NATURALISTA CAMPANO
ISSN: 1827-7160
Volume 28 Issue 1, 2024

Artificial Intelligence and Machine Learning based Se- cured Cardiology: A Meta-Analysis of cyber-risk in Car- diology

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Abstract. An advancement in cardiovascular disease prediction by analysing diagnostic parameters is done with machine learning and artificial intelligence algorithms. This can enormously enhance the decision-making process for clin- ical experts. The clinical experts and highly utilize these Machine Learning al- gorithms to benefit patients if they actively utilize it. The aim of this study is to make specialist and related stakeholders aware about key concepts of advanced techniques to have better understanding of the current techniques and develop- ments for Secured Cardiology. The research directions and latest challenges are studied for Artificial Intelligence and Machine Learning in this emerging field through which the efficient techniques can be determined for future betterment and analysis.

Keywords: Artificial Intelligence, Machine Learning, Cardiovascular Disease,Cardiology.

1. Introduction

With the Recent developments in technology, Machine Learning is being utilized a lot in the cardiovascular field. Machine learning, as a part of Artificial intelligence work on the motto of gathering knowledge from data and making decisions with or without human guidance. The human body is combination of different cells and Heart is one of the majorly sensitive and special organs of it. Clinicians faces many chal- lenges in cardiovascular disease like from identification of AMI-Acute Myocardial Infarction patients to respiratory disease because of congenital lesions (William. J. Brady, 2005). There is a huge development in the techniques and algorithms for as- sessing medical issues in which results can be generated in terms of fatal and non- fatal diseases by taking different variables under consideration. (E. Grossi, 2006). Advancements in Two-dimensional echocardiography is done which can be used to check LV-Left Ventricular EV- Ejection Fraction (C. Corsi, 2005).

As Ejection fraction is becoming highly useful in pharma, the requirement for the same is increasing day by day (M. Cannesson, 2007). Also, the improvements in Three-dimensional echocardiography are increasing the scope of accuracy efficiency of LV and EF (C. Jenkins, 2004). Also, the false or incomplete dichotomization af- fects the accuracy of prediction. The change in the biomarker levels can make the cardiologist change their decisions in terms of responders and non-responders. These kinds of decisions can highly change the accuracy levels (Senn. S, 2005). This issue ishighly famous among statisticians with the name of ‘dichotomania’.

Detection and diagnosis of cardiovascular disease on early basis can optimize the outcomes. Tools and techniques of Artificial Intelligence, Machine Learning and Computer cognitivism plays a key role in early diagnosis of cardiovascular disease along with predictions. (T.B. Murdoch, 2013).

Different datasets including transactional, Qualitative and Quantitative are being generated with the widespread use of electronic health Records in Labs/Hospitals etc. Telephonic consultations/ Telemedicine and E-Health is also taking over in the pre- sent scenario for the detection and prevention of cardiovascular disease. Internet of Things can be another effective tool for prediction and diagnosis of cardiovascular disease. (C. Li., 2017). The purpose of this meta- analysis is to have better under- standing about Machine Learning and Artificial Intelligence in cardiology and the power of these latest techniques in the domain to have better knowledge, effective decision making and interpretation of data. (R. V. Tuckson, 2017). The different waysto utilized Artificial Intelligence and Machine Learning is shown in figure 1.

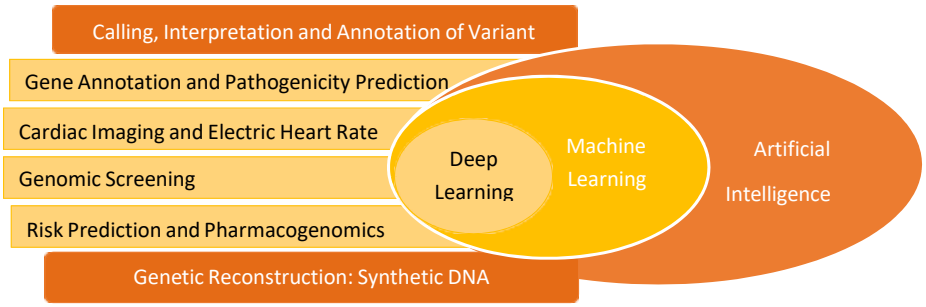


Fig. 1. Cardiology in context of Artificial Intelligence and Machine Learning.

