**CHAPTER 2 Literature Survey**

An increasing number of heart patients worldwide have motivated researchers to do comprehensive research to reveal hidden patterns in clinical datasets. An overview of reported computational studies on pattern recognition in heart disease is covered in this section. Not only are different techniques addressed, but also various heart disease datasets are provided. Finally, the gap in existing literature, which was the main motivation of this study is also mentioned. Some of the key studies are as follows:

**Jyoti Soni, Ujma Ansari, Dipesh Sharma and Sunita Soni:** In this journal the authors provides us with a survey of current techniques of knowledge discovery in databases using data mining techniques that are in use in today’s medical research particularly in Heart Disease Prediction using KNN, Neural Networks, Bayesian classification, classification based on clustering, Decision Tree. It gives us a total overview of heart attack predictions by using predictive data mining for medical diagnosis. [1]

**Shantakumar B. Patil, Dr. Y. S. Kumaraswamy:** In this paper the author is giving us a survey of current techniques of knowledge discovery in databases using data mining techniques that are in use in today’s medical research particularly in Heart Disease Prediction. It also to compare the performance of predictive data mining technique on the same dataset and the outcome reveals that Decision Tree outperforms and some time Bayesian classification is having similar accuracy as of decision tree but other predictive methods like KNN, Neural Networks. [2]

**Anudeep Duba, Rajasekhar Reddy:** This informational collection is utilized to anticipate the odds of an event of heart assault for a patient. Its main objective is to bring down the number of attributes by establishing and quantifying the relationships between attributes like Age, Gender, Chest, Pain, Blood, Pressure, Cholesterol etc. [3]

**Cheryl Ann Alexander**, **Lidong Wang:** The aim of this literature review was to identify usage of Big Data analytics in heart attack prediction and prevention, the use of technologies applicable to big data, privacy concerns for the patient, and challenges and future trends as well as suggestions for further use of these technologies. The national and international databases were examined to identify studies conducted about big data analytics in healthcare, heart attack prediction and prevention, technologies used in big data, and privacy concerns. [4]

**Asha Rajkumar, Mrs. G. Sophia Reena:** According to author the healthcare industry gathers enormous amounts of heart disease data that regrettably, are not “mined” to determine concealed information for effective decision making by healthcare practitioners. In this paper the data classification is based on supervised machine learning algorithms which result in accuracy, time taken to build the algorithm. Tanagra tool is used to classify the data and the data is evaluated using 10-fold cross validation and the results are compared. Naive Bayes, k-nn, Decision List are also used. [5]

**Dr. Hidayet TAKCI:** In this study, author used machine learning and feature selection algorithms together. Their aim is to determine the best machine learning method and the best feature selection algorithm to predict heart attacks. According to the author the best machine learning algorithm is the support vector machine algorithm with the linear kernel, while the best feature selection algorithm is the reliefF method. This pair gave the highest accuracy value of 84.81%. [6]

**Anil Maybhate, Cheng Chen, Yama Akbari etc. all:** In this paper the researchers used controlled laboratory experiment with animal models of CA, their primary focus here is on understanding the functional changes in the thalamus and the cortex, associated with the injury and acute recovery upon resuscitation. Specifically, they studied the changes in thalamocortical synchrony through these periods, they acquired local field potentials (LFPs) from the ventroposterior lateral (VPL) nucleus of the thalamus and the forelimb somatosensory cortex (S1FL) in rats after asphyxial CA. Band-specific relative Hilbert phases were used to analyze synchrony between the LFPs. observed that the CA induced global ischemia changes the local phase-relationships by introducing a phase-lag in both the thalamus and the cortex, while the synchrony between the two regions is nearly completely lost after CA. [7]

**Junyun He, Hongyang Lu etc. all:** In this paper the authors mentioned about their experiment, a full-field high-resolution optical imaging technique, was used for real-time monitoring of the fluctuations of CBF in a rat model of asphyxial-CA. The temporal changes of CBF were characterized and the relationship between CBF and mean arterial pressure (MAP) was evaluated. Their study provides a new technique to study the neurovascular coupling and metabolic regulation of CBF after CA. [8]

**Hsiao-Ko Chang, Cheng-Tse Wu, etc. all:** According to the author more than 54% IHCA patient had abnormal clinical manifestation before they suffered a cardiac arrest. If appropriate steps were taken, patients’ survival rate would be higher and medical expense would be decreased. They construct two types of shifting windows (corresponding to two tasks) that allow machine learning to be applied for their dataset which is severely imbalanced. The results show that their approach can effectively handle the imbalanced dataset for detecting cardiac arrest. [9]

