Doupe Journal of Top Trending Technologies, Vol 1(1), Jan 2025, PP, 1-11

Artificial Intelligence Models for detecting Heart Failures in patients

Timilehin Olasoji Olubiyi [*1]

[1]West Midlands Open University Lagos State Nigeria

Abstract: In the field of healthcare the use of AI in diagnosing heart failure and supporting the treatment plans for patients has been highlighted to be very useful. Hence, based on the literature, this paper seeks to examine how AI has been relevant in this area and also the challenges and new breakthroughs that were made when implementing it. Guided by the explanation of the newest tendencies and trends worth noting in this sphere, this paper aims to explain the efficiency of AI models of heart failures and the impact of the enhanced identification of such failures to improve the methods of treatment and the outcomes for the patients. Thus, the paper further contributes to the already existing body of literature available on the application of AI in the field of cardiology and the likely shift that the application of this technology might bring in the way diagnostic strategies are approached.

Keywords: Artificial Intelligence, Heart Failure Detection, Machine Learning, Patient Health, Medical Diagnosis.

1 Introduction

1.1 Background

Heart failure is a global concern given the increasing incidence rates, and consequently, the role of precise and effective diagnostic tools cannot be overemphasized. Applying artificial intelligence [1].

In the recent past, AI models have been considered promising to assess possible symptoms of early HF and are integrated into patient record analysis [2]. Through the use of such newer solutions, clinicians can react in a faster manner, enhance the effectiveness of the methods, and enhance the potential influence for the persons. This area is poised to revolutionize how heart failure as a condition is diagnosed and addressed well ahead of time within healthcare industries [3].

1.2 Rationale for the Review

This paper seeks to discuss the application of AI models for diagnosing heart failure with a heavy focus on the idea of changing the diagnostic paradigm in cardiology. This paper aims to review existing research literature and trends to establish the extent self-learning methods in AI have in determining heart failures, analyzing existing research gaps, and chart possible future research strategies.

1.3 Overview

The purpose of this paper is to offer a critical review of the application of AI models on the diagnosis of heart failures on patients including methods, challenges, and results. Thus, focusing on the sphere of AI diagnostics in cardiology, this research aims to contribute to a deeper understanding of the role of AI in improving diagnostic and therapeutic approaches to heart failure. From this analysis, the research seeks to enhance the understanding of the current trends in cardiac diagnostics while highlighting the role of artificial intelligence in the delivery of value-based patient care as well as improvement in patient outcomes.

[*1]Corresponding Author Email: timi.olubiyi@westmidlands.university

1.4 Need for Artificial Intelligence Models for detecting Heart Failures in patients

1.4.1 Complexity of Cardiac Conditions:

Cardiac diseases often have non-specific and varied presentations and thus require accurate diagnostic equipment formulating even the subtlest sign of the beginning of heart failure [4].

1.4.2 Variability in Patient Data:

Many types of patient data in cardiology, including medical images, have high variance, making it difficult for conventional diagnostic techniques to detect signs of heart failure [5].

1.4.3 Early Detection and Intervention:

Deep learning or machine learning-based solutions offer the potential for early diagnosis of heart failure from complex patient data and prevent further deterioration of the condition to benefit the patient [6].

1.4.4 Enhanced Diagnostic Accuracy:

Currently, AI models can improve diagnostic reliability through the application of such machine learning techniques as more precise features of heart failure non-interpretable by humans are revealed [5].

1.4.5 Efficient Healthcare Delivery:

The utilization of AI models in diagnosing cardiac diseases enhances the administration of healthcare delivery by aiding healthcare providers to diagnose the diseases accurately and effectively using minimal resources [7].

