Screening of Abdominal Aortic Aneurysms based on Machine Learning Approach

Deepak Bajhaiya, Anju R Babu*
Soft tissue Biomechanics laboratory, Department of Biotechnology and Medical Engineering,
National Institute of Technology, Rourkela, India-769008
Phone: 0661-2462298, e-mail: babua@nitrkl.ac.in

Abstract

An abdominal aortic aneurysm (AAA) is identified as a localized expansion of the abdominal aorta with a 50% increase in the aortic diameter. This cardiovascular condition is usually asymptomatic and rupture can occur at any time without warning, making it difficult for patients to seek help and treatment. As a consequence, a robust early AAA predictor is highly relevant for minimizing the mortality rate due to the aortic wall rupture. This work aims to identify potential attributes for AAA prediction and to find a machine learning model that can be used in a clinical setting for prediction of AAA. In this study, N=424 subject's data (age and maximum aortic diameter) were collected from the works of literature (includes healthy and AAA population).70% and 30% of N=424 subject's data were used for training and testing of the model respectively. Five models named K-Nearest Neighbor (KNN), Decision Tree (DT), Random Forest (RF), and Logistic Regression (LR), and Naïve Bayes (NB) were employed with 10-fold cross-validation for better evaluation. For the prediction of AAA, among five models, RF achieved the best classification accuracy of 99.22 %, precision of 0.98, recall of 0.98 and f1-score of 0.99 with features (age and maximum aortic diameter) incorporation. KNN achieved the second best classification accuracy of 98.22 %, precision of 0.99, recall of 0.98 and f1-score of 0.98 with same features incorporation. Future work will incorporate additional attributes that will improve the sensitivity of the models and help clinicians in their decision-making.

Introduction

- An AAA is detected as an increase in aortic diameter and diagnosed using medical imaging modalities such as computed tomography, magnetic resonance imaging, and ultrasound scan.
- AAAs are asymptomatic, and without medical treatment, the aortic diameter increases to more than 3cm[1].
- The diameter increases until rupture, and a substantial mortality rate of up to 85% is associated with the event of rupture[2].
- Current treatment for AAAs is an elective surgical repair depends on factors such as maximum aneurysm diameter and an aneurysm diameter ≥5.5cm, is broadly recognized as a repair indicator[3].
- This study aims for identification of potential attributes for AAA prediction and to find a machine learning model that can be used in a clinical setting for prediction of AAA.

Methods

- For the prediction of AAA from age and maximum aortic diameter, the dataset was assembled from data reported in the literature (Table 1).
- A total of N=424 data were collected, out of which N=229 belonged to the healthy population while N=195 belonged to the AAA population.
- 70% of the dataset (N=297) was used to train the classifiers and 30 % of the dataset (N=128) was used to test the classifiers.
- Five classifiers: K-Nearest Neighbor (KNN), Decision Tree (DT), Random Forest (RF), and Logistic Regression (LR), and Naïve Bayes (NB) were employed for this study.
- Figure 1 describes an overview of the training phase and the testing phase of the classifiers employed in the prediction of AAA.

Table 1: Literature explored to collect age and maximum aortic diameter data.

S.No.	Title	Author	No. of AAA cases	No. of non-AAA cases
1.	Biomechanical rupture risk assessment of abdominal aortic aneurysms: Model complexity versus predictability of finite element simulations	Gasser et al., 2010	50	-
2.	Effects of age on the elastic properties of the intraluminal thrombus and the thrombus-covered wall in abdominal aortic aneurysms: Biaxial extension behaviour and material modelling	Tong et al, 2011	36	-
3.	The role of tissue remodeling in mechanics and pathogenesis of abdominal aortic aneurysms	Niestrawska et al., 2019	15	-
4.	Layer-dependent wall properties of abdominal aortic aneurysms: Experimental study and material characterization	Sassania et al., 2015	15	-
5.	Human thoracic and abdominal aortic aneurysmal tissues: Damage experiments, statistical analysis and constitutive modeling.	Pierce et al., 2014	08	-
6.	The Role of Geometric Parameters in the Prediction of Abdominal Aortic Aneurysm Wall Stress	Georgakarakos et al., 2009	19	-
7.	The quasi-static failure properties of the abdominal aortic aneurysm wall estimated by a mixed experimental-numerical approach	Forsell et al., 2012	15	-
8.	An update on the "fast-track" abdominal aortic aneurysm repair	Mukherjee et al., 2008	30	-
9.	Abdominal aortic aneurysm screening program using hand-held ultrasound in primary healthcare.	Almirall et al., 2017	07	229
	Total		**195**	**229**