**Usman Rashed, Muhammad Javed Mirza:** This paper introduces work that has been done to distinguish the Electrocardiogram (ECG) of a normal healthy human from that of a patient who may suffer from Sudden Cardiac Death (SCD), but this condition has not been detected. worked on normal portion of SCD ECG and compared its parameters with those of a healthy person’s ECG. The intention is to design an algorithm that may enable doctors to detect chances of myocardial infarction beforehand on the basis of spectral analysis of an ECG. [10]

**Keisuke Kasahara, Masahito Shiobara, etc. all:** This study examined the feasibility of using indices obtained from a long term Holter ECG record for sudden cardiac arrest (SCA) risk stratification. Patients were classified into high and low risk groups according to their clinical diagnosis, and the obtained indices were compared with those of 25 control subjects. The sensitivities and specificities of all three categories exceeded 0.8 except for the sensitivity to detect the high-risk patient group. Other short-term ECG parameters may need to be incorporated in order to improve the sensitivity. [11]

**Archana Singh,** **Rakesh Kumar:** The author uses the biological parameter as testing data such as cholesterol, Blood pressure, sex, age, etc. and on the basis of these calculate accuracy of machine learning algorithms for predicting heart disease, for this, algorithms are k-nearest neighbors, decision tree, linear regression and support vector machine(SVM). On the basis of calculation conclusion is done which one is best among them. [12]

**Mohan etc. all:** The author define how you can combine two different approaches to make a single approach called hybrid approach which have the accuracy 88.4% which is more than of all other. [13]

**Kohali etc. all:** The authors have worked on heart diseases prediction using logistic regression, diabetes prediction using support vector machine, breast cancer prediction using AdaBoost classifier and concluded that the logistic regression give the accuracy of 87.1%, support vector machine give the accuracy of 85.71%, AdaBoost classifier give the accuracy up to 98.57% which is good for predication point of view.[14]

**Himanshu Sharma** **etc. all:** The author utilizes feature vector and its various data types under various condition for predicating the heart disease, algorithms such as Naïve Bayes, Decision Tree, KNN, Neural Network, are used to predicate risk of heart diseases each algorithm has its specialty such as Naive Bayes used probability for predicating heart disease, whereas decision tree is used to provide classified report for the heart disease, whereas the Neural Network provides opportunities to minimize the error in predication of heart disease. All these techniques are using old patient record for getting predication about new patient. This predication system for heart disease helps doctors to predict heart disease in the early stage of disease resulting in saving millions of lives. [15]

**Marjia Sultana etc. all:** Authorshave illustrated about how the datasets available for heart disease are generally a raw in nature which is highly redundant and inconsistent. There is a need of pre-processing of these data sets; in this phase high dimensional data set is reduced to low data set. They also show that extraction of crucial features from the data set because there is every kind of features. Selection of important features reduces work of training the algorithm and hence resulted in reduction in time complexity. [16]

**Amin Ul Haq etc. all:** A hybrid intelligent machine-learning based predictive system was proposed for the diagnosis of heart disease. The system was tested on Cleveland heart disease dataset. Seven well-known classifiers such as logistic regression, K-NN, ANN, SVM, NB, DT, and random forest were used with three feature selection algorithms Relief, mRMR, and LASSO used to select the important features. The K-fold cross-validation method was used in the system for validation. In order to check the performance of classifiers, different evaluation metrics were also adopted. The feature selection algorithms select important features that improve the performance of classifiers in terms of classification accuracy, specificity, and sensitivity, MCC and reduced the computation time of algorithms. The classifiers logistic regression with 10-fold cross-validation showed best accuracy 89% when selected by FS algorithm Relief. Due to the good performance of logistic regression with Relief, it is a better predictive system in terms of accuracy. [17]

**Ansari etc. all:** They performed a work, "Automated Diagnosis of Coronary Heart Disease Using Neuro-Fuzzy Integrated System". In this paper, the author offered a Neuro-fuzzy integrated system for the analysis of heart diseases. To show the effectiveness of the projected system, Simulation for computerized diagnosis is performed by means of the realistic causes of coronary heart disease. The author concluded that this kind of system is suitable for the identification of patients with high/low cardiac risk.[18]