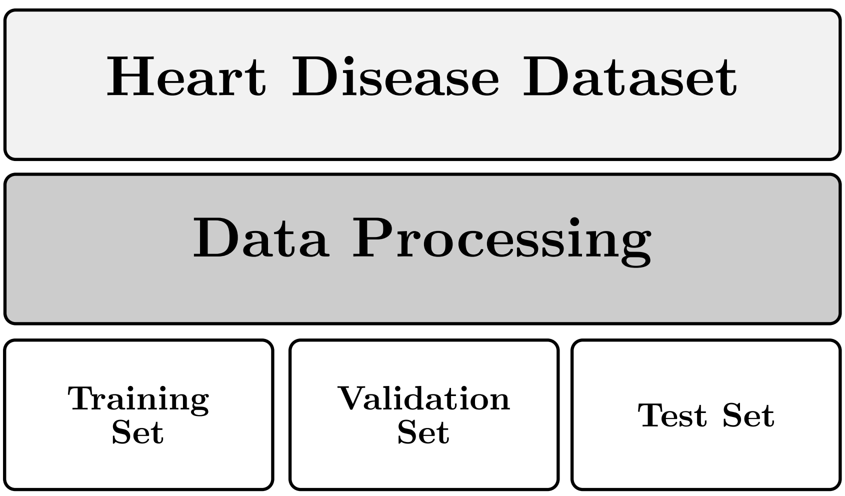

Fig. 1. Detecting Heart Failures using AI
Source: Self-created

2 Methodology

2.1 Search Strategy

The literature review began with a broad search to gather relevant empirical and theoretical knowledge on the use of AI models in the diagnosis of heart failures among patients. The electronic sources that were used to conduct the search include; PubMed, IEEE Xplore, and Google Scholar, and the keywords used included ‘artificial intelligence,’ ‘detection of heart failure,’ and ‘machine learning in cardiology.

2.2 Inclusion and Exclusion Criteria

Research articles particularly from 2019 to 2024 reviewed for this paper were drawn from databases exploring the efficacy of AI models developed for diagnosing heart failures in patients. Only both experimental and observational studies located in peer-reviewed journals were considered. Articles and papers written in languages other than English and papers specifically addressing other cardiac diseases different from heart failure were also excluded from this review.

3 ARTIFICIAL INTELLIGENCE MODELS FOR DETECTING HEART FAILURES IN PATIENTS

The integration of AI models has proven to be a powerful tool in giving cardiology, state-of-the-art solutions for the timely diagnosis and accurate prognosis of heart failures in patients [8]. They are equipped with machine learning algorithms that help the models to consider complex input data sets ranging from medical images, patient records, and physiological signals to identify patterns that indicate heart failure [9]. The present section explores various AI approaches utilized for the identification of heart failures and their central importance on clinical processes [9]

3.1 Machine Learning Algorithms in Cardiology

Deep learning algorithms are pivotal in the improvement of AI models for heart failure diagnosis. Support vector machines and random forest are potentially used in supervised learning algorithms to classify patients by their predisposition to heart failure [10]. These algorithms are trained with labeled datasets that results from feature extraction from patient data, and will predict the probability of occurrence of heart failure [11]. With the use of such advanced analytical tools, AI models can improve the overall diagnostic accuracy, and enable care givers to offer appropriate care to patients at high risk of suffering from heart failure [11].

3.2 Feature Extraction Techniques

Feature extraction remains an important aspect of building algorithms of machine learning for diagnosing heart failure [12]. To identify the susceptible features across different of data sets, several approaches such as principal component analysis, wavelet analysis, and deep learning approaches to feature learning are used mistakenly. These features effectively depict various aspects of cardiac functioning and structure that enable distinguishing patients with heart failure from those without the condition [13]. Due to such enhanced feature extraction methods, experts can enhance the diagnostic performance of deep learning applications and in turn assist doctors to identify patients who are in the pre-heart failure stage.

3.3 Image-based Approaches

Echocardiography cardiac MRI and CT scans have turned out to be more valuable in diagnosing cardiac abnormalities under the integrated model of diagnostic approaches. These imaging techniques are well integrated in AI models more particularly models that employ CNN and other deep learning paradigms in trying to identify peculiarities which may be associated with heart failure [14]. From functional imaging of ventricular mass and thickness in hypertrophic cardiomyopathy to assessment of myocardial viability in acute infarction to identifying valvular abnormalities in degenerative heart diseases, all these apply image-based methods to deliver precise and safe diagnostic information in heart failures [15].