The healthcare field and cyber security can be analysed on four key aspects which are presented in figure 2.

- The data Preservation is to ensure the availability of health data for a long period.
- The Data Updation is to ensure the modifications in data whenever required bymaintaining authenticity and authorized access to it.
- The Data Exchange is to ensure the secured exchange of information between twoor more parties internally or externally.
- Interoperability is to ensure that systems are able to exchange information effi-ciently.
- Compliance is to ensure the maintenance of same standards and regulations for the healthcare data.

Fig. 2. Aspects of Cyber Security in Healthcare.

Key Contributions

Detecting and predicting cardiovascular disease is a challenging task. Early diagnosis can definitely protect lives and can be a great help to clinicians for choosing efficient plans of treatment. This became motivation to work on this meta-analysis. The key contributions of the meta-analysis are as follows:

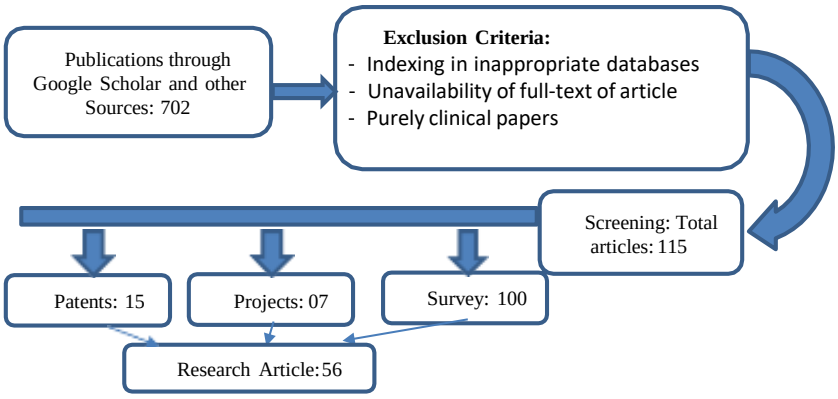
- The meta-analysis on prediction of cardiology using AI and ML techniques makes clinicians and researchers to come up with novel prediction systems. The risks of cybersecurity for cardiology domain are studied in this work. With reference to past meta-analysis on the domain where previous research papers being utilized on cardi- ology domain. In this presented work, the step-by-step discussion for prediction, inte- gration and analysis of cardiology in terms of AI and ML is done rigorously. The meta-analysis is done using previous studies from 2008 to 2022.
- The Recollection of recent studies done on the domain of AI ML in Cardiology for getting clarity on future inventions is done in this meta-analysis. Tabular representa- tions of the key points studied about previous work gives more preciseness in the areato understand it better.
- The recent cyber-attack incidents are being analyzed.

In the presented work, the brief introduction to the domain area is provided and dif- ferent techniques and tools related to cardiovascular analysis is discussed. Section 2 presents the overall methodology to review the studies, Section 3 presents research publications and various tools and techniques used by researchers and detailed analy-sis of the same. The important points are presented in tabular format. Section 4 pre- sents Analysis of different Cyber Attacks in Healthcare Sector. Finally, Section 5 discusses final conclusion and future work in the area of Artificial Intelligence and Machine Learning for Cardiology and cyber security.

2. Review Methodology

This Section presents the Review Methodology for performing meta-analysis in this work. The previous studies considered for the work includes Patents, Research Arti- cles, Funded projects and Surveys on the specified domain. The parameters used for search are Artificial Intelligence in Cardiology, Machine Learning in Cardiology and E-Cardiology. The number of projects, surveys and patents done in the duration of 2008 to 2022 sorted out. Similarly, the Research Articles have been gathered from 2008 to 2022 which are also categorized according to different publishers like Else- vier, IEEE, Springer etc. The stages of the Review methodology are shown in Figure
3. The articles where Cardiology is discussed in terms of Artificial Intelligence and Machine Learning are included in the analysis. The unavailability of indexed articles in appropriate databases was taken as exclusion criteria for the study.