Work flow of AAA prediction

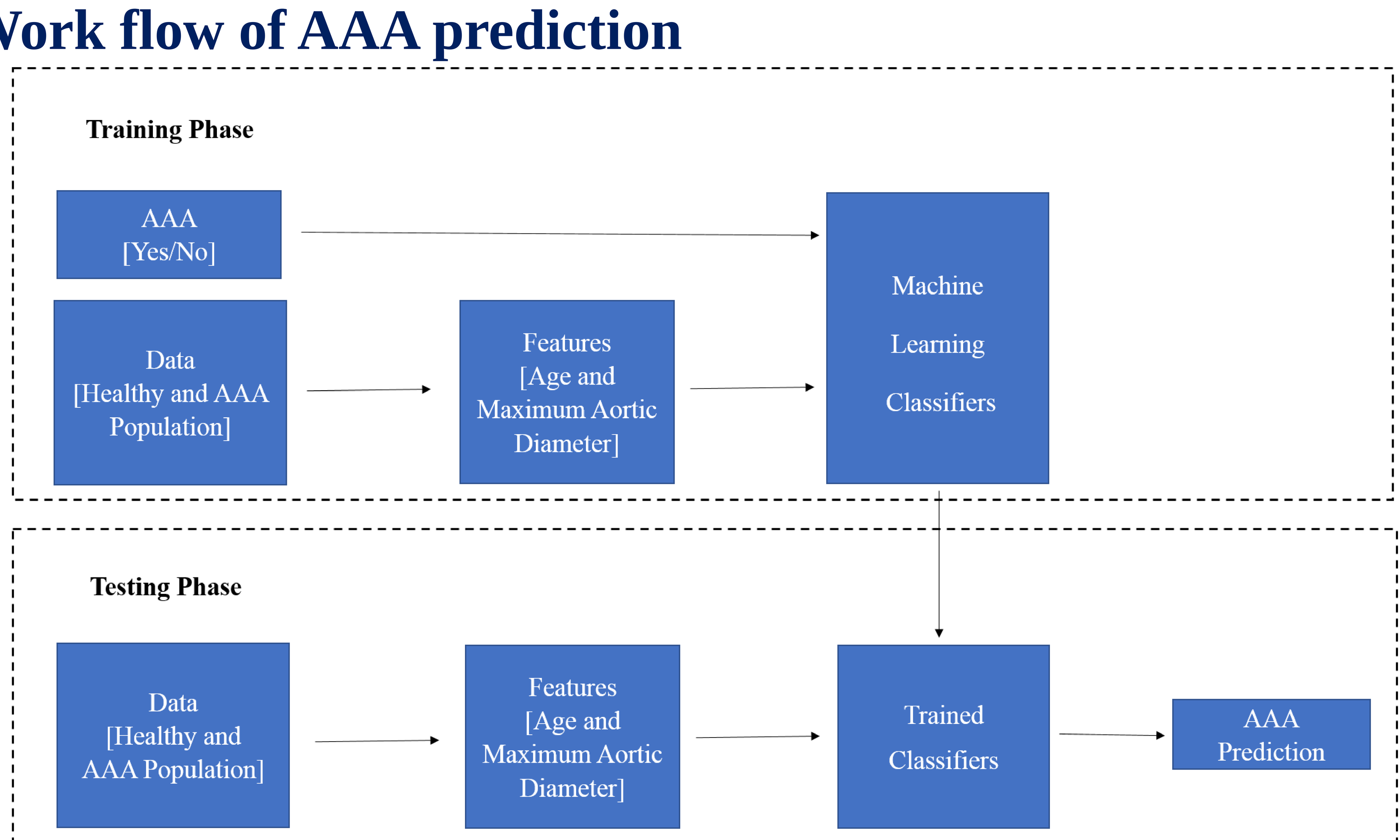

Figure 1: Machine learning process flow chart for AAA prediction

Results and Discussion

Table 2: Comparison of classifier performance metrics for AAA prediction.

S.No.	Classifier	Classification accuracy (%)	Precision	Recall	F1-score
1	K-Nearest Neighbor	98.44	0.99	0.98	0.98
2	Naïve Bayes	96.88	0.97	0.97	0.97
3	Decision Tree	96.66	0.97	0.96	0.97
4	Random Forest	99.22	0.98	0.98	0.99
5	Logistic Regression	97.66	0.97	0.98	0.98

- 10 fold cross-validation were used to assess the predictive performance of the classifiers.
- RF classifier attained the best performance among classifiers with classification accuracy of 99.22%, sensitivity (recall) of 0.98 and f1-score of 0.99.
- KNN classifier attained the 2nd best performance with classification accuracy of 98.44%, sensitivity (recall) of 0.98 and f1-score of 0.98.
- Models were found capable of classifying small size AAA as well as larger size AAA.

Table 3: Confusion matrices for each classifier for AAA prediction.

N=128	Predicted **No**	Predicted **Yes**
	K-Nearest Neighbor	
Actual **No**	73	0
Actual **Yes**	2	53
	Naïve Bayes	
Actual **No**	66	4
Actual **Yes**	0	58
	Decision Tree	
Actual **No**	66	4
Actual **Yes**	1	57
	Random Forest	
Actual **No**	70	0
Actual **Yes**	1	57
	Logistic Regression	
Actual **No**	64	0
Actual **Yes**	3	61

Conclusion

- This study, suggests that the aortic age and abdominal aortic diameters are sufficient for AAA screening.
- RF classifier achieved the best performance among five classifiers with high sensitivity and high f1-score.
- Classifiers worked efficiently for small size AAA as well larger size AAA and showed potential to be used in clinical settings for decision making.

Acknowledgements

- This research work has been supported by the National Institute of Technology Rourkela, India.

References

1. Humphrey JD, Taylor CA. Intracranial and Abdominal Aortic Aneurysms: Similarities, Differences, and Need for a New Class of Computational Models. Annu Rev Biomed Eng 2008;10:221–46.
2. Choke E, Cockerill G, Wilson WRW, Sayed S, Dawson J, Loftus I, et al. A review of biological factors implicated in abdominal aortic aneurysm rupture. Eur J Vasc Endovasc Surg 2005.
3. Metaxa E, Kontopodis N, Vavourakis V, Tzirakis K, Ioannou C V., Papaharilaou Y. The influence of intraluminal thrombus on noninvasive abdominal aortic aneurysm wall distensibility measurement.