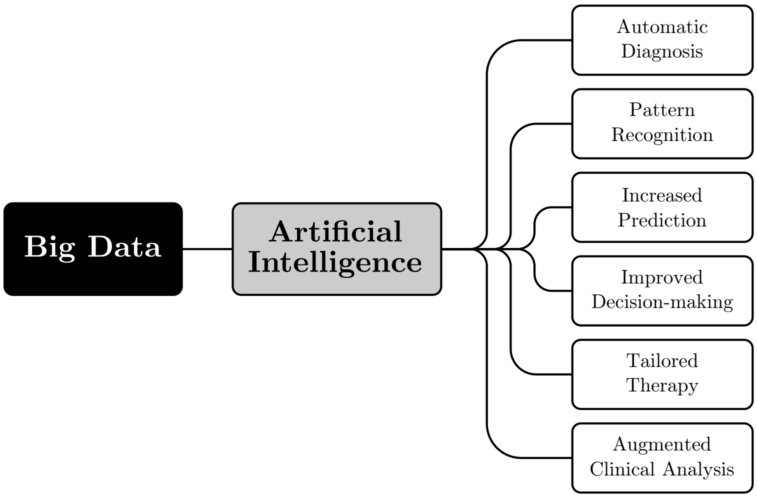

Fig. 2. Use of AI in Cardiovascular Imaging
Source: Self-created

3.4 Electrocardiogram (ECG) Analysis

Electrocardiography is defined as a preeminent technique of cardiological diagnostics used to provide information about the electric activity of the heart. AI undertakings, given the ability to learn from big ECG datasets, are capable of identifying subtle alterations that signify heart failure from normal conditions and diseases such as atrial fibrillation, bundle branch blocks, and ST-segment [16].

Artificial feedforward and recurrent neural networks of deep learning including RNNs and LSTM networks are more effective for the analysis of sequential data, which enables them to closely examine the ECG signals in an efficient manner in order to identify signs of heart failure [16].

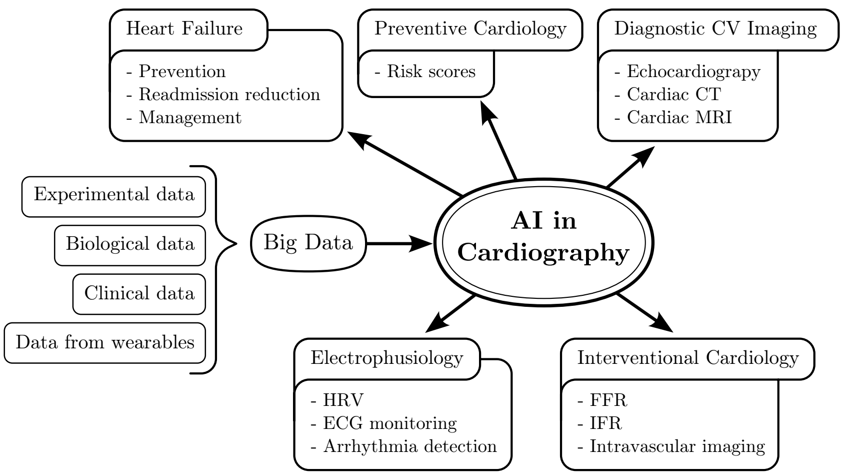

Fig. 3. Artificial intelligence in cardiology
Source: [1]

Clinicians can use ECG analysis with the help of Artificial Intelligence to pinpoint abnormalities that would have previously gone unnoticed thus, the patients would be diagnosed early and given proper treatment to fit their heart failure risk factors [17].

3.5 Integration of Multimodal Data

Using medical images in combination with ECG signals and clinical parameters that represent heart failure multi-modal data synthesis take AI models to a higher level of effectiveness [18]. The late fusion and early fusion are the two approaches that combine information obtained from different sources to improve diagnostic accuracy and reliability [19]. Through the use of the simultaneous signals of various modalities, the AI models provide detailed assessments of cardiac function and structure, and help in the early diagnosis and management of heart failures.

3.6 Clinical Decision Support Systems

CDSS, backed by artificial intelligence, helps the healthcare team to effectively analyze the patient data and come to the best of decisions regarding the diagnosis and the course of treatment required in heart failures. These systems are based on the application of AI models with EHRs and other clinical data repositories and provide timely and individualized actionable recommendations [20]. With the use of CDSSs that effectively combine clinician judgment with AI ideas, diagnostic exactitude, treatment pathways, and overall patient wellbeing in heart failure treatment are enhanced [20]. This approach of integrating AI with the efforts of healthcare practitioners promises a giant leap to precision medicine and individualized patient care.