Fig. 3. Review Methodology.



Research Publications
This Section presents the Review Methodology for performing meta-analysis in this work. The previous studies considered for the work includes Patents, Research Articles, Funded projects and Surveys on the specified domain. Machine Intelligence is a process to mimic the Human abilities (Krittanawong C, 2017). There are still some doubts with the definition of Artificial Intelligence although it came in 1950. (Turing, 1950). As Artificial Intelligence can play a crucial role in enhancing the quality of human being by developing multidisciplinary tech- niques and practices. Machine Learning is a sub part of Artificial Intelligence and same can be utilized in medical diagnosis, clinical areas, predictions of disease and knowledge discovery. The applications of Artificial Intelligence and machine Learn- ing includes Analysis of Data, Cognitive Analysis etc. (Ghahramani Z, 2015).

Failure of Heart is a clinical condition which occurs due to insufficiency of blood pumping as per the demand of body. There are majorly 3 categories on the basis of Left Ventricular Ejection Fraction; Ejection Fraction < 40%, Ejection Fraction be- tween 40 to 49%, and Preserved Ejection Fraction i.e. greater than or equal to 50% (McDonagh TA, 2021). There is huge demand of health data which may help to knowthe IT risks in hospitals. The highly connected network may expose Medical Admin- istration to the new vulnerabilities (Kruse, 2016). The sudden events or any malicious activities can lead to theft. Different types of attacks can occur like DoS, artificial pancreas due to which confidence of patient can be reduce, or a threat to human life. (O'Keeffe DT,2015). The Cyber security plays a crucial role in the safety of a patient which makes is highly essential to consider cyber security as important part. It is also required that a reliable health information is to be exchanged securely between pro-fessionals. The ICT techniques are now in use by cardiologists for different purposes like e-consultation, e-messaging, e-monitoring which can be done using different applications. (Baranchuk A, 2018).
The work is being implemented for the utilization of Machine Learning techniques in the echocardiography. The usage of Cognitive computing has been done to under- stand the differentiation of constrictive pericarditis and restrictive cardiomyopathy. (Sengupta, 2016). It is highly impressive to observe the technical advancement in cardiology which are impactive several lives using digital holters, defibrillators, pacemakers, wearable and portable devices of human body. Also, along with these techniques, the cyber security risks also came into existence which were earlier not possible. Is been stated that there are many medical devices related to cardiology which are at risk of cyber attacks because of their vulnerable behaviour. (Kramer DB, 2017). The e-cardiology, however, is providing high domain benefits in terms of net- working, imaging, classification, prediction and

efficient decision support systems butalso with the same level of cyber security risks. (Ransford B, 2017). The utilization ofmachine learning algorithms which are efficient with complex data can highly affect cardiology in terms of diagnosis and digitized information like ECGs, echocardio- grams etc (Shameer K,2018). Different aspects in healthcare data like wearable devic-es, sensor data, imaging, clinical digitized data etc. has been increasing in a very fast pace (Standford Medicine, 2020) and the same is at different risks of security. It is fine to say that now, the skills, analysis of data is not enough to understand the com- plexity of medicine completely (Obermeyer Z, 2017). The machine learning tech- niques and tools can be utilized efficiently for design, validation and implementation for analysing health related data from heterogenous sources to get effective results for the complex medical situations.

The E-Electrocardiograms can have problem of cyber attacks like display problemsand cyber attack on the same can present wrong results which can mislead the clini- cians. Pacemakers with networking can have different types of attacks which can lead to incorrect responses. The strict rules and regulations are now being implemented in USA and Europe for paying serious attention towards security risks in cardiology (GDPR, 2018). The utilization of Artificial intelligence to guide clinicians in manag- ing patients is very much appreciating. The different developments has been done in embedding capable techniques of diagnosis and decision making along with predic- tive modelling using Machine learning (Fang M.C., 2017). There are numerous ex- amples where Artificial Intelligence and Machine Learning played a crucial role in helping cardiology. Echocardiography needs Sonographer for image acquisition. An- other great tool came into existence based on Convolutional Neural Networks for echocardiograms (Ouyang D, 2020). A convolutional Neural Network based another tool also came up for identification of LV dysfunction (Sun, 2021). Table 1 presents the summary of the Literature Survey done for this work.

