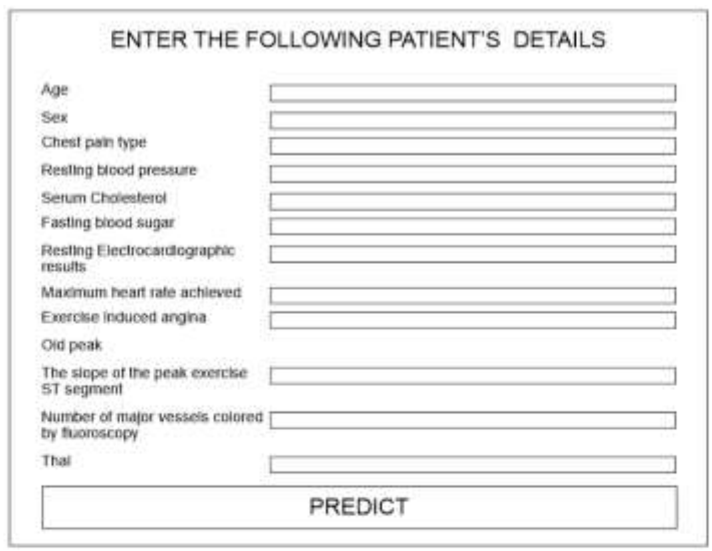


**Figure 3: Patients details**

After the input is processed, the result of prediction is displayed using a dialog box as shown in figure 4.

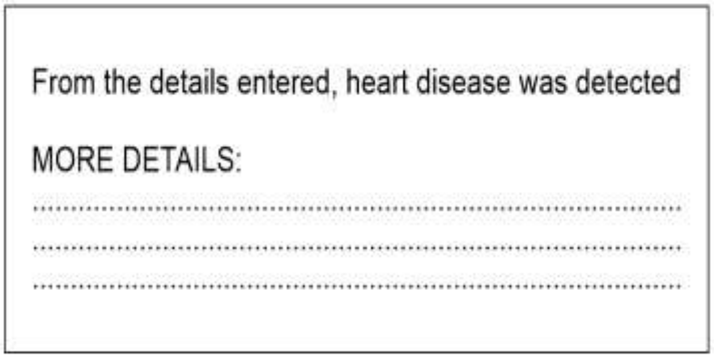


**Figure 4: System Output Design**

### 2.3 Cardiovascular Disease Detection Architecture

The system architecture consists of system components and the sub-systems developed that functions together to implement the heart disease prediction system. Figure 5 shows the various sub-systems whose integration formed the architecture of the prediction system. This was implemented as a software prototype and a standalone software application with the purpose of making it available to individuals and health organization that need a computerized system for diagnosing heart diseases. The system is implemented with a fairly user-friendly interface which means that the user needs little or no guidelines on how to use the heart disease prediction system. As a desktop application, users have to obtain the Java Archive (JAR) or executable file and run it on their local devices having a Java Virtual Machine (JVM).

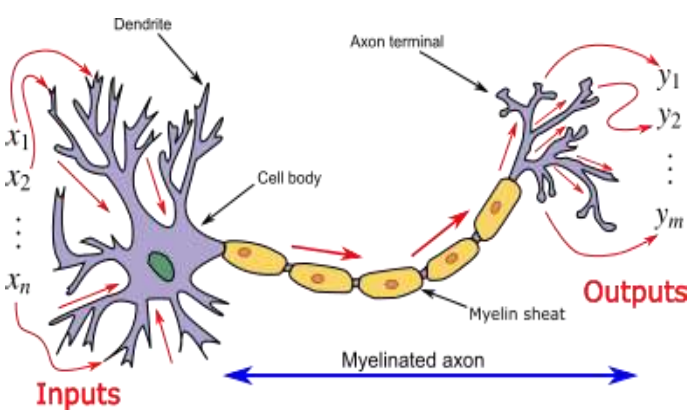


Figure 2: Neuron and Myelinated Axon

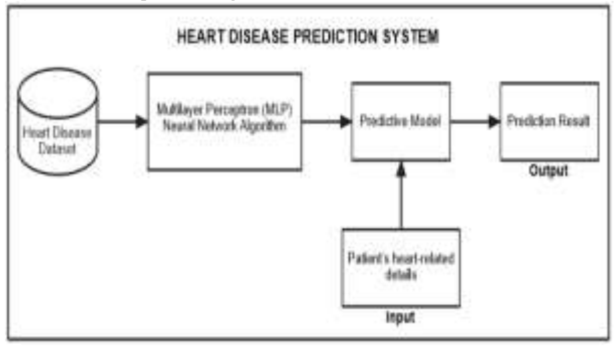


**Figure 5: System Architecture**

### 2.4 GUI-Based Cardiovascular Disease Detection System

The software system of this project work is a GUI-based desktop application. It contains a user-friendly interface for user interactivity enabling a person to enter patient's heart-related record to determine if he/she has a cardiovascular disease or not. This system flowchart is shown in figure 6. The predictive model is not automatically stored into the system therefore a user must first train the selected model before heart disease predictions can be made. The training takes some time due to analysis and data pre-processing but once the predictive model is built, heart disease details can be supplied to get accurate predictions. This system can be used by medical practitioners and individuals who do not have any knowledge of medicine.