**Mrs .G .Subbalakshmi etc. all**: They performed a work "Decision Support in Heart Disease Prediction System using Naive Bayes”. The main objective of this research is to develop a Decision Support in Heart Disease Prediction System using Naive Bayes algorithm. The system extracts hidden useful information from the heart disease database. This model may possibly answer difficult queries, each one with its own potency with respect to ease of model analysis, access to complete information and accurateness. This model can be further enhanced and expanded by incorporating other data mining techniques.[19]

**Mai Shouman, Tim Turner, and Rob Stocker etc. all:** They performed a work “Applying k-Nearest neighbors in Diagnosing Heart Disease Patients”. In this paper the author details work that applied KNN on a Cleveland Heart Disease dataset to investigate its efficiency in the prediction of heart disease. The author also investigated if the accuracy could be enhanced by integrating voting with KNN. The results show that applying KNN achieved an accuracy of 97.4%. The results also show that applying voting could not enhance the KNN accuracy in the diagnosis of heart disease.[20]

**Ashish Kumar Sen, Shamsher Bahadur Patel, Dr. D. P. Shukla etc. all:** They performed a work “A Data Mining Technique for Prediction of Coronary Heart Disease Using Neuro-Fuzzy Integrated Approach Two Level” .In this work, the author has designed a system which could identify the chances of a coronary heart disease. He has divided all parameters into two levels according to criticality of the parameter and assigned each level a separate weightage. Finally, both the levels are taken into consideration to arrive a final decision. The author has implemented neuro-fuzzy integrated approach at two levels. So, error rate is very low and work efficiency is high. The author concluded that this same approach could be used to perform the analysis on some other diseases also.[21]

**Aditi Gavhane etc. all:** They suggest to make use of the easily available sensors in watches and cell phones to measure the simple factors. Provides its users with a prediction result that gives the state of a user leading to CAD. Due to the recent advancements in technology, the machine learning algorithms are evolved a lot and hence we use Multi Layered Perceptron (MLP) in the proposed system because of its efficiency and accuracy. Also, the algorithm gives the nearby reliable output based on the input provided by the users. If the number of people using the system increases, then the awareness about their current heart status will be known and the rate of people dying due to heart diseases will reduce eventually. [22]

**Jayshril S. Sonawane etc. all:** They performed a work “Prediction of Heart Disease Using Multilayer Perceptron Neural Network” The system for prediction for heart disease using multilayer perceptron neural network is implemented in MATLAB R2012. In this system the database is divided in to two sets randomly that is training set and testing set. Out of total records 70% records are used for training and testing is done by using remaining 30% records. The evaluation of performance of the system is done by computing the percentage value of different parameters like Accuracy, Specificity and Sensitivity. [23]

**Yubin Park, Joyce C. Ho, Joydeep Ghosh:** They performed a work “Multivariate Temporal Symptomatic Characterization of Cardiac Arrest”. In this work they modelled the temporal symptomatic characteristics of 171 cardiac arrest patients in Intensive Care Units. The temporal and feature dependencies in the data are illustrated using a mixture of matrix normal distributions. We found that the cardiac arrest temporal signature is best summarized with six hours data prior to cardiac arrest events, and its statistical descriptions are significantly different from the measurements taken in the past two days. This matrix normal model can classify these patterns better than logistic regressions with lagged features.[24]

**Ali Bahrami Rad etc. all:** Theyperformed work “NEAREST-MANIFOLD CLASSIFICATION APPROACH FOR CARDIAC ARREST RHYTHM INTERPRETATION DURING RESUSCITATION” .In these paper in order to monitor the cardiac arrest patients response to therapy, there is a need for methods that can reliably interpret the different types of cardiac rhythms that can occur during a resuscitation episode. These rhythms can be categorized to five groups; ventricular tachycardia, ventricular fibrillation, pulseless electrical activity, asystole, and pulse generating rhythm. The objective of this study was to develop machine learning algorithms to automatically recognize these rhythms. They proposed a detection algorithm based on the nearest-manifold classification approach using a group of 8-time domain features as statistical measures on the signal itself, as well as the first and second differences. The overall accuracy of the cardiac arrest rhythm interpretation is 79%. The sensitivity/specificity of shockable/non-shockable rhythms is 92/95 %. [25]