3.7 Challenges and Limitations

Nevertheless, AI models in the case of heart failure have drawbacks and difficulties in achieving their goals. Accuracy concerns, data heterogeneity, interoperability problems, and high demand for annotated data are some challenges that render model development and validation difficult [21]. However, it should also be noted that despite the high potential and wide area of application of deep learning in the diagnosis and treatment of diseases, the lack of understanding the calculations made by these models, that is, the related problem of explainability and interpretability of such models, can act as a barrier to their implementation in clinics [22]. Overcoming these challenges demands a keen application of interdisciplinary efforts to involve data scientism, clinician, and other significant stakeholders in the delivery of well-established, effective, and transparent AI systems for detecting HF [23].

3.8 Future Directions

Further work on developing AI models for detection of heart failures should continue to address the limitations highlighted and improve on the current performance, effectiveness, and usability. With incorporation of wearables, smart sensors, IoT, and remote monitoring systems [1], there are possibilities of improving the monitoring of patients with heart failures in real life. In addition, continued endeavours to harmonise global data acquisition, labeling and sharing strategies will help build appropriate large scale multi centre datasets for training and validation of the AI systems [23].

4 Emerging Trends in Artificial Intelligence Models

4.1 Integration of Multi-modal Data

This has come due to advancements in technology whereby amalgamation of multi-modal data sources, for instance, medical images, genetic indicators, and wearable sensor data are some of the risings that boosts AI models for detecting heart failures [24].

4.2 Explainable AI (XAI) Techniques

Techniques such as Explainable AI (XAI) has been found to be promising approaches in using diagnostics for heart failures through AI. XAI pattern enables clinicians to gain the understanding of predisposing factors that determine diagnostic conclusions, enhancing confidence and promoting better evidence-based treatments [25].

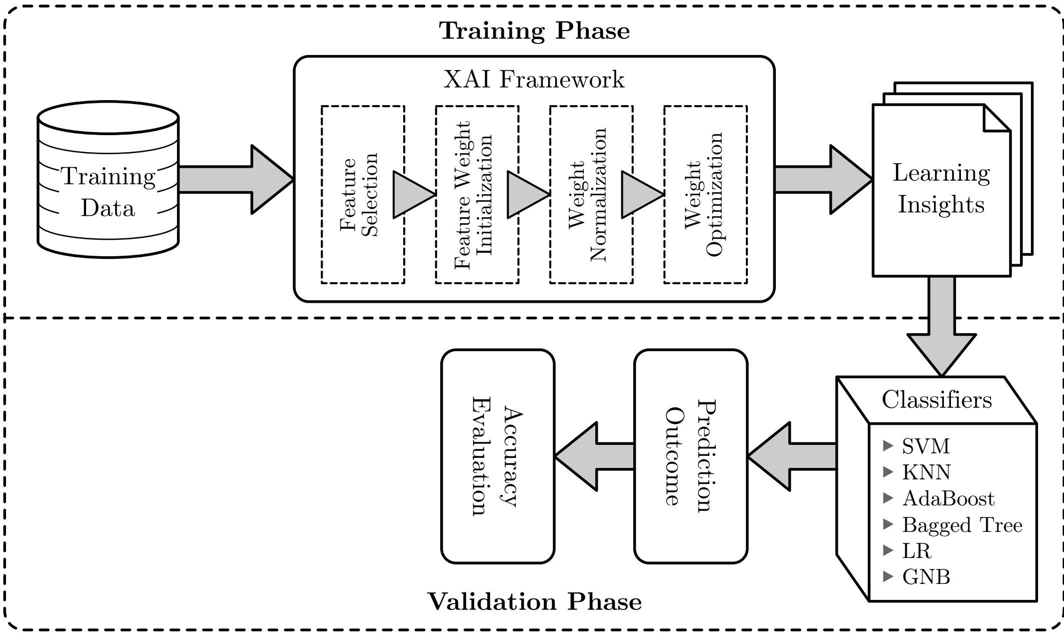

Fig. 4. XAI Framework for Cardiovascular Disease Prediction
Source: [19]

4.3 Continuous Learning and Adaptive Models

In a similar vein, repeated training and the development of AI intelligence models are increasingly being promoted as strategies designed for constantly improving diagnostic results in the future. These models are flexible to integrate changing patient information and trends in clinical practice to guarantee that diagnosis models are up to the required standard as the environment changes [26].