## 3.0 RESULTS AND DISCUSSIONS

With suitable design, implementation, the system was an efficient, functional and reliable cardiovascular disease detection system. The system operated properly and adequately thereby meeting the minimum expectations that was needed initially. It is expected to be beneficial to individuals and health organizations with the need of a computerized system for diagnosing heart disease based on patient's health records. The user interfaces (UIs) of the developed system are presented and discussed in this section which consist of various GUI components such as labels, text fields, checkboxes, text area and buttons. The first window that launches when the application is run is shown in figure 7.

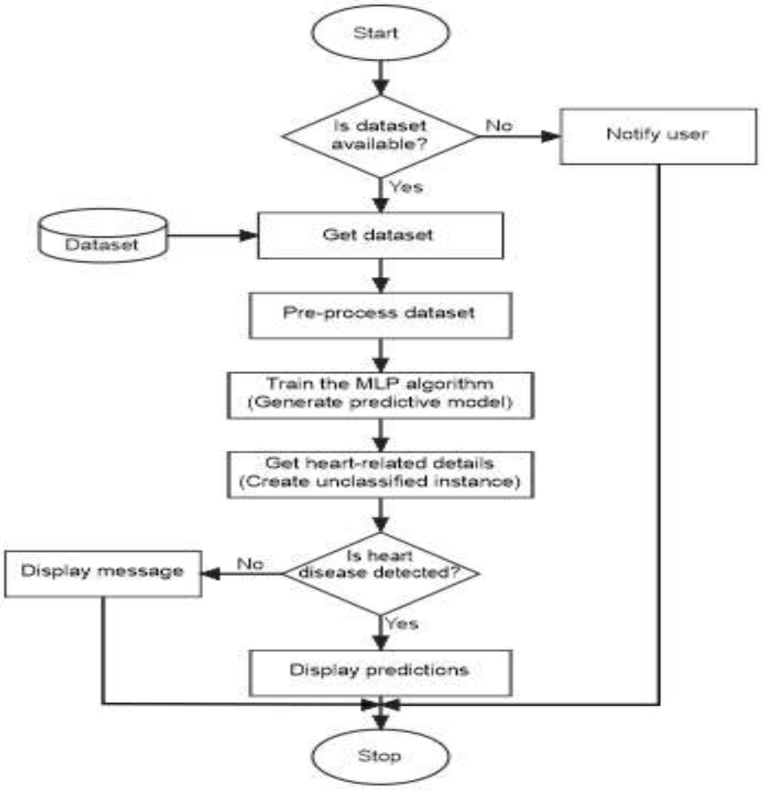


**Figure 6: System Flowchart**


**Figure 7: Get Started Window**

From the 'Get Started' window shown in figure 7, one can select a training data set or allow the system to automatically locate a data set for training. As explained earlier in the report, this data set is required for building the predictive model that will be able to detect the presence of a heart disease in a patient depending on the health details of the patient. To actually proceed with building the model, the system checks if the selected training data set has the same format with the testing data set. If the test succeeds, the user can then build the model by clicking on the 'Get Started' button. This will launch the next window (figure 8) where patient's health details are captured and supplied to the predictive model to detect heart disease presence.


**Figure 8: Main Window**

From the window shown in figure 8, there are thirteen (13) different inputs that are required from the patient. These inputs match the attributes that are found in the training data set. The attributes refer to different cardiovascular system parameters. These attributes and some of their possible values are shown in table 1.

**Table 1: Data set attributes/Inputs Required**

| S/N | ATTRIBUTES | DESCRIPTION |
|---|---|---|
| 1 | Age | Age in years |
| 2 | Sex | Sex (Male = 1, Female = 0) |
| 3 | Cp | Type of Chest Pain (typical angina = 1, atypical angina = 2, non-anginal pain = 3, asymptomatic = 4) |
| 4 | Trestbps | Resting Blood Sugar (in mmHg in case of admission to hospital) |
| 5 | Chol | Serum cholesterol in mg/dl |
| 6 | Fbs | Fasting Blood Sugar > 120 mg/dl (true = 1, false = 0) |
| 7 | Restecg | Resting Electrocardiographic Results (normal = 0, having ST-T wave abnormality = 1, left ventricular hypertrophy = 2) |

| | | |
|---|---|---|
| 8 | Thalach | Maximum Heart Rate |
| 9 | Exang | Exercise-induced Angina |
| 10 | Old peak | ST depression induced by exercise comparative to rest |
| 11 | Slope | Slope of the peak exercise ST segment (upsloping = 1, flat = 2, down sloping = 3) |
| 12 | Ca | Number of major vessels which are colored by fluoroscopy |
| 13 | Thal | Normal = 0, fixed defect = 2, reversible defect = 3 |

When all these data are entered, clicking on the 'Check' button performs the predictive analysis and displays the result of detection. Screenshots showing result after prediction are shown in figure 9 and figure 10.