**N. Suresh etc. all:** Theyperformed a work “Improved Performance of FFT Based Cardiac Analyzer Using Advanced Booth Algorithm” .In these paper they have explained about Cardiac monitoring system which is used to analyze the abnormality of ECG signal using Fast Fourier Transform (FFT) and send comments to the receiver using short message service(SMS) through Global System Mobile(GSM), where the Fast Fourier Transform (FFT) used in this has more delay, which takes much time in computation due to the presence of multiplier in it. Thus to increase the speed of FFT the Advanced booth algorithm is proposed here, in which the number of slice, number of 4-input LUTs and number of bonded IOB gets reduced when compare to the other existing FFT speed increment algorithm, Hence it is proved that the proposed FFT analyzer improved the overall performance of existing system. [26]

**Enrico G. Caiani, Giulia Marelli, etc. all:** In the lambardy region Italy they used Geomatics which is a scientific term for gathering, storing, processing, and delivering geographic information. they hypothesized that approaches based on geomatics applied to CA and AED positions could provide useful information about the distribution of events and the definition of strategies for relocating emergency resources on a specific territory. Accordingly, there aim was to analyze by Health Geomatics methods the 2015 CA and AED database relevant to the Lombardy Region in Italy, and to focus on CA events distribution and AED potential coverage in the territory of the city of Milan, using spatial isochrones, i.e. connected points reached within the same time starting from the same origin. Isochrones are temporal lines that connect points that can be reached in the same temporal interval starting from the same origin. In this work we applied realistic isochrones considering the real path between two points based on the distance traveled along the street (therefore not the trivial and incorrect Euclidean distance), to evaluate the portion of territory effectively covered by the existing AED distribution. The analysis was restricted to the three healthcare districts that refer to the city of Milan, representing the portion of territory with higher population density. [27]

**Dr. C. Nataraj, etc. all:** The objective of the experiments was to determine if titrating CPR to blood pressure would improve 24-hour survival compared with traditional American Heart Association CPR in a porcine model of ventricular fibrillation and asphyxia-associated ventricular fibrillation. After induction of anesthesia and 7 minutes of untreated VF, 17 female 3-month-old swine received manual cardiopulmonary resuscitation. Similarly, 22 3-month- old female swine received manual cardiopulmonary resuscitation after 7 minutes of untreated asphyxia. Furthermore, it was observed that only the data obtained during the first 2 minutes of the resuscitation period in the interval between t ≈ 7 min and t ≈ 9 min is relevant for the purpose of this study, in order to eliminate potential influences on the data introduced through different CPR sequences after t = 9 min. Among other measurements, electrocardiography (ECG) and heart rate (HR)were recorded during the experiment and are the measurements used and referred to as data in this study. [28]

**Jyh-Shing Roger Jang, etc. all:** In this study, the raw dataset is collected from the electronic health records (EHRs) of the adult patients (age ʁ20 years) who visited emergency department (ED) and stayed in the emergency detention area for more than 6 hours during January 2014 to December 2015, and it is provided by National Taiwan University Hospital (NTUH).they perform the data preprocessing and cleaning for the dataset using a resampling technique to balance the data amount of CPR and Non-CPR patients of the dataset, and then they construct a sliding window and apply several classifiers for model training and reducing the possible overfitting problem. Additionally, they use the measures such as the Area Under the Receiver Operating Characteristic Curve (AUROC) and the Area Under the Precision-Recall Curve (AUPRC) to comparative evaluate the performance of their models built. [29]

**Nan Liu, Zhiping Lin, etc. all:** An intelligent prediction model is proposed to compute a risk score on a patient’s clinical outcome, utilizing both HRV parameters and vital signs. The scoring system is built based on the calculation of geometric distances among a set of feature vectors obtained from the records of multiple patients .The geometric distance-based scoring system was used to correlate HRV parameters and vital signs to cardiac arrest within 72 h, and ROC analysis was adopted to investigate prediction performance. In the evaluation results, sensitivity, specificity, PPV, and NPV were reported. [30]

**M. Reza Pazhouhandeh, Omid Shoaei, etc. all:** Two-electrode Impedance-sensing Cardiac Rhythm Monitor for Charge-Aware Shock Delivery in Cardiac Arrest, two-electrode amplifier with real-time body and electrodes impedance measuring capability. The amplifier employs two sinusoidal current sources to interrogate the electrodes/body impedance. Conventional two electrodes amplifiers are highly susceptible to CMV saturation. A CMFB keeps the CMV of the body constant and avoids saturating amplifier by any mismatch in the injected currents. The current sources are implemented with the popular Howland VCCS structure with one integrated circuit and a buffer in a positive feedback path to operate with only one external resistor. To minimize the sensitivity of the output impedance of the VCCS to intrinsic mismatch of components. [31]