4.4 Federated Learning for Privacy-preserving Collaborations

The described federated learning methods allow multiple staff organizations across the healthcare system to train AI models while maintaining privacy [26]. This trend ensures the large-scale sharing and collaboration of such data across various stakeholders, which holds the promise of unleashing the power of diagnostic AI that can leverage such diverse datasets without violating patients' confidentiality and privacy rights.

5 Recent Developments in Artificial Intelligence Models

5.1 Advancements in Deep Learning Architectures

Emerging trends in AI models to diagnose heart failure have shown massive improvements in the application of deep learning frameworks such as CNN and RNN [22]. These complex architectures are highly performant in identifying hidden and complex patterns of patients' multimodal data and improving the reliability and accuracy of AI-based diagnostic methods for heart failures.

5.2 Collaborative research and data sharing initiatives.

Some of the areas of research interest have been on collaboration in research and data sharing which are essential in training or validating AI based HF screening tools [23]. By using the collected and combined data during the development and utilisation of those projects across multiple facilities, the projects enhance the mobility, flexibility and realism of AI diagnostic tools in real-life clinical environments [27].

5.3 Integration of Real-world Clinical Data

It is also emerging from the recent advancement that the clinical data in real-world situations can be incorporated into the AI models, where the research investigations are utilized to develop precise conclusions and render them practicable at the initial stage of clinical practice [25]. Thus, with the help of an AI algorithm that utilize EHRs, wearables, and remote monitoring systems, it becomes possible to offer individual diagnosis at the right time, which will lead to an enhancement of patient outcome as well as the overall functioning of the health care system.

6 Conclusion

6.1 Summary of Key Findings

In conclusion, artificial intelligence models offer a unique breakthrough in the identification of heart failures with applicability in the improvement of cardiology diagnostics. These models build upon machine learning algorithms and use different sources of data to increase precision, prevent adverse events on time, and improve patients' outcome. Nevertheless, there are certain barriers that should be discussed specifically, and those include data heterogeneity and model interpretability so that machine learning can be integrated into clinical practice.

References

[1] M Yoon et al. "Application and Potential of Artificial Intelligence in Heart Failure: Past, Present, and Future". In: *International journal of heart failure* 6 (2024). DOI: 10.36628/ijhf.2023.0050.

[2] D.-J. Choi and S. Lee et al. "Artificial intelligence for the diagnosis of heart failure". In: *npj Digital Medicine* 3.1 (2020), pp. 1–6. DOI: 10.1038/s41746-020-0261-3.

[3] F. Yasmin et al. "Artificial intelligence in the diagnosis and detection of heart failure: the past, present, and future". In: *Reviews in Cardiovascular Medicine* 22.4 (2021), p. 1095. DOI: 10.31083/j.rcm2204121.

[4] A. A. Armoundas et al. "Use of Artificial Intelligence in Improving Outcomes in Heart Disease A Scientific Statement From the American Heart Association". In: *Circulation* (2024). DOI: 10.1161/cir.0000000000001201.

[5] V. Chang and A. Hossain et al. "An artificial intelligence model for heart disease detection using machine learning algorithms". In: *Healthcare Analytics* 2 (2022), p. 100016. DOI: 10.1016/j.health.2022.100016.

[6] M. S. Khan et al. "Artificial intelligence and heart failure: A state-of-the-art review". In: *European Journal of Heart Failure* 25.9 (2023), pp. 1507–1525. DOI: 10.1002/ejhf.2994.

[7] T. Averbuch et al. "Applications of artificial intelligence and machine learn- ing in heart failure". In: *European Heart Journal - Digital Health* 3 (2022), pp. 311–322. DOI: 10.1093/ehjdh/ztac025.

[8] K. Erdem and Murat Koklu et al. "A Detailed Analysis of Detecting Heart Diseases Using Artificial Intelligence Methods". In: *Intelligent methods in engineering sciences* (2023). DOI: 10.58190/imiens.2023.71.

[9] I. U. Haq and B. Xu et al. "Artificial Intelligence in Cardiovas- cular Medicine: Current Insights and Future Prospects". In: *Vascular Health and Risk Management* 18 (2022), pp. 517–528. DOI: 10.2147/VHRM.S279337.

[10] K. Seetharam et al. "Applications of Machine Learning in Cardiology". In: *Cardiology and Therapy* 11.3 (2022), pp. 355–368. DOI: 10.1007/s40119-022-00273-7.