Table 1. Summary of Literature Survey

Author and Year	Dataset used	Method used	Findings and Conclusion
C. Jenkins (2004)	50 patients	2DE and RT-3DE (two-and three-dimensional Echocardiography)	RT-3DE was found as good approach for test-retest variation reduction.
C. Corsi (2005)	30 patients from Philips 7500	Linear Regression, Bland Altman Analysis, LV function, dilated cardio- myopathy	RT-3DE based analysis was found feasible and efficient for Wall Motion abnormali-ty detection automatically.
M. Cannesson(2007)	218 patients	Visual EfAuto EF	Auto EF worked better as compared to Visual EF.
Loughlin S (2014)	---	Roundtable Discussion	The cyber security relatedrisks in healthcare and es-pecially cardiology are crucial to tackle.
P.P. Sengupta(2016)	50 patients	Associative MemoryClassifier	The utilized machine learn-ing classifier provided bet- ter accuracy as compared toother approaches. (90% +)
Ransford B _(2017)	---	Search and analysis	This work analysed recent cases of potential threat of security in medical devices.
Attia Z (2019)	44,959 patients	Convolutional Neural Networks	Proposed work gave fol- lowing results: AUC: 93%, Sensitivity: 86.3%, Specificity: 85.7%, and Accuracy: 85.7%
Ouyang D (2020)	10.030 Echocardiogram Videos	EchoNet: A Deep learning algorithm based on video	Proposed work gave fol- lowing results: AUC: 96%, Absolute error:6%

Sun JY (2021)	26,786 ECG-TTE pairs	Convolutional Neural Networks	Proposed work gave following results: Accuracy: 73.9%, Sensitivity: 69.2%, Specificity: 70.5%, Positive Predictive Value: 70.1%, Negative Predictive Value: 69.9%

Analysis of Cyber Attack Incidents and Future Predictions.
In this section, the Recent attacks related to cyber security in healthcare industry has been covered up. Also, the future predictions for the possible cyber-attacks in healthcare are also covered up.

Recent Cyber Attack Incidents in Healthcare industry
The data in healthcare domain is very easy to attack and many weaklings can be iden- tified in same. Some of the recent Healthcare Cyber-attacks are discussed here to understand the real time scenario of same (Healthcare Weekly, 2022).

- The cyber-attack on Premera Blue Cross in 2014 happened where a malicious email was received by an employee. The data of 11 million patients was stolen from database and Premera settled the complete case with 74 million dollars.
- The cyber-attack on Anthem, Inc. in 2015 happened where a phishing email hacked data of nearly 78 million patients including their insurance information, SSN etc.
- The cyber-attack of WannaCry Ransomware in 2017 because of which many NHS hospitals in UK has to shut down and ambulances were being re-routed.
- The cyber-attack of Magellan Health in 2020 where with a phishing email, hackers were able to steal protected information and 1.7 million records of patients were com-promised.

Predictions for Cyber Attacks in healthcare
There are some attacks that possible can occur and analysis/discussion of same can help in prevention of the same for future (Bitdefender, 2022).

- Ransomware Attacks are expected to be continued because these automatic attacks can impact new healthcare industries easily. Also, there are chances that Ransomware as a service will be utilized more with the help of social engineering. The firms with complex environments, less security makes them vulnerable towards hacking.
- Data Breach are expected to affect healthcare organizations because of less securityand protection of data.
- Medical Devices can be compromised because of low level networking, security, passwords and credentials.
- Vulnerable Patients Data is likely to be the part of attack by hackers. The organiza-tions generally do not care much in fining vulnerabilities in clinical data but it is very important to be detected.

The count of cyberattacks happened are analysed and shown in figure 4 for last five years. Figure 5 presents health care related cyber attacks count and lost in last 5 years (FBI-IC3, 2021).