**Sombat Muengtaweepongsa, etc. all:** In patients, HRV measurement is proposed to be a predictor of 24 hrs. mortality in successfully resuscitated 69 patients without-of hospital cardiac arrest. It has been reported that in non survivors have shown a sudden significant decrease of HRV in rewarming phase compared to those in survivors. The electrocardiogram signals were collected at intensive care unit, Thammasat University Hospital for all phases of study 6, 18 hours during sustainment in mild hypothermia (phase A and B), during rewarming period (phase C) and recover to normothermia (phase D). The 10 minute-lead II ECG with data sampling rate of 1000 Hz was recorded with Power Lab systems (AD Instruments). Then data were stored in personal computer, and RR intervals were extracted by using LabchartPro7 Software (AD Instruments). After extraction of RR intervals, time domain, frequency domain and nonlinear HRV parameters were analyzed by Heart Rate Variability Analysis Software (Kubios-HRV version 2.0). [32]

**Utsav Chauhan, Vikas Kumar, etc. all:** Artificial intelligence is used to solve cardiac arrest disease by predicting the risk percentage using Machine Learning. In Machine Learning, they used several predictive a classification algorithm such as Random Forest, decision tree, Linear Regression, Support Vector Machines (SVM) and Artificial Neural Networks (ANN). ANN is the most powerful tool in artificial intelligence due to its brain like functioning in which a neuron (also known as perceptron) is the fundamental unit of the network and a number of inputs are fed on one neuron which gives an output .The parameters they used while implementing the algorithm were age, sex, chest pain, rest bp, cholesterol, fbs, Rest ECG, Max HR, Ex Ang, Old peak and Decision. While tidying the data, the dataset used contained some missing values which had to be removed before the algorithms could be applied on it. The missing values in the dataset were removed by filling the spots with the mean values of the column. The dataset was checked for the outliers and none were found while mapping the data. After applying Support Vector Machine, Random Forest, Decision Tree, Logistic Regression and Artificial Neural Network algorithms on the dataset to predict the occurrence of cardiac arrest in patients it is found out that the accuracy of the Artificial Neural Network is the highest (~85 %). Also, since the dataset was limited, the accuracy of the algorithm is low. Had the dataset been bigger the accuracy of ANN would also have been much higher than the current average value of the outcome. Thus, Artificial Neural Network can be used as a basis to predict occurrence of cardiac arrest in the patients according to the results of the algorithms performed on the dataset. [33]

**Joyce C. Ho and Yubin Park:** they introduced TTL-Reg, a temporal transfer learning-based model to learn a robust cardiac arrest prediction model. The algorithm learns from different time perspectives by smoothing the estimated coefficients of logistic regression from adjacent time points. We show that the parameters of TTL-Reg can be solved iteratively using existing software packages by transforming the objective function into an `2-regularized logistic regression model. Their model not only yields a coefficient trajectory that can be easily interpreted and potentially uncover new trends but also results in improved early prediction of cardiac arrest patients. The results on 763 ICU patients illustrates the potential of their temporal transfer learning approach. [34]

**Chih-Wei Sung, Jiann-Shng Shieh, etc. all:** machine learning was used to predict Heart Rate Variability for the Detection of Seizures in Comatose Cardiac Arrest Survivors a real-time system predicting seizure events through long-term continuous data recording and extraction was developed. The system displays information on a physiological monitor and extracts real-time bio signals, including ECG and EEG signals. ECG-based HRV analysis can be used to immediately detect seizures in patients who have experienced sudden cardiac arrest and have then been resuscitated using CPR and admitted to the EICU. Four HRV parameters, namely SDNN intervals, HF, LF/HF, and SampEn, can be used to develop a reliable algorithm for seizure detection. Seizures has always been a critical issue in clinical care scenarios, especially for patients who have survived a cardiac arrest, because the long ischemic cerebral perfusion time may cause hypoxic encephalopathy, which deteriorates neurological outcomes. This study shows to overcomes the previous limitations on continuity and accessibility for real-time seizure detection. In this study, seizure events were detected in patients presenting with muscle convulsion through physician assessments and a real-time detection model. Seizure could be also found in anytime when the patients seemed no convulsion because abnormal electrical discharge in these patients only occurred in the cerebral cortex, but not in the limbs or face. [35]