[11] R. Cuocolo and M. Petretta et al. "Current applications of big data and machine learning in cardiology". In: *Journal of Geriatric Cardiology : JGC* 16.8 (2019), pp. 601–607.

[12] H. Y. Mir and O. Singh. "ECG denoising and feature extraction techniques – a review". In: *Journal of Medical Engineering and Technology* 45.8 (2021), pp. 672–684. DOI: 10.1080/03091902.2021.1955032.

[13] S. Kuila and S. Joardar et al. "Feature extraction of electrocardiogram signal using machine learning classification". In: *International Journal of Electrical and Computer Engineering (IJECE)* 10.6 (2020), p. 6598. DOI: 10.11591/ijece.v10i6.pp6598-6605.

[14] C. Martin-Isla et al. "Image-Based Cardiac Diagnosis With Machine Learning: A Review". In: *Frontiers in Cardiovascular Medicine* 7 (2020). DOI: 10.3389/fcvm.2020.00001.

[15] R. G. Barriada and D. Masip. "An Overview of Deep-Learning-Based Methods for Cardiovascular Risk Assessment with Retinal Images". In: 13.1 (2022), p. 68. DOI: 10.3390/diagnostics13010068.

[16] A. Bleich and T. O. F. Conrad et al. "Enhancing Electrocardiogram (ECG) Analysis of Implantable Cardiac Monitor Data: An Efficient Pipeline for Multi-Label Classification". In: *Machine Learning and Knowledge Extraction* 5.4 (2023), pp. 1539–1556. DOI: 10.3390/make5040077.

[17] Y.-X. Guan and J.-X. Wang et al. "Intelligent Electrocardiogram Analysis in Medicine: Data, Methods, and Applications". In: *Chinese Medical Sciences Journal* 38.1 (2023), pp. 38–48. DOI: 10.24920/004160.

[18] T. Zhou et al. "Multimodal data integration for enhanced longitudinal prediction for cardiac and cerebrovascular events following initial diagnosis of obstructive sleep apnea syndrome". In: *Journal of Global Health* 14.2 (2024), p. 0413. DOI: 10.7189/jgh.14.04103.

[19] R. Wali et al. "Integrated machine learning and multimodal data fusion for patho-phenotypic feature recognition in iPSC models of dilated cardiomyopathy". In: *Biological Chemistry* (2024). DOI: 10.1515/hsz-2024-0023.

[20] Y. Lu and H. M. Krumholz et al. "Clinical decision support in cardiovascular medicine," BMJ". In: (2022). DOI: 10.1136/bmj-2020-059818.

[21] R. Sutton and D. Pincock. "An overview of clinical decision support systems: benefits, risks and strategies for success". In: *NPJ Digital Medicine* 3.1 (2020), pp. 1–10. DOI: 10.1038/s41746-020-0221-y.

[22] S. J. Rao et al. "An Update on the Use of Artificial Intelligence in Cardiovascular Medicine". In: *Hearts* 5.1 (2024), pp. 91–104. DOI: 10.3390/hearts5010007.

[23] X. Sun and T. L. Huo et al. "Artificial intelligence in cardiovascular diseases: diagnostic and therapeutic perspectives". In: *European Journal of Medical Research* 28.1 (2023). DOI: 10.1186/s40001-023-01065-y.

[24] A. Bourazana et al. "Artificial Intelligence in Heart Failure: Friend or Foe?" In: *Life* 14.1 (2024), p. 145. DOI: 10.3390/life14010145.

[25] S. Abbas et al. "Artificial intelligence framework for heart disease classification from audio signals". In: *Scientific Reports* 14.1 (2024), p. 3123. DOI: 10.1038/s41598-024-53778-7.

[26] J.-D. Huang and J. Condell et al. "Applying Artificial Intelligence to Wearable Sensor Data to Diagnose and Predict Cardiovascular Disease: A Review". In: *Sensors* 22.20 (2022), p. 8002. DOI: 10.3390/s22208002.

[27] Buhari Ugbede Umar and M.Atama et al. "Artificial intelligence model for prediction of cardiovascular disease: An empirical study". In: *Deleted Journal* 1.1 (2023), pp. 1746–1746. DOI: 10.36922/aih.1746.