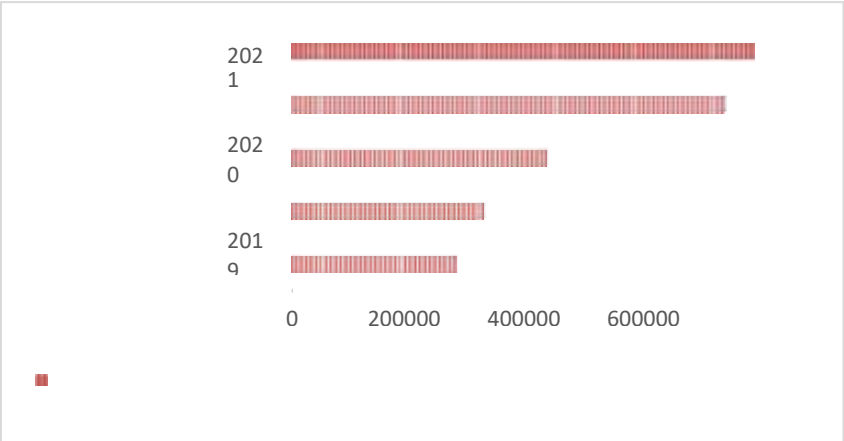
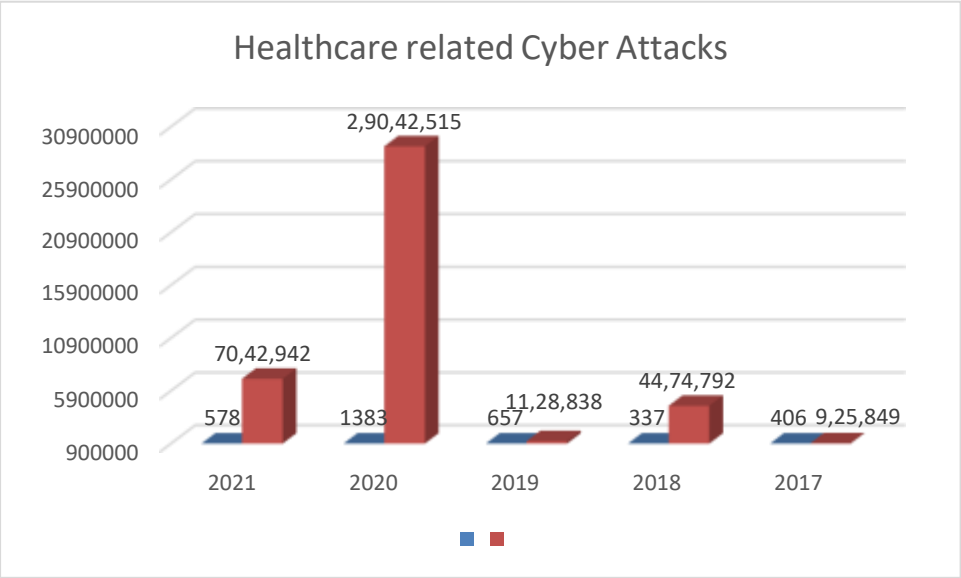


Fig. 4. Number of Registered Complaints related to Cyber Crime (FBI-IC3, 2021).

	2017	2018	2019	2020	2021
Number of Complaints forCyber Attacks	301580	351937	467361	791790	847376

Fig. 5. Cyber Attacks in Health Care Sector(FBI-IC3, 2021).



3. Conclusion

In this meta-analysis, the analysis of security risks in cardiology and role of Machine learning and Artificial Intelligence in Cardiology are covered and discussed. Image Processing is also acting as one of the major techniques in the field of cardiology. It has been observed through the analysis that the link of existing network and devicesin cardiology are exposing towards novel security risks because there is a lot of data available in the medical field and the defense for the same are really weak. The utili- zation of AI and ML in the cardiology has opened many doors for effective treatment of patients and at the same time different security risks also came with these opportu- nities. For getting best results based on Machine Learning and Deep Learning, differ- ent other security related risks can be analyzed. This meta-analysis can be highly useful for academicians who are very much interested in domain of Healthcare and Artificial Intelligence. The work can be extended by studying specific domains of the cardiology field and their related risks.

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