**Figure 9: Main Window (Not Detected)**

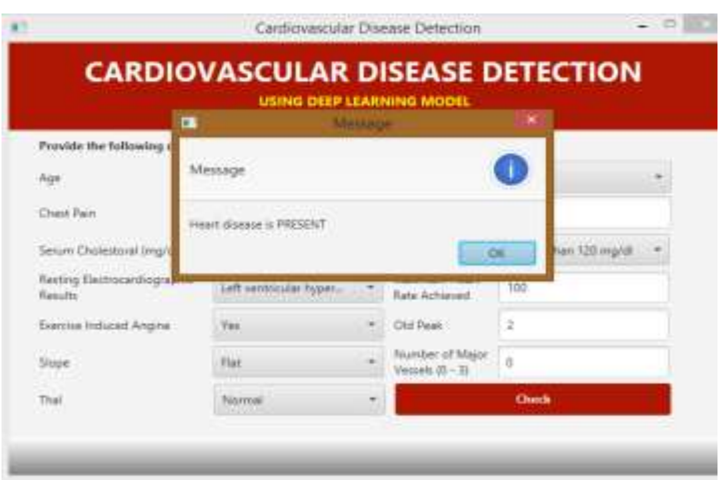


**Figure 10: Main Window (Detected)**

In the course of implementing the project prototype, a machine learning tool known as WEKA was used in testing the accuracy of various machine learning algorithms. The result of the analysis is summarized in table 2 shown below.

**Table 2: Comparison of Various Model**

| S/N | MODEL | ACCURACY |
|---|---|---|
| 1 | Logistics Regression | 77% |
| 2 | Naïve Bayes | 81.48% |
| 3 | Weighted Fuzzy Rules | 57.85% |
| 4 | Artificial Neural Network | 91.10% |

From the comparison made in table 2 above, it is observed that the Artificial Neural Network (ANN) gives more accuracy than the other machine learning algorithms. The algorithm selected for this project work is ANN. Therefore, we can conclude that the newly developed cardiovascular disease detection system is efficient and reliable for diagnosing cardiovascular diseases.

## 4.0 CONCLUSION

A cardiovascular disease detection system using artificial neural network has been developed using Java, FXML, JavaFX, WEKA, NetBeans IDE, JavaFX Scene Builder, JDK8 and a laptop and implemented using waterfall development model. The artificial neural network algorithm selected is Multilayer Perceptron (MLP) Neural network. MLP is a feedforward artificial neural network which consists of at least three layers of nodes: an input layer, a hidden layer and an output layer. The WEKA machine learning suite, together with the training heart disease dataset, are the tools used in building the model used in making detection. The diagnosis and prediction of diseases is a vital job in medicine; therefore, the system developed by this project work is of great importance as it will help non-experts and medical practitioners in diagnosis and detection of cardiovascular diseases. It can serve as a prototype for a continuous real-time cardiac health monitoring. Application of the selected machine learning algorithm in heart disease prediction improves the performance of other existing widely used models like models provided by American College of Cardiology/American Heart Association (ACC/AHA) models in CVD detection and prediction (Weng 2017). It can also be used by healthcare institutions as an optimized decision support system in heart disease detection due to its high accuracy and performance resulting from the chosen algorithm. The system, if implemented in many healthcare industries across the country and beyond, can go a long in reducing the rate of mortality arising from heart attacks and strokes. In educational and research institutions, this system can serve as a tool for conducting research in the area of cardiovascular disease detection. As a recommendation for future work, a real-time cardiovascular disease monitoring system can be built. In this research, patient's data are manually captured through the graphical user interface of the application but a hardware-based system can be constructed that will automatically get most of the patient's health status through the use of sensors. This will eliminate the possibilities of having errors while capturing patient's details.

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**Declaration of conflict of interest**

All authors have participated in the conception, design and implementation of this journal; via drafting the article and revising it critically for important intellectual content. This manuscript has not been submitted to, nor is under review at, another journal or other publishing venue. The authors have no affiliation with any organization with a direct or indirect financial interest in the subject matter discussed in the manuscript.

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