**Andoni Elola, Elisabete Aramendi, etc. all:** a new multi-modal solution to classify circulation states during OHCA using concurrent information derived from the ECG, the TI and the capnogram. The solution allows the classification into two classes (PR/PEA) or three classes such as pseudo pulseless electrical activity, true pulseless electrical activity and pulse generating rhythms, with the final aim of monitoring the circulation state of the patient and the response to resuscitation treatment. The study is based on a unique dataset that includes IBP signals measured using arterial lines during OHCA to provide an accurate ground truth clinical annotation of the circulation state. in an organized rhythm (QRS complexes), and free of chest compression artefacts. The ECG, TI and capnogram were used to develop the algorithms. A clinician and two expert biomedical engineers used all other sources of information to annotate the circulation state pseudo pulseless electrical activity, true pulseless electrical activity and pulse generating rhythms for each interval, including: clinical patient charts with annotated restore spontaneous circulation intervals, the IBP waveform, and cerebral oxygen saturation when available. Systolic (Sys), diastolic (Dias) and pulse pressure were computed for each cardiac cycle and averaged to be displayed during annotation. The distinction between the three circulation states was possible using the objective values obtained from the IBP because systolic and pulse pressures are higher for pulse generating rhythms than for pulseless electrical activity. [36]

**Donald R., AKM Jahangir, A. Majumder, etc. al:** An embedded IoT system to monitor heart rates and body temperatures using smartphones. they use an ECG sensor system and the realtime detection of abnormality in users’ ECG patterns. The results from sensors’ data are also presented to show that this approach provides a high rate of classification correctness in distinguishing between normal and abnormal ECG patterns. The system may also find multiple applications in heart behavior detection for people with various disabilities who are at a high risk of cardiac arrest. The IoT system consists of a pulse sensor, a temperature sensor, an Arduino, and a Low Energy (LE) Bluetooth. A smartphone is used to collect sensors data. They collected data from ECG and temperature sensors using a smartphone. they used multiple subjects and collected data for different events of user daily activity. Data for each subject was collected from a smartphone placed in the subject’s hand or a pocket. In the system, the ECG and temperature sensors are used to collect the raw ECG patterns and body temperature while the user is walking. Then, the resultant outputs are processed inside the mobile phone to identify the user’s ECG pattern. Though the system continuously monitors for ECG patterns and body temperature, it only triggers a warning if the ECG pattern and body temperature of the user reaches a certain threshold where the user might face a potential heart attack. At that time, the system warns the user with a message and vibration to alert them about an imminent cardiac arrest. [37]

**C. Jenefar Sheela and L. Vanitha:** the cardiac prediction system is proposed with HRV parameters as input and support vector machines with RBF kernel as classifier. The prediction system has demonstrated its ability to generate human understandable factors, and has shown its effectiveness to being a powerful predictor of cardiac arrest before 30 minutes. The experimental validations on a time domain and frequency domain show that the proposed system is able to achieve satisfactory prediction results. Hybrid structure may be used to improve the classification efficiency. They predicted sudden cardiac arrest before 30 minutes of its occurrence on the basis of time domain and frequency domain features of Heart rate variability (HRV) obtained from ECG and using SVM classifier to classify SCD patient from Normal patient. The database of cardiac patients obtained from physionet is used to check the validity of the proposed work. Performance of SVM is better giving the classification efficiency of 88%. [38]

**César O. Navarro, Nick A. Cromie, etc. all:** Cardiac Arrest was detected using a Simplified Frequency Analysis of the Impedance Cardiogram recorded from Defibrillator Pads Estimation of the frequency spectrum of the first order derivative of the impedance cardiogram (dZ/dt) recorded through the 2 transthoracic defibrillator pads can be used as a marker of circulatory collapse. The use of less accurate integer filters for the estimation is a feasible solution to be applied in a less powerful CPU operating in a PAD defibrillator. The results provide initial tools for further development of applications for the use of ICG in defibrillators during emergency clinical practice. An in-house fully functional defibrillator was constructed (Samaritan AED; HeartSine Technologies, UK) which apart from the ECG, included the recording of ICG using a low amplitude sinusoidal current (30 kHz; 0.05 mA) between the 2 adhesive defibrillator pads (Samaritan. Its CPU is a Motorola 68336. The ECG and ICG signals were monitored, digitized and stored for retrospective analysis. [39]

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